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Exploitation and Repair of Hydraulic Cylinders Used in Mobile Machinery

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Summary. Hydraulic cylinders are commonly applied in mobile machinery. They are prone to mechanical damage and wear due to atmospheric conditions. The paper presents selected issues related to the exploitation and repair of hydraulic cylinders. On the basis of practical experience, it offers an algorithm of actions to be undertaken in case of damage of a hydraulic cylinder.
Key words: hydraulic cylinder, exploitation, repair, seals, mobile hydraulics machinery.

INTRODUCTION

Reliable and flawless operation of machines and devices depends on many factors, such as their technological advancement, conditions and type of operation, age, as well as frequency of overhauls and maintenance [9]. A number of hydraulic systems include hydraulic cylinders, whose function is to transform the energy of pressure into mechanical energy. A typical hydraulic cylinder performs a back-and-forth linear movement of a limited stroke [3, 7]. Hydraulic cylinders have numerous applications in industry [11, 12] and in mobile machines [2, 10], such as excavators, loaders, backhoe loaders, dump cars, extension arms, cranes, tractors, refuse collection trucks, harvesters, and others (Fig. 1). Hydraulic cylinders are, however, prone to breakdowns [4], especially those used in harsh and changeable working conditions.

OBJECTIVES OF THE STUDY

The aim of this paper is to offer some practical remarks concerning the exploitation of hydraulic cylinders with pistons and to present an algorithm of actions related to the repair of hydraulic cylinders used in mobile machinery.

TYPES AND CAUSES OF BREAKDOWNS OF HYDRAULIC CYLINDERS

One of the most frequently encountered problems in the exploitation of hydraulic cylinders is the loss of tightness, causing leaks outside and inside the cylinder [3]. The worn or damaged seals do not protect the interior of the cylinder from being contaminated by dirt, which increases the risk of a breakdown. It is thus of crucial importance to use appropriate wiper seals, with a wiper ring being in direct contact with the piston rod in order to collect all dirt accumulating on it as well as to collect dirt from the air. Because of that, it is necessary to take into account the required contact between the wiper seal and the piston rod. In order to ensure that the cylinder is leakage-tight inside, it is necessary to apply appropriate piston and piston rod seals, depending on the cylinder type (unidirectional or bidirectional).

Hydraulic cylinders are operated in various external conditions. The part which is especially prone to breakdowns is the piston rod, which is directly exposed to atmospheric factors, such as water, snow, changing temperature and to dirt, particles and soot [15] as well as to mechanical factors. When a long break in the cylinder operation is planned, the piston rod should be protected from the above mentioned factors [11]. Additionally, it has to be kept in mind that hydraulic cylinders are not suitable for transferring lateral loads [1, 11].

Hydraulic cylinders available on the market have their strength parameters calculated with a certain safety margin. In some cases, however, it is advisable to check the piston rod against buckling, especially in the case of hydraulic cylinders with long strokes. The critical load level above which the piston rod undergoes buckling is obtained from Euler's formula [7]:

Fig. 1. Hydraulic cylinders in mobile machinery

$$F_{kr} = \frac{\pi^2 EJ}{l_s^2}, \tag{1}$$

where:

E – Young module of the piston rod material (for steel $E=2.1\cdot10^5$ N/mm²),

J – moment of inertia for the piston rod cross-section,

l_s – free buckling length.

Assuming the safety coefficient as n=3.5 [8], the maximal force F that can be transferred by the piston rod is:

$$F = \frac{F_{kr}}{n}. \tag{2}$$

Typical breakdowns of hydraulic cylinders are presented in Fig. 2.

Damaged parts of hydraulic cylinders are those that have cracks, cavities, deformations, seizures, and may be corroded to various extent.

