Development of High Strength, High Toughness and High Wear Resistant Parts for Mud Pump

M.Srinivas
Assistant professor, Department of Mechanical engineering,
CMR Institute of Technology, Hyderabad-501401,

K.Srinivasa vadayar
Assistant professor, Department of Metallurgical Engineering,
JNTUH college of Engineering, Hyderabad,

B.Sridhar Babu
Associate Professor, Department of mechanical Engineering,
CMR Institute of Technology, Hyderabad-501401

Abstract- Development of high strength-high toughness parts for mud pump has been a target for many years to improve the overall performance of mud pumps. In addition, repair and refurbishment of parts has become synonymous with the Industry owing to the prohibitive cost of spare parts. A mud pump is a reciprocating piston/plunger device designed to circulate drilling fluid under high pressure (up to 7,500 psi (52,000 kPa)) down the drill string and back up the annulus. The fluid end produces the pumping process with valves, pistons, and liners. Because these components are high-wear items, modern pumps are designed to allow quick replacement of these parts. present investigation is carried out to improve the wear resistance of these parts. Paper aims to evaluate the effect of various parameters on the wear resistance. The mechanical properties as well as the corrosion resistance and welding properties of these parts are discussed.

Keywords – Mudpump, fluid end, hardness, corrosion.

I. INTRODUCTION

A mud pump is a reciprocating piston/plunger device designed to circulate drilling fluid under high pressure (up to 7,500 psi (52,000 kPa)) down the drill string and back up the annulus. Mud pump is a large reciprocating pump used to circulate the mud (drilling fluid) on a drilling rig. It is an important part of the oil well drilling equipment.The fluid end consists of pumping process with valves, pistons, and liners. Because these components are high-wear items, modern pumps are designed to allow quick replacement of these parts.To reduce severe vibration caused by the pumping process, these pumps incorporate both suction and discharge pulsation dampener. These are connected to the inlet and outlet of the fluid end. A Mud Pump is composed of many parts including Mud Pump liner, Mud Pump piston, modules, hydraulic seat pullers, and other parts. Parts of Mud Pump: 1. housing itself, 2. liner with packing, 3. cover plus packing, 4. piston and piston rod, 5. suction valve and discharge valve with their seats, 6. stuffing box (only in double-acting pumps), 7. Gland (only in double-acting pumps).Mud Pumps and other mechanical equipment should be inspected and maintained on a scheduled and timely basis to find and address problems ahead of time, in order to avoid unscheduled shutdown. Mud Pump wearing parts should frequently be checked for repairing needs or replacement. The wearing parts for Mud Pumps include pump casing, bearings, impeller, piston, liner, etc. Advanced anti wear measures should be adopted to increase the service life of the wearing parts, which can reduce the investment cost of the project, and improve production efficiency. At the same time, wearing parts and other Mud Pump parts should be repaired rather than replaced when possible.

Fig 1 Mud pump

Drilling Rig can be huge, capable of drilling through thousands of metres of the Earth's crust. Large "mud pumps" circulate drilling mud (slurry) through the drill bit and up the casing annulus, for cooling and removing the "cuttings" while a well is drilled. Hoists in the rig can lift hundreds of tons of pipe. Other equipment can force acid or sand into reservoirs to facilitate extraction of the oil or natural gas; and in remote locations there can be permanent living accommodation and catering for crews (which may be more than a hundred). Marine rigs may operate many hundreds of miles or kilometers distant from the supply base with infrequent crew rotation or cycle.

Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics. Steels are particularly suitable for heat treatment, since they respond well to heat treatment and the commercial use of steels exceeds that of any other material.

Corrosion is the gradual destruction of material, usually metals, by chemical reaction with its environment. In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Rusting, the formation of iron oxides is a well-known example of electrochemical corrosion. This type of damage typically produces oxide(s) or salt(s) of the original metal. Corrosion can also occur in materials other than metals, such as ceramics or polymers, although in this context, the term degradation is more common. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.

