Manufacturing, Testing and Commissioning of Submersible Pumps

[1]Prof.Hinal Shah, [2]Ajay Agarwal, [3]Toshal Somani
[1]Assistant Professor, [2,3]Student
[1, 2, 3] Electrical Engineering Department,
[1, 2, 3] Indus Institute of Technology and Engineering, Ahmedabad, India-382115

Abstract: Submersible pumps are cylindrical type of machine which has a completely sealed motor coupled to the pump body. These pumps are used to be placed under the water inside a bore hole and it carries out its purpose to pump the water upwards. These pumps are mainly used for irrigation purposes and humans being largely depending upon agriculture it is necessary that manufacturing, testing and commissioning of pumps should be efficient and reliable this paper gives basic information about manufacturing, testing and commissioning of submersible pumps and how to make them more robust, reliable and efficient.

Index Terms **– Submersible Pumps, Manufacturing, Testing, Commissioning.**

I. INTRODUCTION

A submersible pump is a device which has hermetically sealed motor close-coupled to the pump body. It is a centrifugal pump. The whole assembly is submerged in the fluid and thus the fluid is pumped. A submersible pump is a pump that is able to be placed under water and still carry out its purpose. These pumps are designed to work while being fully submerged whereas other pumps may be partially submerged or placed in a dry area. A submersible pump pushes water to the surface, instead of pulling the water out of the ground. They have no issue of cavitation, need no priming and are very efficient.

Electric submersible pumps are multistage centrifugal pumps operating in a vertical position. Liquids, accelerated by the impeller, lose their kinetic energy in the diffuser where kinetic energy is converted to pressure energy. This is the main mechanism for operation of radial and mixed flow pumps. Recently submersible pumps have gained huge usage in both industrial and domestic sector due to their high reliability and versatility. Submersible pumps are used in oil production to provide a relatively efficient form of artificial lift, able to operate across a broad range of flow rates and depths. By decreasing the pressure at the bottom of the well, more oil can be produced from the well when compared with natural production.

1.1 Classification of Submersible pumps

The submersible pumps can mainly be classified on the following basis:-

1. Number of phases:-
- Single phase
- Three phase
2. Type of connection:-
- Star(Single cable)
- Delta(Double cable)
3. Diameter of pump set:-
- V3 (3 inch diameter)
- V4(4 inch diameter)
- V5(5 inch diameter)
- V6(6 inch diameter)
- V7(7 inch diameter)
- V8(8 inch diameter)
- V9(9 inch diameter)
- V10(10 inch diameter)

1.2 Advantages

- Requires small space.
- No need for elaborate foundation and pump house arrangement.
- No noise of the motor.
- Economy in operation owing to high overall efficiency can be installed in different sites in narrow boreholes or in confined conditions.
- Pumping system can be made fully automatic.
- Requires very less maintenance.
- No suction problems.

II. MANUFACTURING

2.1 Parts of Submersible pumps

The different parts connected or installed in a submersible pump are as follows:-

