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RISK OF OCCURRENCE OF EMERGENCY SITUATIONS INVOLVING MOBILE AGRICULTURAL MACHINERY AFTER PROLONGED USE

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LIST ABBREVIATIONS

Agricultural sector – the agricultural sector of economy of Ukraine.

AIC – agro-industrial complex of Ukraine.

DTP – traffic accident.

SSMSISU – State Service of Mining Supervision and Industrial Safety Ukraine.

ECT – Eddy current transducer.

ECM – eddy current method.

EMF – electromotive force.

FIS – Social Insurance Fund.

MAPP – Ministry of Agrarian Policy and Food of Ukraine.

MP – machinery and tractors.

M–W–PE – machine – worker – production environment.

LLG – labor law regulation.

NDT – non-destructive testing.

SPFM – self-propelled farm machinery.

SMS – safety management system.

TO – maintenance.

UHF – ultra high frequency.

USV – ultrasonic vibrations.

PREFACE

Asset tracking vehicles, including assessment of waste and residual life of structural units of equipment and systems for the operation is necessary to justify their longevity at the stage of design, construction and extension of the assigned resource exploitation is essential for machines durables designed service life of which is decades. Operating conditions such facilities are characterized by non-stationary multiparametric effects of different nature, thus developing various degradation processes in structural materials and limited resource designed structural elements.

So while operating the machine must monitor individual resource depletion most critical structural elements based on length of operation and changing boundary conditions of the material. If there is no or limited access of non-destructive testing to hazardous areas basic structural elements such control method is produced evaluation and prediction of the residual life of structural elements based on mathematical modeling of the accumulation of damage due to operation of the machine.

Modern approach to operational reliability agricultural machines provides periodic status monitoring or metal parts of the machine when the estimated size of the defects that arise and develop in the operation, in order to avoid the destruction of metal. Having technological and operational defects requires systematic maintenance of mobile agricultural machines in all phases of operation. Systematic approach aimed at detecting defects in the critical areas of hardware (components) are most likely fatigue, determine the optimal duration of turnaround time, and outline the basic requirements for the availability of nodes to monitor their condition, increasing the likelihood of defects in the elements of the design.

It is necessary to detect defects at an early stage of their occurrence, which requires knowledge of dynamic characteristics of metal damage in conditions that are typical for conditions of agricultural units. Modern approaches of physical mechanics of materials and defectoscopic equipment provides early detection of damage to the metal by the impact of operational stress. However, some details may over time be in operation cracked, while their size they reach critical values.

Theoretical and practical approaches to occupational risk assessment are numerous studies [1-3], which mostly consider general issues of management of labor and social protection of workers, particularly in the form of compulsory insurance against industrial accidents and occupational diseases. But the problem of complex evaluation of risk of injury to production based on the probability of an accident and the severity of its consequences for the agricultural sector remains relevant.

Until recently, as indicators of occupational hazards in agriculture mainly considered and analyzed rates of frequency and severity of workplace injuries. Now even risk indicators for key professions agro-industrial complex (AIC) no, not developed classifications of agricultural occupations by the criteria of risk of injury and illness in the workplace.

The specificity of working conditions in agriculture, including mechanics, defines high risk of injury. For example, in Ukraine agricultural sector the proportion of injuries with lethal outcome among machine is about 30% of all those killed at work in the field, and rates of injuries among machine several times higher than the average for other occupations in agriculture. Data on occupational risks in agriculture needed to develop measures to reduce their excessive levels, and to justify the benefits and compensation to employees for performance for hazardous and harmful conditions.

The need for a systematic approach to study the problem of providing a safe working environment determines the nature of machine processes crop production and livestock, causing the functioning of the machine – worker –production

environment (M–W–PE). Specifically production environment formed by both natural processes and from human activities (such as hygienic conditions in cabs of tractors and combines, the state of farm roads and bridges, industrial facilities, etc.).

A certain lack of coordination between different elements of the M–W–PE and numerous technical and technological failures worker machine operator has to compensate for the additional physical and psychological costs, which reduces the reliability of industrial activity and increase risk of injury. The use of high-energy farm machinery and new technology, chemical and biological agents has increased the exposure of workers AIC harmful and hazardous factors.

On the other hand a large resource of existing agricultural enterprises mobile technology to expire after quite long (over 10 years) lifetime is obsolete and outdated, leading to increased occupational risk. Under these conditions, avoid risky situations in agriculture is now almost impossible.

Over the past decade the ratio of fatal accidents in agriculture Ukraine on general significantly decreased. Some problems in reducing occupational injuries now occur, but the risk of accidents in agriculture still remains high, particularly in the mechanized crop and livestock production. Most injured workers while repairing, maintenance and regulation of machines and tools for the field.

For performance evaluation of occupational risk should have on the number of techniques and mechanisms of a certain type (brand) and the number of workers involved in the work. Information about the number and condition of agricultural machinery for getting the final results of its inspection. Also risk indicators during the operation of agricultural machinery can be obtained as the ratio of accidents mechanized agriculture to the number of mobile agricultural units, which were found to malfunction.

To determine the occupational hazards must use methodological approaches of systems analysis of industrial hazards and methods for integrated quantitative assessment of danger that provide information about the risk of injury

mechanics, the degree of operational reliability engineering and production harm the environment. Development of methods for the quantitative assessment of conformity of technical characteristics of units and components farm machinery safety requirements will calculate the value of reducing losses from injuries in agriculture through improvements in the safety system M–W–PE.

The book presents the scientific principles of development of methodology for assessment of occupational risk in mechanized agriculture, which should be the basis for tracking potential hazards in the agricultural sector on the basis of a risk-based approach. The necessity of taking into account the availability of operating defects of various sizes in detail units of tractors and self-propelled agricultural vehicles after a long life for stochastic characteristics of the danger of further mobile agricultural machinery. The possibility to include reliable detection of cracks spreading in detail tractor units when using portable flaw Eddy current type.

The publication should be useful for specialists in the reliability of mobile agricultural machinery and workers to health and safety of agricultural enterprises, students and graduate students of higher agricultural education.

CHAPTER 1. OPERATIONAL DETAILS AND HARDWARE DAMAGE OF AGRICULTURAL MACHINERY AS ONE OF THE KEY CAUSES OF ACCIDENTS (TRAUMATIC) SITUATIONS

Statistics of accidents that have occurred over the last decade involving mobile agricultural machinery shows that the main reason most of them are serious violations of workers safety regulations, traffic rules and maintenance of machines and equipment. However, for emergency can cause poor technical condition of tractors and self-propelled farm machinery (SPFM), caused by the high degree of damage of parts. The proportion of crashes and accidents associated with the human factor can reduce the introduction of high technologies operating mobile equipment and application systems of safety measures, including those that provide in-depth training of safe methods of work and arrangement of means security

As for the causes of injuries caused by poor technical condition of tractors, motor vehicles, trailers and SPFM, the reduction of injury mechanics and other workers contribute to the implementation of operational regulations, technically equipped and systematic monitoring of mobile agricultural machines. This will detect operational defects in the early stages of their education and timely repair units replacing damaged parts in the repair units and not in the field and on the road in conditions of shortage of time and the right tools, the lack of machine operators (drivers) needed qualifications.

As the technical causes of occupational injuries in agriculture predominantly indicate structural flaws of equipment and the lack of means of protection [4]. But the direct connection of agricultural technical units with professional risk of mechanics studied not enough. In particular, this is due to the fact that often causes injuries to the technical background of organizational seen

as related, without specifying them as definitive documentation for the investigation of accidents.

1.1. Influence of exploitative defects in danger of occurrence of accidents involving mobile agricultural machinery

Operation of tractors and other self-propelled agricultural machinery in terms of reliability chassis parts, brake and other systems, components and fasteners available fretting process is characterized by certain features: transience cyclic and dynamic loads and corrosive environment for metal [5]. Power load leads to sudden destruction of interface units of real and long-term stealth action fretting corrosion and uncertainties include the origin of operational damage makes it impossible to predict the occurrence of accidents [6].

Based on the research *L. A. Tomilenko, S. I. Kruk, I. A. Oleinik and others* found that during the overhaul agricultural machines largely reduced means of working conditions according to metrics such as noise, vibration, temperature, dust and gas air tightness cab from drafts, moisture and dirt to exercise controls, lighting. Degradation of agricultural machinery to increase its operating lifetime is uneven on certain categories of performance conditions. With increasing life of tractors and combines assessment of conditions on these parameters decreased significantly after the fourth and fifth years of operation. This conclusion is based on expert opinion.

The authors *M. Zinchuk and Y. Shalapko* found a significant decrease in mobile security structures of agricultural machinery after 10-14 years of operation. In particular, in observance of safe working conditions and accident prevention *M. Kostomahin* proposed to implement a periodic control of harmful physical factors and indicators of safety on tractors and combines, in operation for over ten years.

Table 1.1

The list of accidents that have occurred over the past decade due to operational failures

Date of accident	Members accident	The accident	Description of accident	The consequences of an accident	The main cause of accidents
07/05/2017	The truck "MAZ 551608-236"	Starokostyantyniv district, Khmelnitsky region, Ukraine	At the time of entry on the bridge over the river Sluch a car "shot" front right wheel. Truck trailer broke through a protective fence and slid into the river	In the fall, two people were caught by metal structures tormented cab truck and suffered serious injuries	The truck was overloaded with grain and wheel while driving could not stand the weight and "shot"
18/09/2018	Truck «Mercedes»	Village Remeniv, Lviv region, Ukraine	On the move came off the wheel of the truck trailer «Mercedes»	The wheel flew on public transport, where the 41-year-old woman was. She suffered serious injuries and died before the arrival of ambulance	Destruction wheel fastening elements
21/05/2016	Tractor MTZ-80	c. Kyiv, Ukraine	In the tractor while driving came off the wheel. Tractor overturned on SUV	Drivers were not injured. However SUV passenger were seriously injured	During motion axis of the tractor wheels was broken
15.06.2009	Tractor K-700 with a loaded trailer	Kustanai region, Russian Federation	Disconnecting of trailer from the tractor	Tractor started an emergency brake, but due to insufficient stopping distance to avoid a collision failed	Operating fault of parts pull-coupling of a trailer (cracks)

Continues Table 1.1

Date of accident	Members accident	The accident	Description of accident	The consequences of an accident	The main cause of accidents
12/12/2018	Tractor MTZ-82 and truck "IVEKO"	Highway near v. Nesterov, c. Kaliningrad, Russian Federation	Due toovertaking truck "IVEKO" and tractor, both vehicles were in the ditch	The drivers of vehicles tractors and trucks "IVEKO" injured,	The driver of truck lost control due to a technical mal-function of truck steering system
10/01/2017	Tractor T-150K trailer	c. Izum, Kharkiv region, Ukraine	Tractor that sprinkled the road, rammed several vehicles, including a police car	As a result of the accident no one was injured	Hitting caused jamming of a steering hydra-ulic cylinders
08/06/2018	Bus «Neoplan»	Italy	The bus crashed into a pole and then caught fire	16 injured people were hospitalized	Faulty steering system parts
15/11/2018	Truck KamAZ with a trailer	Near the village Olhopil on the road Aleksandrovka - Kropyvnytskyi - Mykolaiv, Ukraine	When driving in "KAMAZ" detached the trailer and the car went into the oncoming lane, where faced with yet another truck	As a result of the accident the driver of the injuries to the medical establishment.	The presence of defects in the trailer coupling
17/11/2018	KamAZ truck with trailer	city Alexandria, Ukraine	Because of the failure of chassis driver lost control of the loaded trailer, which collided with a parked car	The injured driver of the car "Opel Combo"	Cracked one of the trailer chassis mounts

Continues Table 1.1

Date of accident	Members accident	The accident	Description of accident	The consequences of an accident	The main cause of accidents
08/04/2011	KamAZ Truck	city Brovary, Kyiv region, Ukraine	Broken bus started towing. At this time, KAMAZ trailer full of sand crashed into the bus	At the vehicle fleet were two workers. The collision hurt them. One of the men suffered serious injuries	Faulty brake system.
15/05/2012	Tractor MTZ-82 with a loaded trailer	Road Bohashevo-Nekrasov (Tomsk region, Russian Federation)	Tractor drove into oncoming traffic, and then – to stop for passengers, where people were	5 injured people who were at the bus stop (one person died)	Technical fault tractor steering system
08/04/2018	Tractor MTZ-80 trailer	Road Knyazhytsi - Gorki - Lenino (Mogilev region., Belarus)	Tractor, suddenly drew aside, drove into the oncoming lane and hit the bus	17 injured people were hospitalized	Faulty steering system parts
22/04/2017	Fuel truck MAZ-5337 trailer-tank	Near the village. Novoivanivka Azov district of Zaporozhye region, Ukraine	Trailer disconnected from a car, slid into a ditch and overturned	On the ground flowed about 2 tons of gasoline	Operating fault coupling

Continues Table 1.1

Date of accident	Members accident	The accident	Description of accident	The consequences of an accident	The main cause of accidents
15/09/2018	Truck «MAN» trailer	On the bypass road near the village. Zaychivske (Mykolaiv region, Ukraine)	Trailer mount of truck came off, trailer then went into the oncoming lane, where he collided with another car	As a result of an accident, with received injuries 33-year-old passenger KIA Sorento and her son three years delivered to medical institutions.	Operating coupling fault (crack)
20/08/2018	Garbage truck "ZIL"	city Zaporizhzhya, Ukraine	While loading of garbage, mechanism bin garbage truck fell on stranger	The man, who was near the garbage truck, was seriously injured	Operating failure of garbage truck hydraulic system

Emergency situations using mobile agricultural machinery can be caused by the proliferation of operational defects in parts and structural elements that defects of a degree should be considered as potential causes of accidents mechanized and transport works.

In excess of (exhaustion) of the resource in certain sections of metal parts having operational defects (cracks, wear rubbing surfaces, etc.) that can lead to sudden destruction of the details (design elements) tractor or SSM, and then the creation of an emergency. The greatest threat to life and health machine (tractor–driver) and drivers are traffic accidents (RTA), due to the destruction of parts of automobiles, chassis, coupling (hinged) device and so on [7].

There are examples of high-profile accidents that occurred in Ukraine, the Russian Federation and Belarus in recent years due to the destruction of parts and components for motor vehicles and wheeled tractors (Table 1.1). Common reasons as to create accidents on the roads in these accidents is the uncontrolled growth of cracks in critical parts: the coupling, fastening systems wheel steering system of the tractor and others. The presence of these examples buses and trucks only reinforce the thesis of the dangers of staying on highway road vehicle with faulty (faulty) technical condition. Movement faulty truck, tractor or combine on the road no less dangerous compared to a motor vehicle for machine operators in the cabin, and for other road users.

Table 1.2 presents list of circumstances of the accidents that have occurred recently during repair work mechanization.

As seen from the Table 1.2 single source of injury to machine operators and drivers of agricultural production is the performance of repair work in the field or road conditions. In agricultural enterprises, particularly farms and other small businesses, agricultural machinery repair themselves mostly tractor-driver in the absence of the necessary tools (supplies) and safety skills needed repairs. This often leads to injury mechanics of moderate and severe consequences.

Table 1.2

A perelik of circumstances of the accidents that occurred during repair work mechanization

Date of accident (HB)	The company, which occurred with the employee NV	Description NV	Consequences NV	The main cause of accidents
05/03/2017	Teofipolske branch of JSC "MHP Zernoproduct" Ukraine	When repairing the unit for liquid mixtures spewed ammonia mixture eye injured victim	The employee according to medical opinion received chemical burns of the cornea and conjunctiva of both eyes	The worker did not use personal protective injured during the work.
16/11/2018	Ltd. IEC "Native Land" (v. Sosnovka, Ukraine)	A worker with a hammer chopped off of metal cable. During the work, while another blow hammer, metal vein with a rope hit him in the left eye	According to the medical report the worker received injuries penetrate of scleral left eyeball.	The worker did not use of personal protective equipment (goggles) during the work.
07/03/2017	VAT in Novahrudak district, Ukraine	While repairing of the loader before removing tires air are not lowered. This led to the destruction of pressurized air wheels. As a result, scattered parts of the drive wheels injured worker	Mechanics was injured. He was hospitalized, but despite the efforts of doctors, the man died	Repair works without compliance of safety rules
26/08/2016	Subsidiary "Vymno" JSC "Milk" (c. Vi-tebsk, Belarus)	When transporting tractor harvester reaper crawled under to catch coupling device and reaper suddenly fell on him	A worker was seriously injured	Tractor-driver did not record reaper supports.

Especially dangerous is the repair of equipment failure due to operability node that occurred in the field or on the road by the shortage of time while performing seasonal work.

It should be noted that examples from the Table 1.1 and Table 1.2 is not limited to cases of injury to workers because of defects in parts and agricultural and construction vehicles units. By official statistics of occupational injuries do not fall accidents that have occurred with employees whose work is not executed properly.

On the safety of agricultural work with mobile technology affects a large number of factors. Security agriculture unit depends on: the established standards of safe working life; the period during which the machine works after installing the last guaranteed lifetime; safety equipment and a large number of adverse factors of the production environment. The adverse impact on the safe operation of the unit different factors may be associated with exceeding the allowable values of process parameters, extreme values of the parameters of the production environment, the influence of other factors, technological nature. To account for these factors suggest using as an indicator of safety risk index functioning source of danger.

Growing and harvesting sustainable yields should be based on high culture of farming and the use of modern systems of machines in the relevant lines: preparation and fertilization; basic and preplant tillage; sowing; integrated control weeds, pests and diseases; combine harvesting etc. Each of these mechanized manufacturing operations should be viewed as related to high risk. Much of the dangers associated with operating defects in parts and components of mobile agricultural units.

So, when working with liquid fertilizers and pesticides greatest contact with harmful substances observed in auxiliary operations solutions preparation, fueling vehicles and their disinfection. To reduce the duration of workers contact with toxic substances of great importance to technical and technological reliability of

the machine. If the destruction of structural elements, clogging nozzles, complex regulation equipment, mechanic had contact with toxic substances. As a result of mineral and organic fertilizers, pesticides, machinery are quickly cording, reducing their reliability and unnecessarily increase efforts to control organs, leading to sudden destruction.

Technological service machines for cultivation is not a complex and not characterized by specific complications. With auto hitch machine easily attached or mounted on tractors. But during assembly units with plows, harrows and other mechanisms often involve support workers, and this is due to the risk of injury in the event of residence in the area of the tractor or under a raised (batches) tool. Defects in the hydraulic system parts can lead to sudden lowering of raised platforms and tools or cause serious injury.

Transportation of large-sized units (seeders, harvesters, etc.) of agricultural aggregates on public roads are dangerous operations. And the reason is not only that their dimensions in transport position bother overtaking and counter travel while driving on the roads. If the destruction of fasteners that hold the shoe, bars and other items during transport, there is a high risk of road accidents and traumatic situations.

According to the State Service of Ukraine on Labor essential part of road accidents causing by technical failures of vehicles. If all such accidents to 100%, the defects of individual components and assemblies car will be:

- braking system – 47.1%;
- steering – 16.4%;
- tires wheels – 13.9%;
- lighting and signaling devices – 7,4%;
- chassis – 6.2%;
- mirrors, windshield wipers, glass defects – 1.9%.

Thus, the destruction of indigenous letters or central bolt spring can lead to twisting bridges vehicle deviation from the set its direction of movement and

departure off the road or into oncoming traffic. The movement of a vehicle with defective Pull-coupling or support-coupling device can lead to tearing of the tractor trailer, loss of control and accident.

In particular, the technical condition of the vehicles and their equipment are factors that affect road safety, it is the Criminal Code of Ukraine (article 287) provides for liability for discharge operation obviously technically defective vehicle.

You can specify that approximately 10% of accidents in agriculture is a technical factors associated with the presence of operational damage in parts and structures of tractors and SSM, leading to accidents or injury during an emergency repair equipment.

Therefore, to develop recommendations to limit the operation of tractors and SPFM, the details of which may develop defects that lead to accidents and accidents be investigated intensity accumulation of cracks in critical parts and components agricultural units.

1.2. Analysis of modern flaw parts and structures

Non-destructive testing of parts and structural elements makes it possible to assess their technical condition, possible to establish whether further operation node or system without replacement or rejection of damaged elements (parts). However, given the fact that many units because of un satisfactory defectoscopic manufacturability (difficulty of access to the surface of details) early detection of defects subcritical size is difficult, it is necessary to establish fault detection methods can be used to control components and structural elements of tractors and SPFM with the highest efficiency and reliability. It should be understood that the effectiveness of control often determines not minimalism of parameters (size) defects, but reducing of the duration of control, reliability and accuracy of

detection of cracks, repeatability of results under the same conditions of research, training costs and other controllable surface.

In most of the technical recommendations for monitoring agricultural machinery, such as control cards for monitoring the safety parameters, stated that the existing cracks and damage to parts of machines detected during visual inspection. Currently, regulations flaw units and details of tractors and SPFM mostly involve the detection of visible damage and cracks, determining changes configuration and size (which is achieved by measuring ruler or caliper size operation, curvature, distortion, beating, warping, non-perpendicularity and other mutual mate violations of surfaces and axes).

But this approach only indicates a dangerous situation on the stress-deformed state of the machine parts. To assess the risk of further exploitation of useful data is available in the details and design elements not only large cracks, but such that, at this stage do not pose the immediate threat of sudden destruction on the details of individual units, but may spread into the details of the critical variables.

In the Technical Regulations safety of machines [8] proposed to assess risks, given the severity of the possible injury or loss of health workers and the likelihood of accidents and ergonomic machines, but do not consider the dangers that may result from expansion of operational damage.

Now various methods defectoscopic control of machine parts and structural elements are proposed for engineering and other industries [9-11]. Features of each method flaw impose certain restrictions on their use in the evaluation of technical condition of parts and structural elements, including tractors and SSM. So, as proposed setting flaw engine crankshaft using the method of free oscillations should be used permanently on stand repair business. Under the conditions of agricultural production, when technical state of tractors and SPFM assessed directly in the machine-tractor fleet (MTF), preference should be given

flaw detectors, which allow to detect dangerous cracks and characterized by a minimize of restrictions under the conditions of the production environment.

Complexity of using of defectoscopic control methods to assess the technical condition of tractors and SPFM is the need to disassemble components for cracks in some detail. Disassemble components primarily in the technology overhaul, and during some types of maintenance. It is then advisable to use portable flaw detectors to detect dangerous defects.

Modern methods of fault detection based NDT divided into the following main types – optical, capillary, acoustic, magnetic, eddy current, electrical, radio wave, thermal, radiation [12].

Most types of methods are intended for special studies and monitoring. Thus, by capillary flaw detection methods are: the color, brightness, luminescent, fluorescent-color, capillary-electrostatic, capillary electric inductive, capillary-magnetic, capillary-radiation. The advantages of capillary method is that it can be used not only to identify cross-cutting and surface defects, but also to get information about their location, length, shape and orientation of the surface.

Among the types of acoustic methods in laboratories and production are widely used varieties: shadow, mirror-shadow, velocimetric, echo-method, the delta-method and others.

To detect defects using a fairly simple method and it is complicated to use (tomography or penetration of radioactive gases – as in radiation methods) that require expensive equipment and protection from hazards experts conducting control. For visual, radiographic, capillary, magneto-powder, Eddy current and some other methods for flaw detection in Ukraine introduced national standards NDT.

Overview variety of methods for flaw detection shown in Fig. 1.1. Choosing to apply the most appropriate and effective method of detection, should focus on the nature of the defects that may be in the details and design elements.

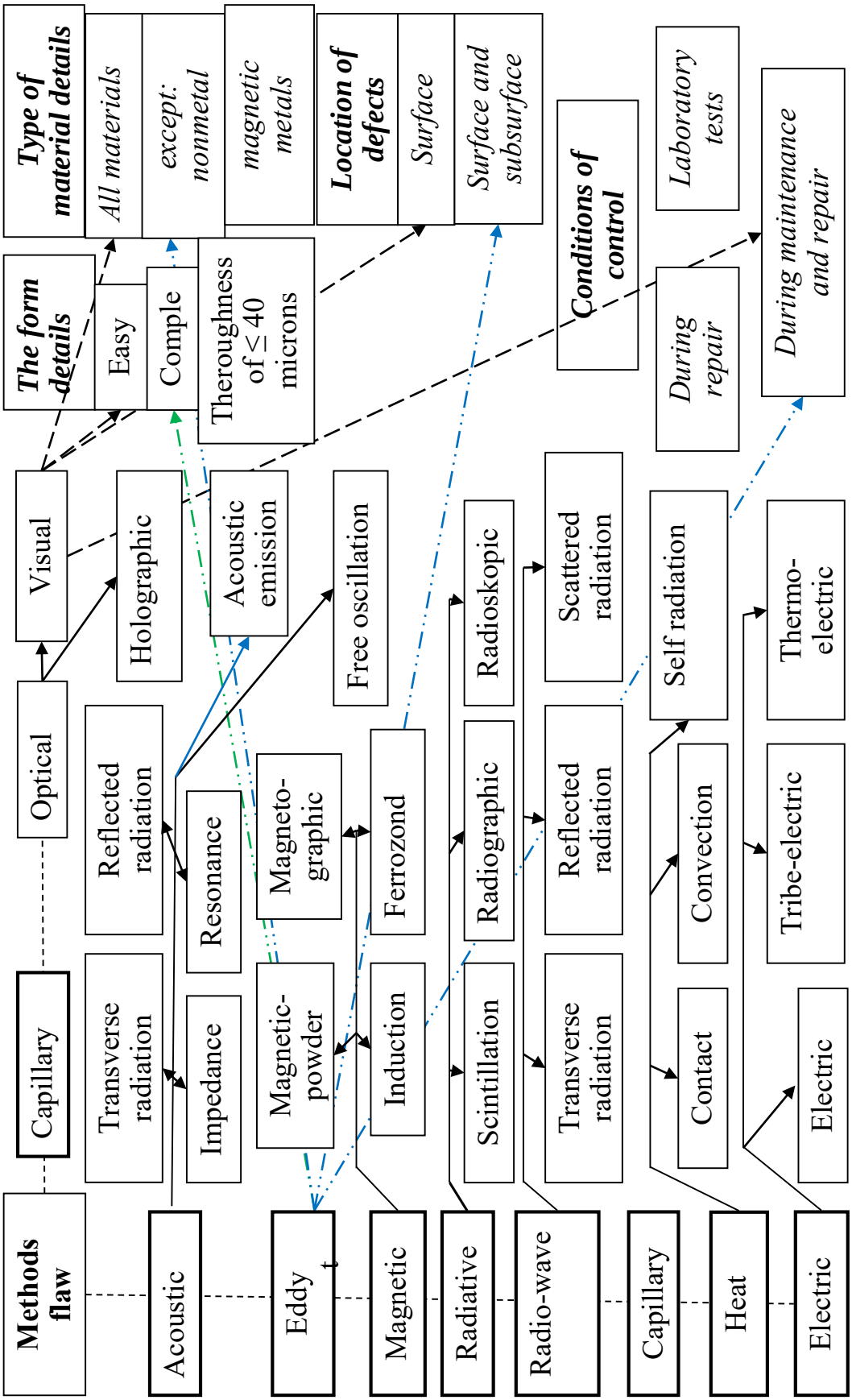

Fig. 1.1. The variety of methods for fault detection on the type and form of controlled parts

Table 1.3 indicates that the method of detection prefer to find of cracks that formed as a result of various processes of manufacturing parts and heavy conditions of use.

