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Received: 2018-12-17 ; Accepted: 2019-02-15

CAVITATION DEFECTS IN FARM VEHICLE ENGINES

Summary

The article identifies and analyses selected examples of cavitation erosion occurring in farm tractor engines and their systems at different mileages. The analysis has been carried out on the basis of known theoretical rudiments of this phenomenon. The paper presents photographs from maintenance work selected by the authors, which illustrate the discussed matter graphically. There is a discussion on how to prevent cavitation phenomena occurring in coolant, which induce engine defects.
***Keywords**: internal combustion engine, cavitation, cavitation defects, prevention*

USZKODZENIA KAWITACYJNE W SILNIKACH POJAZDÓW ROLNICZYCH

Streszczenie

W artykule poddano identyfikacji i przeanalizowano wybrane przykłady występowania erozji kawitacyjnej w silnikach ciągników rolniczych i ich układach, po różnych przebiegach. Analizę przeprowadzono na podstawie znanych podstaw teoretycznych tego zjawiska. Zamieszczono zdjęcia wybrane przez autorów z pracy serwisowej, które graficznie przedstawiają zagadnienie. Omówiono również jak zapobiegać zjawiskom kawitacji w cieczy chłodzącej powodującej uszkodzenia silników.
***Słowa kluczowe:** silnik spalinowy, kawitacja, uszkodzenia kawitacyjne, zapobieganie*

1. Introduction

The term "cavitation" originates from Latin word *cavitare* - penetrate. This phenomenon consists in formation of bubbles in rapidly flowing liquids, which then disappear instantly. Cavitation in a coolant results from its pressure changes. This is due to vibrations induced by moving piston during engine operation. The vibrations are transmitted onto water jacket surrounding cylinder sleeve. When cylinder wall withdraws, vacuum bubbles are formed in coolant. When pressure rises again, the bubbles implode and molecules are torn out from the sleeve surface. Prolonged phenomenon duration results in component damage.

The main tractor components (subassemblies), in which cavitation occurs, include:
- internal combustion engines, and in particular the crankshaft-slide bearings system (the main pans and the connecting-rod pans), the piston-cylinder sleeve system,
- injection equipment of compression ignition engines, especially in injectors,
- needle seat and nozzle holes,
- liquid-based engine cooling systems with different pumps, most often centrifugal and controlled at high temperatures by circulation of coolant washing engine block, and cylinder sleeves of different types and sizes,
- turbines in engines upper charging systems,
- compressors and their lubrication systems, working systems [1, 2, 5].

According to its cause, cavitation in slide bearings of crankshaft in internal combustion engines may be divided into four different types: suction, discharge, flow and impact. Some reasons of occurrence of different cavitation types in vehicle combustion engines were examined to learn more about these phenomena and to carry out analyses and draw conclusions.

2. Cavitation defects - engine cylinder block

In very simple terms, the cavitation phenomenon follows abrupt, explosive liquid to gas transition. Energy generated through cavitation has so much power that impact microwave being formed is capable of tearing out molecules of very hard metals and thus damaging their surfaces. All of them occur in micro-scale, although effects are often very well visible as deep pits in metal surface. Cavitation always takes place when metal makes very fast movements in a liquid, e.g. vibrates in it. These vibrations are generated in engine cylinder sleeves while in operation and when they Deeper and deeper cavitation pits are formed on their external surfaces then, which may damage sleeve walls and induce coolant flow into the cylinder. Fig. 1 demonstrates strong cavitation impact on the walls of wet cylinder sleeves in the GZP area as a result of using cheap liquid and operating the engine in an improper way are directly cooled by liquid.

