# METHODS OF IMPROVING THE MUD PUMP VALVE LIFE

Miruna BĂLTĂREȚU IANCU[1], Anton HADĂR[2], Vlad ULMANU[3]

**Rezumat.** *Instalațiile de foraj petrolier sunt folosite pentru identificarea rezervelor geologice și pentru crearea sondelor în vederea extracției. Pompele de noroi ale instalațiilor de foraj funcționează la viteze mari ale fluidului de foraj, pentru a îndeplini cerințele forajului. Rezistența la uzura erozivă a supapelor pompelor de noroi, datorată acțiunii fluidului de foraj abraziv, depinde de forma lor constructivă și de viteza de curgere a noroiului. Această lucrare analizează câteva metode de creștere a rezistenței la uzură a supapei pompei de noroi.*

**Abstract.** *Petroleum drilling rigs are used for identifying geologic reservoirs and for creating wells for extraction. The mud pumps of drilling rigs are operated at high mud rates to make possible the drilling process. The durability of the mud pump valves to erosive wear, due to the action of abrasive drilling fluid containing solid particles, depends on their constructive form and on the mud flow velocity. This paper analyzes a few methods of increasing the wear resistance of mud pump valves.*

**Keywords:** mud pump, valve, seat, wear.

## 1. Introduction

Oil and gas drilling rigs are used to drill in different environments to facilitate the extraction of oil and gas from hydrocarbon reservoirs. In rotary drilling, the rig through its mud circulating system uses the drilling fluid to aid the advance of the bit into the earth.

The mud pump of the drilling rig circulates the drilling fluid (mud) at high pressures down the drill string inside the hole and back up the annulus (void between drilling tubular system and earth).

Due to the reciprocating movement of the piston, the drilling fluid starts moving from the mud pump's chamber and from the suction and discharge lines of the pump. To ensure fluid movement in a certain sense, the mud pump is fitted with valves, alternately interrupting the communication between the cylinder and the suction and discharge lines.

[1]PhD Student, Eng., Department Strength of Materials, University "Politehnica" of Bucharest, Romania (mirunabaltaretu@yahoo.com).
[2]Prof., PhD, Eng., Department Strength of Materials, University "Politehnica" of Bucharest, Romania (anton.hadar@upb.ro).
[3]Prof., PhD, Eng., Department Mechanical Engineering, University Petroleum-Gas of Ploiesti, Romania (vulmanu@upg-ploiesti.ro).

The valves are important elements in the mud pump operation, their construction and their state largely influencing normal operation of the pump.

The mud pump valve is a direct component in the drilling process and one of the most important wear parts in a mud pump. Erosion and corrosion are the most important phenomena that affect the life of the valve, and they are related to drilling fluid pressure and flow rate. The bigger they are, the stronger is the erosion-corrosion process.

The valve assembly has four main components: *valve* body, *valve* seat, *valve* spring and *valve* insert, as shown in Figure 1.

**Fig. 1.** Valve assembly: 1. Valve body; 2. Valve seat; 3. Valve spring (helical); 4. Valve insert.

The appearance of erosive wear is influenced by technological conditions such as the base material used to manufacture the valve components, the hardening method used for the active surfaces of the valve assembly, the constructive form of the valve and by mud flow conditions as flow velocity and pressure.

## 2. Mud pump valve functional and constructive characteristics

Modern mud pumps used in rotary drilling are triplex piston pumps (three pistons), single-acted, operated at flow rates up to 3600 *l*/min. and pressures up to 50 MPa (according to different drilling steps). The drilling fluid has the function of gathering and bringing to the surface the debris from the walls of the well during drilling.

For mud pumps, there are used valves charged by coil springs and sealed by elastic gaskets (rubber or urethane), having contact surfaces with a high grade of processing. The complete valve kit has the following main components: the valve body (single piece construction), the valve seat, the valve spring (helical), the valve insert (gasket). In Figure 2 it is presented a section through the valve assembly and the Figure 3 presents the mud pump valve assembly.