The list of methods for fault detection (Fig. 1.1 and Table 1.3) shows that a universal method of cracks exist, each with specific hardware and metrological advantages and limitations both in terms of location of the defect, and the form and material details.

Table 1.3

Recommendations for the use of methods for flaw detection of cracks that occurred during certain processes [13]

№	The name of the process	Type crack	Methods flaw
1.	Melting and Casting	Cracks	Acoustic emission (a transparent or reflective), Eddy current, scintillation, electric
2.	Pressure treatment	Internal	Acoustic emission (a transparent or reflective), flux-gate, induction
		External	Acoustic emission (a transparent or reflective), Eddy current, magnetic powder, flux-gate, induction
3.	Thermal treatment	Thermal	Acoustic emission (a transparent or reflective), Eddy current, magnetic powder, flux-gate
		Hydrogen	Eddy current, magneto-graphic, flux-gate

Continues Table 1.3

№	The name of the process	Type crack	Methods flaw
3.	Mechanical treatment	From machining processing	Eddy current, magnetic powder,
		From grinding	Eddy current, magnetic powder
4.	Metal compounds	Cracks defamation	Acoustic reflective radiation
5.	Operational impact	Fatigue	Acoustic reflective radiation, acoustic emission, magnetic powder, Eddy current, ferro probe, holographic, electric
		Corrosive	Acoustic reflective radiation, Eddy current, holographic

Much of the known methods for fault detection can only detect defects in laboratory conditions, the size of which is much less critical, leading to the destruction of machine parts and structures in operation. The use of such methods for production (field) conditions causes major difficulties in placing defectoscopic equipment, reliability obtain data on the location and size of defects. The value is also the possibility of defectoscopic control for an array of details in a short time with a minimum equipment changes.

Further analysis hardware capabilities flaw detection methods to detect cracks in structural parts and tractors and SPFM.

The simplest method is visual flaw. But visual flaw detection can detect only surface defects (cracks) in metal products and internal defects in products made of glass or transparent to visible light plastic. To inspect the internal

surfaces, deep cavities and hard to reach places using special tubes with prisms and miniature films (diopter tube) and television tubes. The minimum size of defects that reveal the naked eye, is 0.1-0.2 mm and at times the use of optical systems – tens of microns.

More widespread is the method of optical inspection through the use of optical lasers. Use it to control the geometric dimensions of products with complex configuration, discontinuities, heterogeneity, deformation, surface roughness products.

Methods permeable radiation effective to identify of discontinuities (lack of penetration, cavities, cracks, etc.) in cast products and welded structures. The methods of X-ray permeable belongs radiation and gamma ray (wavelength of 10 to 10^3 A). Identify the cracks with these methods is possible only provided that the rupture plane coincides with the direction of rays falling on X-ray film, or makes an angle not exceeding typically, 10-15°. In this case, the crack width should be at least 0.015 mm.

X-ray inspection of defects based on the absorption of X-rays, the degree of which depends on the density of the material and the controlled object. By registering the intensity distribution passing rays can detect the presence and location of various material irregularities. A prerequisite for the X-ray control is to allow bilateral approach to the controlled object. The sensitivity and resolution depend on the size of focal spot X-ray tube.

X-ray inspection of defects sensitivity depends on the ratio of the defect in the thickness direction of translucence to detail in this section (for different materials is 1-10%). Application r X-ray inspection of defects is effective for a relatively small thickness parts as permeable ability of X-rays to increase its energy consumption increases slightly.

X-ray inspection of defects used to determine shells, large cracks, segregation inclusions in cast and welded metal products thickness to 80 mm and

products of light alloys to thickness 250 mm. For this purpose, the installation of industrial X-energy radiation from 5-10 to 200-400 kEV.

For gamma-radiation flaw detection using the energy of several tens kEV to 1.2 MEV for large parts ray thickness. This method is characterized by significant advantages unlike X-ray inspection: apparatus for gamma flaw is relatively simple, compact radiation source, which allows remote areas to inspect products. In addition, this method can be used, if using of X-ray inspection is difficult (in field conditions). While working with X-ray and gamma-ray sources must be an effective biological protection of workers.

The advantage of radiation methods [14] is the ability to determine the coordinates and shape defects (using tomography), drawback – the bulkiness and complexity of the equipment used, which is unacceptable on the needs of operational control of agricultural equipment. Using X-ray equipment for defectoscopic control in farms or repair subdivisions requires training of relevant professionals, conclusion of an agreement for the survey of businesses that received a license for this type of non-destructive testing of high risk.

Radio flaw detection based on micro radio waves permeable properties and can detect defects on the surface of products mainly from non-metallic materials. Radio flaw detection metal products is very limited because of the low penetrating ability micro radio waves. This method of determining defects in the steel sheet during their manufacture, as well as measure their thickness or diameter, thickness of the dielectric cover. From generator, working in continuous or pulsed mode, micro radio waves through the horn antenna penetrate the product after amplification of the receiver records.

In the radio zone control methods used ultra-high frequency (UHF) of electromagnetic radio waves with a wavelength from a few centimeters to 1-2 mm. UHF radio waves directed to a controlled object with the open end of the waveguide and horn antennas. To register, use the automatic signal lines or measuring devices that are used in radar. The presence of defects leads to

additional reflections of electromagnetic fields that change the interference pattern and cause additional losses of energy.

Infrared flaw uses infrared rays to detect opaque to visible light defects, inclusions. Infrared images obtained in defect transmitted, reflected or own radiation investigational product.

Acoustic testing of cracks allows you to control in detail relatively simple form. Identify flat, three-dimensional, linear and spot defects and those that having due to corrosion.

The basis of ultrasonic flaw detection capability charged ultrasonic vibrations (USV) in the metal cover long distances in a directed beam and reflected on the boundary between two areas of different densities. For ultrasonic flaw detection using pulse-echo method and the method of sound shadows, acoustic methods, impedance and free of vibrations. Apply six types of elastic waves, longitudinal, sliding (lateral) surface (Rayleigh) bending, twisting and normal (Lembov) waves.

In controlled object enters the ultrasonic wave pulse or continuous mode using a piezoelectric sensor dry contact, oil contact, jet (slot) methods through immersion liquid medium, usually water, or using electromagnetic-acoustic sensors way through air gap. This method of control is defective parts relatively simple form.

Discontinuity causes hopping or smooth change of acoustic characteristics and affects the conditions of propagation of ultrasonic vibrations. When analyzing vibration amplitude control their phase, frequency, rate of spread, the spectral composition of the reflected pulse.

Most common method of detecting defects in acoustic flaw is the pulse echo method, the principle of which is directing short ultrasonic pulses and reflection of them from the surface defect and back of the details or design elements. Using the flaw, which sold echo method, it is possible detect defects over an area of

1 mm^2 (sinks, bundle and other), which are at a greater depth below the surface of the metal.

The sensitivity of this method is much higher than shadow. It depends on the oscillation frequency, power sent to the pulse of radiation characteristics, acoustic characteristics of the material.

In echo-method using all kinds of elastic waves. Shear waves detect defects that occur at shallow surface and oriented perpendicular or nearly perpendicular. Surface waves are used to detect surface defects in products relatively simple forms. In such cases, the condition affects the results of controlled surface. When the control method of longitudinal waves when the contact input fluctuations observed "dead zone" that at frequencies of 2-3 MHz is 6-8 mm. Reducing the "dead zone" depends on pulse width and length of the transition.

The greatest sensitivity depends on the frequency of ultrasonic vibrations, the thickness of the metal section, acoustic characteristics of the material. For thick aluminum alloy 200-250 mm at a frequency of 10 MHz reference reflector diameter exhibit 0.3 mm.

In industry such devices operating in the frequency range from 60 kHz to 6 MHz. They can be used to detect defects area of 1 mm^2 (shells, slag inclusions, stratification etc.), located at a considerable depth below the surface of the metal.

Shadow method is based on the appearance of zones of sound shade defect larger than the transverse length of elastic waves. This method allows to control of products simple shape and a small thickness when providing bilateral approach to the controlled area.

The main disadvantages of echo-sound method and shadow details about the flaw tractors and SPFM are: inability to detect cracks in parts of complex shape; high sensitivity to surface roughness of the details, so you must carefully (time consuming) to prepare a surface that limits mass control; the difficulty of determining the parameters of surface defects and cross.

To identify the bundles in structural elements (corrosive or between layers of dissimilar materials) resonance, bicycle symmetric and impedance methods, the method of free oscillations are using.

Resonance methods based on the occurrence in metal of a controlled longitudinal standing waves. Standing waves occur when external force matches the frequency of the oscillation frequency of the system. Resonance zone by showing corrosion damage, a bundle of thin connections and sheets, measure the thickness of the sheets and the walls of the pipes. Improved designs of resonant devices to monitor wall thickness of 0.5 to50 mm with an error not exceeding 2%.

Based impedance control method laid effect changes depending on the forces of reaction compound (glued or soldered) on the product contact with him (without lubricant) core that varies. Impact resistance (mechanical impedance) controlled facility on a core action determines the stiffness of the whole structure as a whole.

If the bar is located above the zone of faulty connection, the top sheet will fluctuate independently of the lower layers of the material. The rigidity of the top sheet is less than the stiffness of the whole structure, and therefore the reaction force of the sensor is reduced. This force is measured with a special pies element placed at the bottom of the bar. The method used to control glued and welded constructions from metal and non-metallic sheathing and lightweight aggregate in between.

Using impedance devices showing zones breach between the metal sheet thickness to 2,5 mm and non-metallic materials, non-soldered zones between the outer sheet metal and filler cell diameter of about 5-10 mm.

Velocimetric method used to identify stratification in reinforced fiberglass. Its action is based on the change in the speed of bending waves and registration of change of the rate of phase waves at the point of acceptance. The method used to monitor frequencies up to 100 kHz. Use it to find bundles of plastic and breach

zones to a depth of connections 25 mm. The smallest area of defect determination 1.5-2.5 mm^2.

The principle of the method of free oscillations based on an analysis of the dynamic properties of oscillatory systems given that external force depends on the initial amplitude. Other characteristics (frequency and rate of oscillation extinction) – depending on the parameters of the oscillating system: mass, stiffness and mechanical resistance. If the controlled object with defects will be excited free oscillations, the frequency of these oscillations and the rate will vary extinction of the same characteristics of the object without defects. This method of determining the presence of delamination, porosity, unclipped places of non-metallic materials and adhesive bonding. The thickness controlled parts of 2-3 cm.

The method of Hlandy figures is based on creating in controlled object powerful bending vibrations given or variable frequency with simultaneous visualization controllable surface oscillation pattern by drawing on her finely dispersed powder. If sufficiently strong fluctuations powder surface of the object begins to move and gradually shifting to sites fluctuations, paints a picture of the distribution of nodal lines (figure chill). Operating frequency range is about 30-200 kHz. Its sensitivity is high enough. In multilayer product of the thickness of the top sheet 0.25 mm defects length 1.0-1.5 mm are detect.

It should be noted that the above methods are difficult to apply in the production (in the agricultural sector repair shops), given the large range of tractors and parts SPFM to be defectoscopic control and the need for frequent regulation of equipment.

In the electromagnetic-acoustic methods ultrasonic vibrations resulting from the interaction of constant and alternating magnetic fields with metal of controlled object. This method was also suitable for the general control of parts of tractors and SPFM, which used to manufacture steel and alloys of varying permeability.

Methods capillary flaw can detect with the naked eye fine surface cracks and other discontinuities in material produced during the manufacture and operation of the machine parts. Fluorescent color and flaw detection method using the phenomenon of capillary penetration of liquids with high wetting characteristics in cracks, pores and other surface heterogeneity. Capillary flaw detection based on artificial increase of light and color contrast of defects on intact areas controlled areas of metal.

These methods are not effective for control of parts of the rough surface and inapplicable to verify porous materials. Disadvantages of them are the need for removal of protective covers and duration control process (several hours), low probability of defects in materials with significant compressive residual stresses. All this imposes significant limitations on the use of capillary repair methods in units of agricultural enterprises.

The method of capillary flaw can be used for quality control blanks and components made from any non-magnetic materials, non-ferrous alloys, plastics, ceramics, except for materials with a porous structure.

Sensitivity capillary flaw determine the size of defects to be detected. Lower limit of sensitivity is different discontinuities deadlock with a width of less than 1 micron disclosure, the top – no more 0.4 mm any length. Defects of the width of opening and design with a rounded bottom, the depth does not exceed 70-80% of its width, not recommended to detect using capillary flaw detection through intensive leaching penetrants defects of metal.

Method of metal magnetic memory – a type of control based on the detection of magnetic stray fields occurring around defects. Apply magnetic powder, magnetic graphic, ferro probe and induction methods, galvanic magnetic and other methods of display fields scattering. Most engineering companies main method of detection of surface and subsurface defects in metal parts are powder magnetic method. On the railways and steel mills use induction and flux-gate methods.

Magnetic flaw detection is based on a study of distortion of the magnetic field arising in the field of defects in products made of ferromagnetic materials. For the study used magnetic powder (oxide – iron oxide) or a suspension in oil dispersion of particles 5-10 microns. During magnetization powder products deposited in the locations of defects (magnetic powder method). Magnetic particle method can detect cracks and other defects to a depth of 2 mm.

Field dissipation can be fixed tape that is placed upon the investigated area magnetized object (magnetic method). This method is mostly controlled welds pipe thickness to 10-12 mm and show them thin cracks and lack of penetration.

Using of magnetic graphic method can determine the scattering field arising around defects, magnetized of magnetic media in the residual magnetic field controlled object. The process involves controlling magnetization zone controlled weld, recording flows scattering on the attached magnetic graphic tape, and then play back recorded on tape signals from defects. The method can detect lingering defects (cracks, lack of penetration, chains and clusters slag inclusions). Restricting the use of the method is that the height of the strengthening welds should not exceed 25% of the thickness of the base metal products. Irregularities on the surface of joints should also not be more than 25-30% of the height gain.

Magnetic graphic method found application mainly for quality control of welds during production pipelines. Can detect cracks and lack of penetration depth of 10% of the wall thickness and larger chains gas pores and large slag inclusions.

As a method of magnetic flow indicator scattering in magnetized controlled object using winding inductance. Effective use of induction method to control hot rolled pipes, steel bars without scaling. In such cases, the cracks show depth from 0.2 to 0.3 mm.

Using magnetic powder flaw detect surface defects and defects to a depth of 2.0 mm under the surface. The sensitivity of the method greatly depends on the quality of the applied powder, orientation of magnetic field configuration controlled

facility. This method is effective enough to detect all sorts of cracks, but it is difficult to use under conditions of repair enterprises of agriculture.

In the method ferro probe using small sensors (ferro probe) that when driving on a controlled object in place to replace the defect indicating pulses, which is registered on the oscilloscope screen. Ferro probe most appropriate method to detect defects at a depth of10 mm and in some cases, 20 mm products in the correct form. This method allows fully automated monitoring and sorting out.

Electromagnetic method is used to determine the physical and mechanical properties of the parts made of magnetic material and registration of fatigue cracks. In a controlled object detection of defects is due to the interaction of alternating and constant magnetic fields of metal. Mainly as a source of electromagnetic field using a flat spiral winding as well as the source of the magnetic field – electromagnet. Magnetic flaw detection methods found predominant use for stationary laboratory and factory.

Electromagnetic flaw detection is based on detecting changes in the eddy currents in a controlled objects created alternating magnetic field sensor flaw. With help of induction flaw detector can detect lack of penetration and cracks in welded joints rods and cables that are used in lifting devices. However, the main branch of the use of these devices is fixed plant and laboratory conditions.

In the thermal method (method of infrared radiation) is used after radio wave method frequency range, i.e. wave length 0.8-10 mcm. Thermal imager responsive to small temperature difference (a few tenths of a degree).Regarding control of parts of tractors and SPFM using thermal methods without proper surface preparation and removal of coatings on them (degreasing, grinding rust, paint) ineffective.

Thermoelectric flaw detection is based on measuring the electromotive force (thermal electromotive force – thermal EMF) that there is a vicious circle by heating the place of contact of two different materials. If one of these materials

are considered as a reference, then for a given temperature difference between the hot and cold contacts size and sign thermal EMF will be determined by the chemical composition of a material. This method is mostly used when you need to determine grade material, which consists of a product or element of design.

Tribo electric flaw detection is based on measuring the electromotive force that occurs when the friction of dissimilar materials. By measuring the potential difference between the reference and tested materials, can discern certain brand alloys.

The method of electric potential is one of the easiest flaw methods that allows you to measure the depth of the curved surface cracks, that is to investigate the kinetics of its shape. Its drawback – the relatively low sensitivity.

The method uses electrical resistance to detect discontinuities in metal parts, determining the depth of cracks, recorded in other ways, revealing pores in paintwork surfaces.

Electric method used in rail flaw. In the electrical industry with this method quality control of soldering connections conductive high electric vehicles, including electric compensation winding of dc electric machine, rotor winding of turbine generators, inter polar jumpers of hydro generators.

So, generalizing methods analyzed flaw, it should be noted that the optical and capillary methods that are widely used in engineering, do not allow to detect internal defects. The most common practice now in maintenance departments farms visually-optical control method compared to other parts characterized by low sensitivity, low reliability and authenticity of defects.

Opportunities to find defects in material or inaccessible side components for most methods are limited flaw, it is used mostly acoustic, and radiation Eddy current methods. But radiation techniques, including the most common radiographic provide for the use of X-ray and gamma radiation, and therefore cannot always compete with ultrasonic method.

To control the machine parts and structural components without removing them from the machine and cut the most widely used methods Eddy current and ultrasonic flaw detection [15, 16]. But the efficiency of a particular method of detection is the ability to determine not one, albeit very important parameter, and their complex, which ensures safe and reliable operation of machines and structures suitable for the economic costs of flaw detection. The most important parameters that determine the efficiency of a method of detection is the sensitivity and accuracy of the method, the ability to detect defects without removing parts of the machine without training or controlled surface complexity and cost control, productivity.

Currently, there are two trends to improve methods flaw. The first is a complication, automation, computerization NDT devices. So, the method of study of the morphology and microstructure of fatigue cracks based on the use of laser scanning microscopy to measure the depth and shape of the front of a short (15-65 microns) cracks. The basis of noncontact measurement system for the rapid determination of the existence of fatigue cracks in a controlled facility is long focus microscope with a special camera and a personal computer. This complicated laboratory equipment that requires precision installation and maintenance, preventing adverse effects on equipment conditions of the production environment.

These complex hardware systems used primarily in the case study model sample material without the real conditions of loading of structural elements. Most of them involve special methods of preparation surface samples.

For a practice of defectoscopic control over the conditions of agricultural production is recommended portable flaw of modern means of registration, storage, processing and analysis of defects parameters in controlled facilities [17-19].

1.3. Substantiation of whirlwind stream method for the detection of emergency dangerous cracks in detail units of tractors and other mobile agricultural equipment

Now the problem of reliably forecasting resource exploitation critical structural elements of mobile agricultural machinery at the stage of designing and residual life on the stage of operation given much attention in all industrialized countries.

Most methods of assessment and calculation of strength hardware resource element refers structural defect-free structures. Given the high concentration of stresses in welds areas, the availability of technical defects, specific operational loading, damage stage (development defects of the original size to the critical value) in most cases is crucial to assess the reliability of support basic and functional systems and describes the work resource of the machine general [20-22].

The task of ensuring the operational reliability of parts and structural elements of mobile agricultural machinery is among the most important in modern agricultural production. to reduce the duration of unpredictable downtime agricultural units due to technical problems and to avoid accidents with severe consequences, you should increase the requirements for diagnosing the technical condition of structural elements of mobile machines and tractors [23].

Detecting the presence of operational damage to hardware structure is complicated and time consuming process, which provides for many consecutive operations. Thus, the method of determining the state of the bridge crane erection provides a controlled cleaning the surface area of the crane, the magnetization of the metal, causing the emulsion, visual inspection of the presence of defects in the structure of the metal, the metal determination and others.

Research of damage of metal constructions showed that damage reliably control of metal constructions provides a comprehensive approach to the analysis

of damage, namely Eddy current and acoustic methods and method of electric potential. A comparison of the reliability of these methods showed that the smallest errors characterized by Eddy current method [12].

Vortex currents in metals resulting from exposure to electromagnetic alternating or moving magnetic field. Sources converters and electromagnetic fields are windings of inductance – inductors, so this equipment is called induction. According to the law of electromagnetic induction relative movement of the magnetic field and the body, which is current in the body leads electromotive force. If a closed electrical circuit, the current flows in it. Depending on the shape of the body and controlled task using overhead, checkpoints and screen sensors, coils are fed with alternating current wide range of frequencies.

Eddy current method (ECM) is based on registration of changes in the electrical magnetic field eddy current, which excitation winding results in electric conductive object control. The intensity and distribution of eddy currents in the object depends on the geometry and electromagnetic parameters and the relative position of the measuring Eddy current transducer (ECT) and the object. As inductive transducer windings are using (one or more). Sinusoidal or pulsed current that flows in winding of ECT creates an electromagnetic field that excites vortex currents in the electrical conductive object. The electromagnetic field eddy current effect on winding of converter, giving them electromotive force (EMF) or changing their impedance. Registering voltage at the terminals of winding or their resistance, receive information about properties'

Useful information about the controlled object includes the effective electromagnetic field. The resulting signal depends on the availability and location of discontinuities, which increases the eddy current path from the electrical conductivity (electrical conductivity), permeability, hysteresis loop area, shape and relative position of the source field and controlled object, frequency and test current form.

EMF (or resistance) converter depends on many parameters of control objects, that is, its information is multi parameter. This determines the advantage and difficulties implementing of ECM. On the one hand, ECM ensures multi parameter control; on the other hand, require special methods for isolating information on individual parameters controlled object. If one of the parameters controlling influence on other signal converter is harmful, and this influence should be reduced.

Another feature of the electromagnetic control is that it can be done without contact transducer and the object. Their interaction is usually at distances small but sufficient for free movement of the transducer on the object (from a millimeter to several millimeters). Therefore, this method allows defectoscopic control of high speed control objects. Getting information about availability of damage to metal in the form of electrical signals, contactless and high performance ECM identify opportunities for automation control. In addition, one of the features of the ECM is that the signals do not affect humidity, pressure and gas environment, radiation, contamination of surface control object of non-conductive substances.

The advantages of ECM also include simple design of the converter. In most cases winding placed in a safety casing and poured compound. Because of this, they are persistent to mechanical and weathering, can work in the aggressive environment in a wide range of temperatures and pressures.

ECM characterized by small depth control zone, defined penetration depth in the controlled environment of electromagnetic field limiting detection of defects (damage) in the deep layers of metal. However, the application for the ECM low frequencies can detect defects as deep or detect material defects surface, if the surface is covered with metal or dielectric.

The depth of penetration of the eddy current depends on the shape of the excitation source, the frequency of electromagnetic waves, electrical conductivity, magnetic permeability, shape and size of the controlled object. Low-vortex currents penetrate more deeply into the metal, high-limited to a thin surface

layer of metal. With increasing frequency excitation field, increasing the conductivity and permeability most of the electromagnetic field is reflected from the metal as well as light rays reflected from the mirror. So the heat loss in the metal are reduced. A relatively small frequencies or for testing materials that conduct electricity poorly, the value of the field and reflected the loss of heat in the material will be minimal.

Vortex currents round the obstacles in the form of cracks and other discontinuities. Then symmetry, amplitude and phase of the secondary magnetic field change. This field interacts with the field excitation is then formed resultant field whose parameters can inform about the nature of the defect, the electromagnetic characteristics of the material, the distance to the object of control, change the shape and size of objects control.