1. Submersible induction motor:-
   It is the heart of submersible pump. The motor used to drive the pump is typically a three phases, squirrel cage induction motor, with a kW nameplate power rating in the range 7.5 kW to 560 kW. This motors used in water pumps comes with a 3 phase ac supply. Such motors are less efficient as they are standardized and not individually designed for specific applications. An induction motor rotates the shaft to which other equipment's are connected such as impeller, bowls. The shaft in turn rotates pump impellers to lift fluid through production tubing to the surface. The power of a pump depends on the capacity of the induction motor installed in it. It has two main parts rotor and stator. They are mostly squirrel cage motor and the windings used are insulated. They are normally water cooled or oil cooled. Induction motors are most commonly used for the water booster pumps.
   Stator: - Stator is the stationary part of rotating system. Energy flows through a stator and provides rotating magnetic field. It guides the flow of fluid from the rotating part of system. No. of stampings are decided on the basis of length of stator body. These stampings are collected on a rod which is inserted in their slots. Laminations are provided at ends of the stampings. Then it is fitted inside a steel pipe and these stampings are locked by a small diameter steel pipe, which is fitted inside by a press machine. After proper arrangement of stampings rods are pulled out and another steel pipe of smaller diameter is pushed inside the steel pipe and thus the stampings and laminations are locked inside the steel pipe. The shape and size of assembly is adjusted by lathe machine. Casting and housing remains adjusted due to operation of lathe machine on the assembly. Smoothening of assembly is done by buff machine.
   Rotor: - It is the non-stationary part of electric motor. Rotor has 28 slots. No. of stamping depend on the size of submersible pump. Laminations are provided to control the rpm of motor. The rotation of motor is not possible without the laminations. Copper rods are put in every slot of the stampings. Shaft is put inside the center of stampings by press machine. Brazing operation is performed on stamping, lamination and copper rod to create magnetic field and thus allows rotation of rotor. The shape and size is adjusted by lathe machine. A hole is put in the shaft for fixing the bearings with the help of lathe machine. The shaft is adjusted for bushing size. A hole is made on the other side of shaft for a coupler which joins pump to the motor. Grinding operation is performed on the rotor to smoothen the assembly.
2. Impellers:-
   An impeller is a rotor used to increase the pressure and flow of fluid. Impellers are the rotating part of a centrifugal pump, compressor, or other machine designed to move a fluid by rotation. Impeller transfers energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid outwards from the center of rotation. The speed achieved by the impeller is transferred into pressure when the outward movement of the fluid is restricted by the pump casing. An impeller is usually a short disc type cylinder with an open inlet to accept incoming fluid, push the fluid radially and a bore to accept the shaft. The different types of impeller are open impeller, semi-open impeller and closed impeller.
3. Shaft:-
   It is a rotating machine element used to transmit power. A shaft is a straight rod on which impellers and other rotating equipment's are installed.
4. Bowl:-
   Bowls are used as covering for the impellers so that any outside object cannot damage them and also so that the force generated by the impellers goes only in the upward direction and does not spread out.
5. Bush:-
   Bushes are used to connect moving parts.
6. Stampings:-
   Stamping are thin metal plates combined together to make a stator or rotor to prevent eddy current losses.
7. Submersible cable:-
   It is PVC insulated cable which can supply power through water to submersible motor. It is flat in shape and usually three cores.
8. Winding wire: - The winding wire used is specially PVC or BOPP insulated with EC grade copper used in it.

2.2 Manufacturing process

The process of manufacturing involves getting the castings from foundry according to requirement and designing. The shaft and pump impeller casting are machined as per there size requirements. The stator lamination stamping is inserted in motor body and the Stator Winding is carried out. The rotor is assembled followed by assembly of rotor core staking, pressing of rotor core with shaft, brazing of rotor core with copper conductors as well end rings and coating insulation in rotor followed by assembly of motor and testing is carried out. PVC wiring is carried out in stamping of both rotor as well as stator. Terminals are brought out from the motor and are connected with the cable. Pump has number of parts which are made out of various metals. The raw material is cut to size, turned on lathes, key-way cut on milling and slotting machine. Some of the parts are ground and some are balanced on balancing machines. All component parts are inspected at every stage before taking for assembly. The pump

impeller bearings/bushes etc. are mounted on motor shaft to get the final submersible pump-motor assembly. The pump set is tested on the testing station for pump head, flow rate and motor power rating. Pump sets are then painted and name plate is fixed with pump specifications.

2.3 Material of construction

Product	**Material**(As per IS standards)
Stamping	M-45 sheet having silicon
Winding wire	EC grade copper
Copper rod	EC grade copper
Bearing set	SS 304 grade steel and plate made from high grade Teflon having high head resisting capacity.
Bush	Leaded in bronze and rubber bushing
Bowl	CIFG 200 grade
Motor rotor	Dynamically balance with throughout grinding size and epoxy painted
Motor and Pump body	Made from heavy thick SS 304 grade pipe and internally epoxy painted
Pump sleeve	Made from SS 410 and 431
Submersible cable	ISI rated with EC grade copper

Table 1. Materials of construction

III. TESTING

3.1 Types of test

Different tests performed on submersible pump are as follows:

1. Type tests
   - Insulation resistance test (after HV test)
   - Measurement of Stator and Rotor resistance.
   - Temperature rise test at rated voltage.
   - Pump performance test.
   - Hydrostatic pressure test.
2. Routine tests
   - Insulation resistance test (before HV test)
   - High voltage test.
   - No load test of motor.
   - Blocked rotor test of motor.