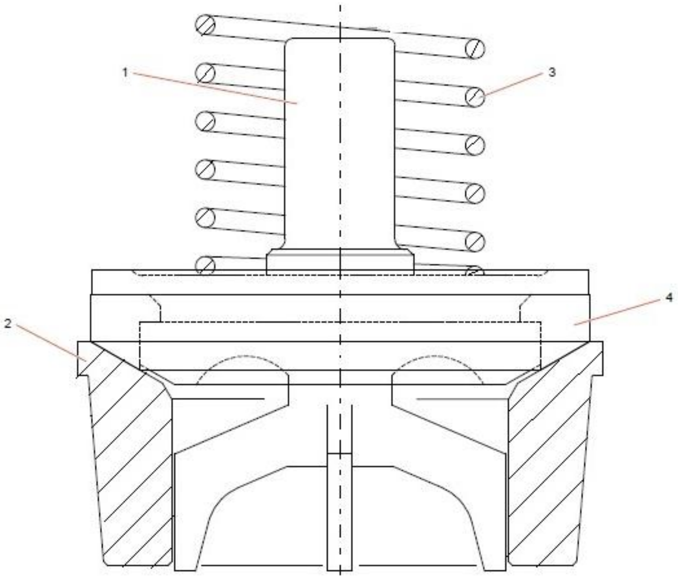


**Fig. 2.** Mud pump valve: 1. Valve body; 2. Valve seat; 3. Valve spring; 4. Valve insert.

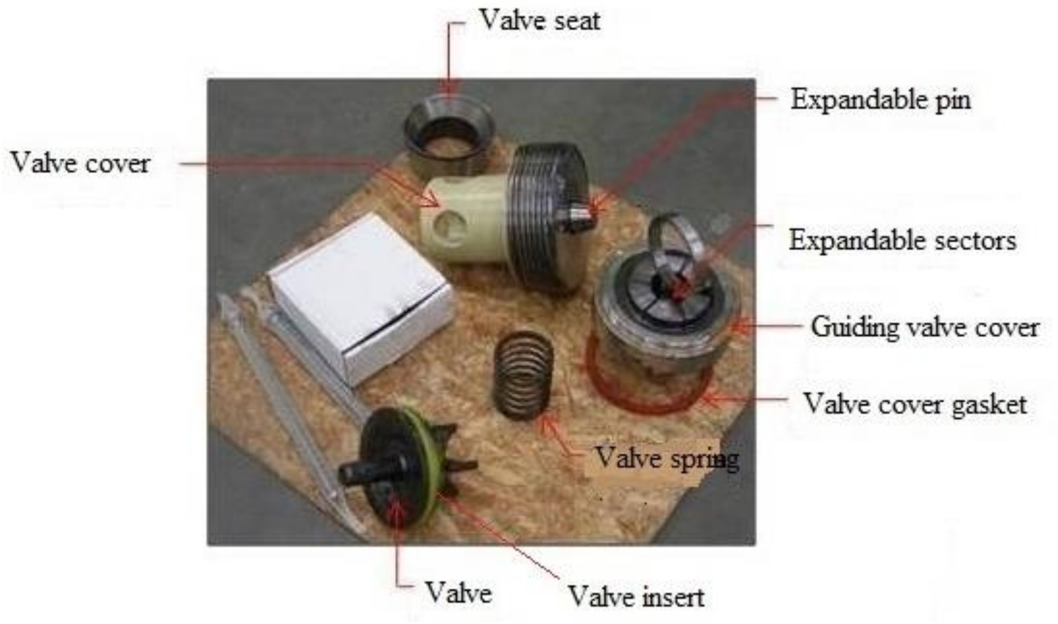


**Fig. 3.** Complete mud pump valve.

The constructive main characteristics of the valve are:

-the valves have central guide with low resistance to the flow direction of the fluid.

-the valve insert can be symmetrical, with two sides and can be turned and used further after the first side wear. The gasket can be replaced or not, the valves being classified as snap-in insert valves and cast-in insert valves (when drilling at high

-the valve seat is mounted on the hydraulic body by pressing the conical surface (metal to metal contact).

-the valve spring ensures the stability of the valve during operation.

The valve assembly components, especially the valve insert and the valve seat are eroded and corroded due to high flow values of the drilling fluid containing debris, sand and salt, and this decreases the life of the assembly. The valve wear intensity depends on the drilling fluid flow rate through the interspace between the valve body and its seat, and also on the impact of the valve body contact with the seat.

To increase the life of the valve components must be taken into account:

-the valve seat made of alloy steel obtained by forging or precision casting;

-the contact (wear) surface of the valve seat hardened by induction method, carburizing or nitriding procedures, in order to obtain a hardness up to 65 HRC (832HV);

-precise polishing of the contact surface to achieve high roughness requirements;

-the valve insert made from high quality rubber or polymer (polyurethane).