The magnitude of the eddy current effect relative position of winding and control detail; their shape and size, the presence and thickness of the protective cover. The availability of parts (metal) defects can have an idea of the change in amplitude and phase current in excitation winding or receiving winding. Often this is used the same winding (in which case it is called parametric converter). On the results of the tests are judged by the change of components of complex (complete) resistance of parametric winding [27].

Vortex currents excite by sinusoidal alternating or pulsed electromagnetic field, wandering or rotating field, variable frequency field. Measured or compared amplitude, phase natural frequency signal, estimated spectral composition, duration and rapidity of the front pulse and so on.

During the interaction of the eddy current transported to a defect arises "modulation" effect. In this case, information about the existence and nature of the defect evaluated by size or shape detected signal.

In the present work to identify operational and technological defects in design details and elements of mobile agricultural machinery have been developed portable Eddy current flaw. The structural scheme of this flaw is shown

in Fig. 1.2. Wiring diagram defectoscopic device structurally consists of the following modules and assembly units: the main unit (base unit) and remote module of sensor of crack (can be variable for different research tasks). Modules integrated in electrical circuit boards, located in the base unit.

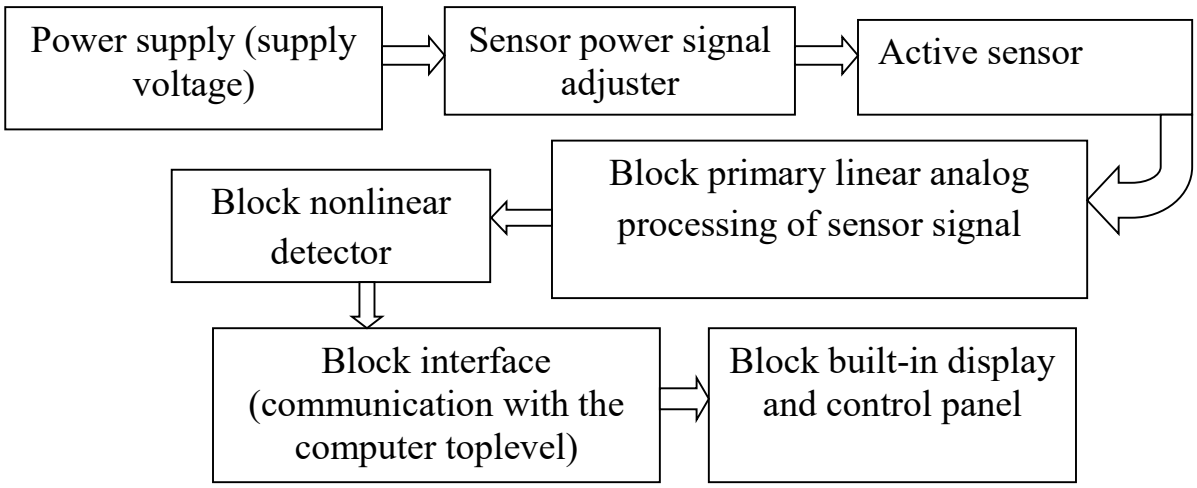

Fig. 1.2. Block diagram of defectoscopic device

Based on analysis of published data and previous studies found that cracks should be used with the sensor of a flaw geometry consistent with a form of metal that avoids harmful effect on the measurement of irregular shapes scanned surface metal surface. Designed defectoscopic device operates on the physical principle of interaction of electromagnetic fields with ferromagnetic and diamagnetic materials, construction elements parts and components farm machinery.

Power and converters of electromagnetic field of device can perform both structurally as inductor winding, transformer type sensors or semiconductor sensors. Depending on the form of controlled object and task used overhead, checkpoints and screen sensors, which feed winding alternating current of wide range of frequencies up to 250 kHz. Amplitude-time parameters of the electric field, the above Eddy current sensor device in probed metal surface, depends on the size of a mechanical defect that is covered by the secondary vortex field. These

changes can analyze hardware and get some information about the geometric parameters of cracks in damaged controlled facility.

The design of the sensors of developed defectoscopic device used type of sensors designed according to the requirements of control, based on the size and shape controlled tractor parts and their availability for the flaw, the location of the node, type and orientation of possible defects and speed control.

Conclusions to Chapter 1

1. Analyzed circumstances of the accidents that have occurred in recent years on the road because of defects in vehicles and tractors and during repair work mechanization. Established a direct link of agricultural technical units and vehicles with risk of injury mechanics. It is noted that often causes injuries to the technical background of organizational seen as related, without specifying them as definitive documentation for the investigation of accidents.
2. Most of the known methods for fault detection can only detect defects in laboratory conditions, the size of which is much less critical, leading to the destruction of machine parts and structures in operation. But their use for the production conditions leads to significant difficulties in placing defectoscopic equipment, reliability obtain data on the location and size of defects. Therefore, the need of the method of detection of damage in the early stages of their development as a basis for predicting the residual life of equipment after prolonged use, including mobile agricultural machinery.
3. Current control methods of machine parts and structural components primarily based on Eddy current and ultrasonic flaw detection method. Found that the most appropriate for their practical adaptation in solving problems continued designated resource of agricultural machinery and is therefore particularly promising is the use of electromagnetic resonance techniques flaw characterized by particularly selective about available small defects such as cracks.

CHAPTER 2. RESEARCH PATTERNS OF ACCUMULATION OF OPERATIONAL DEFECTS IN THE SAMPLES OF METAL

2.1. Functional specifications developed portable eddy current flaw

In the present work to establish patterns of accumulation of operational damage to metal ware used data on the availability of operational cracks in the array of parts tractor units. For crack detection using portable eddy current flaw (Fig. 2.1) developed by National University of Life and Environmental Sciences of Ukraine together with the G.S. Pisarenko Institute for Problems of Strength, National Academy of Sciences of Ukraine.

Fig. 2.1. Appearance advanced pulsed Eddy current flaw

This portable flaw to detect cracks in the details and controls of agricultural equipment satisfies the requirements related to the specific details of the control units of tractors and SSM. The main ones are:

– small size (200×100×30 mm), lightweight (0,6 kg), Autonomous power supply (battery capacity of at least 1000 mA h);

– simplicity, ease of use and maintenance;

– versatility studied on metal parts (automatic settings to control metal objects);

– informative about the presence of damage investigated detail (the smallest size detected cracks: depth – more 0.2 mm; length – more 3 mm; width – more 0.1 mm);

– to vary the sensitivity (the ability to set the minimum size of defects);

– no need for special training controllable surface details (flaw practically not sensitive to surface roughness and is able to detect defects on the surface roughness R_z 60 or less);

– lack of edge effect, the effect of removal of the sensor, wear sensor;

– cracks at the maximum gap between the sensor device and tested surface to 3 mm;

– wide temperature range environment (+5 to +40 °C);

– wide range of environmental relative humidity (40-80%).

Device used in this technical solution can detect defects such as cracks, sinks, discontinuities, corrosive ulcers, stratifications in the surface layers of ferromagnetic and nonferromagnetic conductive material and defects during Paintwork or other cover. It is important that the built-in rechargeable battery device supports device without recharging within two working weeks, allowing the use of the device in field conditions and in maintenance departments of agricultural enterprises.

This portable flaw has the ability to switch the range of sensitivity and selectivity of the device, it is possible to detect cracks larger dimensions are a certain size, which is especially important flaw parts and components SMS.

It was determined Eddy current flaw hardware capabilities, including linear zone defined depending on the electrical signal from the sensor flaw crack length.

Having stated linearity allows reasonable set of parameters flaw duration triggering signaling the presence of a certain length cracks in the surface layers of the material.

To determine the location of cracks on the surface of parts or design element you want to move a contact sensor flaw in the zone of possible occurrence of cracks. The distance from the sensor to the sample surface while scanning the surface can vary within certain limits (1-3 mm). That defines the established range of measurement sensitivity flaw. During the study, the sensitivity of flaw on changing the crack length distance from the sensor to the sample surface should remain unchanged. Therefore, the installation area linear dependence of the electrical signal from the sensor flaw crack length method was used when the sensor is rigidly fixed on a certain spot control sample, where the conditions for the emergence and spread of cracks.

These studies were performed on samples of titanium alloys VT1-0 and PT-7M and aluminum alloy AMG6N. Standard samples were used for fatigue testing along the working part of which suffered two symmetrical longitudinal width coots 6 mm each (Fig. 2.2). Flat on surface of samples previously polished mechanically and then performed electro polishing to be able to determine the length of the crack using metallographic microscope.

To achieve crack nucleation in a given workplace of samples, their surface in the median section of one of flats using a diamond pyramid of hardness micro tester PMT-3 pressed so that the indentation diagonal pyramids were oriented along the axis of symmetry of the sample. Efforts pressing a diamond pyramid to sample surface selected so that the length of the diagonal imprint on the surface of the sample was1 mm.

As diamond indenter pressed on a flat, equally prepared surface coots sample of some of each alloy the load, and the orientation of the print on the longitudinal axis of the sample was also unchanged, for all sample size of the

initial defect (representation) should be considered the same, confirming measurement deposited prints using an optical microscope.

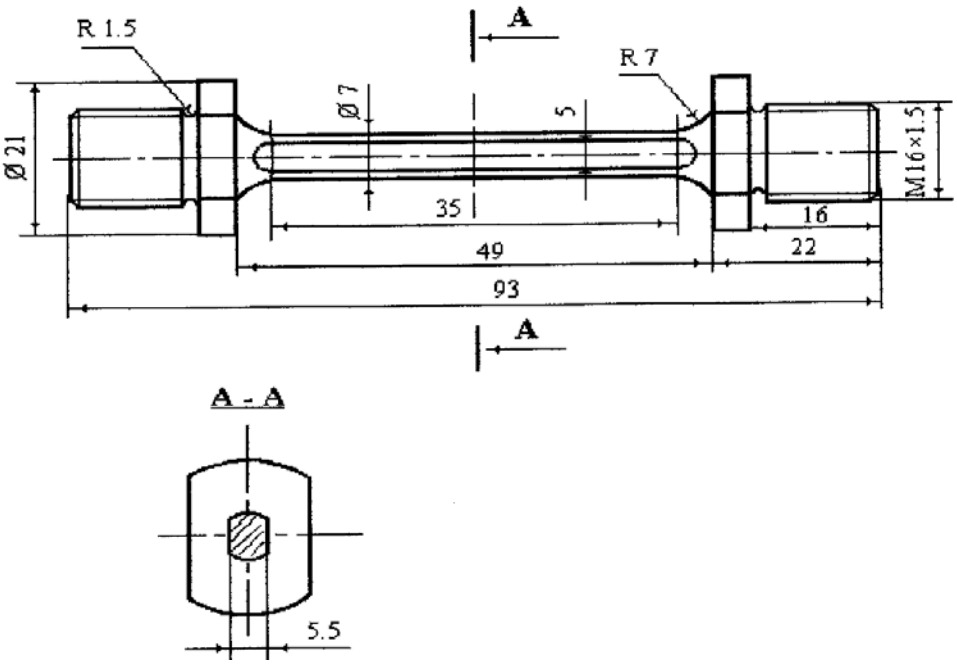

Fig. 2.2. Drawing a sample of gloss for fatigue tests

Fatigue test samples coated with the reflection carried out by uniform tension – compression testing machine to electromagnetic type «Amsler» cyclic loading at a frequency of 100 Hz. Over a distance of reflection1 mm coots set of surface flaw detector with a diameter face surface 2.5 mm. For precise sensor of the pyramid reflection mechanism of three-axis precision displacement used.

According to the established system of Eddy current Eddy current flaw defect indicating the extent of the crack characterize changes of the electrical signal from the sensor flaw. This electrical signal proportional to the electrical resistance of eddy current in a controlled sample volume. Un Entry level electrical signal sensor for all tested samples set at a level consistent with relatively defect-free material (without the presence of a print cracks).

If after a period of cyclic loading sample level electrical signal of the sensor changed by a certain amount from baseline ($\Delta U = U_i - U_n$), the test was

terminated, the specimen removed from the testing machine, and then measuring the length of the fatigue crack using metallographic microscope MIM-8 (increase ×200).

If cracks developed from both corners print, for constructing a calibration depending took into account the total length of two oppositely oriented cracks. You need to set the minimum length of the crack, which was able to determine, following test method as described, was 0.1 mm.

Then again, like fixed delighted testing machine, a reflection of the indenter on the same as in the previous step tests, set a distance sensor. If necessary, corrected initial level, its value must equal the magnitude of the signal at which completed the preliminary stage test), and then continued loading cycles like the previously established level of cyclic stress.

Estimate of resolution of the proposed method can graph in Fig. 2.3, where coordinates: fatigue crack length l – relative (normalized) change in the electrical signal of the sensor U/U_{op} presented results of the regression line phased determine the length of fatigue crack all the samples of alloys.

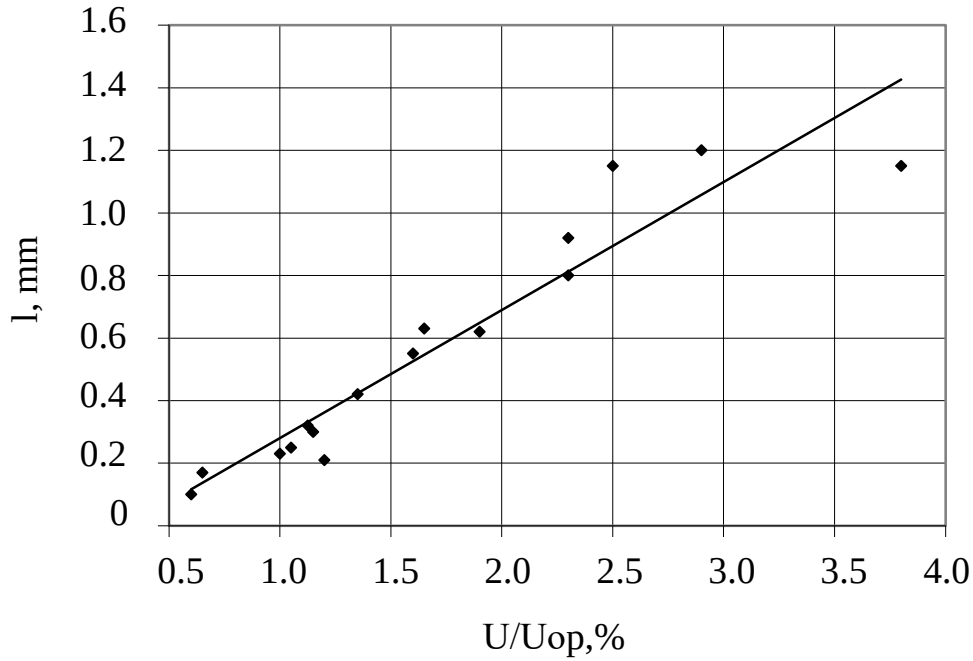

Fig. 2.3. Relative change the electrical signal from the sensor eddy current flaw crack length

A graph describing the flaw sensitivity to the changing length of the crack. Scatter of experimental points with regard to approximating line related with different electrical conductivity alloys and studied material misstatement path length over cracks 4 mm. The resulting graph to determine the lower limit of detection of cracks using the proposed method, the relative change in signal level from the sensor flaw responsible for 1% change in crack length 0.2 mm.

From experimental data on the location of the approximating line can conclude about linear dependence of the electrical signal from the sensor Eddy current flaw crack length in the investigated wavelength range.

The reliability of test results determine the sensitivity degree of detection of cracks and repeatability of results. It is based on careful calibration devices employed.

Prior studies defectoscopic parts and structural elements is mandatory verification of flaw in control samples. Control samples received cracks in sheet metal alloy samples as a result of the spread of fatigue cracks from stress concentrators made on the edge of the sample. Cyclic loading of samples was carried out by the stress concentrator uniform tension – compression testing machine to electromagnetic type «Amsler» cyclic loading at a frequency of 100 Hz. It is specified using a technique able to get cracks of varying length, including a length of less1 mm. Without plastic deformation of the metal in the crack tip that might prevent a precise definition of the lower range of sensitivity Eddy current flaw.

Controlled crack length grown using an optical microscope MBV-9, mounted on the guide supports testing machine. It received a number of discrete values of crack length in the range of 0.5 to 5.0 mm on leaf samples and aluminum alloy structural steel (Fig. 2.4).

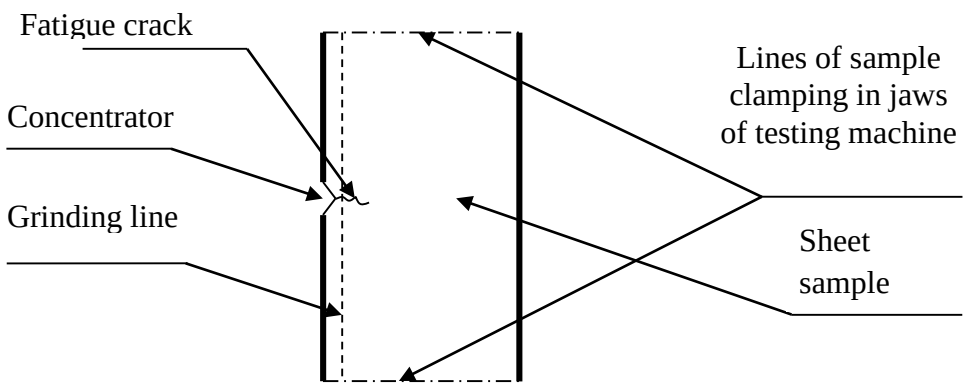

Fig. 2.4. Chart control sample with crack given length

In order to avoid the influence of the sensitivity Eddy current flaw primary hub designs polished caused by the hub on the grinding machine to extinction hub. After re-measuring the length of cracks microscope BMY-1c cracked samples were used as controls for the study of the sensitivity threshold device (determining the minimum cracks, which signaled the presence flaw).

Studies hardware parameters of eddy current flaw was performed on samples of control nodes and details of wheeled tractors. During the studies used control samples, which suffered cracks of different lengths, BMY-1c microscope, micrometer MG, set the dielectric plate device MIP-10, conductivity meter B-20.

2.2. Classification details tractor units on the boundary cracking

To specify objects defectoscopic control and narrow the cracks available details of individual units of tractor was separated into several categories:

1) highly tense parts with a high probability of destruction;

2) details the technical condition which is caused by the cumulative effect of power factor with aggressive environmental conditions;

3) the parts that undergo small damaged action;

4) parts which show damage only visually (small, non-metallic, etc.).

In the proposed methodological approach was not considered a potential crack an unconcern and damaged third and fourth categories of components: fasteners, rubber, nonmetallic more.

Set of operational documents for tractor duration of its use in a calendar year is difficult, mainly because we know only the year. Therefore, the relative lifespan tractors are based on the following assumptions.

In this paper defectoscopic control units conducted parts for the tractors, which for some time been involved in mechanized and transport works, were loading force that led to the emergence of operational cracks. Some of these defects were discovered during repairs of tractors disassembling units. It is believed some degree of certainty, that all tested tractors were one model year to operate the same period. As the base was chosen 17-year lifetime of tractors twice their design life [16].

From the published data we know that the cracks that lead to accidents and failure of tractors and agricultural machinery, occur in the engine, hinged system, cardan transmission, chassis and other sites. Summarizing the literature data on the presence of cracks in engine parts and given the conditions of the diesel engine and place stress concentration in detail to defectoscopic control was proposed following the tractor engine parts:

1. Details of the crank mechanism: bolt and crown flywheel, flywheel, piston, connecting rod bushing, finger crankshaft, counterweight rod cover, pulley, cog-wheel of occasion ester drive pump.

2. Details of the mechanism gas of distribution: leading to cylinder block, intake and exhaust valves, bushings, plates and cover valves, rocker, distribution gear shaft drive the fuel pump and the crankshaft, the intermediate gear.

3. Details lubrication system: oiled sump, pump casing olive, finger driven gear, top gear and the knowledge, trunk lid, gear and shaft drive pump pin.

4. Details of the cooling system, water pump shaft, spline, pulley, corps water pump and thermostat.

5. Details of the power supply system, fuel tank, fuel pump housing, spun.

6. Case details: block cylinder, cylinder head, main bearing caps, bearing crankcase, cylinder liners, front support.

After the destruction of these and other engine parts tractor accidents can happen, which is presented in the block diagram in Fig. 2.5.

Brief note and details of other nodes tractor recommended by defectoscopic control. Thus, by controlling defectoscopic were offered the following details gearbox tractor:

1. Pinions.
2. Gear (primary, intermediate, mid).
3. Fork.
4. The axis of the intermediate gears.

By defectoscopic control was proposed following details steering tractor:

1. Steering, intermediate, middle and front rollers.
2. Pipe steering column.
3. Ear-ring.
4. Universal joint.
5. Stand.
6. Intermediate support.
7. Castle-type sleeve.
8. Post.

After the destruction of these and other details of steering system of tractor accidents can happen, which is presented in the block diagram in Fig. 2.6.

By defectoscopic control was proposed following details rear axle:

1. Shafts.
2. Pinion.
3. Axis.

4. Cross-piece.

5. Shells.

By defectoscopic control was proposed attaching the following details:

1. Upper thrust.

2. The rotary shaft.

3. The rear end of the rods.

4. Ear-ring.

5. Ties.

6. Lower link.

7. Arms.

8. Lever cylinder.

9. Right brace.

10. Leading and slave gear.

11. Cross-bar.

12. Fork.

13. Screws.

After the destruction of these and other details of attaching a tractor accidents can happen, which is presented in the block diagram in Fig. 2.7.

In this paper, for each of the studied systems (nodes) were suspended tractor singled out parts of small, medium and large sizes.

By small engine parts include: valves, piston pin, bolt flywheel cover the connecting rod, connecting rod bushing, bolt flywheel cover the connecting rod, connecting rod bushing, bolt flywheel cover the connecting rod, connecting rod bushing.

Up to medium size parts include engine, connecting rods, pistons, crankshaft gear, crown flywheel counterweight pulley, gear distribution shaft, intermediate gear, body olive pump, led gear, gear pump drive shaft pump drive gears, main bearing caps, bearing case, the front prop shaft water pump, building water pump housing thermostat housing the fuel pump.