Many structural alloys corrode merely from exposure to moisture in air, but the process can be strongly affected by exposure to certain substances. Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is a diffusion-controlled process, it occurs on exposed surfaces. As a result, methods to reduce the activity of the exposed surface, such as passivation and chromate conversion, can increase a material's corrosion resistance. However, some corrosion mechanisms are less visible and less predictable

The main objective of this paper is to impart high strength, high toughness and wear resistant to parts in mud pump by implementing various methods. The main cause for the heavy loads which get imparted on parts of the mud pump is due to the heavy pressure mud which is being pumped by the mud pump. To with stand there high pressures on the parts of the mud pump, improvement of mechanical properties of these parts is essential and appropriate measures to be taken to overcome corrosion. The main problem with the mud system is that there is a major problem of corrosion to the parts which this mud gets in contact. So appropriate methods are implemented to prevent corrosion. For this purpose many additives are added to the mud.

II. MATERIALS

Material used for crank shaft is ductile iron, also known as Spheriodal iron or nodular iron, that is described as cast iron with the graphite substantially Spheriodal in shape and essentially free of other forms of graphite, composition shown in table 1and. Fluid end is made up of carbon steel forging and its composition is shown in table 2.

Table 1 Crank shaft Material :A 536-84 ductile iron casting composition

GRADE / ALLOYS	C	Si	Mn	P	S
60-40-18	3.5-4.0	2.0-2.7	0.3_{max}	0.05_{max}	0.02_{max}
60-42-10	3.5-4.0	2.0-2.7	0.3_{max}	0.06_{max}	0.02_{max}
80-55-06	3.5-4.0	2.0-2.5	0.4-0.5	0.06_{max}	0.02_{max}
80-60-03	3.5-4.0	2.0-2.5	0.5-0.8	0.06_{max}	0.02_{max}
100-70-03	3.5-4.0	2.0-2.5	0.5-0.9	0.06_{max}	0.02_{max}

Table 2 .Fluid end Material: AA 193 33 carbon steel forging composition.

Element	C	Si	Mn	S	P	Ni	Cr	Cu	Mo	V	Sn	B
%	0.4-0.5	0.15-0.35	0.6-0.9	0.04	0.04	0.30	0.30	0.25	0.15	0.05	0.05	0.0003

III. EXPERIMENTS

A Heat treatment of crank shaft material:

Different heat treatment processes were carried out to different grades of cast iron Material designation: A 536-84 ductile iron as shown in table 3 to Impart strength and toughness.

Table 3 :Heat treatment process for crank shaft material

S No	: A 536-84 ductile iron Grade	Heat treatment Process
1	60-40-18	Annealed after casting. 700^0C
2	65-45-12	As-cast (No Heat treatment)
3	80-55-06	As-cast with higher manganese content
4	100-70-03	normalizing heat treatment.900^0C
5	120-90-02	Oil quenched and tempered.860^0C-480^0C

B Heat treatment and hardening processes for fluid end material

To improve the impact strength and toughness of AA 193 33 carbon steel the following heat treatment conditions and hardening processes were applied

Table 4 :Heat treatment and hardening process for fluid end material

SNo	Heat treatment/Hardening process	condition
1	Normalising	Heated to 900^0 C, cool in air
2	Annealing	Heated to 845^0 C, furnace cool to 650^0 C, rate not to exceed 28^0 C per hour
3	Hardening	Heat to 845^0 C. Quench in water or brine./ Water quench in agitated water and temper at 900˚C for 4 hours
4	Surface hardening	Flame hardening, carbonitriding, and liquid carburising
5	Tempering	Tempering up to 540^0 C is then applied

C Thermal spray coating:

HVOF (high vacuum oxygen fuel) thermal spray process or wire arc spray process with Ferrous/nickel/Al/SS/Cr based metal powder was carried up to Thickness of coating 0.3 to 3.0 mm and Temperature maintained was 150-200 degrees centigrade ,Bond strength 5000-6000 Psi

D Corrosion Testing

Corrosion testing is done to check whether the fluid end and the crank shaft can with stand the environment of mud for some specific period of time to ensure smooth running of drilling process. The corrosion test is done in the lab by using the environment of mud.Corrosion rate:Also known as corrosion ratio. It is calculated by taking uniform corrosion over the whole surface. Corrosion rate is measured in terms of mpy (mils per year penetration). mpy =weight loss due to corrosion in grams x (23,300)/(A) (dt).