Type tests

The tests which are performed only one on a single product per batch or on a single product per design is known as type tests. The different types of type test to be performed on a submersible pump are as follows:-

1. Insulation resistance test(after HV test):-
   In this test the insulation resistance of the windings is measured after the high voltage test. The insulation is measured with the help of a megger. One terminal of the megger is grounded and the other is connected to one terminal of the winding, than a DC voltage in range of 500-1000Volts is applied and the resistance is measured. Normally the resistance of a healthy winding should be more than 50MΩ. If the resistance of the winding is lower than 30MΩ the test is considered as failed and the windings are needed to be replaced.
2. Measurement of stator resistance:-
   The stator resistance is measured with the help of a highly precise multi meter in the range of 0.0001Ω. Than the terminals of this multi meter are connected to the ends of stator winding of different phase and the value of resistance per phase is noted. The average resistances of all the three sets are taken and are considered as stator resistance. The total winding resistance is measured by Blocked rotor test, and the rotor resistance is calculated by subtracting the Stator resistance from the total resistance.
3. Temperature rise test:-
   Temperature rise test is also known as heat run test. In this test the rated voltage and rated current are applied to the motor and the temperature rise during this is noted, generally if we are using materials according to IS standards than there is no need to perform this test because the temperature rise can be easily calculated through the given parameters of IS standards.
4. Pump performance test:-

Pump performance report can be easily calculated through the readings of No-load and blocked rotor test. Once the readings are noted the efficiency, power factor, slip of motor, maximum torque etc. can be calculated through circle diagram.

5. Hydrostatic pressure test:-
   This test is conducted so that the pressure handling capacity of each and every part can be known. Water is filled and it is pressed so that the pressure can be created inside that part if the part manages to survive the pressure it is labelled as pass while if there occurs any crack or any unwanted thing during test it is labelled as failed.

Routine tests

The tests which are performed on each and every product of the batch or design are known as routine tests. The different types of type tests to be performed on a submersible pump are as follows:-

1. Insulation resistance test(before HV test):-
   In this test the insulation resistance of winding wire is measured before the HV test is performed. The winding wire is immersed in a tank full of water, than with the help of megger resistance is measured. One end of megger is immersed in the tank while the other is connected to the copper at terminal of winding wire it is to be noted that both the ends of winding wire should be above the water level and then a DC voltage at range of 500-1000V is applied. If the insulation is not punctured than the resistance of wire will be shown infinity in the megger, while if there is any puncture than the resistance of wire will be very low i.e. below 50MΩ and thus that winding wire can't be used in motor as it will cause a short circuit and motor will not operate.
2. High voltage test:-
   This test is performed to check the durability of winding wire so that it can't get damaged during any surge or abnormal condition. A High voltage transformer of secondary voltage 5kV AC and maximum .load current of 1000mA is used. Winding wire is immersed in water and one end of the wire is connected to one end of terminal of HV transformer and the other terminal is immersed in water. A high voltage is than applied to the winding wire for a few seconds, if the wire survives the test it is considered to have passed the test and if wire gets burn during this test it is considered as failed.
3. No load test of motor:-
   No load test is performed so that the iron loss and fixed losses i.e. friction and windage loss can be known. In this test the motor is given supply nearby its rated voltage and current is noted the motor is made to run at no load i.e. it is free to rotate without a load over it. The copper losses in this test are neglected because the rotor is moving freely and hence only core losses are taken into account.
4. Blocked rotor test:-
   Blocked rotor test is performed to find out the copper losses of the motor. In this test the rotor of the motor is blocked mechanically and voltage is applied it should be noted that the short circuit current of the motor should not exceed its rated current. Here, Core losses are neglected.