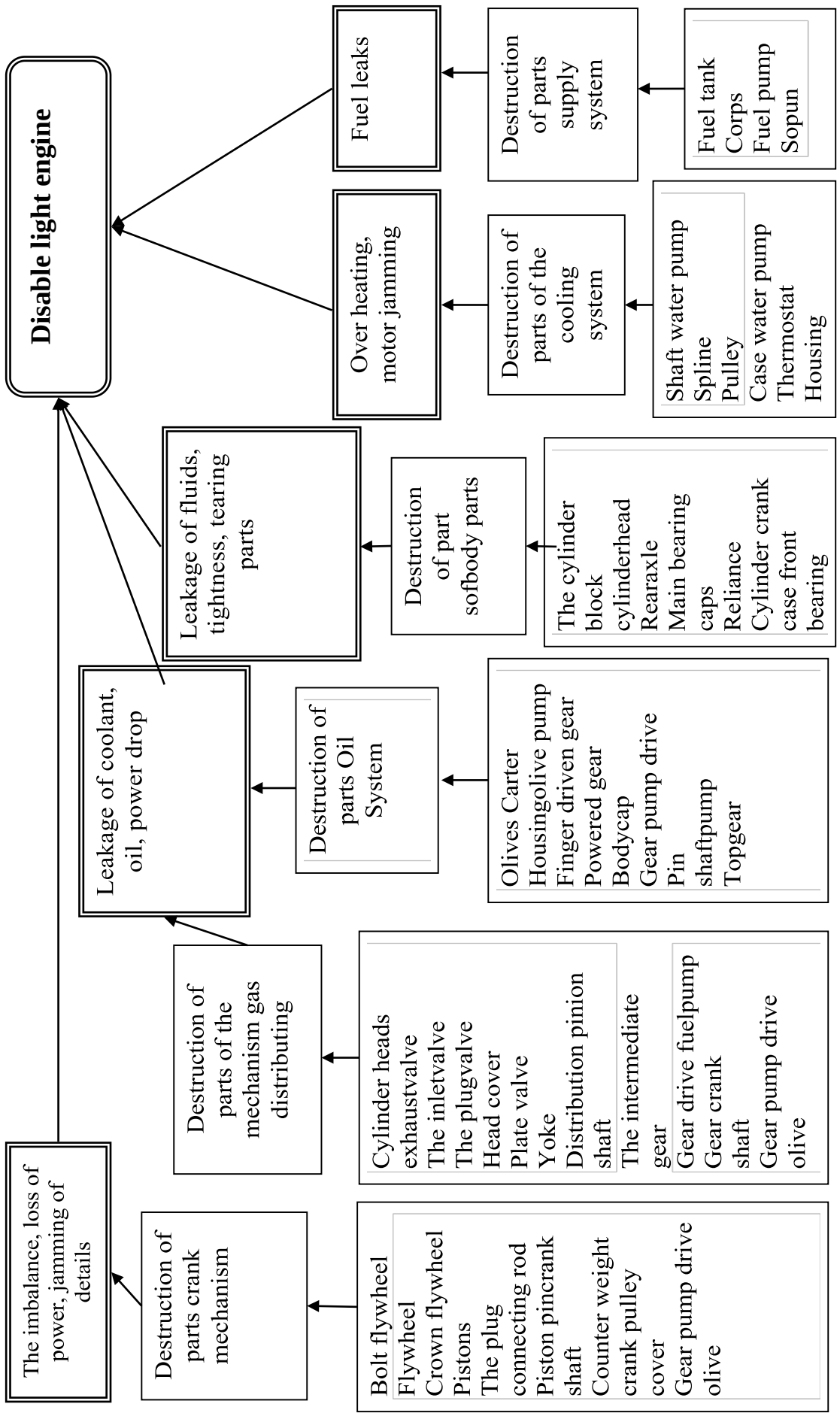

Fig. 2.5. Block diagram creation through destruction emergency engine parts tractor

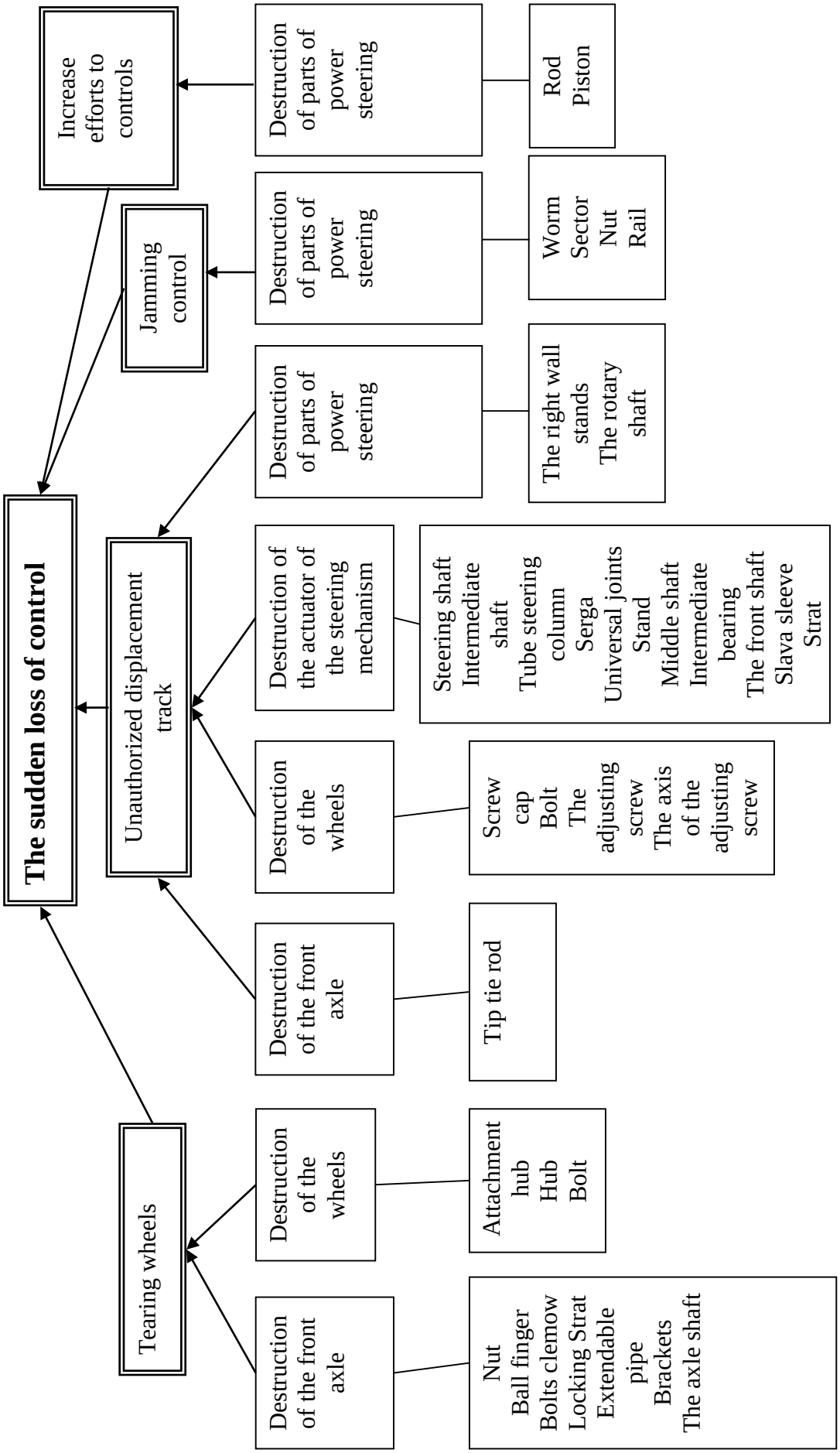

Fig. 2.6. Block diagram creation through destruction emergency steering system parts tractor

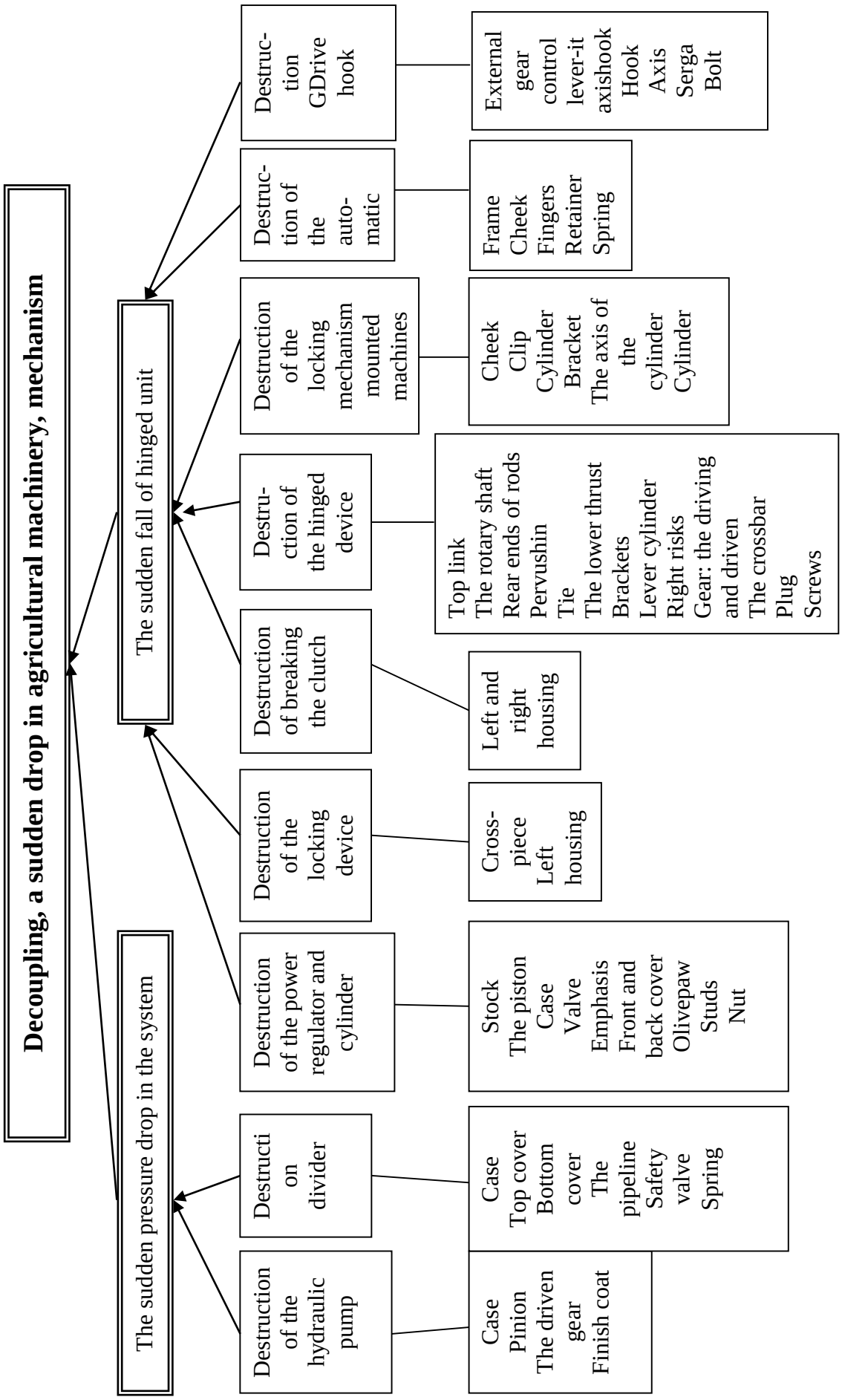

Fig. 2.7. Flowchart creating emergencies through the destruction of parts attaching tractor

By large parts of the engine include: flywheel shells, block, block crankcase, the cylinder head. flywheel, crankshaft, cylinder head, head cover, oiled crankcase, housing cover, cylinder block, cylinder head, cylinder liners, spun.

By small parts steering include: fry, turning lever, earrings, nut, ball finger bolt clamps, locking pin, investment hub, hub, bolt, screw cap, screw, adjusting screw nut.

Before details of medium size automobiles are: steering column (shaft), building power steering, intermediate shaft, intermediate shaft, front shaft tip tie rod axis adjusting screw, universal joint, stable, intermediate support, castle-type sleeve, pin, right wall rack, worm sector, rail, rod, piston.

By large parts of automobiles include: tube sliding, arms, axes, pipe steering column, steering shaft, rotary shaft.

By small parts hanging hydraulic system include: bracket tie, tie, adjusting clutch, fork, top gear, led gear rod, piston, valve, cross, arm cylinder and slave gear traction, crossbar, bracket, bracket cylinder.

Before details of medium size hydraulic hanging system include: the axis of the lower rods, brace, loose arm cylinder body of the hydraulic pump lid, the upper lid, lower lid, pipeline safety valve, focus, front and rear mercury oil track, pins, nut, left and right housings, screws, cheek, the axis of the cylinder, cylinder, finger lock, earrings, external gear control lever

By large parts hanging hydraulic system include: central thrust (top). lower link, rotary shaft rear end traction, castle-type, ties, brackets, right brace, fork, frame, axle hook, hook axis.

On the basis of separation of parts size cracks were detected symbols as small, medium and large depending on their relative size on the dangerous section details which it may collapse. During defectoscopic control every detail tractor units flaw sensitivity range changed so as to detect cracks of more than 2.5 and 7 mm. Depending on the size of the dangerous section details revealed cracks

were classified as small, medium and large. This allowed the next section to offer method of estimating probabilistic risk indicators tractors operating on the basis of the control of units defectoscopic tractor.

2.3. Results defectoscopic control different parts of tractors of release

Results defectoscopic control of the developed Eddy current flaw of details of wheeled tractors of different years of production availability of an array of operational cracks are presented in Table of Annex 1-5 and summarized in Table 2.1.

Table 2.1

Summary results defectoscopic control of parts wheeled tractors of different years of release

№ p/p	Host name tractor	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								To-gether
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
Steering										
1	Cracks found	10	20	10	23	10	13	12	8	114
2	Inspection details	22	47	18	43	27	41	48	40	303
3	The relative number of defective parts	0.45	0.42	0.56	0.53	0.37	0.32	0.25	0.2	

Continues Table 2.1

№ p/p	Host name tractor	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								To-gether
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
Attaching										
4	Cracks found	3	18	7	22	9	10	10	9	95
5	Inspection details	8	48	15	55	29	34	38	39	278
6	The relative number of defective parts	0.4	0.37	0.46	0.4	0.31	0.29	0.26	0.23	
Engine										
7	Cracks found	4	22	11	17	10	16	9	7	108
8	Inspection details	7	45	23	38	26	50	29	28	263
9	The relative number of de-fective parts	0.56	0.48	0.47	0.44	0.39	0.32	0.31	0.25	
Back axle										
10	Cracks found	6	16	7	14	9	8	7	8	80
11	Inspection details	13	43	20	41	27	25	23	30	232
12	The relative number of de-fective parts	0.46	0.37	0.35	0.34	0.33	0.32	0.3	0.27	

Continues Table 2.1

№ p/p	Host name tractor	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								To-gether
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
Transmission										
13	Cracks found	12	11	5	8	9	9	9	7	81
14	Inspection details	29	35	16	25	31	32	42	39	273
15	The relative number of defective parts	0.41	0.31	0.31	0.32	0.29	0.28	0.21	0.18	
Cracks found		35	87	40	84	47	56	47	39	435
Inspection details		79	218	92	202	140	182	180	176	1269
The relative number of defective parts		0.44	0.39	0.43	0.41	0.33	0.3	0.26	0.22	

Overall defectoscopic control was performed on 1269 details of tractors, which was discovered 435 cracks.

The kinetics of accumulation of cracks in parts and assemblies of wheeled tractors of different duration of operation shown in Fig. 2.8 and Fig. 2.9.

Coordinates schedules are as follows: the vertical axis – the probability of critical state P $=n_d/N$ (ratio of detected cracks n_d in the total population studied, significant in terms of limit state security service, parts N); x-axis – relative durability D = t_{eks}/t_{baz} (attitude lifespan tractors t_{eks} on the base t_{baz}, that in the calculation of 17 years).

Experimental data for individual operating ranges of tractors describes exponential trend line type. Fig. 2.8 and Fig. 2.9 also recorded their reliability equation and fitting R^2.

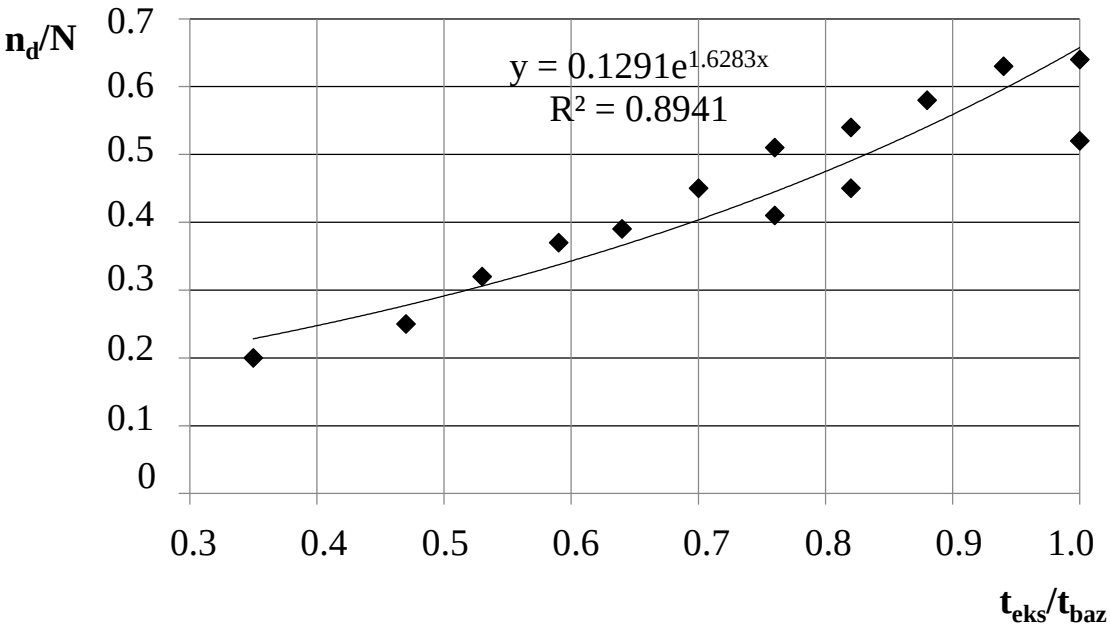

Fig. 2.8. Kinetics of accumulation of cracks in detail steering system of wheeled tractors of different lifespan

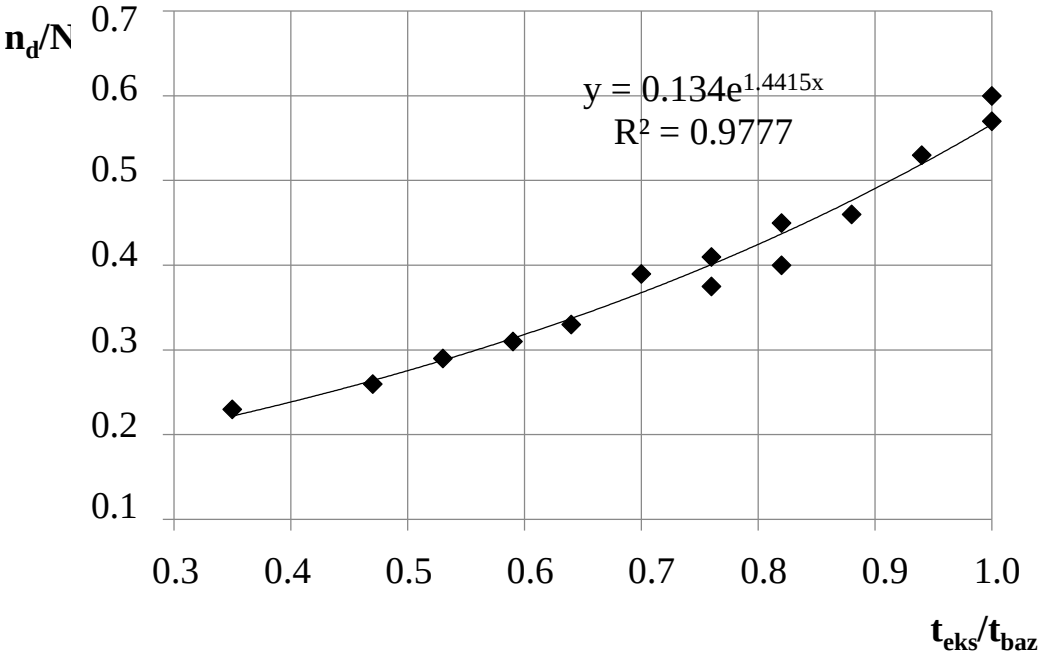

Fig. 2.9. Kinetics of accumulation of cracks in the attaching details of tractors of different lifespan

Shown in Fig. 2.8 and Fig. 2.9 depending for kinetics accumulation of cracks in parts (units) tractor is exponentially within the range studied lifespan.

Note that the exponential dependence is characteristic of monotonous accumulation patterns in samples of construction materials fatigue damage represented hurst parameter (*H*) [24, 25].

This paper charts the accumulation of operational defects in arrays of individual components (nodes) tractors analyzed similar kinetics statistical parameters *H* strain hysteresis surface layer of metal [25, 26].

The same as a criterion the degree of accumulation of operational defects, which can lead to accidents mechanized and transport works involving tractors, it is worth noting at the likelihood of the critical state $P \approx 0.4$.

Overall analysis of the kinetics of the data (Fig. 2.8 and Fig. 2.9) on the basis of published literature [27], to predict the nature of the stepwise accumulation kinetics of cracks in parts (units) tractors outside investigated lifespan

Such a priori prediction of kinetics characteristics of destruction points to a probable change in the intensity of cracks that in excess of the critical parameter corresponds to its damage increased likelihood of sudden onset emergencies or mechanized transport work.

The relative amount of detail of cracked performance in each of the surveyed units overall ensemble tractor is about the same for the entire sample of each tractor parts.

Critical lifespan of tractors probability at D_{crit}= 0.7-0.8, which corresponds to 13-14 years of operation.

Thus, this figure can serve as a criterion for the decommissioning of tractor parts of flaw detection to detect cracks and restore (replace) the defective parts.

2.4. Analysis of operational intensity of occurrence of cracks in various parts and components tractor lifespan

Results defectoscopic control the availability of small cracks in the details of wheeled tractors of different years of producing are presented in Table of Annex 6-10 and summarized in Table 2.2.

Table 2.2

Summary results defectoscopic control the availability of small cracks in the details of wheeled tractors of different years of release

Host name tractor	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								To-ge-ther
	15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
The relative lifespan relative to the base (17)									
	0.88	0.82	0.76	0.71	0.65	0.59	0.53	0.41	
Steering									
Small cracks found	3	3	5	5	5	9	8	4	42
Inspection details	15	22	27	23	27	41	48	40	243
The relative number of defective parts	0.2	0.13	0.18	0.21	0.18	0.21	0.16	0.1	-
Attaching									
Small cracks found	2	0	7	9	8	5	8	4	43
Inspection details	12	8	35	39	29	34	38	39	234

The relative number of defective parts	0.16	0	0.2	0.23	0.27	0.14	0.21	0.1	-
Engine									
Small cracks found	4	1	9	5	7	8	9	5	48
Inspection details	17	7	24	22	26	50	29	28	203
The relative number of defective parts	0.23	0.14	0.37	0.22	0.26	0.16	0.31	0.17	-
Back axle									
Small cracks found	0	2	5	6	7	6	7	7	40
Inspection details	10	13	32	39	27	25	23	30	199
The relative number of defective parts	0	0.15	0.14	0.15	0.25	0.24	0.3	0.23	-
Transmission									
Small cracks found	4	6	3	5	7	6	6	7	44
Inspection details	24	29	25	16	31	32	42	39	238
The relative number of defective parts	0.16	0.2	0.12	0.31	0.22	0.18	0.14	0.17	-
Small cracks found	13	12	29	30	34	34	38	27	217
Inspection details	78	79	143	139	140	182	180	176	1117
The relative number of defective parts	0.17	0.15	0.20	0.22	0.24	0.19	0.21	0.15	-

Overall defectoscopic control was performed on 1117 details of tractors, which was discovered 217 small cracks.

With increasing lifespan due to adverse effects of the power and the corrosive factors of production environment increases the degree of degradation of the material structure of metal (parts), which increases the intensity of the origin of fatigue cracks and corrosion. Fig. 2.10 a graph of intensity occurrence of operational cracks with increasing duration of operation of tractors, described the trend line (4 degree polynomial) approximation with certainty $R^2 = 0.70$.

Coordinates the following schedule: vertical axis – relative amount detected for a certain year lifespan tractors small cracks in the total population studied, significant in terms of operational safety, parts N; x-axis – relative lifespan tractors (calculated on the base duration 17 years).

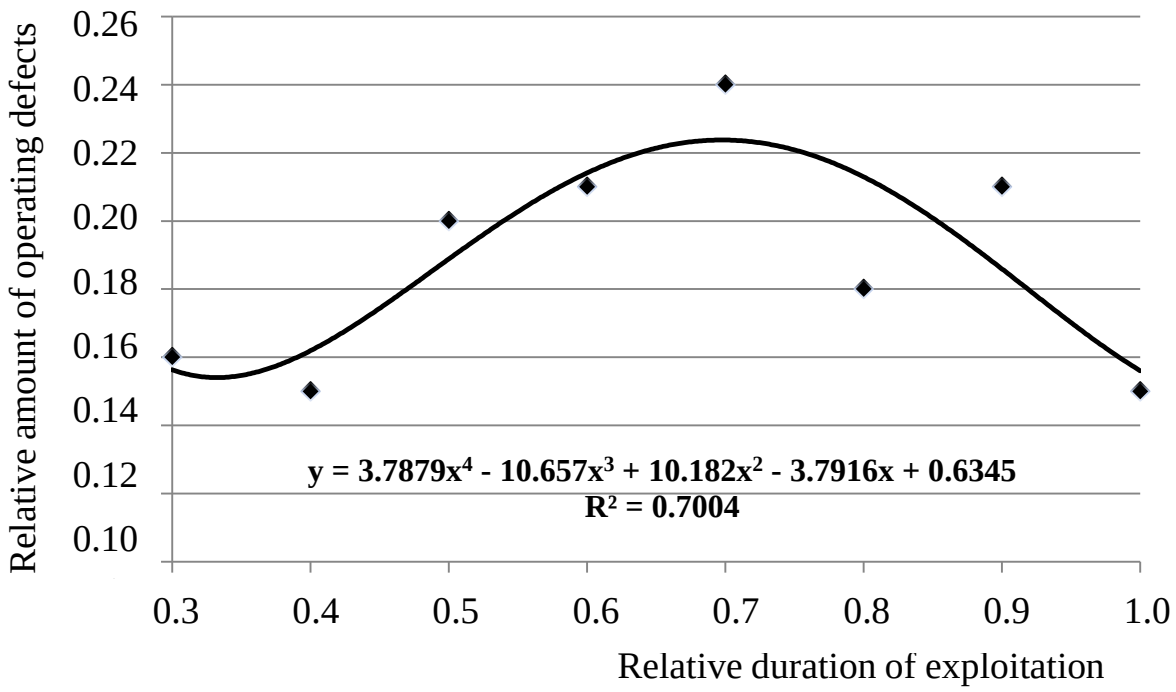

Fig. 2.10. Kinetics intensity occurrence of cracks in the operational units wheeled tractors details varying duration operation

From Fig. 2.10 shows that the nucleation kinetics operational intensity cracks in the array of parts tractors is not monotonous and characterized by a peak that is in the range of 0.6-0.7 relative lifespan, or about 11-13 years. Thus, this figure can serve as a criterion for the decommissioning of tractor parts of flaw detection to identify and eliminate cracks (replace defective parts). This maximum corresponds most the likelihood of sudden destruction of tractor units and creating emergency situations or mechanized transport operations.

2.5. Evaluation of diagnostic efficiency regulations established intervals defectoscopic control tractor units

In this paper during each study defectoscopic control hydraulic parts hanging system tractor sensitivity range flaw changed (lowered) so as to separately detect cracks longer than 2, 5 and 7 mm.

According to the size of a dangerous section details the length of cracks detected qualitatively classified as small, medium and large (dangerous trunk).

Said approach is not meant to quantitative assessment of damage as a result of operational modes details loading tractor units, but allowed to offer a methodology for evaluation of probabilistic risk indicators tractors operating on the basis of defectoscopic tractor control units [28].

Consider the results defectoscopic control of parts of one of the tractors that were subject to repair after prolonged use, such as hanging the hydraulic system.