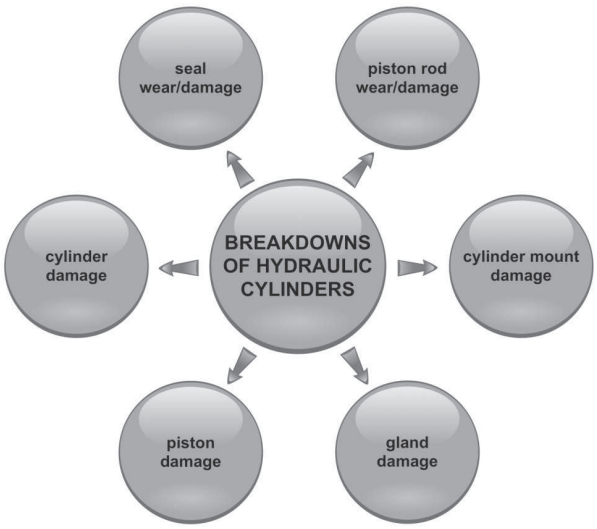

Fig. 2. Possible types of breakdowns of hydraulic cylinders

SEALS IN HYDRAULIC CYLINDERS

A number of types of seals are applied in hydraulic cylinders. They include wiper seals, piston seals, piston rod seals, gland seals and static seals. Examples of typical seals in hydraulic cylinders are presented in Fig. 3.

The main purpose of using seals is to ensure leak tightness inside the cylinder and to protect it from external dirt (wipers). Besides, selecting the shape, material, and tightness of seals affects the magnitude of friction loss between the piston and the cylinder barrel and between the piston rod and the gland. If the seals are inappropriately chosen or mounted, the energy loss can be significant (up to 25%) [7]. When the loss is kept at the minimum level, the total efficiency of a hydraulic cylinder can be at the level of 78÷99% [7].

The most popular static seals are O-rings, with V-rings and X-rings following closely. Among dynamic seals (for pistons and piston rods), the most popular are pack seals (chevron rings, including highly wear-resistant rubber-fabric seals), seals with anti-extrusion rings as well as seals with wear rings and support rings.

When selecting the right seals, one has to take into account the kind of working liquid (mineral oil, non-flammable liquids) so that it is neutral towards the seal material. Besides, the seal has to be suitable for the operating pressure and temperature [12].

Seals come in different cross-section and can be made of different materials [5, 12, 13, 14, 15], such as polyurethane (TPU, H-PU, G-PU, S-PU), fluorine rubber (FPM), silicone MVQ (methyl vinyl silicone rubber) and ethylene propylene diene rubber (EPDM). Most often, however, the material is nitrile rubber – NBR (acrylonitrile- butadiene rubber). Besides, seals can contain components made of other materials to enhance their performance and applicability conditions (e.g. POM, PE-UHMW, PTFE+40% bronze).

Apart from that, wear bands are used in hydraulic cylinders to keep the piston and piston rod precisely along the cylinder axis and to prevent contact between the metallic surfaces of the piston and cylinder [3, 13, 14]. Wear bands are made of polyoxymethylene plastomeres (POM), characterized by very low grinding ability and self-lubrication [14].

REPAIR AND RENOVATION OF HYDRAULIC CYLINDERS

Fig. 4 presents a block diagram of repairs of hydraulic cylinders. The user of the cylinder, referred to as "customer", notices a breakdown and commissions the repair to a specialised service. The servicing company accepts the commission and undertakes repair as agreed with the customer. After the hydraulic cylinder is transported to the service, it is registered and prepared for repair. At this stage the customer should be notified about the predicted duration of repair.

MEASUREMENTS AND DIAGNOSIS OF THE TECHNICAL CONDITION

When the hydraulic cylinder is disassembled, its parts and seals have to be diagnosed. It is recommended that all measurements and tests should be performed twice, by two different service workers. On the basis of the test results, the technical condition of the hydraulic cylinder can be assessed on the basis of the following criteria:

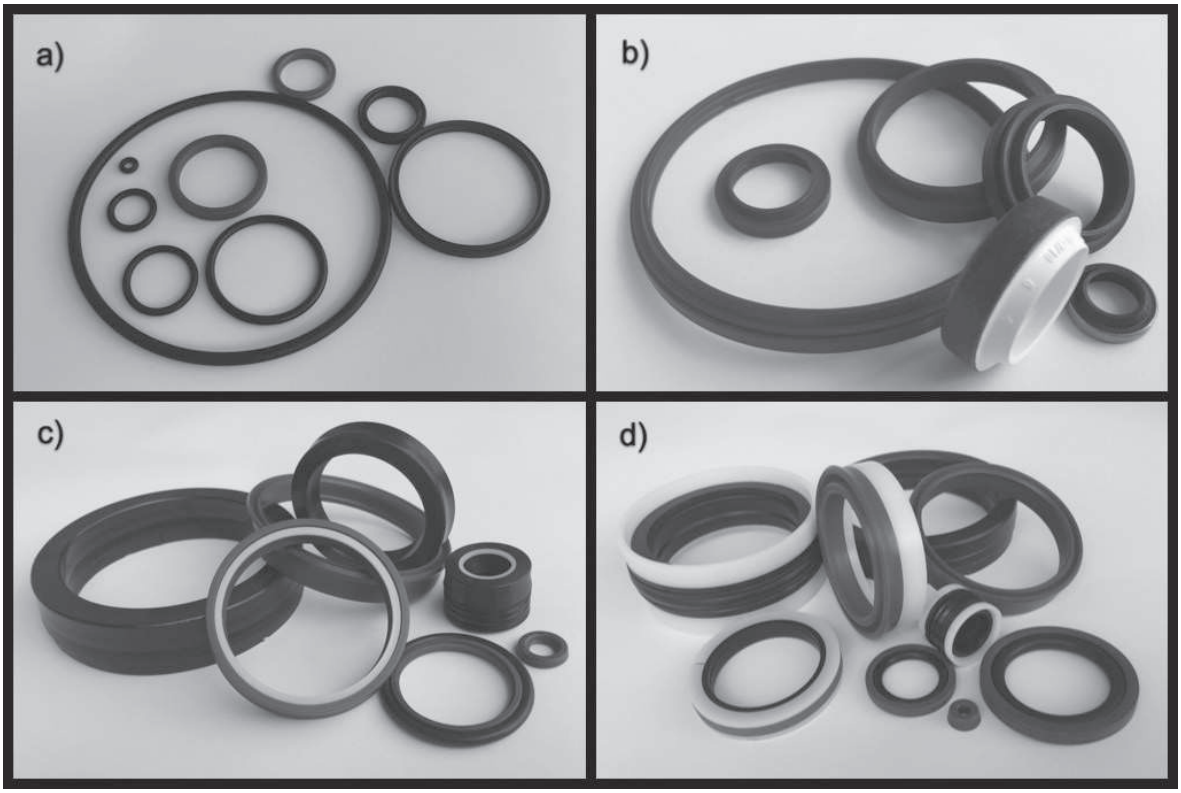

Fig. 3. Seals applied in hydraulic cylinders a) static seals, b) wiper seals, c) piston rod seals, d) piston seals

- Whether it is feasible to repair the hydraulic cylinder depends on economic and technological considerations.
- Components made of cast iron or steel casting may have cracks, which makes them unsuitable for repair [6].
- Hydraulic cylinders displaying high degree of wear or damage, with such symptoms as seizing, deep corrosion, deep cracks, deformations, cavities, etc. are considered not suitable for repair. An exception can be made for untypical designs, in which case the repair cost will be lower than the cost of producing a replacement cylinder. For instance, in the case of cast hydraulic cylinders with extensive damages, a solution preferred to producing a new cylinder on economic and technological grounds will be bushing [6].
- Repair is the optimum solution for hydraulic cylinders with low degree of damage (scratches, small traces of corrosion).
- Highly damaged piston rods are typically replaced by new ones.
- The final decision on whether a hydraulic cylinder is suitable for repair or not is taken by qualified personnel on the basis of technical and economic considerations.

If a customer requests to be consulted after the hydraulic cylinder is diagnosed, they should be informed about the technical condition and recommendations concerning the repair. With the customer's acceptance, the servicing company can undertake work.

