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# Optimization of a water cooled Submersible motor journal bearing length using CFD

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## ABSTRACT
**The journal in case of a water cooled Submersible motor is the bearing surface of the rotor which consists of hard chromed stainless steel material. The bearing consists of a Leaded bronze material (Bronze grade LTB 2,3 or 4 of IS 318 or Nitrile / cutless rubber) which is the softer part out these two. The failures of the bearing bush accounts for 90% of the failures in a submersible motor. The implication of this failure is the complete breakdown of the Motor i.e. the windings will get damaged and expensive repairs would be required to be carried out. This clearly suggests that the design of such a journal should be properly investigated. A CFD approach would assist in establishing the dimension (length) of the bearing. This paper presents step by step application of CFD to optimize the bearing length and is an outcome of around 3 years of extensive research in an attempt to solve a manufacturer's long standing problem.**

***Keywords-*** **Submersible motor, journal, bearing, rotor, CFD**

## I. INTRODUCTION
In India the water cooled type Submersible Motors are extensively manufactured and available in the market due to its simplicity in design and manufacture. The maintenance of such motors is also very simple and can be carried out at ease compared to the oil filled version.

Even with such advantages water cooled submersible motors too pose various problems especially with its bearing bushes as indicated in Figure 1.0 and 1.1.

Figure 1.0 Worn out bearing bush (Courtesy VIRA PUMPS)

Figure 1.1 Worn out bearing surface of the Rotor, (Courtesy VIRA PUMPS)

## II. PROBLEM IDENTIFICATION
This was a long standing problem at M/s VIRA PUMPS, Kolhapur, Maharashtra, INDIA for around 5 years. This Industry is a reputed manufacturer and exporter of Submersible Pumps. It has started producing 100 mm (4") Submersible motors since 2001. Figure 1.2 shows a sectional view of such a Submersible motor

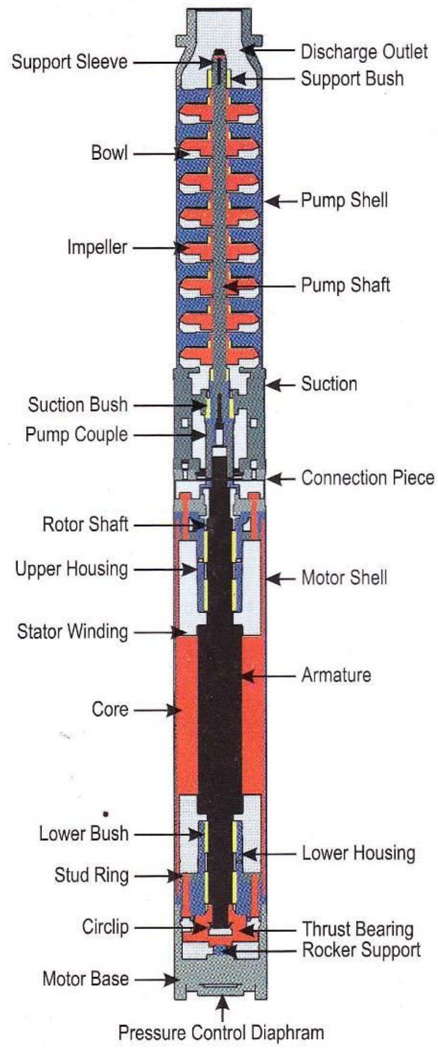


Figure 1.2 Sectional View of a 100 mm (4") Submersible motor

For motors above 1.5 hp, it experienced bearing bush failures after just few months of operation. Where as its earlier products i.e. 150 mm and 200 mm Submersible motors operated smoothly for more than 25 years. Due to this the Industry faced huge problems in their operations. Their reputation had been at stake. They were now thinking to discontinue this problematic range of products. They were not only the ones who suffered but, similar manufacturers in India experienced the same problem.

This problem was taken as a challenging project in 2006 as an attempt to save this particular range of Motors and to recover the loss incurred for the last few years. An extensive study was made by referring various literatures as well as the IS guidelines for manufacturing this particular motors. Several national and international brands of these specific motors were thoroughly analyzed.

The root cause analysis suggests that the following factors are responsible for such bearing bush failures:

1. Material of the bearing bush.
2. Poor Surface finish of the journal.
3. Wrong length and clearances maintained.
4. Machining defects like run-outs, etc.
5. Overall design of the Motor.

The materials being used absolutely confirmed to IS 318 with correct percentage of copper and minimum lead as the basic requisites. So, the material issue was ruled out. The surface finish was also maintained below 0.7 microns which was desired in the range of 0.2 to 0.4 microns. There was also no problem whatsoever in the run outs, etc. as the rotor was dynamically balanced on superior balancing machine. This came to the decision that the length of the Bearing bush needed to be investigated.

As a test the bearing length was increased up to 30% and the said motor being manufactured and assembled. The motor was coupled with a suitable pump and the system was installed and run for around a year.

The results were encouraging as the bearing bush did not failed at all. This pointed out that the long standing problem can be solved by evaluating the correct bearing length and optimizing the same scientifically. The important factor i.e. the Permissible bearing pressure is vital in the design of such bearings. This calculation can be assisted with a CFD analysis to establish its correct value of this factor so as to assist correct calculations.