The presence of cracks in details considered as a separate system of signs hanging technical condition of the hydraulic system, which is considered relatively intact (diagnosis D_1) Or faulty (diagnosis D_2).

Based on previous diagnoses and other outages.

Table 2.3

Probabilities of expansion of cracks of a certain size $P\left(k_{js} / D_i\right)$ for the serviceable and faulty states of the hydraulic system of the tractor and the probability of the feature $P(k_{js})$

State D_i	Diagnostic intervals				Probability of states $P\left(D_i\right)$
	$\{l \le l_1\}$ *(No cracks observed)*	$\{l_1 < l \le l_2\}$ *(Small cracks were found)*	$\{l_2 < l \le l_3\}$ *(Middle cracks were found)*	$\{l > l_3\}$ *(Large cracks were found)*	
Serviceable D_1	0.6	0.2	0,133	0.067	0.312
Faulty D_2	0	0.061	0.091	0.848	0.688
Probability of the feature $P(k_{js})$	0.188	0.104	0.104	0.604	

It considered four diagnostic interval lengths detected cracks l :

$\{l \le l_1\}$ (*it is not educed in the details of knot of cracks*);

$$\{l_1 < l \le l_2\};\{l_2 < l \le l_3\};\{l > l_3\},$$

where l_1, l_2 and l_3– lower limits on separated cracks implemented under the control of three measuring ranges flaw. That is a sign of the technical state of hydraulic hanging system tractor $\boldsymbol{k_j}$ can be seen as four–parameter takes four possible values k_{j1}, k_{j2}, k_{j3}, k_{j4}. If after the test revealed that the sign $\boldsymbol{k_j}$ a value for the object k_{js} Then this value is called realization signs $\boldsymbol{k_j}$.

Based on statistics defectoscopic hydraulic control parts hanging system tractor was obtained priori probability of cracks in these diagnostic range for the healthy D_1 and faulty D_2 states of the system (Tab. 2.3).

Probability of signs $P(k_{js})$ determined by the formula [13]

$$P(k_{js}) = \Sigma\left(P\left(D_j\right) \cdot P\left(k_{js} / D_i\right)\right), \tag{2.1}$$

where j = 1, 2; s = 1, 2, 3, 4. For example,

$$P(k_{j4}) = 0.312 \cdot 0.067 + 0.688 \cdot 0.848 = 0.604.$$

Weight implement diagnostic signs k_j for state D_i determined from the formula

$$Z_{Di}\left(k_{js}\right) = log_2\left(P\left(D_i / k_{js}\right) / P\left(D_i\right)\right), \tag{2.2}$$

where $P\left(D_i / k_{js}\right)$ – the probability of state D_i provided that the sign k_j value received k_{js}; $P\left(D_i\right)$ – priori probability state.

Diagnostic weight there are signs $\boldsymbol{k_j}$ in the interval s can be written in a more convenient form for calculation

$$Z_{Di}\left(k_{js}\right) = log_2\left(P\left(k_{js} / D_i\right) / P\left(k_{js}\right)\right), \tag{2.3}$$

where $P\left(k_{js} / D_i\right)$ – the probability of the existence interval s features $\boldsymbol{k_j}$ for facilities with state D_i; $P(k_{js})$ – the probability of the existence of this interval all objects from different states.

Informative (diagnostic value) control takes into account all the possible features and implementation is a mathematical averaging the value of information that make some sales. For m-bit signs

$$Z_{Di}\left(\boldsymbol{k_j}\right) = \Sigma\left(P\left(k_{js} / D_i\right) \cdot Z_{Di}\left(k_{js}\right)\right), \tag{2.4}$$

where $s = 1, 2, \ldots m$.

The value of diagnostic signs of weight intervals defined by the formula (3), are presented in Table. 2.4.

Table 2.4

Diagnostic weight of the intervals of flaw detection of cracks

State D_i	Diagnostic intervals			
	$\{l \le l_1\}$ *(No cracks observed)*	$\{l_1 < l \le l_2\}$ *(Small cracks were found)*	$\{l_2 < l \le l_3\}$ *(Middle cracks were found)*	$\{l > l_3\}$ *(Large cracks were found)*
Serviceable D_1	1.678	0.941	0.356	-3.180
Faulty D_2	-∞	-0.781	-0.196	0.490

The condition for hanging the hydraulic system of the tractor separate diagnostic value (informative) survey was calculated using the formula (2.4):

$$Z_{D1}\left(\boldsymbol{k_j}\right) = 0,6 \cdot 1,678 + 0,2 \cdot 0,941 + 0,133 \cdot 0,356 + 0,067 \cdot \left(-3,180\right) = 1,031;$$

$$Z_{D2}\left(\boldsymbol{k_j}\right) = 0,104 \cdot \left(-0,781\right) + 0,104 \cdot \left(-0,196\right) + 0,604 \cdot 0,490 = 0,350.$$

The total diagnostic value (informative) survey is

$$Z_D\left(\boldsymbol{k_j}\right) = \Sigma\left(P\left(D_i\right) \cdot Z_{Di}\left(k_j\right)\right) = 0,312 \cdot 1,031 + 0,688 \cdot 0,350 = 0,563.$$

The calculation of the diagnostic value (informative) defectoscopic control units allow tractors to justify the legality of the choice of diagnostic intervals. To this end, the results were systematized defectoscopic control as well as implementation and two bit and three bit signs. As a sign of the healthy and two bit whack consider the presence or absence of dangerous cracks in detail hanging tractor's hydraulic system. Three bit symptoms seen as a case where using crack flaw was demarcated medium and large, and their absence.

Passing intermediate mathematical calculations for two bit and three bit and features that have been made in accordance with formulas (2.3) and (2.4) for a similar four-signs. The calculated values of diagnostic weight intervals for signs of different dimensions are presented in Table 2.5.

Table 2.5

Diagnostic value (informative) of flaw monitoring for feature of various dimensions

Dimension of feature	Diagnostic value of flaw detection control		
	$Z_{D1}(\boldsymbol{k}_j)$	$Z_{D2}(\boldsymbol{k}_j)$	$Z_D(\boldsymbol{k}_j)$
Two-digit	0.7997	0.2452	0.4185
Three-digit	1,000	0.2605	0.4916
Four-digit	1.031	0.350	0.563

Comparison of the diagnostic value (informative) defectoscopic monitoring for cases of simple detection of cracks and their separation on the degree of expansion in the details shows that the diagnostic value (informative) control increases with the transition to more diagnostic intervals, but if healthy state node is advisable to limit three bit feature.

Conclusions to Chapter 2

1. With Eddy current flaw monitored for cracks in the details of a given size units wheeled tractors over time, 17 years from date of manufacture involved in mechanized and transport works, were loading force that led to the emergence of operational cracks.

2. Established that nucleation kinetics operational intensity cracks in the array of parts tractors is not monotonous and characterized by a peak that is in the range of 0.6-0.7 relative lifespan, or about 11-13 years. This figure can serve as a criterion state and its damage threshold to be designated for the creation of specifications and decommissioning of tractor parts flaw detection to identify and eliminate cracks (replace defective parts). Maximum intensity of origin corresponds to the operational cracking largest the likelihood of sudden

destruction of tractor units and creating emergency situations or mechanized transport operations.

3. The calculation of the diagnostic value (informative) defectoscopic control units allow tractors to justify the legality of the choice of diagnostic intervals to assess the relative size of cracks in tractor.

CHAPTER 3. CALCULATIONS RISK OF ACCIDENTS MOBILE AGRICULTURAL MACHINERY AFTER PROLONGED USE

3.1. The analysis of the applicability of methods for estimating occupational risk of high hazard in the agricultural sector

Research the causes of high levels of occupational injuries among agricultural machine belongs to the complex problems that require comprehensive research. It should be noted that most studies on risk assessment of industrial concerns of industry, energy and transport and agriculture is left unattended. However, statistics of accidents in recent years, including fatalities, shows that agricultural production remains the industry with a high level of industrial injuries.

This confirms the thesis that problem comprehensive assessment of risk of injury to production based on the probability of an accident and the severity of its effect on agriculture is pressing [29]. Safety management system (SMS) in agriculture should be based on the implementation of effective mechanisms to reduce to an acceptable level of professional risk [30]. However, indicators of risk in agriculture should be calculated on the basis of objective statistical parameters that are not only analyzing the causes of injuries, but also on the basis of technical diagnostics hardware, which is one of the preventive measures.

In papers devoted to analyzing hazards to production processes using agricultural machinery, largely considered a technical condition units and its deterioration during operation [31]. In developed models of the accident in production processes in agriculture tend to use probability of erroneous actions of employees, are difficult to identify correctly. In addition, often they are not crucial, as is indicated in the instruments of investigation of accidents.

To assess the degree of danger of agricultural production, now usually used only statistical indicators of occupational injuries – factors of frequency, severity, disability and others. For the analysis of occupational risk in a certain economy is reasonable, it is known statistics on the total number of workers in the sector (sub), accidents and lost workdays. But national and sectorial statistical reports about the circumstances of accidents in agricultural production are no data on the dangers of certain types of vehicles, machinery and equipment, which does not allow them to assess the risk of exploitation.

Professional risk tractor – driver agro industrial production associated with the possibility of occurrence of traumatic situations during the operation of the MT, and combines CCM, that set of circumstances and events that violate staff (project planned) the process and create an uncontrollable concentration dangers that threaten life and health workers operability of technical systems or natural environment.

Development, implementation and operation of new equipment and technology intensive expansion of automation and computerization of production processes now qualitatively change the character and productivity, the relationship between man and technology in a production environment, which inevitably affects the professional risk. This makes the search relevant professional risk assessment methods tractor-driver (machine) AIC that would objectively describe the process flow traumatic situations and on this basis to develop effective preventive measures to prevent occupational injuries.

The issue about the ways and methods of quantitative evaluation of occupational risk in the agricultural sector. But as for the definition of the terms "risk" and "safety" and on methods and means of assessment of risk among scientists there is no single best approach is confirmed by numerous publications on this subject.

The use of the most appropriate methods for evaluating occupational risks many scientists consider the priority. However, choosing such methods should

take into account industry and business activities, and used their technology and state of the existing technical means of production.

A comprehensive approach to selecting and applying appropriate risk assessment methods are presented in ISO IEC / ISO 31010: 2013 "Management of risk. Methods of risk assessment", which presents the methodology of assessment of risks and their comparative analysis. This standard is basic and is not limited to industry man-caused environmental security or safety, as is common in the field of risk management.

Existing methods of risk assessment, for which the main element is the identification of hazards, some experts are classified into the following types [32]:

– priori (used during research to occurrence of undesirable events);
– posteriori (after use of unwanted events).

You should also list other risk assessment methods used:

– statistical evaluation of frequency of occurrence of hazardous events;
– "two-stage" analysis, which used mathematical apparatus of graph theory;
– expert assessments;
– based on fuzzy sets theory;
– simulation;
– conceptual design;
– structural modeling and more.

In addition to the methods for risk analysis process equipment operating propose to use these methodological approaches:

– engineering (based on statistics calculations the frequency of hazards, probability safety analysis processes, building tree hazards, etc.);
– model (involves developing models of harmful and dangerous factors of production workers);
– expert (probability of adverse events is determined based on the findings of experts or qualified).

Developed other methods for calculating occupational risk: monographic,

technical, statistical and analog likelihood, ergonomic, economic and others.

The statistical and analogue methods used in the presence of a sample of similar accidents or hazards which can not always be implemented in the case of mobile agricultural machinery operation under various conditions of the production environment.

Experts often use a method that is based on estimates by experts (experts) the significance of the impact of a production factor in the safety of processes. Under this method developed point scale assessment of probability of risk and its consequences [33]. It is important not value assessments (points) and their comparison with the effects of hazardous production factors.

The expert method to assess the degree of probability of an accident (work accident, poisoning, etc.) using the following symbols: A – high probability; B – average probability; C – unlikely. The severity of the consequences assessed according to the three-level scale: I level – an accident, the death of the employee; II level – serious injury; III level – minor injuries.

After such separation set risk category 5 – very high (unacceptable); 4 – high (unacceptable); 3 – average (acceptable); 2 – small (acceptable); 1 – very small (acceptable).

Next, set for a mechanized production process (machines, equipment, mechanism) expert points summarize the production risk in the form of sticks identification, assessment and elimination of unacceptable risks in the workplace, that allows to assess the risk of performance. Workplace risk categories as determined in accordance with the highest expert assessment of all analyzed harmful (dangerous) production factors. If the workplace revealed serious violations of safety standards, the category of risk increases by one point.

Map of identification, assessment and elimination of unacceptable risks complements Card sanitary condition in the workplace (working conditions map), which is used for setting benefits and compensation to employees for work in hazardous or difficult conditions. Comparison of these maps shows the difference

of views of scientists on identification of risk position of occupational medicine (occupational health and occupational diseases) and health.

Today other approaches designed to assess the risk of mechanized work in agriculture that are not widely recognized. Thus, *M. S. Dmytriev* to justify measures applied labor of guard rate risk of injury mechanics combine harvesters, which is determined through the degree of customization process control. For this evaluation method developed ballroom setting combine harvesters on process control parameters such as usability, accessibility, complexity, security, complexity and frequency of process execution control. The basis of the risk assessment assigned authored generalized indicator setting which takes into account the above mentioned parameters and allows a safety position to evaluate each technical regulation, a set of regulations specific working bodies and various types of machines.

Issues methodology for risk in agriculture is devoted to the work of *E. N. Hrystoforov.* This paper theoretically grounded probabilistic safety indicators, including probabilistic measure troubleshooting vehicles, methods of determining methodological approaches for the safe movement of vehicles on farm roads, grounded technical solutions which allow to eliminate the danger arising. The practical significance of the research results are mathematical models of probabilistic safety indicators. The paper was developed technique using probability theory to estimate traffic injuries and evaluation methodology degree of danger due to malfunction vehicles. But these developments relating to road safety not perform mechanized works in agriculture. In addition, the proposed model does not take into account the technical condition of vehicles.

V. P. Baskakov found that the deviation parameters of the production process in the coal mines of technologically reasonable values of more than 7% leads to achieving an unacceptable risk of injury and accidents. The dependence of the risk of deviation values is as follows:

$$P = 1.8645e^{0.011\delta},$$

where P – risk; δ – the value of deviation from production schedules. These mathematical models of risk assessment can be used to change the level of risk for mechanized production processes in agriculture.

In scientific and technical literature on safety and risks, there are many works on the methodology of accounting blunders operator – artist of some processes, including in agriculture [34]. But the range of possible operator errors within the system "man – machine – environment" is very wide, it is analyzing them to resort to simplifications. The models not formalized, they usually do not yield quantitative measures of safety equipment, and provide only qualitative picture of the reasons for creating a dangerous situation. As for facilities of agricultural production for them in logical simulation model likelihood basic set of events, usually without statistics causes of occupational injuries or other statistical characteristics,

Most really complex models designed for emergency objects high risk (nuclear power plants, chemical reactors, etc.) because they introduced a system for recording and analysis of operational equipment during long previous operation lay in allowing calculation models reasonable probability statistics on the destruction of some elements of a complex system [35, 36]. Therefore, in recent years to ensure trouble-free operation of potentially dangerous objects, including special attention to be nuclear power plants, missile and space systems, aircraft, chemical reactors et al. Proposed an integrated approach, which try to consider as many hazards generated during the design, construction, testing and operation of objects. The proposed strategy for security management of complex technical systems developed based on systems analysis, multivariate evaluation and multi minimize the risk of emergency operation. These methodologies security objects is achieved by timely detection of critical situations or significant risk and prevent their consequences.

The basis of the analyzed methodological approaches laid understand that emergencies production, leading to accidents – is a random variable, so a

quantitative evaluation of consequences of emergency operation should be described probabilistic mathematical models [37].

A large group of researchers to determine the probability of accidents at hazardous industrial facilities and industrial injuries or occupational diseases offers apply logical and probabilistic methods of safety engineering systems "fault tree» (fault tree) and "tree event »(events tree). Such methods are effective for establishing the degree of safety of technical systems that can objectively identify the most dangerous places, the causes and conditions of transition to the dangerous condition of operation and more.

To calculate the probability of occupational diseases in the machine, *V. V. Begun* have used logic-graphic model – fault tree. Qualitative and quantitative risk assessment was performed using a computer program based on the code IRRAS, developed for the probabilistic safety analysis of nuclear power plants. This revealed the most dangerous combination of events and calculate the likelihood of occupational disease. But the technical condition of the units assessed only on two parameters (in good condition – not in good condition), which makes it impossible to take into account the intensity of accumulation of operational defects in design elements agricultural units.

Another way to study the safety of complex technical systems is to construct graphs of states based on the concept of causality of events and their subsequent qualitative and quantitative evaluation. The above method allows the study process flow traumatic situations and predict the likelihood of host system in a particular state after a certain period of time.

At the same time probabilistic assessment approaches danger of accidents is not distributed on powerful tractors and SSM, which should be considered as potentially hazardous objects. This thesis confirms the analysis of the technical support of agricultural production, which implies that the current agriculture Ukraine ICC reached a critical point, morally and physically obsolete decreased in quantity does not ensure timely implementation of mechanized and transport

works and is a constant threat for machine operators and other workers and the environment to the production.

Basically the principles of mathematical modeling and statistical analysis used in the design stages and testing agricultural machines. So, to improve the accuracy of machine reliability assessment of the limited amount of data about the refusal suggested to use methods of forecasting resource allocation based on the results of redundant testing and the presence of gradual failures. While most of these methods development used statistical modeling techniques [38].

In particular, these methods to assess the risk of destruction because of the construction multi-cycle fatigue crack propagation in the areas of stress concentration on the basis of operational irregularities loading and stochastic distribution of defects in structural elements [39-43]. In this study it was shown that increasing the reliability of equipment due to the discovery of the most dangerous damage to the periodic defectoscopic control structure.

Thus, analyzing the various methods and approaches to assessment of risk, you can select the most used are: the method of "tree" method "Markov processes", statistical method, peer reviews, etc., which are based on modeling of studied processes and phenomena. As for methods of risk assessment professional staff agribusiness in general and the tractor-driver in particular, they find their foundation in the methods and approaches that are commonly used in other industries, although the scope and depth of research in agriculture is much smaller.

Summing up the review of existing research methods of occupational risk, it should be noted that taken separately, are not to describe a complete picture of the real state of safety in agriculture, and the specificity of agricultural production often makes any analysis rather relative and conditional. Hence, it becomes necessary to search for such theoretical principles and methodological approaches, the use of which would make it possible to more accurately and objectively examine the risk of professional mechanics AIC, and on this basis to

suggest ways to reduce it.

3.2. Modeling traumatic situations that arise during the operation of tractors, using the method of Markov chains

System introduction of security measures and preventive measures to prevent occupational injuries agricultural workers should be based on an analysis of the causes of injury to workers by improving existing methods of probabilistic risk assessment of occurrence of emergency situations, taking into account the characteristics of the mechanized processes in agriculture. Therefore, studies the formation mechanism of traumatic situations, conditions and circumstances, facilitating the study of the nature of the events that lead to the hazards of a mechanized agriculture, is now urgent task. Need to move from qualitative methods of analysis of the causes of occupational injuries based on expert assessments to Quantitative assessment of the likelihood of accidents involving mobile agricultural machinery

Machine and tractor units, machine operators – mobile operators of agricultural machinery and industrial environmental parameters during execution of mechanized work in agriculture are interrelated elements of an integrated system [44]. According to some researchers weak link of the system may be employees of their wrong actions and violations of safety requirements, other researchers justify the high risk of injury mechanics parameters influence the production environment [45]. The common understanding is that the change in status of any of the elements of the car – a man – a production environment (N–L–ID) inevitably leads to changes in the state system as a whole. However, the role of technical state machine functionality and arranged on it means safety in the formation of traumatic situations often left unattended.

The changes of N–L–ID nature of their temporal manifestations considered largely separate: a gradual, such as the accumulation of multiple operational

damage in the array of parts machine components or accumulation of fatigue worker during the shift, and suddenly that occur at a particular time (destruction of parts, loss focus operator or expression critical environmental parameters) [17, 18]. However, the gradual accumulation of operational defects in parts (structural elements) eventually leads to cracks and distribution backbone critical size, which leads to sudden refusal of machine components (unit), and thus the onset of dangerous situations [19].

For the analysis of sudden changes in the M–L–ID using mathematical tools developed in probability theory for Markov random processes with discrete states and continuous time when the transition of the system from one state to another is possible at any advance is unknown, random time ***t***. But The mathematical model of a working shift system to whack regarded primarily as a result of erroneous actions of the operator machines (a worker) without analyzing the degree of accumulation of operational defects in the array of parts unit, which may be crucial for the establishment of an emergency (traumatic) situation.

In this paper, the method of calculation of occupational hazards machine by analyzing current count status of traumatic situations during the operation of the MTA.

According to the methodology [46] consider stochastic processes with discrete states and continuous time, and transitions S system from one state to another are described as occurring under the influence of some streams of events. Then the transition probability density λ gets a sense of intensity (density) of the flow of events. If these flows are Poisson (ordinary and without aftereffects, constant or time-dependent intensity), the process that occurs in the system S, will *Markov*.

The degree of degradation of the tractor after a long exploitation in this paper (§ 2.3 and 2.4) evaluated according to the intensity on the accumulation of defects (cracks) in the array of parts tractors, discovered during defectoscopic control critical parts (structural elements) tractors. In the used Eddy current flaw

could allow you to degree all switch sensitivity for finding defects of different size, which allowed the total number of identified operational defects isolate small in size (on the threshold of sensitivity of the flaw) that at the time control did not constitute a threat to the safe operation of the tractor.

For the analysis of traumatic situations can happen in a mechanized agriculture, built graph states that shown in Fig. 3.1.

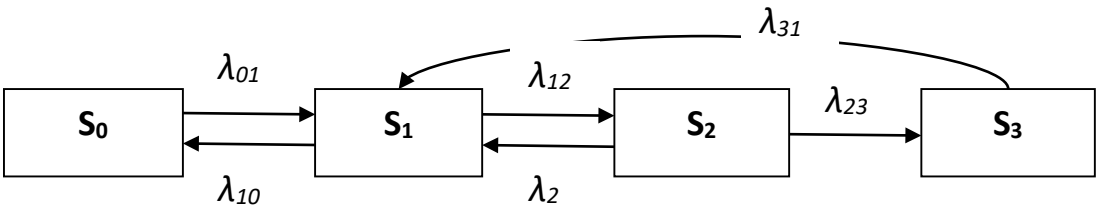

Fig. 3.1. Count status of current traumatic situation: S_0 – the system is in the initial (proper) condition; S_1 – the system is in operation (suspended serviceable) condition; S_2 – system is in failure condition; S_3 – state of the system is dangerous for workers who serve the agricultural unit

First MT operating system is in good condition S_0, and after a period of time from the action flow events with intensity λ_{01} deteriorating state of the system, but for the time being it does not affect the serviceability of the system and it can still continue to function. This situation can be described as a work (conditionally defective) condition of S_1. While in state S_1, from the action flow events with intensity λ_{10} system may return over time in the state S_0. On the other side of the action flow events with intensity λ_{12}, such a machine failure through regular inspection timing or distribution of major cracks in parts and components (cell structures), the system can move in a faulty state S_2.

Consider the following scenario:

a) on the action flow events with intensity λ_{21} (for example after the repair certain node tractor or replacing defective parts), the system returns to the S_1, which may be still or later from the effects of flow events with intensity λ_{10}, can

return to the state S_0;

b) the action flow events with intensity λ_{23} system goes to state S_3 dangerous consequences of possible injury as machine operators or returning to a state of S_1 action flow events with intensity λ_{31} (e.g. due to overhaul AIT).

Analyzing Earl states analyzed in Fig. 3.1 determine the probability of a test system states $P_0(t)$, $P_1(t)$, $P_2(t)$ and $P_3(t)$ as a function of time. These probabilities must satisfy the system of differential equations *Kolmogorov*, probabilities of states of the system are as unknown functions [27]

$$\begin{cases} dP_0/dt = -P_0\lambda_{01} + P_1\lambda_{10} \\ dP_1/dt = -P_1\lambda_{10} - P_1\lambda_{12} + P_0\lambda_{01} + P_2\lambda_{21} + P_3\lambda_{31} \\ dP_2/dt = -P_2\lambda_{21} - P_2\lambda_{23} + P_1\lambda_{12} \\ dP_3/dt = -P_3\lambda_{31} + P_2\lambda_{23} \end{cases}$$

where $P_0 + P_1 + P_2 + P_3 = 1$ – normalizing condition.

If you enter into consideration vector function $P(t) = (P_0(t); P_1(t); P_2(t); P_4(t))$ and matrix intensities

$$\Lambda = \begin{pmatrix} -\lambda_{01} & \lambda_{10} & 0 & 0 \\ \lambda_{01} & -\lambda_{10} - \lambda_{12} & \lambda_{21} & \lambda_{31} \\ 0 & \lambda_{12} & -\lambda_{21} - \lambda_{23} & 0 \\ 0 & 0 & \lambda_{23} & -\lambda_{31} \end{pmatrix},$$

Kolmogorov equation then the system takes the form of linear matrix system of differential equations:

$$\begin{cases} \dfrac{d\vec{P}(t)}{dt} = \Lambda\vec{P}(t), \\ l\vec{P}(\cdot) = \sum_{i=0}^{3} P_i(0) = 1, P_i(0) \geq 0 \end{cases}$$

After solving the system of differential equations using Laplace transform, we can find the probability of the states analyzed system.