D Hardness test

Brinell hardness wass determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simply the Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters. The result is a pressure measurement, but the units are rarely stated.

E Izod Toughness testing

A specimen of standard size with a notch on one side is clamped in a vice. A heavy pendulum is lifted to a height h_0 above the vice and is released. It swings under gravity, strikes the specimen and continues to height h_1 shown by the final reading on the dial gauge.

Impact energy = energy absorbed = mass of pendulum * g * (h_1 - h_0) ,where g is the acceleration due to gravity

F Tensile testing

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's, Poisson's ratio, yield strength, and strain-hardening characteristics

IV. RESULTS AND DISCUSSION.

A Crank shaft results

Mechanical properties of the crank shaft after heat treatment and metal spraying Readings of hardness test.(brinell's)

Table 5 Mechanical properties of crank shaft material after different heat treatment processes

Grade and Heat Treatment	Tensile strength minimum		Yield strength minimum		Percent Elongation min.2'	Brinell Hardness	Matrix Micro-structure	Toughness
	psi	MPa	psi	MPa				joules
60-40-18 (1)	60,000	414	40,000	276	18	172	Ferrite	16
65-45-12 (2)	65,000	448	45,000	310	12	196*	Ferrite and pearlite	18
80-55-06 (3)	80,000	552	55,000	379	6	232	Pearlite and ferrite	20
100-70-03 (4)	100,000	690	70,000	483	3	254	Pearlite	22
120-90-02 (5)	120,000	828	90,000	621	2	275	Tempered martensite	24

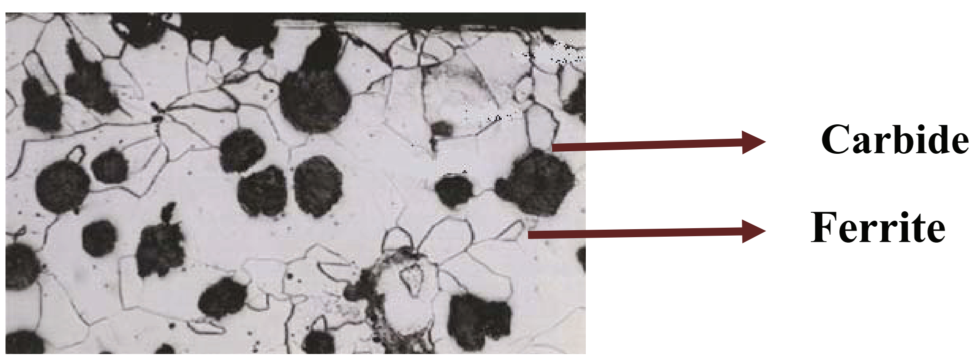

Fig2 : The microstructure of ductile iron after heat treatment (transformed all pearlite to carbid).

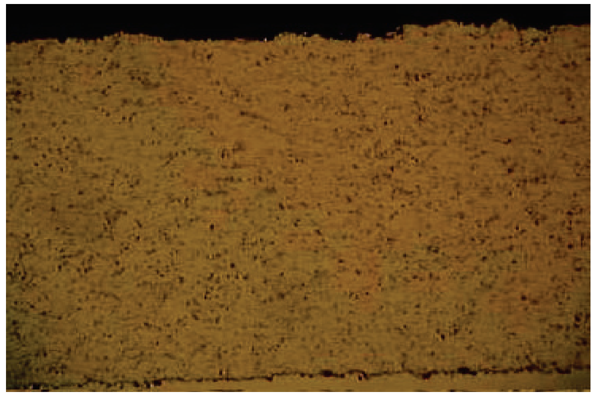

Fig 3 HVOF sprayed Chromium Carbide/Nickel Chromium Coating on Cast Iron Substrate (1.0 mm)