Fig. 1. Cylinder sleeves with cavitation defects - sharp edges of cavitation pits [1]
Rys. 1. Tuleje cylindrowe z uszkodzeniami kawitacyjnymi - ostre krawędzie wżerów kawitacyjnych [1]

3. Cavitation defects - cooling system

Efficient cooling system generates overpressure. As a result of it, coolant has higher boiling point and is more resistant to cavitation. However, even minor leakage-e.g. caused by damaged gasket under equalising tank cap, is the reason why there is no overpressure generated. It may induce cavitation and sleeve damage [1]. Non-operational thermostat or jammed viscous coupling unit in radiator fan may cause lasting insufficient engine temperature (under 70^{o}C), at which cavitation phenomenon is particularly intense. At higher temperature range (90-100^{o}C), higher coolant pressure prevents the occurrence of bubbles. Elementary mistakes made by farm tractor users include applying water in cooling system [1, 4]. Below, Fig. 2 shows an observed example of cavitation defect in cooling system water pump.

Fig. 2. Cavitation defects with intense characteristic son fixed components of water pump [1]
Rys. 2. Uszkodzenia kawitacyjne o intensywnym przebiegu na elementach nieruchomych pompy wodnej [1]

Gas bubbles accumulated in a coolant burst in an explosive way, making pits in individual pump components. Surfaces damaged in this way are then subject to corrosion. The reason is the occurrence of gas bubbles at coolant inlet into the pump. The bubbles explode and damage the surface as pressure in the system increases. In this case, it is required to replace water pump. Wash cooling system thoroughly before new water pump is installed and fill it with proper medium recommended by the manufacturer.

Coolant composition is a common reason for cavitation defects. Many engines are operated without an additive protecting cooling water from freezing. The antifreeze additive not only protects against freezing but prevents cavitation corrosion as well. Proper antifreeze improves physical and chemical properties of a cooling medium - reducing its freezing point and at the same time increasing its boiling point. It reduces air bubble formation, and thus the risk of changes due to cavitation. The following activities are needed to prevent cavitation occurrence in cooling system:

- necessarily check cooling system leak tightness (radiator cover, hoses, bands, etc.),
- add sufficient amounts of antifreeze and anticorrosive agents,
- check operation of the cooling system (thermostat, fan, thermal protection switch).

4. Cavitation defects in injection systems

Besides fatigue and erosion-friction wear, the injection equipment shows wear induced by the so-called flow cavitation. The contact surface of nozzle needle and housing seat is a good example. As soon as the needle is lifted, pressure in liquid drops as a result of fuel outflow to combustion chamber via nozzle holes [3].The so-called cavitation cloud appears on valve edge, which consists of cavitation bubbles and induces cavitation erosion. Much the same physicochemical phenomena are observed in injector nozzle holes. They are shown in (Figs. 3-4). During the injection, fuel stream from nozzle chamber (1) reaches small injection hole (2), where the flow channel contracts considerably. The flow rate increases and at the same time pressure drops as per the Bernoulli equation. At the edge of outflow and inflow of ducts the stream becomes discontinued and backflow (or turbulent flow) appears. The so-called imploding cavitation cloud inducing cavitation erosion emerges.