In this paper, a probability distribution system changes state N–L–ID received for traumatic situations that may occur due to malfunction steering system.

Fig. 3.2 presents the kinetics of accumulation of cracks in the steering system of tractors of different lifespan form the intensity of accumulation of small defects as a generalization of kinetic dependences presented in § 2.3 and 2.4. Coordinates schedules are as follows: the vertical axis – n_d/N – the relative number of detected cracks n_d in the total population studied, significant in terms of operational safety, parts N; x-axis – t_{eks} / t_{baz} – attitude lifespan tractors t_{eks} relative to the base length t_{baz}=17 years. Kinetics accumulation of cracks described trend line, the equation approximation and reliability are shown on Fig. 3.2.

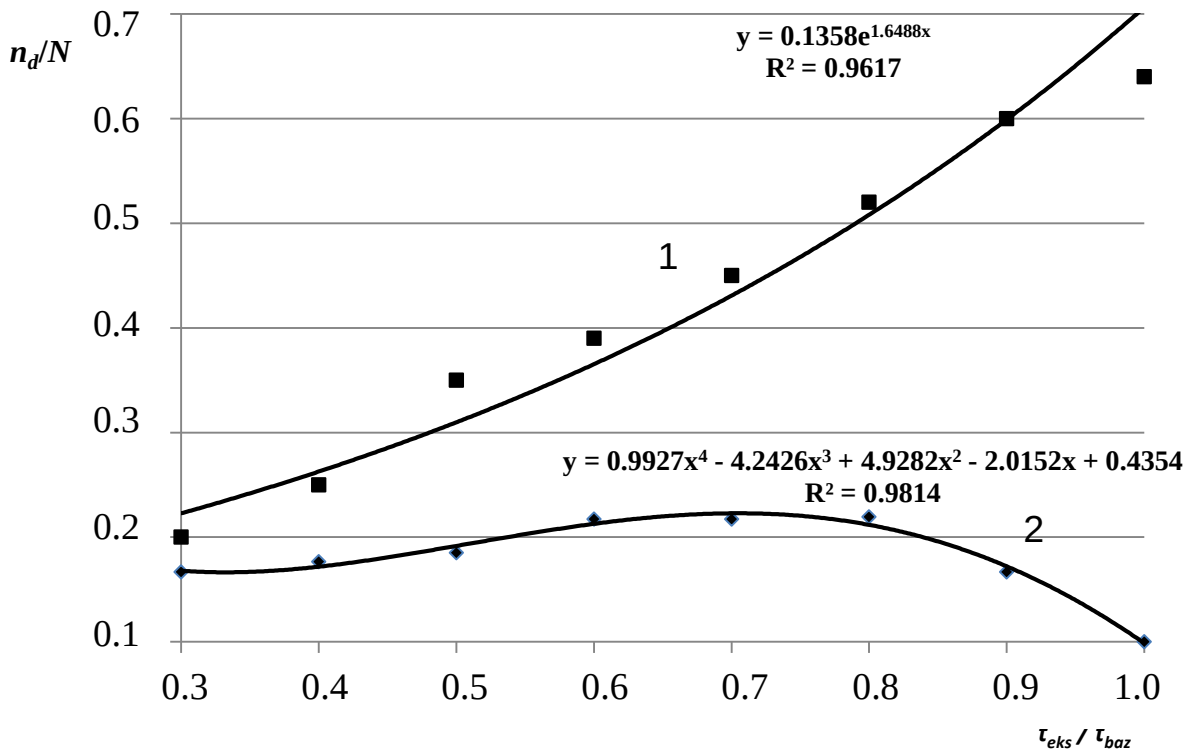

Fig. 3.2. Kinetics accumulation of cracks in detail steering system operating tractors of varying duration: 1 – crack without separation size; 2 – small cracks

These were considered the main causes malfunction of the steering tractors: availability of operational defects (cracks) in the details that reveal defectoscopic control; availability backlash, incurving parts and other irregularities in the

system that detect visual inspection and testing; violating the terms of the inspection tractors.

Elements of the matrix intensity events (transition of the system) established based on the following assumptions.

In health and safety for installation faults units tractors and other mobile agricultural machinery developed Maps monitoring safety parameters in specifying the frequency and places control of regulatory parameters trouble-free operation machines units (unit), but the emphasis on the visual (optical) control without using defectoscopic equipment. It can detect a significant mismatch of pre safety on stage. That failure frequency of the condition monitoring will indicate high probability of transition to a dangerous condition.

It was believed that the transition from the healthy state of the system to a dangerous condition (safety machine operators) among other circumstances related to the activities of mechanics, may be due to the presence of certain (critical) number of operational defects in multiple parts tractor units, held defectoscopic control. That is a defective state of the system considered the lack of operational defects or defects in the initial stages of their formation (i.e. only small) that in the near future will not lead to sudden failures (accidents) technology.

Whack system will meet the lack of line of means of security or the presence of cracks that could eventually grow into a trunk and cause system failure (emergency situations). If the company will not take steps to repair the unit, the situation becomes dangerous (corresponding to the dangerous state of the system). How can assume dangerous situation (dangerous state of the system) when the density of defects in the array of parts unit exceeds a critical value.

In the calculations used statistics 2010 annual state inspection of mobile agricultural machinery tractors on the number of faulty steering system. Thus, the number of tractors that were on the balance of agricultural enterprises totaled 190375 units. From them to pass state inspection were submitted 146172 tractors.

When checking the technical problems were found in 33383 tractors, which is 22.8%.

The analysis diagram in Fig. 3.2 was proposed following factors characterizing the intensity intermediate states of the system:

1. We believe that in the initial stages of operation (t_{eks} = 0.3) ratio of intensities will be λ_{00} = 1.00 – 0.22 – 0.16 = 0.62, corresponding to good condition tractors.

2. At the intermediate stage of operation (t_{eks} = 0.5) the technical state of tractor passes to conditional discharge because of the healthy performance in the details of defects (λ_{01} = 0.38). For tractors that are in operation (suspended serviceable) condition, small cracks are not currently pose a threat of sudden failure, the same λ_{10} = 0.22. Then working (conditionally defective) condition is characterized tractors intensity factor λ_{11} = 1.00 – 0.38 – 0.22 = 0.40.

3. For faulty condition is characterized by maximum intensity of occurrence of small cracks (λ_{21} = 0.22) significant accumulation of cracks critical (dangerous) size (λ_{12} = 0.44 – 0.22 = 0.22).

4. Unless held defectoscopic control critical parts of the tractor, then the system during operation (t_{eks} = 0.9) will be dangerous for workers (λ_{23} = 0.6 – –0.17 = 0.43).

5. If the inspection of tractors under the control chart performance security will be detected non-compliance of parts and components of tractor safety requirements, these parts will be replaced and the condition of the tractor will go to dangerous work (λ_{31} = 0.228).

So we have a matrix conversion system states:

$$\Lambda = \begin{pmatrix} -0.38 & 0.22 & 0 & 0 \\ 0.38 & -0.44 & 0.22 & 0.228 \\ 0 & 0.22 & -0.65 & 0 \\ 0 & 0 & 0.43 & -0.228 \end{pmatrix}.$$

The set of probabilities of the system can be obtained after solving *Kolmogorov* equation given normalization condition:

$$\begin{cases} P_0(t) = 0.907c_1 - 0.302c_2(0.477)^t - 0.052c_3(0.514)t - 0.608c_4(0.747)^t, \\ P_1(t) = 1.567c_1 + 0.495c_2(0.477)^t + 0.067c_3(0.514)t - 0.243c_4(0.747)^t, \\ P_2(t) = 0.53c_1 - 1.194c_2(0.477)^t - 1.015c_3(0.514)t - 0.149c_4(0.747)^t, \\ P_3(t) = c_1 + c_2(0.477)^t + c_3(0.514)t + c_4(0.747)^t. \end{cases}$$

In order that the condition of normalization is necessary to put constant $C_2 = C_3 = 0$; $C_1 = 0.25$; $C_4 = 0.01$.

The functions of the states represented in the following form:

$$\begin{cases} P_0(t) = -0.00608(0.747)^t + 0.23, \\ P_1(t) = -0.00243(0.747)^t + 0.39, \\ P_2(t) = -0.00149(0.747)^t + 0.13, \\ P_3(t) = 0.01(0.747)^t + 0.25. \end{cases}$$

Charts kinetic dependencies calculated probabilities P states of the system shown in Fig. 3.3.

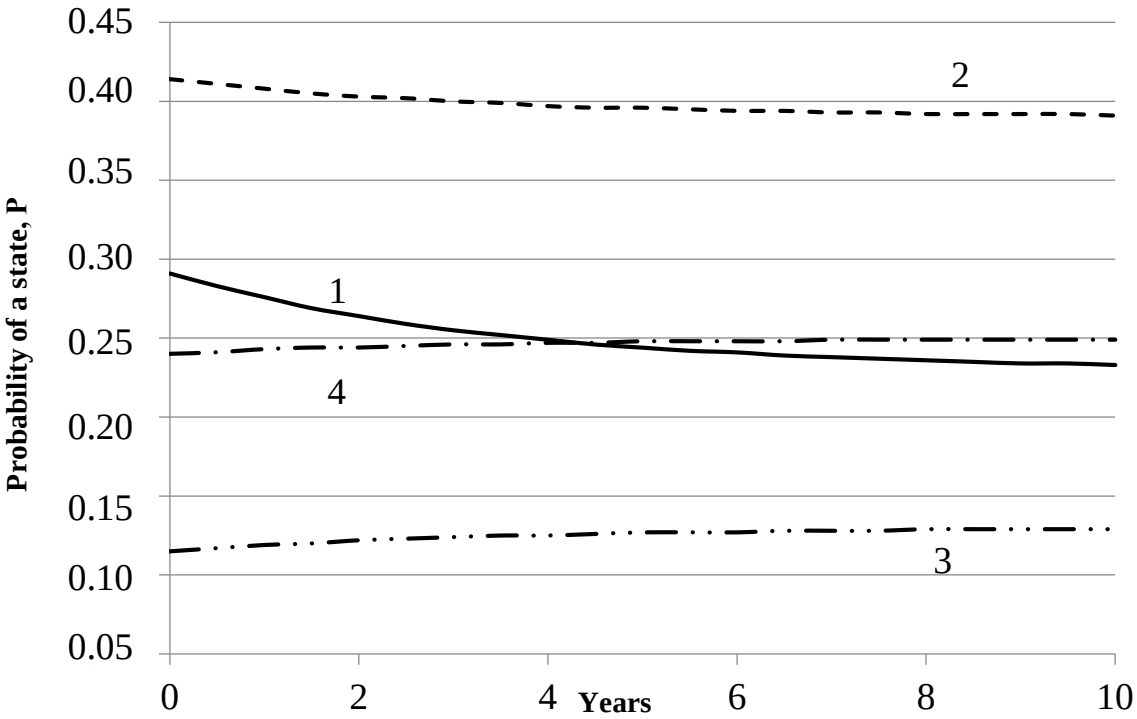

Fig. 3.3. Charts kinetic dependencies probability P states of the system: 1 – serviceable state S_0; 2 – conditionally defective condition S_1; 3 – faulty state S_3; 4 – S_4 dangerous condition

The final probability states of the system are: P_0 = 0.23; P_1 = 0.39; P_2 = 0.13; P_3 = 0.25. This means that in the long term (10 years) 23% of the units will work in good condition S_0, 39% and 13% respectively faulty switch S_1 and S_2 dangerous conditions, causing the onset of a dangerous situation. Probability system switch in critical condition S_3 (injury to machine operators) in this case will be 25%. Probability system switch in critical condition S_3 (injury to machine operators) will be 25%.

3.3. New possibilities of probabilistic approach for estimating the degree of danger on the basis of operating tractors defectoscopic control

For the assessment of the likelihood of accidents during the operation of tractors in this study also used statistical methods of technical diagnostics recognition tasks with an analysis of the data defectoscopic control. Methods of technical diagnostics to assess (identify) the state of the object under conditions of limited information. It is important to correctly select the parameters that describe the state of the facility and be informative enough that for a selected number of diagnoses to assess the state of the object.

Objects diagnosis in this study was selected individual components of the tractor. Considered two states (diagnosis) of these sites: D_1 – serviceable and D_2 – is defective.

Analyzed cases where fault tractor units due to the presence of cracks in parts and components. Diagnosed objects (nodes tractor) for complex traits k, namely: k_1 – the presence of small cracks; k_2 – cracked medium size; k_3 – the presence of large cracks.

The proposed method of calculation allows us to estimate how likely can be attributed to one of these classes tractor unit, the details of which were found cracks that will result immediately or over time, the destruction of the site, and therefore will create an emergency situation.

In the developed method of calculating the likelihood of accidents data are not used for linear dimensions of defects, such as signs that cracks found varying degrees of safety for the destruction of parts. In practice, the size of cracks in the array of parts and components of various tractors lifespan characterized by a continuous distribution. In this case, through a set of characteristics k received discrete representation of the distribution. Such fuzzy representation without specifying linear dimensions of the cracks is because tractor units consisting of a plurality of parts of different cross-sectional areas in the spreading of cracks. Three bit representation corresponds to the relative size of the crack in the expansion section details of the time of the diagnostic control.

If previously examined N objects, and are characterized as N_i D_i, on the basis of available data state probability (a priori probability) can be determined by the formula

$$P(D_i) = N_i / N; \text{where i = 1,2.} \tag{3.1}$$

Since the objects are in one of these states, the $\sum P(D_i) = 1$.

Conditional probability $P(k_j / D_i)$ there are signs kj facilities in the state Di injected so. If among Ni objects Di diagnosed characterized in Nij found signs kj, then

$$P(k_j / D_i) = N_{ij} / N_i; \qquad i = 1.2; \qquad j = 1, 2, 3. \tag{3.2}$$

The probability of the absence of designated P (j / Di). Then $\bar{k}$

$$P(\overline{k_j} / D_i) = 1 - P(k_j / D_i). \tag{3.3}$$

The resulting diagnostic control statistics for attaching a tractor presented as diagnostic array (Tab. 3.1), which is formed based on the presence of cracks in the device.

Table 3.1

Conditional probabilities and signs priori probabilities conditions attaching tractor

Status node D_i	$P(k_1/D_i)$	$P(k_2/D_i)$	$P(k_3/D_i)$	$P(D_i)$
Was in working order at the time control, D_1	0.41 (6)	0.13 (2)	0.066 (1)	0.31 (15)
Out of operation, D_2	0.54 (18)	0.48 (16)	0.91 (30)	0.69 (33)

Table 3.1 and subsequent similar tables in brackets below the values calculated conditional probabilities signs $P(k_j/D_i)$. Unknown number identified during the monitoring cracks defectoscopic appropriate relative size. When the values of a priori probabilities of the unit $P(D_i)$. Set the number of nodes that are in the repair of tractors considered defective (this is why the tractor subject to repair) and serviceable (suspended) – they bounce was not recorded.

As a result, diagnosis becomes known implementation of each feature k_j * (k_j presence or lack there of $\overline{k_j}$ – detected or not during the control of split defectoscopic certain relative size). We mention all the possible realization of complex traits: $k_1k_2k_3$, $\overline{k_1}\,\overline{k_2}\,\overline{k_3}$, $\overline{k_1}k_2k_3$, $k_1\overline{k_2}k_3$, $k_1k_2\overline{k_3}$, $\overline{k_1}\,\overline{k_2}k_3$, $k_1\overline{k_2}\,\overline{k_3}$, $\overline{k_1}k_2\overline{k_3}$. These characteristics correspond to the presence of both small, medium and large cracks ($k_1k_2k_3$) in parts and components, parts and components without imperfectness ($\overline{k_1}\,\overline{k_2}\,\overline{k_3}$). The presence of both medium and large cracks ($\overline{k_1}k_2k_3$) and other possible combination of features.

Di conditional probability diagnosis after the object was found in complex traits k *, defined by the formula [19]:

$$P(D_i/k^*) = P(D_i)\cdot P(k^*/D_i)\Big/\Big[\sum P(D_S)\cdot P(k^*/D_S)\Big], \qquad (3.4)$$

which implies that $\sum P(D_S/k^*)=1$. Index * indicates a certain value (implementation) signs and the number of states s = 2.

For independent diagnostic features (assuming that the cracks in the details node does not affect the distribution of defects in others):

$$P(k^*/D_i)=P(k_1^*/D_i)\cdot P(k_2^*/D_i)\cdot P(k_3^*/D_i), \tag{3.5}$$

and therefore formula (3.4) can be written as:

$$P(D_i/k^*)=P(D_i)\cdot P(k_1^*/D_i)\cdot P(k_2^*/D_i)\cdot P(k_3^*/D_i)\Big/\Big[\sum P(D_S)\cdot P(k_1^*/D_S)\cdot P(k_2^*/D_S)\cdot P(k_3^*/D_S)\Big]. \tag{3.6}$$

First calculate the probability state D1 node if found all three features k_1, k_2 and k_3, found that the crack of small, medium and large sizes. Because these features are independent, then use the formula (3.6). Then the probability of staying in good condition node determined from the formula:

$$P(D_1/k_1k_2k_3)=(0,31\cdot 0,41\cdot 0,13\cdot 0,066)/(0,31\cdot 0,41\cdot 0,13\cdot 0,066+0,69\cdot 0,54\cdot 0,48\cdot 0,91)=0,007.$$

We estimate the probability of the healthy state D1 node, if after examination it was discovered cracks only small to medium size, i.e. no signs k_3. k_3 no evidence can be interpreted as the opposite event – 3. Then sign$\bar{k}$ $P(\overline{k_3}/D_1)=1-0,066=0,934; P(\overline{k_3}/D_2)=1-0,91=0,09.$

Thus, replacing the formula (6) P value (k_3 / D_1) to the value of P (3 / D_1), we get $\bar{k}$

$$P(D_1/k_1k_2\overline{k_3})=(0,31\cdot 0,41\cdot 0,13\cdot 0,934)/(0,31\cdot 0,41\cdot 0,13\cdot 0,934+0,69\cdot 0,54\cdot 0,48\cdot 0,09)=0,486.$$

After similar calculations for other options whether or not the relative size of various cracks in the details of attaching the tractor, the values of conditional probabilities of states based on complex implementations of features presented in the form Table 3.2.

Table 3.2

Aposterior probability classes D_1 and D_2 diagnosed hinged mechanism tractor

Aposterior probability	Realization of complex traits							
	$k_1k_2k_3$	$\overline{k_1}k_2k_3$	$k_1\overline{k_2}k_3$	$k_1k_2\overline{k_3}$	$\overline{k_1}\,\overline{k_2}k_3$	$k_1\overline{k_2}\,\overline{k_3}$	$\overline{k_1}k_2\overline{k_3}$	$\overline{k_1}\,\overline{k_2}\,\overline{k_3}$
*R (D1 / k *)*	0.007	0.012	0.040	0.486	0.068	0.855	0.625	0.900
*P (D2 / k *)*	0.993	0.988	0.960	0.514	0.932	0.145	0.375	0.088

Similar calculations of probability of failure was performed for other tractor units. Table. 3.3 and 3.4 are presented are calculated according to the methodology developed by the conditional probability aposterior characteristics and probabilities of the system in accordance with steering the tractor.

Table 3.3

Conditional probabilities and signs priori probabilities of the steering system of tractor

Status node D_i	$P(k_1/D_i)$	$P(k_2/D_i)$	$P(k_3/D_i)$	$P(D_i)$
Was in working order at the time control, D_1	0.54 (6)	0.27 (3)	0.09 (1)	0.22 (11)
Out of operation, D_2	0.49 (18)	0.38 (14)	0.97 (36)	0.77 (37)

Table 3.4

Aposterior probability classes D_1 and D_2 diagnosed tractor steering system

Aposterior probability	Realization of complex traits							
	$k_1k_2k_3$	$\overline{k_1}k_2k_3$	$k_1\overline{k_2}k_3$	$k_1k_2\overline{k_3}$	$\overline{k_1}\,\overline{k_2}k_3$	$k_1\overline{k_2}\,\overline{k_3}$	$\overline{k_1}k_2\overline{k_3}$	$\overline{k_1}\,\overline{k_2}\,\overline{k_3}$
*R (D1 / k *)*	0.021	0.017	0.035	0.876	0,028	0.921	0.852	0.875
*P (D2 / k *)*	0.979	0.983	0.965	0.124	0.972	0.079	0.148	0.095

Analyzing the calculated probability states (is in good condition or not), we can estimate how much will increase the probability of failure of a node. For example, if the details are non-critical crack size (average), this case is characterized by complex traits $\overline{k_1}k_2\overline{k_3}$. These values (reduce the chance of working state unit) correspond to increasing probability of failure and node correlated with an increase in the risk of accidents.

Applying the logic simulation methods and setting probability of basic events of E_I as the conditional probability of failure of individual units, you can calculate the likelihood of accidents mechanized and transport works involving tractors.

The probability of occurrence of events E_1, E_2, ... E_N independent in combination, can be calculated by the formula:

$$P\left(E_1 \cap E_2 \cap \ldots \cap E_N\right) = P\left(E_1\right) \cdot P\left(E_2\right) \cdot \ldots \cdot P\left(E_N\right). \quad (3.7)$$

Probability of at least one of N independent set of events to be determined by the formula:

$$P\left(E_1 \cup E_2 \cup \ldots \cup E_N\right) = 1 - \left(1 - P\left(E_1\right)\right) \cdot \left(1 - P\left(E_2\right)\right) \cdot \ldots \cdot \left(1 - P\left(E_N\right)\right). \quad (3.8)$$

The following is the calculation of the likelihood of an emergency on the tractor, two nodes is detected cracks of various sizes. For example, in parts attaching tractor developed subcritical crack size (case $\overline{k_1}k_2\overline{k_3}$), And in detail steering system – found a large crack (case $\overline{k_1}\overline{k_2}k_3$). Then the probability of emergency due to failure of at least one node is determined from the formula (3.8):

$$P = 1 - \left(1 - 0,375\right) \cdot (1 - 0,972) = 0,986.$$

The calculation shows how increasing the likelihood of an emergency, and thus the risk of injury to workers, with the number of cracks, even those that have not reached the critical (dangerous) values.

3.4. Calculation of the degree of danger of prolonged use of tractors on the basis of data flaw details

Development models create dangerous situations in the form of block diagram (tree) involves identifying combinations of connections between basic and intermediate events (erroneous actions of employees acquired operational defects and failures of equipment, adverse external influences production environment) that form the main event with some risk injury to workers or accidents. Currently not offered detailed procedure of a tree events or faults which would specify how to combine logical connections between basic and intermediate events, taking into account their significance and degree of completeness of the considered set of initial events. There is discussion on the rationale basic probability events. It is important to develop logical-simulation models for a large number of different operations in mechanized agriculture,

As an example of developed logical simulations presented in this paper calculate the likelihood of traumatic situation for mechanized works in agriculture – due to a sudden lowering of tractor mounted implement, the details of which can be spread and operational cracks. Logical simulation occurrence of such traumatic situation shown in Fig. 3.4.

To analyze the logical simulation model offensive traumatic situation and determine the risk of injury to workers who are in the area of sudden lowering of tractor mounted implement, in this study used a computer program SAPHIRE. Description of individual elements developed logical simulation model presented in the Table 3.5, which also indicated certain basic values of events, including subcritical and critical accumulation of cracks in the details tractor units (item J).

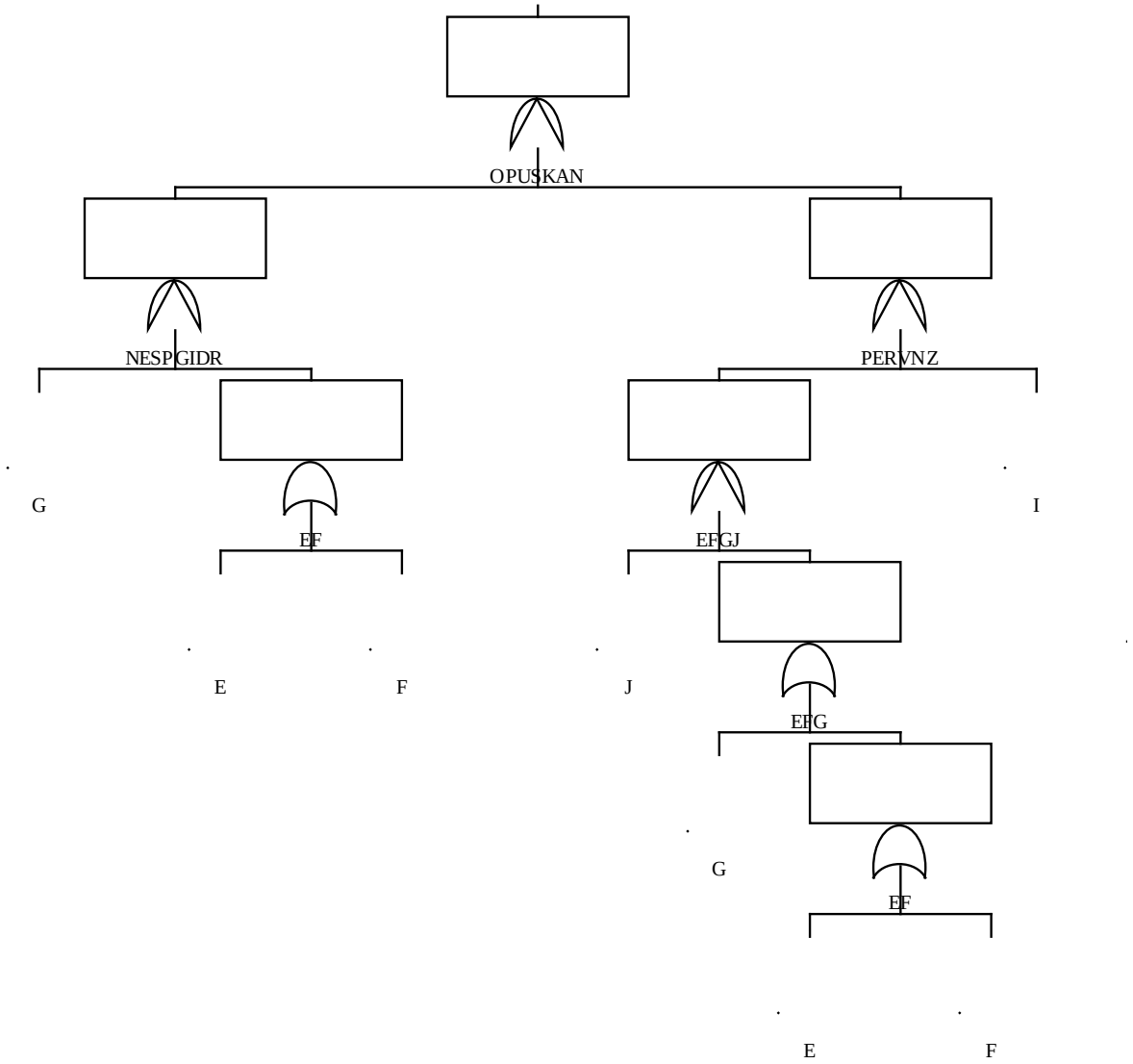

Fig. 3.4. Flowchart logical simulation model of a dangerous situation "sudden lowering of tractor mounted implement"

The probabilities of basic events in the logical simulation model of dangerous situations defined as complying with the statistics of occupational injuries in the agricultural sector of Ukraine, averaged over the past 5 years.