In a first approach of the problem there are analyzed different hardening methods used for contact surfaces of the valve seat depending on its base material. Further on, in order to increase the wear resistance of mud pump valves, it will be studied the influence of flow velocity on the valve's life.

## 3. Methods for increasing the wear resistance of mud pump valves

In this paper there are analyzed different methods to increase the resistance of the mud pump valve. There are two main conditions on which the valve set life depends:

-the technological condition, as: the valve's base material, the hardening method used for the active surface, the valve's design;

-the flow condition regarding the flow velocity of the drilling fluid.

Types of wear of mud pumps valves and seats:

-Level steps appeared on the valve and its seat due to the action of abrasive drilling fluid and to the mud pump operation at a high working pressure;

-Oval shape of the valve seat caused by the valve body wear;

-Premature wear of the valve body and seat caused by the wear of the valve insert.

The erosive wear destroys the valve assembly components and no longer allows perfect sealing of the contact surfaces. In Figure 4 there are presented the mud pump valve components affected by wear.

**Fig. 4.** Valve components (valve body, valve insert, valve seat) affected by erosive wear.

### 3.1. Technological conditions influencing the mud pump valve wear

The technological conditions that can influence the wear resistance of mud pumps valves are:

#### A. Mud pump valve design

There are three main categories of valve designs:

-**Full open valve**: is a premium valve, characterized by a solid body construction which is required by high drilling pressures in the range of 34.5-51.7

MPa. The valve seat is completely open and allows easier access for maintenance operations. The standard valve insert is field replaceable and is made of rubber or polyurethane. Standard valve springs are made of carbon steel.

-**Three webs valve**: is a standard valve, being the most popular valve style used in the oil field applications. Its construction is center guided, the valve body is supported, during mud pump operation, by the center of the valve seats webs. The valve insert is designed for a perfect sealing of the drilling fluid above the valve even when the pump is not operated. The standard insert is field replaceable and the spring is helical.

-**Four webs valve**: is used for low and medium pressure drilling operations, being cost effective. The construction is center guided, the valve seat has four webs and the load application is similar to the three web style. The valve insert is secured with a threaded plate which ensures easier access for field replacements. The standard insert can be made of rubber or urethane (mostly used in the present) and the standard spring is made of carbon steel.

For all valve types there are available upgrades for inserts and springs depending on the drilling applications. The valve insert can be made of a high-temperature polyurethane or of Buna-N rubber that can resist drilling mud temperatures of 100 °C. The life of the standard polyurethane valve insert is of maximum 5 years and of the high quality insert is of maximum 10 years. The valve spring is available also in stainless steel for longer shelf life.

The standard valve insert is field replaceable, but for high pressures drilling conditions the valve can be equipped with a non-replaceable bonded insert that ensures a better sealing and has higher wear resistance. In figure 5 below there are shown different designs of mud pump valves.

**Fig. 5.** Types of mud pump valves.

**Valve seat base material**

The valve seats are usually made from low alloyed, case hardening steels with hardened contact surfaces. The steel used for manufacturing valve seats should keep a balance between high hardness and high wear resistance. A few examples of the steels used for mud pump valve seats are given below:

-30CrNiMo8: C 0.26-0.34%, Si max. 0.40%, Mn 0.30-0.80%, P max. 0.035%, S max. 0.035%, Cr 1.80-2.20%, Mo 0.30-0.50%, Ni 1.80-2.20%;

-17MoNi35: C 0.14-0.20%, Si 0.20-0.35%, Mn 0.30-0.70%, P max. 0.025%, S max. 0.025%, Cr max. 0.25, Mo 0.20-0.30%, Ni 3.20-3.80%;

-AISI 4340: C 0.38-0.43%, Si 0.20-0.35%, Mn 0.60-0.80%, P max. 0.040%, S max. 0.040%, Cr 0.70-0.90%, Mo 0.20-0.30%, Ni 1.65-2.00%;

-AISI 5120: C 0.17-0.22%, Si 0.15-0.30%, Mn 0.70-0.90%, P max. 0.035%, S max. 0.040%, Cr 0.70-0.90%.

**C. Hardening methods used to increase wear resistance of valve seat active surface**

The active surfaces of the valve seats are hardened using different methods that have different wear resistance levels. Some of the hardening methods (used by manufacturers and proposed by authors) of valve seats are:

-carburizing/ carbonitriding;
-induction;
-weld cladding;
-thermal spray.

The authors obtained in laboratory tests for the four hardening methods conclusive results.