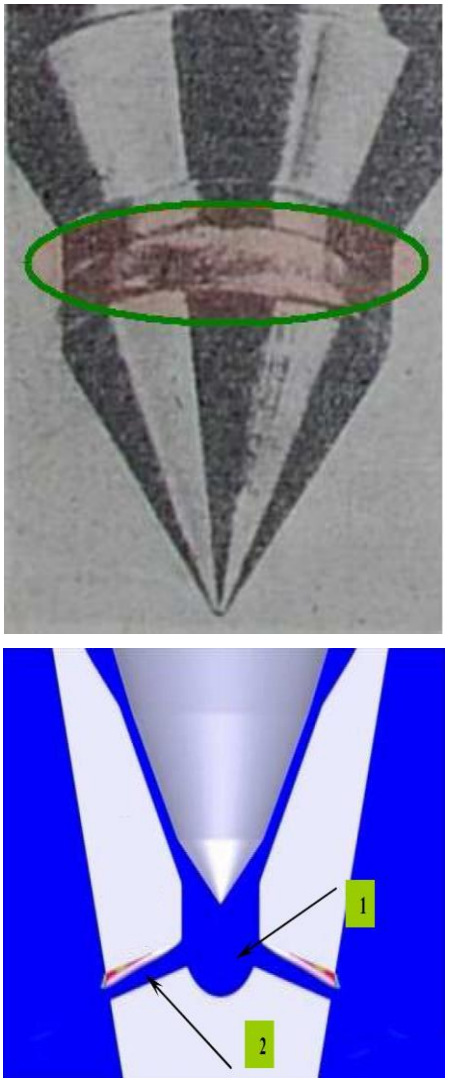

Fig. 3. Cavitation wear on contact surface of a needle and nozzle, under - illustrative view of the occurrence of the so-called backflow accompanying the cavitation and cavitation erosion phenomena [2]
Rys. 3. Zużycie kawitacyjne na powierzchni styku iglicy z rozpylaczem, poniżej - ujęcie poglądowe powstania tzw. przepływu wstecznego przy zjawisku kawitacji i erozji kawitacyjnej [2]

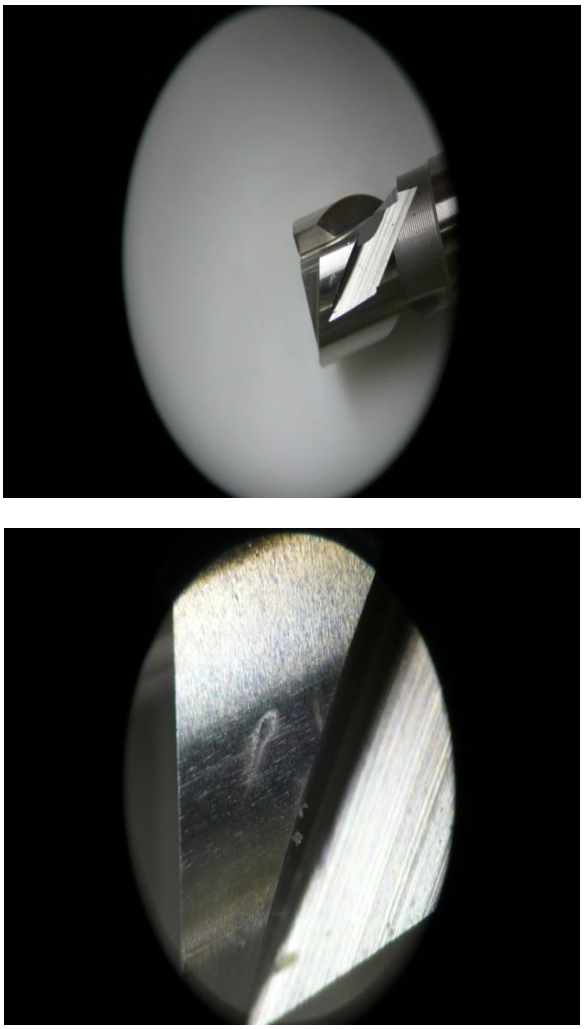

Fig. 4. Plungers in pumping sections (from Bosch) with cavitation pits [8]
Rys. 4. Tłoczki sekcji tłoczących firmy Bosch z wżerami kawitacyjnymi [8]

In this case cavitation wear proceeds as follows - flow capacity is disturbed when filter gets clogged. The pump tries to draw in fuel, which is impossible with clogged filter, and negative pressure is generated in the system between the pump and clogged area. It may be strong enough to induce tearing out of molecules from the material.

Cavitation wear characteristic is quite similar to that of erosion wear. Therefore, both these phenomena combined induce the so-called cavitation erosion. In modern Common Rail fuel injection systems both cavitation and cavitation erosion are facilitated by high injection pressure and fuel flow at very high rates inducing the so-called dynamic phenomena in fuel. Moreover, cavitation is enhanced by fuel dose portioning and small holes located on the way of fuel flowing at high rates, which belong e.g. to small valves or couples of precision electromagnetic injectors. This problem affects the CR rather occasionally, but the repairs of the Denso high pressure injection pump are more frequent. Nevertheless, Common Rail injection is still the most advanced among all Diesel engine systems, continuously upgraded and improved. Fig. 5 and 6 show photographs of injection system components damaged by cavitation.

a)

b)