They were taken from the Annual Statistical Bulletin "injury at the workplace" State Statistics Service of Ukraine.

Table 3.5

Description of elements logical simulation model of a dangerous situation

Marking elements (basic and intermediate events)	Description elements (basic and intermediate events)	Certain probability of basic events
E	In the agricultural enterprise is not created public service work	0.15
F	The company has been established effective work on health (in particular, not to provide training and instruction on safety, not control technical condition of vehicles and equipment from the standpoint of safety, do not appreciate the professional competence of employees, etc.).	0.25
EF	Control of safety at the plant recognized as unsatisfactory	
G	Lack of skills and abilities machine	0.15
EFG	Violation of terms of regulatory technical inspection and maintenance of tractors	
J	The presence of cracks in parts and components	0.2 / 0.45
EFGJ	Operating the tractor with a defective hinged system	
I	The need to perform manufacturing operations and reviews for deficiencies in the system hanging or other reasons that make	0.25

	the employee (machine operators) stay in the danger zone lowering rig tractor attachments	
PERVNZ	Staying in the danger zone worker lowering mounted implement	
OPUSKAN	The sudden sinking mounted implement	

The calculation was performed for two lifetime tractors, namely 6 and 13 years old when the relative number of cracks in the overall array tractor surveyed was respectively 0.2 and 0.45.

Changes parameters for a production risk logic-element simulation model show a dangerous situation increases the risk of injury in the event of interim and full exposure to hazardous factors (Table 3.6).

Table 3.6

Indicators for risk logical simulation model of a dangerous situation "sudden lowering of tractor mounted implement"

Hazard (action, event, situation)	Conditional Hazard characteristics –the relative number of cracks in the overall array studied Tractor	Calculated risk indicator, P	Changing risk weight if the dangers times
J (cracks in the detail node)	0.2	2.998×10^{-3}	-
	0.45	6.739×10^{-3}	2.25

From Table 3.6 shows that the risk of injury due to workers sudden lowering of tractor mounted implement increased 2.25 times after reaching a critical density of cracks in operational detail hanging system tractor.

The proposed method of assessment of danger prolonged use of mobile agricultural machinery can be used to develop professional risk classifier for

mechanized agriculture. In contrast to the method of expert assessments and other qualitative methods of assessment of occupational hazards developed a quantitative method based on objective ratios that correlate to statistics of occupational injuries in storage and data on operational damage in a common set of parts unit. Especially important is not only the absolute values of statistical indicators, but their change in relative terms, as illustrated by the Table 3.6.

However, the proposed method will provide an objective assessment of changing occupational risk only when used defectoscopic modern equipment that allows you to find hidden defects (cracks) which can lead to sudden failure equipment and emergency situations that lead to accidents. Visual inspection applied to detection of visible damage and cracks, and instrumental control with a ruler or calipers to determine changes configuration and size (arcuate, twisted beating, warping, and other violations not perpendicularity mutual accommodation and surfaces of the axes) must recognize insufficient to detect all potentially dangerous defects in the array of parts agricultural machine.

The data on the increase of professional risk mechanized work can be used how for ground acceptable level of risk using mobile agricultural machinery operating with damaged parts and structural elements, and for predicting the residual life of the unit after prolonged use.

The calculation results to assess the importance to create an emergency (dangerous) situation as machine operators erroneous actions of his level of training and physical and psychological state, and technological factors. Analyzing the importance of technical factors in the mechanism of dangerous situations, it is necessary to distinguish its two components – the constructional and operational directly affect the technical safety of the machine. Therefore it is necessary to implement the logic simulation techniques at the design stage and testing of agricultural machinery, considering these methods as an important tool for reducing occupational risk mechanized.

Conclusions to Chapter 3

1. A method for the study of changes in occupational risk mechanized work in agriculture, taking into account the degree of accumulation of operational defects in the array of parts MTA. Established that process flow traumatic situations and their consequences can be present graph structures, Limiting the system four states "Man–Machine–Production Environment": working and whack tractor (machine), machine operators falling into disrepair and dangerous (situation).

2. It is shown that the results allow in the medium and long term, to predict the likelihood of system states "Man–Machine–Production Environment" in terms of occupational risk of injury mechanics of agriculture.

3. In the developed method of calculating the likelihood of accidents involving agricultural machinery and mobile data analysis is not linear dimensions of defects, and there are signs that revealed cracks of varying degrees of danger on the destruction of parts. This allows you to evaluate the failure probability tractors in the aspect depending on the implementations of complex traits that options for the presence or absence of cracks and limit the allowable size.

4. The complex method of assessment of occupational risk for long-term operation of mobile agricultural machinery for the effect of organizing (and errors of machine heads work) and technical (operational availability details damage) factors. It is shown that the construction of models of hazardous work situations shall be based on the isolation of one (major) events actually dangerous situation and many assumptions - erroneous actions of employees, equipment failures and adverse external influences production environment.

5. Results of calculation elements logical process flow simulation model of traumatic situations to assess the risk of injury to workers who operate mobile agricultural machinery, in particular due to the accumulation of operational

damage to critical parts of nodes. The resulting values in impermissible professional risk should be the basis for meeting regulatory deadlines passing the maintenance of mobile equipment and replace damaged parts.

6. It is shown that a comparative analysis of the calculated values of occupational risk tractor-drivers before and after the removal of technical and organizational deficiencies allows to distinguish the most dangerous elements of the production activities of mechanics, clearly explain to them the risks of performance of individual manufacturing operations without technical protection measures and in violation of applicable security requirements that will reduce occupational injuries in the field.

CHAPTER 4. RECOMMENDATIONS FOR MONITORING OF SAFETY INDICATORS AND APPROACHES TO REDUCING THE RISK OF LONG-TERM OPERATION OF MOBILE AGRICULTURAL MACHINERY

4.1. Organization of checking the technical condition of tractors and SMS

To ensure the safety and health of workers in agricultural enterprises Ukraine adopted a number of regulations that constitute the legal framework of labor protection in the agricultural sector.

The main documents on health and safety in agriculture include: the Labor Code of Ukraine, the Economic Code of Ukraine, Laws of Ukraine "On Labor Protection", "On collective agricultural enterprise", "On agricultural cooperatives", "On Cooperation", "On the farm", "On pesticides and agrochemicals", "On ensuring sanitary and epidemiological welfare" and others. It should be noted that the legislation on labor protection applies to all employees who are employed by businesses, institutions and organizations irrespective of ownership and management, including individual (private) employers, farmers, and members of cooperatives and associations, collective farms, farms and more.

With specific agricultural general requirements of these laws specified in special (sectoral) regulations, namely the various policies, guidelines, regulations concerning the performance of agricultural machinery, agrochemicals, animals and more.

Requirements for condition monitoring wheeled farm tractors and their structural elements define:

– ISO 3649: 2010 "Wheeled vehicles. Safety requirements for the technical condition and methods of control";

– GOST 7057-2003 "Tractors, agricultural. Test methods";

– ISO 789-1: 2005 (2006) "Agricultural tractors. Methods of testing": Part 1: Power tests PTO mechanisms; Part 2. Lifting the rear three-point hitch; Part 3 diameters of circles described wheels and parts that best serve during rotation; Part 4: Measurement of exhaust smoke emissions; Part 5. Mechanism PTO partial transmission capacity. Non-mechanical transmission capacity; Part 6. The center of gravity; Part 7. Determination of power to the driving wheels; Part 8 engine air filter; Part 9. Determination of capacity on the coupling bar; Part 10. Hydraulic for tractor equipment; Part 11. Manageability wheeled tractors; Part 12. Low start;

– ISO 3463: 2005 "Agricultural and forestry wheeled tractors. Protective structure. Method of dynamic testing and acceptance conditions";

– ISO 12368: 2006 "Agricultural vehicles. Mechanical connection hook-type tractors. Test methods and specifications";

– ISO 5696: 2007 "Towed agricultural vehicles. Brakes and brake actuators. Laboratory test method";

– ISO 5700: 2004 "Agricultural and forestry wheeled tractors. Protective structure. Static test method and acceptance conditions";

– ISO 14269-2: 2013 - 5: 2013 "Agricultural and forestry tractors and self-propelled machines. The environment in the cab operator": Part 2. Test methods and performance of heating, ventilation and air conditioning; Part 3. Determination of the effects of solar heating; Part 4: Test method of filter element; Part 5: Test method system creating overpressure.

The technical condition of tractors are allowed to drive on public roads must comply with:

1. Traffic rules, approved by the Cabinet of Ministers of Ukraine of 10.10.2001 p. 1306 number;

2. Procedure for obligatory volume control and checking the technical condition of vehicles approved by the Cabinet of Ministers of Ukraine of 30.01.2012 p. 137 number;

3. NPAOP 00-1.62-12 "Rules of safety in road transport," approved by the Ministry of Emergencies of Ukraine 09.07. 2012 r. Number 964.

Entities engaged in the design, manufacture and repair of tractors and mechanization made on their basis must comply with the DSP 3.3.2.041-99 "Sanitary rules on the device equipment and tractors and agricultural machinery", approved by the Chief Medical Officer Ukraine on 01.12.1999, the number 41.

Requirements for the operation of batteries that use starter for starting an internal combustion engine, determine:

1. Guidelines on its use rechargeable lead-acid starter batteries wheeled vehicles and special vehicles carried on wheeled chassis approved by the Ministry of Transport and Communications of Ukraine of 02.07.2008 p. 795 number.

2. Performance standards average life rechargeable lead starter batteries wheeled vehicles and special vehicles carried on wheeled chassis approved by the Ministry of Transport and Communications of Ukraine of 20.05.2006 p. 489 number.

You also need to take into account the "Guidelines for the prevention of occupational injuries and occupational disease while working on foreign and domestic agricultural machinery on the basis of professional risks", approved by the Ministry of Agricultural Policy and Food of Ukraine of 12.13.2012 p. 768 number, which summarizes the requirements for safe operation tractors and mounted on their base of mechanization.

Visual inspection determine the overall condition of the tractor and set for visible defects (performance). Examples of typical devices for inspection of tractors APC shown in Fig. 4.1.

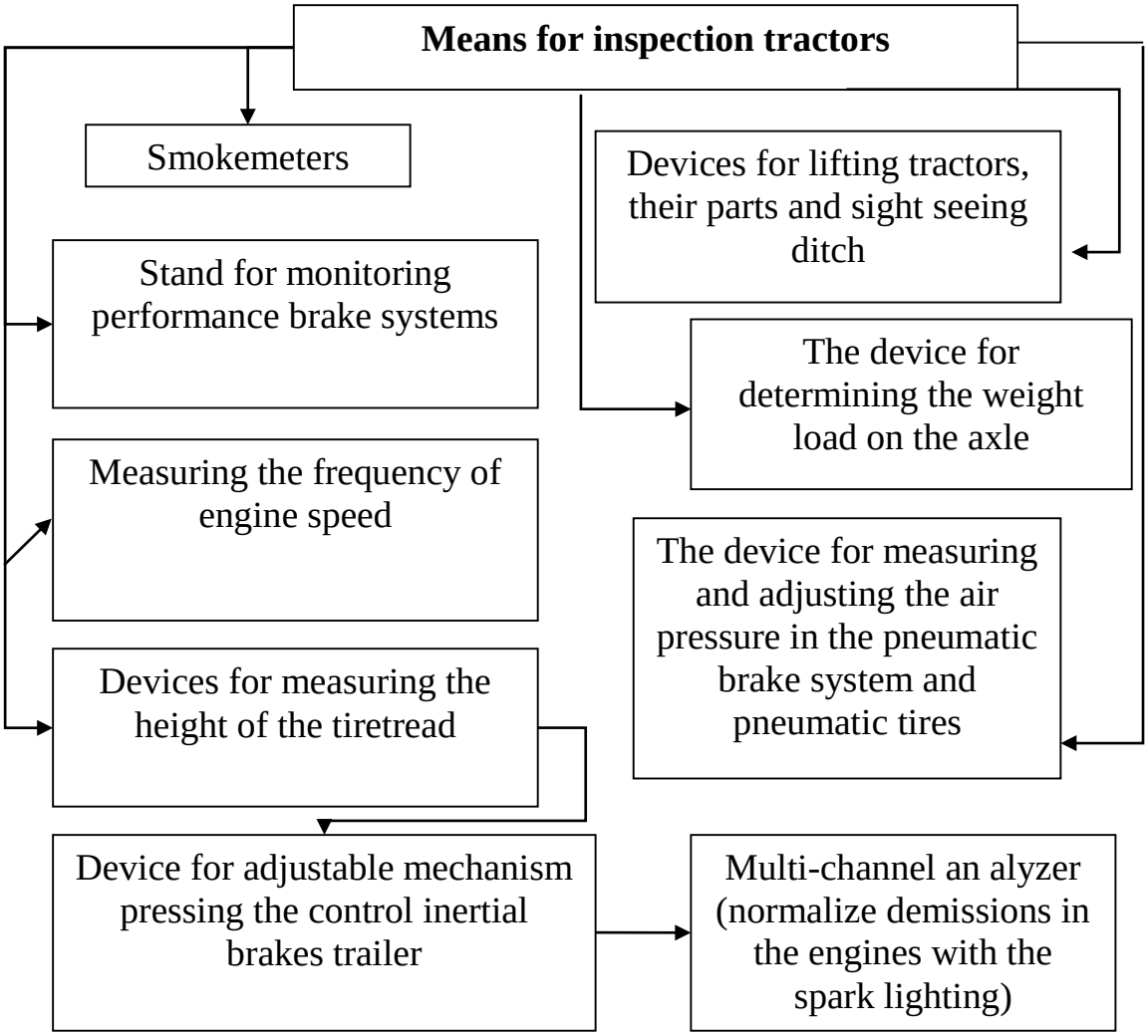

Fig. 4.1. Tools for the inspection and control of safety parameters tractors AIC

Test invalid move allows all nodes to test a tractor (engine, braking systems, lighting and alarm systems, etc.). After testing under load, determine compliance with its actual parameters Tractor specifications.

Data on the volume made maintenance and repairs recorded in a special journal (Journal of maintenance or repair of machinery magazine). Also, the results of maintenance and repair need to record quarterly passport (form) machine.

List of tractor units to be periodically checked and tested to ensure safe operation, shown in Fig. 4.2.

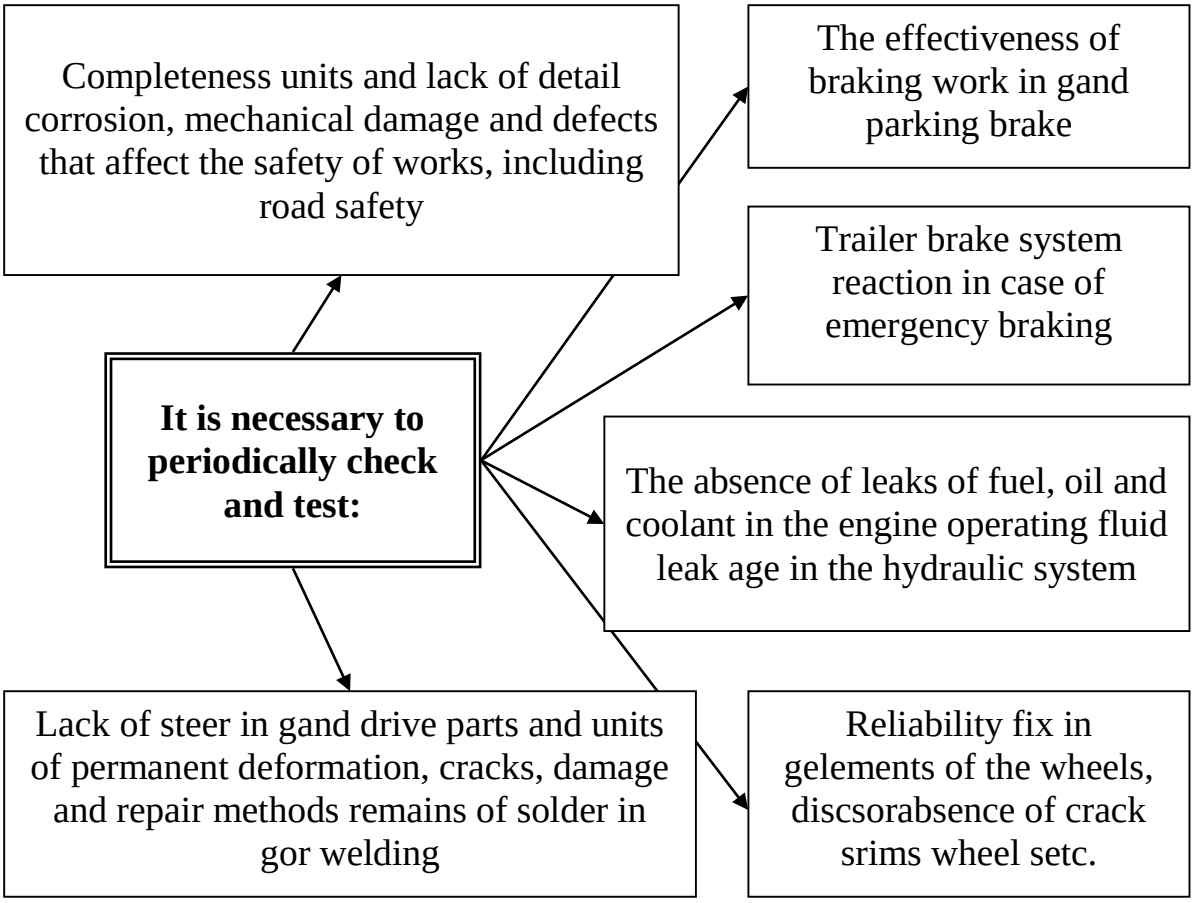

Fig. 4.2. List of parameters Tractor units that contribute to operational safety

A review of the technical state of tractor recorded in the operational log (for example, Journal of acceptance and delivery changes), which noted: changing the state of a tractor for changes malfunction that violate his or performance requirements of safe operation; the measures taken to deal with problems; cases of violation of operational documentation tractor or technology. These operational log is used to determine the range and scope of maintenance tractor.

After the renovation, upgrading or technical re envisages expert inspection machines specialized organization (expert technical center of the State Service for Labor Ukraine).

4.2. The principles of control parts defects and metal mobile agricultural machinery

In the workshops farmers flaw parts mainly conducted on-site dismantling of machine components. Control the manufactured or remanufactured parts, usually on technical control station or a mechanical fitter-station where performing final operations of mechanical processing. Workplace defector controller and equip universal and special measuring tool: calipers, micrometers and calipers indicator measuring various intervals, and trammel heads, line checkout, a set of probes for measuring the flatness and other violations.

Mandatory part of a flaw to be using technical requirements for detection of defects in machine parts, which depict details of a sketch, indicate possible defects, the size of surfaces in accordance with manufacturer's drawings and allowable amount necessary measuring instrument. But now new brands of domestic and foreign mobile agricultural machinery such requirements do not develop.

To control parts defects and structural elements of agricultural units currently used mostly visual inspection (for detection of visible damage and cracks). However, it is important to practice (regulations) maintenance of agricultural machinery defectoscopic introduce the use of modern devices that allow to find hidden defects (cracks, sinks unboiled place, etc.) which can lead to sudden failure equipment and emergency situations that lead to accidents. For evaluation risk of operating a mobile agricultural machinery is necessary to have data on the availability of parts and construction not only of major cracks, but also those that may spread further into the details of the critical variables. So in Fig. 4.3 the presented algorithm evaluation serviceability mobile agricultural machinery.

Indicators safe operation of tractors and agricultural machinery as determined in accordance with the procedures approved by state and industry

standards, specific recommendations, instructions and other documents. These documents include security monitoring indicators Cards tractors, combines and other machinery. Such cards for individual units need to specify a list of indicators, frequency control, standardized metrics to measure during the control technology.