Date:- 13/02/2019			Motor HP/kw:-05/3.7			Resistance at		
Pump/Motor Sr no.:- 05HP			Stack length:- 150mm			RR/RY:-2.5		
Pump type :- 5(1 HP)			Voltage:- 415			YY/YB:-2.5		
Pump Sr no.:- 262M			Current :- 10			BB/BR:-2.4		
Duty point head:- 35			R.P.M:-2780			Connection:- Parallel		
Duty point discharge:- 400ltr			Phase:- 3 phase			Megger and HV:- OK		
Sr. No	Total Head	Voltage (V)	Current (A)	Input (W)	Speed (RPM)	Pin (KW)	Pout (KW)	Overall efficiency
1.	46.19	414.2	7.828	3481	2900	3.48	0.37	10.63
2.	41.24	414.5	8.935	4558	2854	4.56	1.31	28.73
3.	36.39	414.7	9.579	5105	2828	5.11	1.76	34.44
4.	31.29	414.6	9.936	5409	2818	5.42	1.87	34.5
5.	26.27	415.5	10.2	5655	2815	5.66	1.83	32.33
6.	21.28	417	10.23	5705	2812	5.71	1.73	30.3
7.	5.49	413.7	10.08	5534	2814	5.54	0.55	9.93

Table 2. Test Data

IV. COMMISSIONING

4.1 Steps of commissioning

1. Well is inspected for checking if any external damage to the casing is present and also to check the depth and standing water level.
2. Components of submersible pumps are inspected to check various details. It includes checking the details on the submersible motor for power supply rating, to identify whether it is a 2 wire single phase or 3 wire single phases and needs a pump stator box or 3 phase configuration. It also includes checking that the submersible pump drop cable suits the motor cable and motor and is rated correctly for submersion in water. Apart from this it is also checked that the fittings match the outlet on the pump, the rising main and the bore cap.
3. Then the motor is fitted to pump. To lubricate and seal shaft on the assembly supplied grease is used. Poly pipe is taped with thread tape and screw into the pump.
4. Drop cable is spliced to motor cable with supplied cable splice kit.
5. Pump assemble is laid next to water well. Rising main is fitted to pump and rolled out. Bore cap is fitted to the other end of rising main.
6. Drop cable is rolled out alongside rising main. Stainless steel safety cable is attached to pump and roll out with rising main and drop cable. Safety cable end is attached to bore cap allowing for the rising main to stretch.
7. The drop cable/ is attached to the rising main with 4-6 turns of grey duct tape every 4-6 meter apart. Some slack is allowed for the rising main to stretch. The full length of the cable splice is taped to the rising main to protect it. A couple of meters extra drop cable is allowed to be doubled up and taped to the rising main below the bore cap. This may be required if the cable splice or motor need replacement at a later date.
8. It is checked that the fittings are tight and it is also checked that the cables are secure and slack to allow for stretch.
9. If the assembly of submersible pump is light enough to handle in weight, the pump end is gently lowered into the well and an assistant is required to hold the bore cap end. The assembly is feeded down the hole and is paid particular attention for preventing damage to the electric drop cable. The assembly should be suspended by the bore cap on top of the casing. In the case, the weight of the assembly cannot be safely handled a roller made from a car wheel may be used.
10. Pump controller, pump starter and pump protection device is connected to power supply and test pump. Wait for a few moments and allow the water to reach the surface.
11. Complete the initial test and then proceed to connect the required pipe work to the bore cap.
12. Finally pump operation and operation of pump protection devices and controls are tested.

4.2 Pre-Commissioning checklist

- Unit Check.
- Pipe Work.
- Checking of electrical parameters.

4.3 Post-Commissioning checklist

- Stuffing box
- Oil level.
- Checking direction of rotation.
- Priming the pump.
- Starting up.
- Stopping.
- Restarting.

V. CONCLUSION

- For the perfect quality of submersible pumps required by the user it is crucial to take parts of submersible pump as per IS standards as shown in table 1 which makes the pump robust and efficient.
- Different tests performed on submersible pump shown in table 2 shows that if pump is operated near duty point head, overall efficiency is greater and vice versa.
- Pre-commissioning and commissioning after installation are required so that the working life of submersible pump becomes greater.

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