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Prevention of Combine Harvester Fires against a Dangerous Evolution of Heat in Friction Units

Vadim A. KOVTUN[1], Vladimir N. PASOVETS[2], Yordan N. MIRCHEV[3]

[1] Gomel Branch University of Civil Protection of the Ministry for Emergency Situations of the Republic of Belarus, Gomel, Belarus, e-mail: vadimkov@ya.ru

[2] University of Civil Protection of the Ministry for Emergency Situations of the Republic of Belarus, Minsk, Belarus, e-mail: pasovets_v@mail.ru

[3] Institute of Mechanics of the Bulgarian Academy of Sciences, Sofia, Bulgaria;
e-mail: mirchev@imbm.bas.bg, nntdd@abv.bg

Abstract
A significant number of fires on combine harvesters occurs due to heating of frictional surfaces and ignition of plant matter. The ways of solution of the complex problem of increasing the fire safety of combine harvesters are presented in the work. A rational solution to this problem is the use of new composite materials, the use of modern control and fire extinguishing systems. In addition, the fire safety of cereal-harvesting machines is ensured by controlling the temperature of the friction units, preventing them from overheating, timely maintenance and keeping the combine clean.

Keywords: combine harvester, friction, ignition, fire, composite material, control and fire extinguishing system, evolution of heat.

1. Introduction

The combine harvester is a versatile machine designed to efficiently harvest of grain crops. The modern combine harvester do four separate harvesting operations (reaping, threshing, gathering and winnowing) into a single process. Among the crops harvested with a combine are wheat, rice, oats, rye, barley, corn, linseed, sunflowers and canola. The separated straw, left lying on the field, comprises the stems and any remaining leaves of the crop with limited nutrients left in it: the straw is then either chopped, spread on the field and ploughed back in or baled for bedding and limited-feed for livestock.

Harvest is a particularly hazardous time as it combines hot and dry conditions with a very flammable crop. The risk of fire is only set to worsen as climate change will create longer periods of hot and dry conditions, changes in harvester design that create a more efficient, clean and higher producing machine also create additional fire hazards on the machine.

The demands placed on the modern combine harvester many and varied, the machine must be able to harvester the crop at just the right time when the crop reaches its peak and often only has a very short window to do this once this window is reached, sometimes less than two week.

A small part of the combines has any type of fire detector or fire suppression system.

For everybody else the only fire detection they have is their own senses and the method of fire suppression is a handy fire extinguisher.

Agricultural losses due to fires on a combine harvester are not limited, in the short term, to the destruction of crops, but, in the medium term, result in production capacity losses that have been estimated in 35–45 % in subsequent years [4]. [1].

The modern combine harvester is a very large, complex and highly capable machine that processes a very large amount of grain in a very short amount of time. Because of this, modern combine harvesters have increasingly become more and more costly, in the range of hundreds

of thousands of dollars for the average machine and nearing a half a million dollars or even more for the very largest, highest capacity machines. This coincides with the hotter and drier weather of the summer months. Once harvest has begun, farmers, workers and contractors will work from sunup to sunset harvesting, moving, storing and processing crops until the job is completed. 12 hour days are standard and 18 hour days are not uncommon. This leaves very little time for even essential maintenance to be completed.

Combine harvesters contain a large number of friction units, which are located in headers, conveyors, threshing and separating devices, straw walkers, shredders, various drives, motors, etc. At the same time, providing these units with lubricants is the most important condition for reliable and safe operation of the entire combine harvester.

A characteristic feature of this type of machines is the need to check them before the harvest season and control them from time to time during operation. The control involves checking the temperature and condition of the bearings, as well as their lubrication and cleaning.

A damaged bearing can be heated during operation to very high temperatures which often leads to fire of both the machine and surrounding crops (Figure 1). For this reason, a system alerting the operator on bearing failure at a sufficiently early moment can prevent such dangerous situations.

a) b)

Fig. 1. – Combine harvester fire (a) and fire consequences (b)

The purpose of the work investigation of ways to prevent combine harvester fires arising from heat generation processes in friction units and plant materials.

2. Application of new materials

In general, the following requirements are imposed on the materials of friction units: high wear resistance, low coefficient of friction, resistance to shock loads and fatigue, high thermal conductivity and low temperature coefficient of linear expansion, which provides resistance to seizing. To date, bronzes, babbits, antifriction cast irons, composite materials on a polymer or metal base are used as materials for friction units (Table 1).

In this case, the most promising materials for friction units are composite materials containing carbon nanostructures as a strengthening and antifriction filler. So, to date, composites have been developed for friction units with low wear rates and friction coefficient, as well as a high thermal conductivity coefficient [13, 14].