**Carburizing** is a heat treatment process used on steels as a hardening method for the outer surface transforming austenite in martensite. The thickness of the hardened layer is approximately 2-2.5 mm and the hardness is 52.5-57 HRC.

**Induction** as a hardening method is used to increase the hardness of the surface layer of the valve seat by induction heating and quenching. The layer obtained has a controlled depth of about 2 mm and the highest hardness of 58 HRC, specific for a martensitic structure. The induction hardening method offers good wear resistance of the working surface and enough hardness of the base material.

**Welding with hard alloys** in active gas environment is a hardening method consisting in cladding active surfaces with hard steel alloy layers. The depth of the deposited layer (one) varies between 3-5 mm. The highest hardness ranges between 55.2-59 HRC.

**Thermal spraying** using **HVOF** (High Velocity Oxygen Fuel) method it can be used to deposit wear resistant layers on steels. The process implies spraying the coating powder, into a hot spouted mixture of oxygen and fuel. The material is then ejected, with a controlled direction, at supersonic velocity, toward the surface to be coated. The powders that are usually used are tungsten carbides (WC), chromium carbide, alumina. The resulted coating has high wear resistance and low porosity. The thickness of the deposited layer was approximately 0.4 mm and after grinding was approximately 0.2 mm. The highest hardness of the coating ranges between 70-74 HRC.

HVOF hardening method offers the best results of the four studied methods with the highest hardness (74 HRC) and lowest layer thickness (0.2 mm).

### 3.2. Flow condition influencing the mud pump valve wear

The mud pump valve wear resistance is influenced by the drilling fluid velocity field in the flow area of the interspace between valve body and valve seat. The flow velocity of the abrasive and corosive drilling fluid is a cause of the appereance of wear on mud pump valve components. The higher the flow rate is, the appereance of wear increases as well.

In a first approach of the problem it can be used the **finite element method** (FEM) to highlight the velocities profile. For conclusive results the velocity profile in the interspace is determined for various values of the valve lift height and of the valve seating angle. The finite element method is helpful to determine how the constructive form of the valve seat (height of the interspace between valve body and seat and active tapered surface angle) can influence the wear resistance of the valve components.

One of the software programs that can be used for finite element modeling is **ANSYS**. For our purpose it is used the FLOTRAN CFD module in ANSYS. The hypotheses for the finite element analysis are:

-the cycle analyzed is considered for one stroke of the valve, correspondent to a certain interspace between valve body and valve seat;

-the flow is considered stationary, in a turbulent regime;

-the drilling mud can be considered a Newtonian incompressible fluid.

For the finite element method used in the flow velocity application to obtain results there should be analyzed different design types of the valve assembly.

## Conclusions

The valves are important elements in the mud pump operation, their construction and their working state largely influencing normal operation of the pump.

The durability of the mud pump valves to erosive wear, due to the action of abrasive drilling fluid containing solid particles, depends on their constructive form, the hardness and the microstructure of the material used for the working surfaces of the valve assembly and on the mud flow velocity.

Improving the working life of mud pumps valves leads to significant cost savings by reducing the cost of valves replacement or repair and also the associated downtime.

The characteristics of the valve seat material must achieve a balance between hardness and high resistance to erosion/abrasion wear of the working surface.

In order to increase the wear resistance of the valve seat, its active surface is hardened.

From all the 4 analyzed hardening methods, the HVOF thermal spraying has the best results, with a layer hardness of 1201 HV (74 HRC) and a thickness of 0.25 mm.

The carburizing hardening method offers a layer depth of approximately 2 mm and a hardness of 632 HV (57 HRC).

The induction hardening method provides high hardness of 700 HV (60 HRC) for the working surface of the valve seat, corresponding to good wear resistance.

The first two hardening methods proposed and analyzed by the authors are traditional methods used by manufacturers to harden the active surface of the valve seat.

Using the Metal Inert Gas Pulse Arc welding method we obtained a hardness of 700 HV (59 HRC) and the highest layer deposited on the wear surface from all the studied methods. This cladding method can be used also for making repairs on worn surfaces.

All the hardening methods analysed are comparable and offer good wear resistance for the valve seat working surface.

Weld cladding and HVOF spraying had the best hardness results and can be used for extending the valve life, both in manufacture and repair processes. These hardening methods are not commonly used, but they are better alternatives with higher wear resistance of valve seats active surface.

The influence of the flow velocity of the drilling fluid to the valve wear resistance can be studied using finite element method through a specialiazed program.

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