REPAIR OF A HYDRAULIC CYLINDER

The first step is to remove dirt from all surfaces. The hydraulic cylinder is rinsed with a cleaning agent at a special stand, with a container to collect the used agent. The cleaning agent is petroleum ether, which is sprayed with an airbrush. Then, the hydraulic cylinder is wiped with a soft, white cotton cloth. It is essential that the cloth must not leave any fibres on the cylinder. After that, the parts should be moved to the place allocated for the repair. Then, depending on the diagnosis, the piston and/or piston rod can undergo grinding, chromium plating, and polishing. Similarly, the cylinder surface can be subject to chromium plating and honing. The next stage is making grooves for wear bands and processing the collar, if necessary. After that, appropriate seals and wear bands have to be selected.

ASSEMBLY

After the repair is complete, and the seals and wear bands are chosen, the hydraulic cylinder is to be reassembled from its parts. It is essential that no dirt or other contaminants get into the cylinder. The piston, piston rod, and cylinder have to be lubricated with a thin film of hydraulic oil. Seals are mounted by means of special pliers (Fig. 5) with smooth surfaces. Still, special care has to be taken not to damage the seals or scratch the sealed surfaces. A layer of metal-bond-

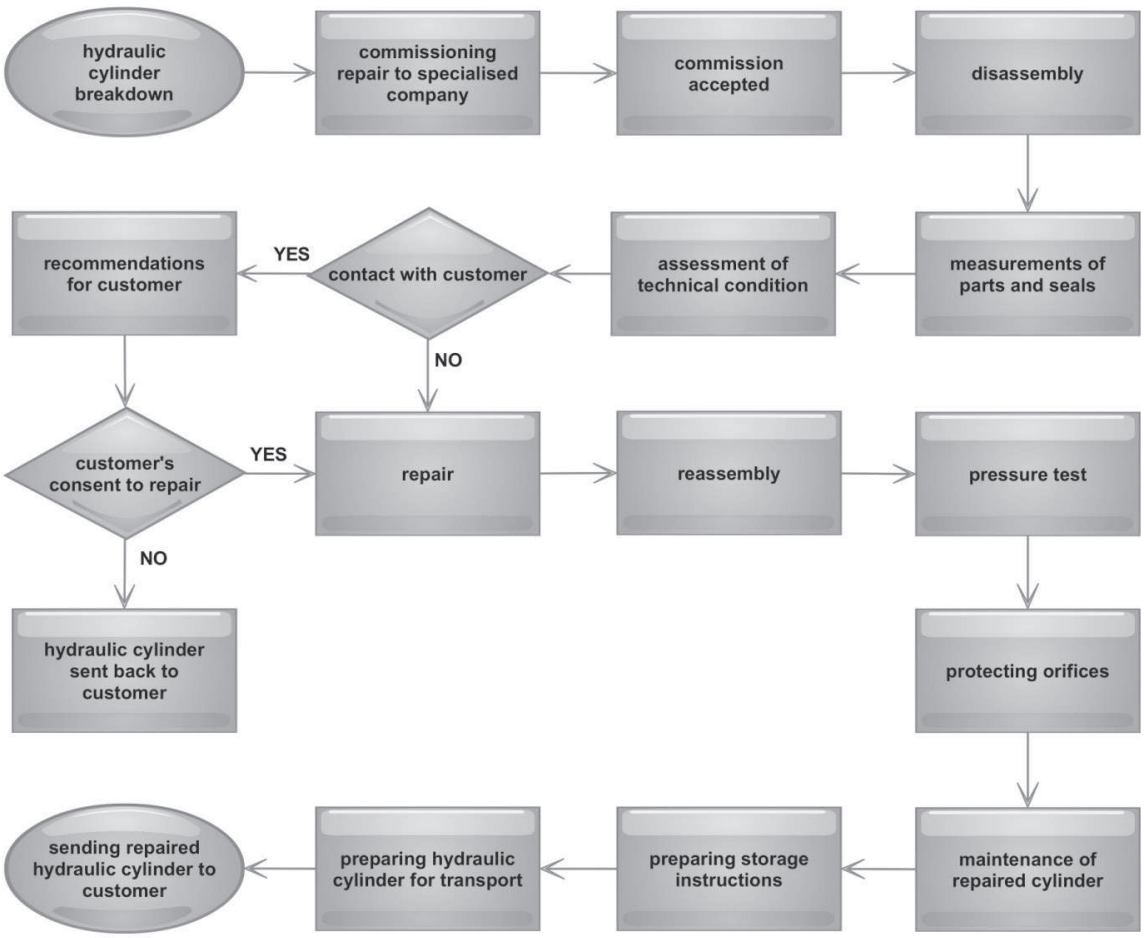

Fig. 4. Algorithm for repair of a hydraulic cylinder by a specialised company

ing glue (e.g. Loctite 243) is then applied on the piston rod-piston screw joint. Depending on the construction, a layer of retainer (e.g.Loctite 638) should be applied on co-axial joints. The piton has to be screwed on the piston rod and the joint is to be protected with a lock-nut. Then, the piston-piton rod couple is inserted in the cylinder. After the assembly, a pressure test should be performed with great care. Optionally, the external surface can be coated with paint to improve its appearance.

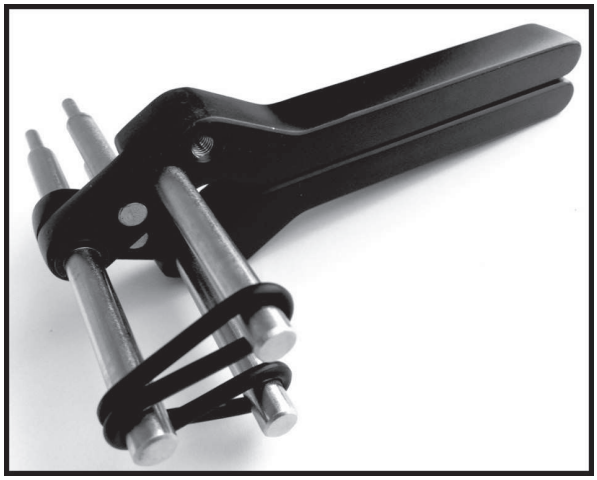

Fig. 5. Pliers for mounting seals

TRANSPORTING THE REPAIRED CYLINDER

If the hydraulic cylinder passes the pressure test, the orifices have to be protected by plugs and the hydraulic cylinder can be prepared for transport. It is necessary to provide a packaging that protects it from damage during transport. Together with a repaired hydraulic cylinder, the customer should also be provided with instructions for storing the hydraulic cylinder.