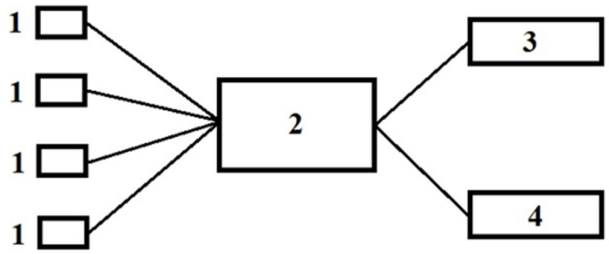
Table 1 – Tribotechnical and physical-mechanical characteristics of composite materials for friction units without lubrication

Material (country)	Friction coefficient	Intensity of the wear , μm/km	Compressive strength, MPa	Porosity, %
CuG15 (Russia) [15]	0,22 – 0,26	1,46 – 1,5	175	–
RU 2031173 (Russia) [16]	–	0,21 – 0,29	340	–
RU 2024639 (Russia), [17]	0,1 – 0,12	0,19 – 0,21	–	–
UA 70080 (Ukraine) [18]	0,12 – 0,14	–	210 – 235	–
BY 21703 (Belarus) [19]	0,1 – 0,13	0,06 – 0,07	156 – 165	2 – 4

3. Application of control systems

Based on the empirical experience of operating grain harvesters, it can be argued that the friction units of the header, conveyor, threshing apparatus and straw chopper require temperature control. Analysis of literary sources indicates the absence of special temperature control systems for friction units in grain harvesters.

To control the temperature of friction units, it is advisable to use systems designed for timely notification of the operator about exceeding temperature thresholds, based on temperature sensors, logic elements and alarms [20]. The designs of these systems are simple and reliable, and the principle of operation is as follows: signals from temperature sensors are transmitted to a logic element, processed, and when the threshold values are exceeded, the signal is sent to the sound and light alarm systems (Figure 2). At the same time, the operator is notified in two ways: light and sound, which is explained by the difficult working conditions of the combine operator during harvesting. For example, strong noise from both the engine and the machine tools can prevent the operator from hearing the sound signal, and working in the sun can limit the visibility of the light signal. Thus, the use of two types of signaling provides adequate information delivery to the operator, and the versatility of this temperature control system allows it to be used on any agricultural machinery.



1 – temperature sensors, 2 – logic element, 3 – light alarm, 4 – sound alarm

Fig. 2. - Scheme of the friction unit temperature control system

4. Application of fire extinguishing systems

To detect and extinguish a fire on a combine harvester, systems have been developed, consisting of fire alarm and fire extinguishing subsystems. The fire alarm subsystem allows you to determine the temperature rise in the protected space above the standard values and transmit the "Fire" signal to the control panel, which is located in the operator's cab. If no actions are taken to start the fire extinguishing system of the combine harvester, and the temperature in the protected volume reaches a critical level, then an independent signal will be sent from the processor to start the fire extinguishing installation. A thermal linear fire detector is adopted as a fire detector, which is located in the upper part of the protected compartment, for example,

the engine compartment or threshing space, since they carry the greatest fire load and assume the presence of ignition sources under various operating modes. It is proposed to use a modular aerosol fire extinguishing system as a fire extinguishing subsystem. [21]

Also today, an automatic fire alarm and fire extinguishing control system for cars and agricultural machinery is known, based on heat detectors that are connected to a central control unit, which in turn is connected to a block for manual activation of fire extinguishing installations and automatic control of fire extinguishing installations. The use of this system increases the likelihood of fire detection, increases its reliability and ensures the safety of people in the vehicle [22, 23].

Improved designs of fire-fighting devices have also been developed, the use of which is possible not only on agricultural equipment, but also on passenger and freight transport, as well as on construction, road and special equipment. These fire-fighting devices have similar designs, provide targeted triggering of a fire extinguishing agent and are equipped with uninterruptible power supplies, filters of electromagnetic interference, units for registering changes in the state of the system in non-volatile memory and microcontrollers [24]. It should be noted that fire-prevention devices and warning systems acquire particular importance with the further development of agricultural engineering, for example, when developing a grain harvester with remote or robotic control, characterized by the absence of a combine operator that could take measures to extinguish a fire that has arisen with sufficient promptness. Also, on grain harvesters, it is possible to use aerosol-powder fire extinguishing devices containing fire extinguishing aerosol generators, the principle of which is based on the use of combined means in the form of an inhibiting aerosol and a fire extinguishing powder. [25]

Of particular interest is the issue of the use of fire extinguishing agents in automatic fire extinguishing systems. For example, on-board fire suppression systems installed on heavy off-road vehicles and agricultural vehicles operating under severe conditions use a dry chemical such as monoammonium phosphate to extinguish the fire. It is known, however, that dry extinguishing chemicals provide insufficient protection against possible re-ignition.

Justified for extinguishing fires on agricultural machinery is the use of dispersed water, characterized by high fire extinguishing efficiency and environmental friendliness [26 - 28]. Promising fire extinguishing materials for use in on-board fire extinguishing systems on agricultural machinery are compositions that provide the formation of an aqueous low-expansion film-forming foam, which allows you to cool the combustion zone and protect it from re-ignition. At the same time, the subsequent removal of the remains of burnt plant mass and fire extinguishing agents will not affect the operational properties of the grain harvesting equipment.

5. Conclusions

A significant number of fires on combine harvesters occurs due to heating of rubbing surfaces and ignition of plant matter due to friction against moving parts of parts of units and assemblies. Ways of rational solution of a technically complex and urgent task of increasing the fire safety of operation of grain harvesters through the use of new composite materials, as well as the use of modern control and fire extinguishing systems are presented. Fire safety of grain combine harvesters can be ensured by controlling the temperature of friction units, preventing them from overheating, timely maintenance and keeping the combine clean.

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