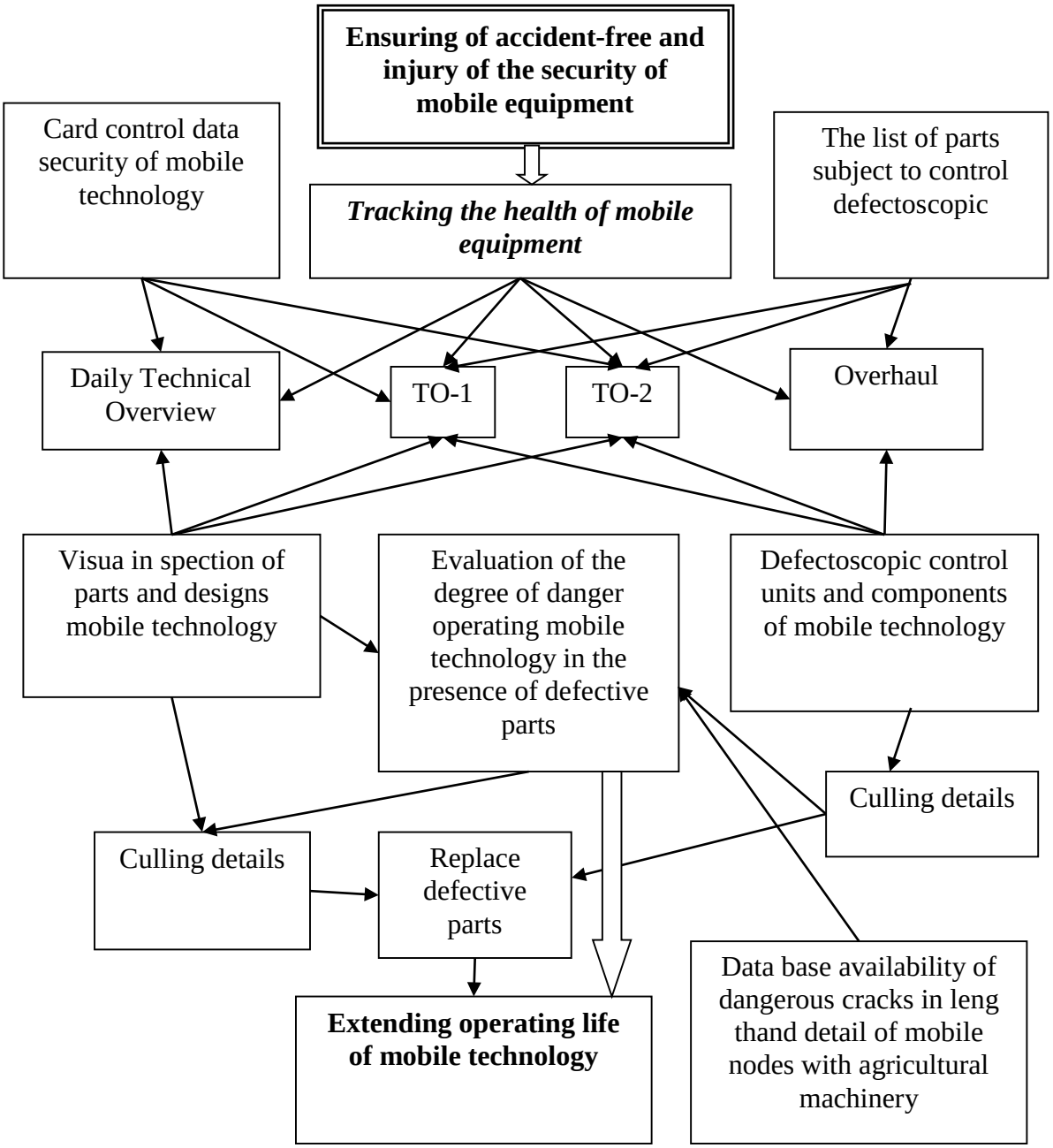

Fig. 4.3. Algorithm evaluation serviceability mobile agricultural machinery

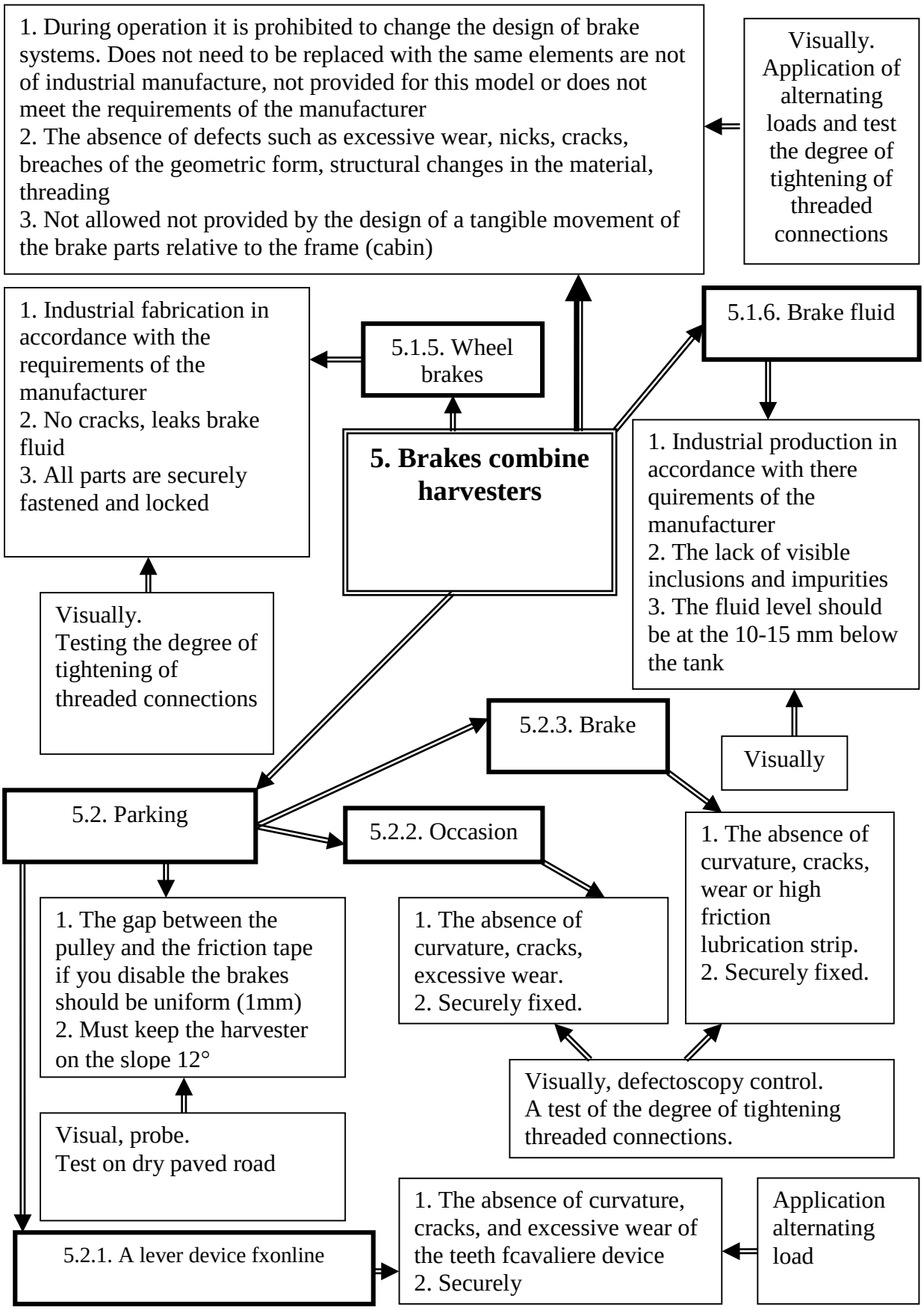

Fig. 4.4. Flowchart Maps control safety performance braking system combine

Map control performance security devices and systems combine features are presented 4.4. For illustrative table that corresponds Card security monitoring indicators formed as a block diagram to test the braking system combine (its individual components, subsystems, components and materials).

Maps requires monitoring safety performance tractors, combines and other machinery necessary to periodically check and test elements such nodes determining safe operation of the unit:

– completeness units and lack of detail corrosion, mechanical damage and defects that affect the safety of works, including road safety;

– braking performance working and parking brake;

– operation of the braking system of the trailer in the event of emergency braking;

– lack of steering and drive parts and units of permanent deformation, cracks, damage and repair methods soldering residues or welding;

– no leakage of fuel, oil and coolant in the engine operating fluid leaks in hydraulic systems of machines and their working bodies;

– a secure element wheels. The absence of cracks drive wheels or rims and others.

Particular attention should be paid to the technical condition of assemblies, damage which can cause injury to machine operators and other workers.

Thus, the hook and the machine must have semi trailers tight coupling. Machines should be equipped with mechanical locks that keep their bodies working in the transport position. Vehicles with tipping bodies must be equipped with devices for recording body in the raised position. Parking brake should hold the vehicle on a slope of at least 10° (18%).

In welded joints cab or protective cages should not be cracked, shells, unreliable connections cab car frame and frame deformation. Levers and pedal working bodies of machines and tools should move freely and have a reliable locking device. Support (footrests and ladders) and rail (handrails and handles)

should be kept in good condition.

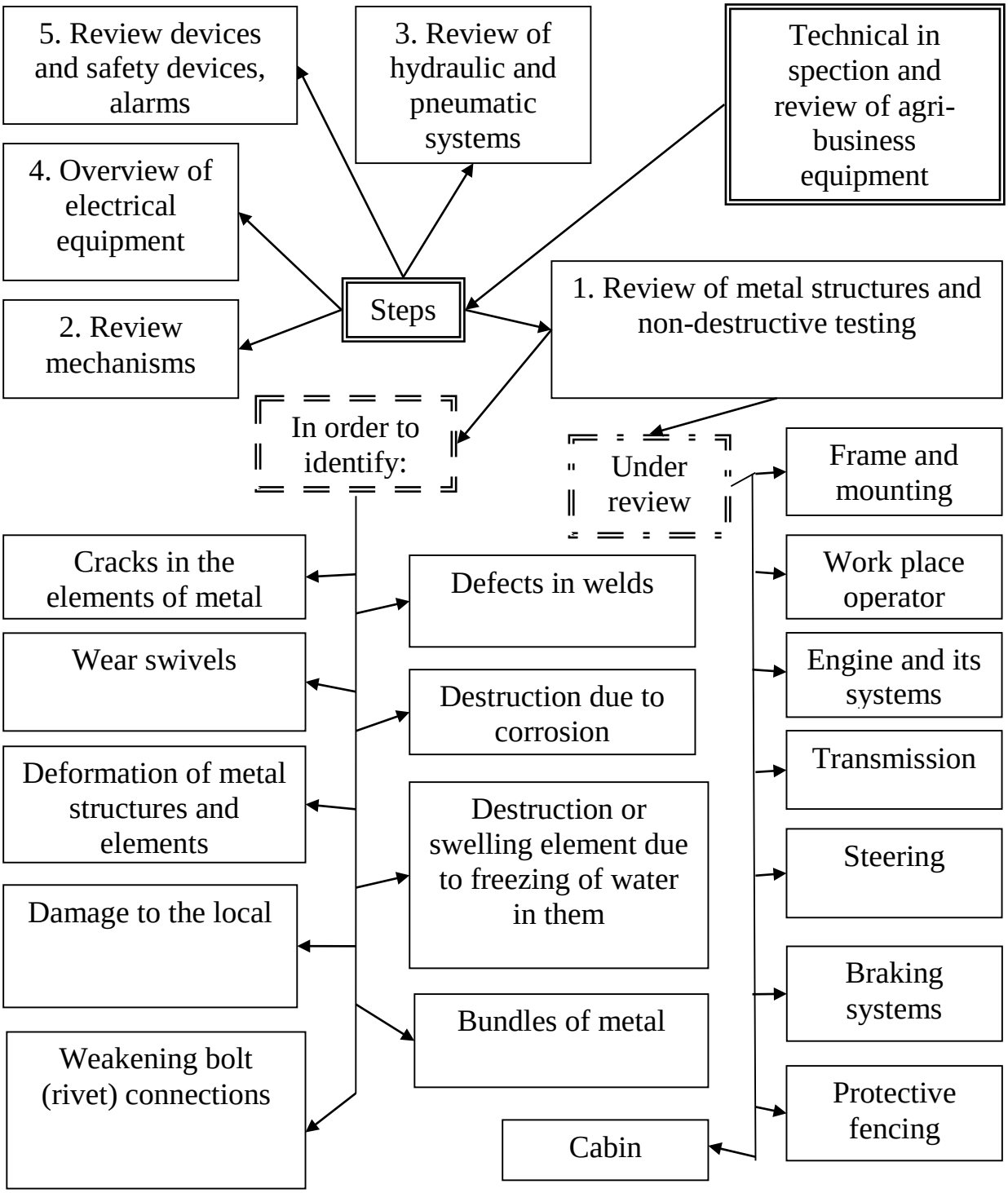

Fig. 4.5. Procedure for technical examination and inspection of mobile agricultural machinery

In mechanical drive brake should not be binding levers and pads, pined connections and the presence of cracks.

Technical inspection and review of agricultural machinery to ensure the safety parameters should be carried out in stages (Fig. 4.5).

During the inspection of metal structures of agricultural machinery must pay attention to the following parts: frame and mounting; The driver; engine and its systems; transmission; Steering; braking systems; protective enclosures, shower. Depending on the design of agricultural machinery may be subject to review other part.

To detect defects in parts and components of tractors, combines and agricultural units can recommend portable flaw detectors. As shown in this study met the study, preference should be given Eddy current flaw portable type.

These need to equip flaw repair shops and maintenance departments farms. Workers repairing farm units must undergo practical training and skills to identify cracks portable flaw in the presence of the surfaces of paint, grease, rust and other barriers to control.

The results of the control should be drawn up and regularly updated database of locations of potential defects in parts and components of agricultural units. Some database correctly formed can be summarized that will quickly assess the risk of further operation of the mobile agricultural machinery after cracks critical or critical length.

The guidelines for the maintenance and repairs of mobile agricultural machinery is necessary to make demands on the tool (using portable flaw) detecting cracks dangerous proportions in parts and components, and visual inspection regarded as insufficient. Value defectoscopic control significantly increases with the duration of stay of tractors, combines and CCM operation, especially after 10-12 years.

Quantitative data for increasing the risk of accidents involving agricultural units that threaten the lives and health of workers should be a warning to the

leaders and officials of middle senior management of agricultural enterprises, allowing technically faulty operation of mobile equipment.

Implementation of operational defectoscopic control and methodology of assessment of the risk of operating a mobile agricultural machinery defects critical length of parts and components will annually significantly increase the level of detection of faulty agricultural units, and thus reduce the number of injured workers who operate (in the fields and roads) and serving tractors, combines and SMS.

Now the task is urgent safety justification mobile resource units of agricultural machinery after prolonged use. It is necessary to establish further period of trouble-free service agricultural machine after being subjected to standard time, which may be ten years or more. During the operation in the fields, farms roads and parts and structural elements of machines experiencing the adverse effects of different nature, which leads to the expansion of operational damage in structural materials and depletion of resources. Due to the limited access of defectoscopic control in dangerous areas of structural elements which can develop dangerous damage, the main method of predicting the residual life of structural elements is modeling processes operational damage [47].

Fig. 4.6 shows a diagram illustrating a methodology for estimating the residual life (T_{kryt} - T_{fact}) Tractor after a certain length of operation using the resulting savings performance charts intensity of cracks in the array of parts tractors (§ 2.4). The chart was constructed after defectoscopic control more than 50 tractors that were in use 17 years from the date of issue. Defectoscopic control performed during flaw detection of details of tractors delivered for repair.

Coordinates the following diagram: the vertical axis – the relative number of detected cracks n_d in the total population studied, significant in terms of operational safety, parts N; x-axis –relative lifespan tractors (calculated on the base duration 17 years).

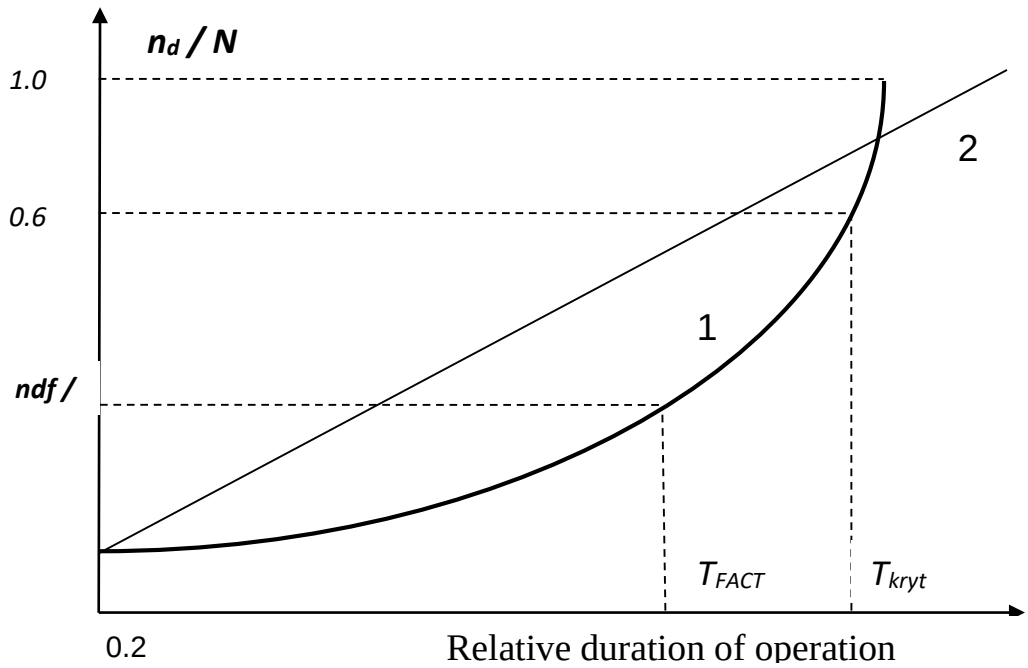

Fig. 4.6. Scheme evaluation methodology residual life of tractors after prolonged use 1 – Diagram of operational intensity accumulation of cracks in the array of parts; 2 – Diagram of linear damage accumulation law

Fig. 2.10 was found the relative duration of the operation, when the maximum intensity of cracks and consequently in excess of this value increases the likelihood of sudden destruction of tractor units and creating emergency situations or mechanized transport operations. For tractor units investigated this value (T_{kryt}) is about the same and is in the range of 0.6-0.7 relative lifespan, or about 11-13 years. The actual time (T_{FACT}) operating the tractor can be assessed to find a certain number of defects (cracks) in the array of parts, calculating their the relative amount of the total population studied details and horizontal spending to Chart intensity accumulation of operational cracks as shown Fig. 4.6.

Conclusions to Chapter 4

1. Recommendations on trouble-free and safe operation of mobile agricultural units. The specified characteristic malfunction individual units of

tractors, which should indicate Maps monitoring safety parameters. According to the requirements of these cards are periodically need to check and test elements of units that determine safety of agricultural units.

2. The guidelines for the maintenance and repairs of mobile agricultural machinery is necessary to make demands on the tool (using portable flaw) detecting cracks dangerous proportions in parts and components, and visual inspection regarded as insufficient. Value defectoscopic control significantly increases with the duration of stay of tractors, combines and CCM operation, especially after 10-12 years. The algorithm for estimating the serviceability of mobile agricultural machines.

3. The algorithm identifying potential industrial hazards and quantitative assessment of risk in the workplace agricultural production, allowing to switch to an improved level of safety regulation in agriculture – based on a risk-based approach.

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APPLICATIONS

Table A.1

Results of defectoscopic control of steering system components wheel tractors of different years of production

№ p/p	Names steering system	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	Steering column (shaft)	1	4	2	3	4	3	-	-	20
2.	Case hydraulic power steering	4	3	1	6	2	3	2	2	24
3.	Fry	1	2	1	2	-	-	2	2	11
4.	Average shaft	1	1	2	1	1	3	3	2	15
5.	Swivel arm	1	2	1	3	-	1	1	1	11
6.	Countershaft	2	4	2	4	2	1	1	-	17
7.	Serg	-	2	-	2	1	2	-	-	7
8.	The front shaft	-	2	1	2	-	-	3	1	9
Total found cracks		10	20	10	23	10	13	12	8	114
Total monitored components		22	47	18	43	27	41	48	40	303
The relative number of parts with cracks		0.45	0.42	0.56	0.53	0.37	0.32	0.25	0.2	

Table A.2

Results of defectoscopic control of parts attaching wheeled tractors of different years of production

№ p/p	Names hanging hydraulic system	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	The central thrust (top)	-	6	1	7	1	4	2	2	24
2.	Arm ties	-	2	1	3	4	1	2	1	16
3.	Lifting cylinder lever	1	1	1	1	1	1	2	-	10
4.	Brace	-	1	-	-	1	1	-	-	5
5.	Tightening	-	1	1	2	1	-	2	2	10
6.	Regulatory couplings	1	3	-	4	-	-	-	4	12
7.	Lower link	1	1	1	2	-	1	1	-	7
8.	Fork	-	1	1	1	1	1	-	-	5
9.	The axis of the lower rods	-	2	1	1	-	1	1	-	6
Total found cracks		3	18	7	22	9	10	10	9	95
Total monitored components		8	48	15	55	29	34	38	39	278
The relative number of parts with cracks		0.4	0.37	0.46	0.4	0.31	0.29	0.26	0.23	

Table A.3

Results of defectoscopic control of engine parts wheeled tractors of different years of production availability

№ p/p	Name of engine parts	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	Cylinder heads	-	5	3	1	1	5	-	2	18
2.	Valves	-	2	1	1	1	-	2	1	11
3.	Block crankcase	2	1	1	3	-	-	3	-	12
4.	The cylinder block	-	3	2	1	2	2	1	-	12
5.	Sleeves	1	1	1	1	-	2	-	-	7
6.	Piston pin	-	1	1	1	-	-	-	-	4
7.	Pistons	1	4	1	4	3	2	1	1	19
8.	Gear crankshaft	-	2	-	1	-	1	-	-	6
9.	Flywheel	-	2	-	1	1	2	1	-	7
10.	Rods	-	1	1	2	2	2	1	3	12
Total found cracks		4	22	11	17	10	16	9	7	108
Total monitored components		7	45	23	38	26	50	29	28	263
The relative number of parts with cracks		0.56	0.48	0.47	0.44	0.39	0.32	0.31	0.25	

Table A.4

Results of defectoscopic control of parts rear axle wheeled tractors of different years of production

№ p/p	Names steering system	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	Top gear bevel gear	2	3	2	3	-	2	1	-	14
2.	Powered by the main transmission gear	1	2	1	3	2	-	-	-	10
3.	Powered pinion bevel gear	1	3	1	2	2	-	-	-	9
4.	Rear axle housing	1	-	1	1	3	3	3	2	14
5.	Semiaxis	1	4		2	1	3	1	-	13
6.	Secondary shaft gear	-	2	1	1	1	-	1	1	8
7.	Cover rear axle	-	2	1	2	-	-	1	5	12
Total found cracks		6	16	7	14	9	8	7	8	80
Total monitored components		13	43	20	41	27	25	23	30	232
The relative number of parts with cracks		0.46	0.37	0.35	0.34	0.33	0.32	0.3	0.27	

Table A.5

Results of defectoscopic control of details gear wheel tractors of different years of production

№ p/p	Names gear	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	Countershaft	2	1	1	1	1	2	3	-	13
2.	Primary shaft	2	1	-	1	-	2	1	-	8
3.	Slave gear of trigger reducer	1	1	1	1	2	-	-	1	7
4.	Leading gear of III transmission	1	2	-	1	1	-	-	1	8
5.	Leading gear	-	1	1	1	1	2	1	2	9
6.	Corps gear	3	1	-	2	1	1	1	1	12
7.	Intermediate of trigger gear reducer	1	1	-	-	1	-	-	-	6
8.	Shaft I gear and reverse	-	1	1	1	2	1	2	2	11
9.	Leading first degree gear reducer	2	2	1	-	-	1	1	-	7
Total found cracks		12	11	5	8	9	9	9	7	81
Total monitored components		29	35	16	25	31	32	42	39	273
The relative number of parts with cracks		0.41	0.31	0.31	0.32	0.29	0.28	0.21	0.18	

Table A.6

Results of defectoscopic control of steering system components wheel tractors of different years of production availability of small cracks

№ p/p	Names steering system	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	Steering column (shaft)	1	1	-	1	1	2	-	-	6
2.	Case hydraulic power steering	1	-	1	2	1	1	2	1	9
3.	fry	1	1	-	1	-	-	1	1	5
4.	Average shaft	1	-	1	1	1	2	2	1	9
5.	Swivel arm	-	1	-	1	-	1	1	-	4
6.	Countershaft	1	1	-	1	1	1	1	-	6
7.	Serg	-	1	-	1	1	2	-	-	5
8.	The front shaft	-	1	1	1	-	-	1	1	5
Total found small cracks		5	6	3	9	5	9	8	4	49
Total monitored components		22	47	18	43	27	41	48	40	286
The relative number of parts with small cracks		0.2	0.13	0.17	0.21	0.18	0.21	0.16	0.1	

Table A.7

Results of defectoscopic control of parts attaching wheeled tractors of different years of production availability of small cracks

№ p/p	Names hanging hydraulic system	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	The central thrust (top)	-	1	-	4	1	1	2	1	10
2.	Arm ties	-	1	1	1	3	1	1	1	9
3.	Lifting cylinder lever	1	1	-	1	1	1	2	-	7
4.	Brace	-	1	-	-	1	1	-	-	3
5.	Tightening	-	2	1	2	1	-	1	1	8
6.	Regulatory couplings	1	-	-	1	-	-	-	1	3
7.	Lower link	-	1	-	2	-	1	1	-	5
8.	Fork	-	-	1	1	1	-	-	-	3
9.	The axis of the lower rods	-	1	-	1	-	-	1	-	3
Total found small cracks		2	8	3	13	8	5	8	4	51
Total monitored components		8	48	15	55	29	34	38	39	266
The relative number of parts with small cracks		0.12	0.16	0.2	0.23	0.27	0.14	0.21	0.1	

Table A.8

Results of defectoscopic control of engine parts wheeled tractors of different years of production availability of small cracks

№ p/p	Name of engine parts	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1	Cylinder heads	-	1	1	-	1	3	-	2	8
2	Valves	-	1	-	1	1	-	1	1	5
3	Block crankcase	1	1	1	1	-	-	2	-	6
4	The cylinder block	-	2	-	1	-	1	1	-	5
5	Sleeves	-	1	1	1	-	-	-	-	3
6	Piston pin	-	1	-	1	-	1	-	-	3
7	Pistons	1	2	1	1	1	1	-	1	8
8	Gear crankshaft	-	1	-	1	-	1	-	-	3
9	Flywheel	-	1	-	1	1	1	1	-	5
10	Rods	-	1	1	1	1	1	-	1	6
Total found small cracks		2	12	5	9	5	9	5	5	52
Total monitored components		7	45	23	38	26	50	29	28	246
The relative number of parts with small cracks		0.28	0.26	0.22	0.23	0.19	0.18	0.17	0.17	

Table A.9

Results of defectoscopic control of parts rear axle wheeled tractors of different years of production availability of small cracks

№ p/p	Names steering system	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1.	Top gear bevel gear	-	1	-	1	-	-	1	-	3
2.	Powered by the main transmission gear	-	1	1	-	-	1	-	-	3
3.	Powered pinion bevel gear	-	1	1	1	1	1	-	-	5
4.	Rear axle housing	1	-	-	1	2	-	1	1	6
5.	Semiaxis	1	2	-	1	-	1	-	-	5
6.	Secondary shaft gear	-	2	-	1	1	-	1	1	6
7.	Cover rear axle	-	1	-	1	-	-	-	2	4
Total found small cracks		2	8	2	6	4	3	3	4	32
Total monitored components		13	43	20	41	27	25	23	30	222
The relative number of parts with small cracks		0.15	0.18	0.15	0.14	0.14	0.12	0.13	0.13	

Table A.10

Results of defectoscopic control of details gear wheel tractors of different years of production availability of small cracks

№ p/p	Names gear	Duration (years) operating tractors (in parentheses indicate the number of tractors, parts of which were defectoscopic control)								Together
		15 (3)	14 (8)	13 (4)	12 (7)	11 (7)	10 (7)	9 (8)	7 (7)	
1	Countershaft	1	1	1	-	-	1	1	-	5
2	Primary shaft	-	1	-	1	-	-	1	-	3
3	Slave gear of trigger reducer	1	-	1	-	1	-	-	1	4
4	Leading gear of III transmission	1	1	-	1	1	-	-	1	5
5	Leading gear	-	-	1	-	1	1	1	1	5
6	Corps gear	-	1	-	1	-	1	1	1	5
7	Intermediate of trigger gear reducer	1	1	-	-	1	-	-	-	3
8	Shaft I gear and reverse	-	1	-	1	1	1	1	2	7
9	Leading first degree gear reducer	1	-	-	-	-	1	1	-	3
Total found small cracks		5	6	3	4	5	5	6	6	40
Total monitored components		29	35	16	25	31	32	42	39	249
The relative number of parts with small cracks		0.17	0.17	0.18	0.16	0.16	0.15	0.14	0.15	

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