When the customer does not intend to use the repaired hydraulic cylinder within a short period of time, it is advisable to protect it from corrosion by filling it with hydraulic oil and by covering the piston rod with a thick grease.

CONCLUSIONS

The algorithms of actions to be undertaken in case of hydraulic cylinder breakdowns and repairs is universal and can be applied for any hydraulic cylinder, including those applied in industry (e.g. in hydraulic presses).

If the operating temperature of the hydraulic cylinder is high, the effect of temperature on the working liquid and on other parts, especially rubber seals, has to be taken into account.

The parts that are worn or damaged should be repaired, if possible. If not, such parts must be replaced by new ones.

Whenever a hydraulic cylinder undergoes repair, all seals must be replaced by new ones.

Rubber seals mounted in a hydraulic cylinder can work for years, whereas seals stored in inventories have to be used within a limited period of time, typically up to two years. otherwise rubber hardens and loses its sealing properties.

With appropriate machines and practical experience at one's disposal, it is possible to repair hydraulic cylinders without hiring a professional help. This is feasible, however, when the repair involves a minor issue, such as replacing seals. In the case of major overhauls and repairs, it is much more advisable to hire a specialised company.

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EKSPLOATACJA I REGENERACJA SIŁOWNIKÓW HYDRAULICZNYCH W MOBILNYCH MASZYNACH ROBOCZYCH

Streszczenie. Siłowniki hydrauliczne są powszechnie stosowane w maszynach hydrauliki mobilnej. Ze względu na pracę w zmiennych warunkach, narażone są one na uszkodzenia mechaniczne oraz działanie czynników atmosferycznych. W pracy przedstawiono aspekty związane z ich użytkowaniem oraz regeneracją. W oparciu o praktyczne doświadczenia przedstawiono algorytm postępowania z uszkodzonymi siłownikami hydraulicznymi.

Słowa kluczowe: siłownik hydrauliczny, eksploatacja, regeneracja, uszczelnienia, hydraulika mobilna, maszyna robocza.