B Fluid end results

Table 6 Mechanical properties of fluid end material befor heat treatment and after heat treatment

S.No	Properties	Before heat treatment	After Heat treatment
1	Ultimate tensile strength	510N/mm2	620
2	Yield strength	255 N/mm2	320
3	elongation	8%	15%
4	Brinell Hardness	139HB(Avg of 5tests)	170
5	Charpy impact toughness	11j	13j

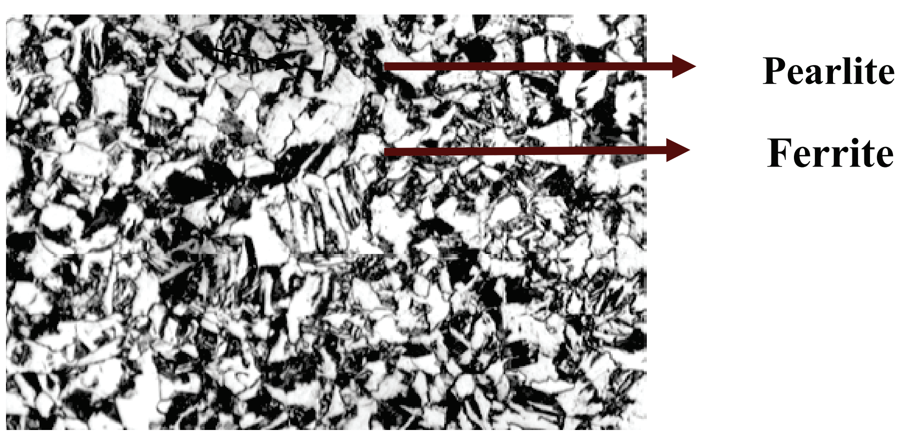

Fig 4 Microstructure of as received material consisting of pearlite colonies(dark contrast) and ferrite grains (light contrast).

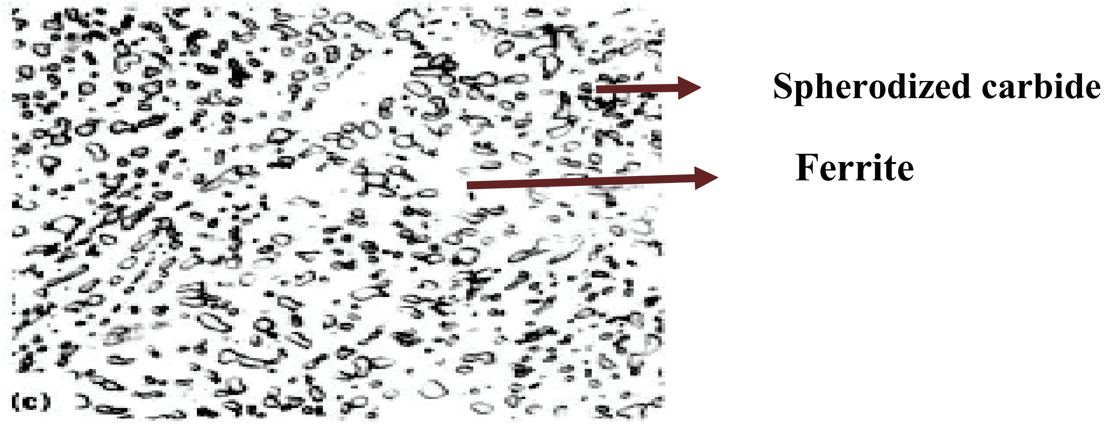

Fig5 Austenitized at 800°C ,40 min.held at 705 °C ,6h,for isothermal transformation.structure is spherodized carbide in ferrite matrix.