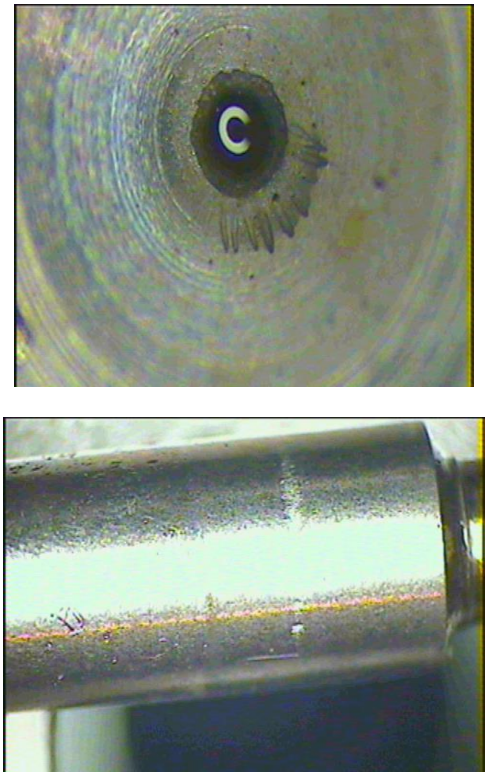

Fig. 5. Cavitation defect in injector overflow valve (a), cavitation defect in pointed follower (b) [8]
Rys. 5. Uszkodzenie kawitacyjne: zaworu przelewowego wtryskiwacza (a), popychacza iglicy (b)[8]

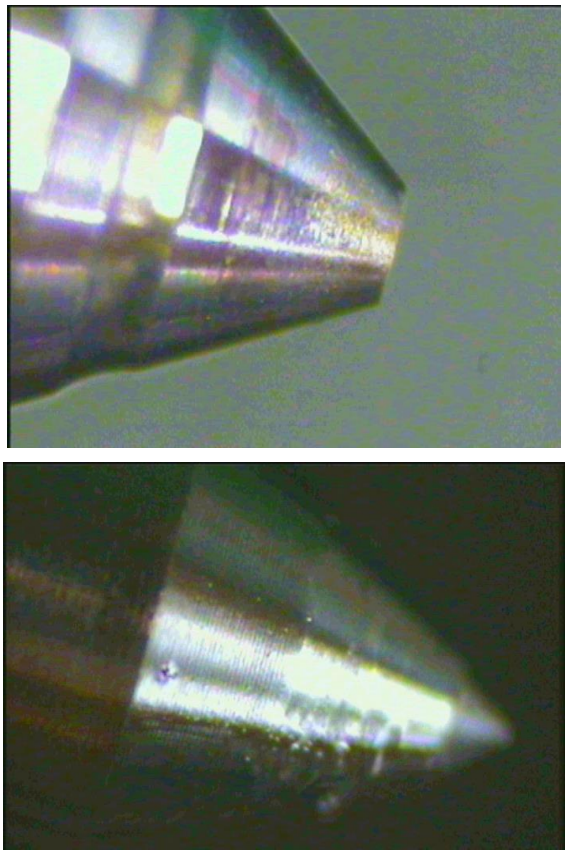

Fig. 6. Visible cavitation pits on conical surfaces of injector needles [8]
Rys. 6. Widoczne wżery kawitacyjne na powierzchniach stożkowych iglic wtryskiwaczy [8]

5. Summary

Cavitation defects in engines appear in all hydraulic subassemblies of an engine: lubrication system, cooling system and fuel delivery system. The only way to prevent cavitation without any harm to the parameters reached by the engine Common Rail injection system is to develop new methods to protect surface layers of particularly exposed components. Faults in tractor operation cause defects and induce prolonged farm machinery downtimes [6, 7]. It is necessary to use antifreeze additive with anticorrosive properties, as recommended by engine manufacturer. To some extent, harmful cavitation effect can be also reduced by adding to coolant some surface-active agents and small volumes of thin oils, capable of forming emulsion with coolant. These agents should have negligible foaming properties, since then they will be much more effective when mixed with oils. Regular checks of cooling systems, thermostats and radiator fans are recommended. Overpressure must be ensured in cooling system (replace radiator plug if necessary).

6. References

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