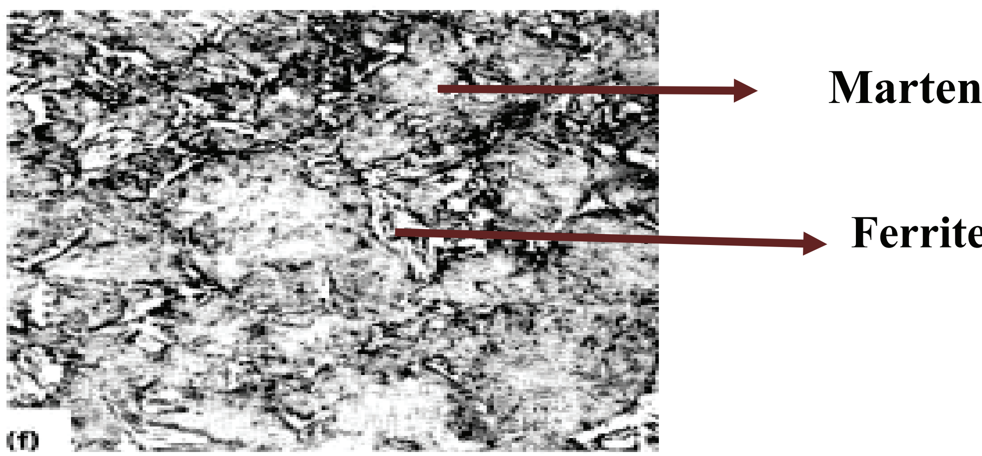

Fig 6 austenitized at 915 °C 30 min. oil quenched.tempered at 205°C.Tempered martensite (gray); ferrite (white)

C Corrosion test results.

Corrosion test is conducted by allowing the equipment to get exposed to “mud” on the parts of the mud pump for several hours and finally to find out if there is any material loss or corrosion on the parts of the mud pump ,By using bentonite the test was conducted for a period of 200 hours and it was found out that there was no loss of material and no corrosion taken place. This is in case of fluid end and crank shaft.

V. CONCLUSIONS

1. The project was mainly aimed at getting a better properties of the materials used in mud pump.
2. Various papers were studied and a survey was carried out to find out the various processes implemented in improvement of wear resistance and mechanical properties.
3. Use of mud with better composition and additives was studied to improve the corrosion resistance.
4. Thermal spray processes were studied for improvement of wear and hardness.
5. Heat treatment processes were implemented to impart high strength and high toughness to parts in mud pump.
6. The various processes implemented to increase the hardness, toughness and strength had shown desirable results.
7. There was a considerable improvement in the corrosion resistance for the parts of the mud pump.

8. The thermal spray coating on the crankshaft has improved its strength and hardness.
9. The heat treatment processes implemented had shown considerable improvement in the hardness and strength of fluid end.
10. Considerable improvement in the corrosion was observed due to the various additives added to the mud which has bentonite as the main constituent.
11. Overall there was a considerable improvement in the mechanical properties of the parts of the mud pump

REFERENCES

[1] Surface coatings-gas welding coatings. - G.R Bell.
[2] Thermal spray coatings – H. Hermann and s. sampath.
[3] Cr_3C_2–NiCr and WC–Ni thermal spray coatings as alternatives to hard chromium for erosion–corrosion resistance-N. Espallargas,J. Berget, J.M. Guilemany , A.V. Benedetti, P.H. Suegama
[4] Evaluation of local bentonitic clay as oil well drilling fluids in Nigeria-O.A.Falode , O.A. Ehinola , P.C. Nebeife
[5] Polypyrrole coating doped by molybdo-phosphate anions for corrosion prevention of carbon steels. Toshiaki Ohtsuka. Masahide Iida. Mikito Ueda
[6] Heat treaters guide and practices and procedures for iron and steel.Fontana. M. G., Corrosion Engineering, McGraw-Hill, (1986)
[7] ASTM G99-95a, ASTM Standard Test Method for Wear Testing
[8] Properties of ductile iron casting guide.
[9] Weatherford. Mud pumps parts and service.
[10] Locally Austempered Ductile Iron (LADI),Christopher Bixler, Kathy Hayrynen, John Keough Applied Process, Inc. – Technologies DivisionGeorge PfaffmannAjax
[11] Tocco Magnethermic Corporation, Scott Gledhill, ThyssenKrupp Waupaca, Inc.
[12] ASTM Standards for test methods and definitions for mechanical testing of steel