## III. CFD ANALYSIS OF JOURNAL BEARING :

The conventional method in designing a Journal bearing is by using a bearing pressure recommended for specific application. In the case of a Submersible Motor it is recommended to use a bearing pressure in the range 0.7 to 1.4 as shown in the table 1.0

| Machinery | Bearing | l/d | Permissible bearing Pressure ($N/mm^2$) |
|---|---|---|---|
| Gas and oil engines (4-stroke) | Main<br>Crank pin<br>Wrist pin | 0.6-2.0<br>0.6-1.5<br>1.5-2.0 | 4.9-8.4<br>10.8-12.6<br>12.5-15.4 |
| Gas and oil engines (2-stroke) | Main<br>Crank pin<br>Wrist pin | 0.8-1.8<br>0.7-1.4<br>1.5-2.2 | 5.6-11.9<br>10.5-24.5<br>16.1-35.0 |

| | | | |
|---|---|---|---|
| Aircraft and automobile engines | Main<br>Crank pin<br>Wrist pin | 0.8-1.8<br>0.7-1.4<br>1.5-2.2 | 5.6-11.9<br>10.5-24.5<br>16.1-35.0 |
| Reciprocating compressors and pumps | Main<br>Crank pin<br>Wrist pin | 1.0-2.2<br>0.9-1.7<br>1.5-2.0 | 1.75<br>4.2<br>7.0 |
| Centrifugal pumps, motors and generators | Rotor | 1.0-2.0 | 0.7-2.0 |
| Railway cars | Axle | 1.9 | 3.5 |
| Marine steam engines | Main<br>Crank pin<br>Wrist pin | 0.7-1.5<br>0.7-1.2<br>1.2-1.7 | 3.5<br>4.2<br>10.5 |
| Punching and shearing machines | Main<br>Crank pin | 1.0-2.0<br>1.0-2.0 | 28<br>56 |
| Rolling Mills | Main | 1.0-1.5 | 21 |

Table 1.0 Permissible bearing pressure

Instead of taking the value directly from the above table, we will perform CFD Analysis on the bearing. By this we will also be able to verify the value of bearing pressure 'p'. We can then use the value obtained from the analysis and perform the design steps to calculate the length of bearing.

Figure 1.5 shows the assembly for the CFD Analysis. Solidworks Flow simulation software is used for the CFD Analysis. Figure 1.6 represents the Surface plot indicating the Maximum bearing pressure. The journal in this case is rotated at 2800 rpm which is the rated speed of the motor. The centers of the journal and bearing bush are offset to around 0.015 to mimic the real working condition. The working fluid is chosen as water.

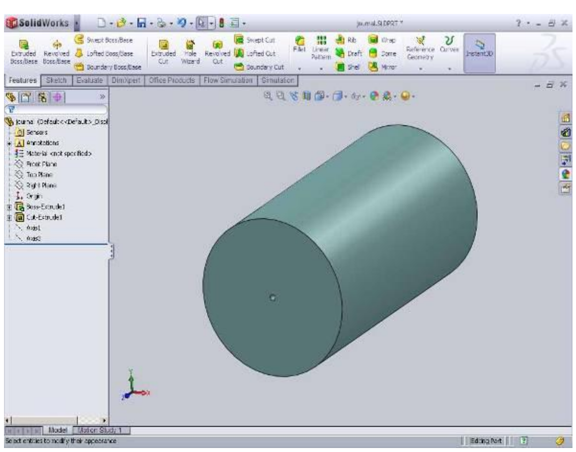

Figure 1.3 Representation of the journal

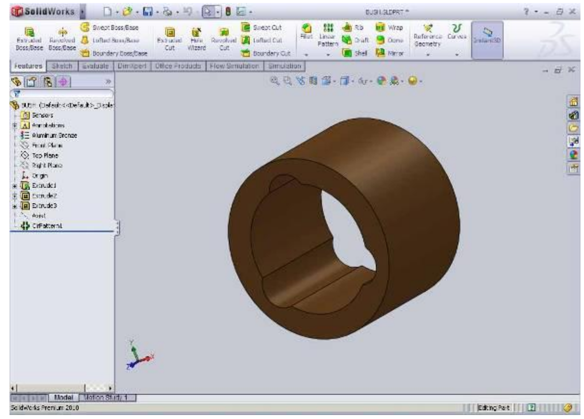

Figure 1.4 Bearing bush of the Submersible Motor

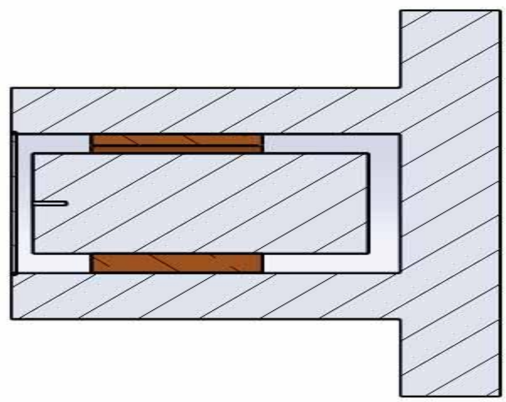

Figure 1.5 Assembly for the CFD analysis

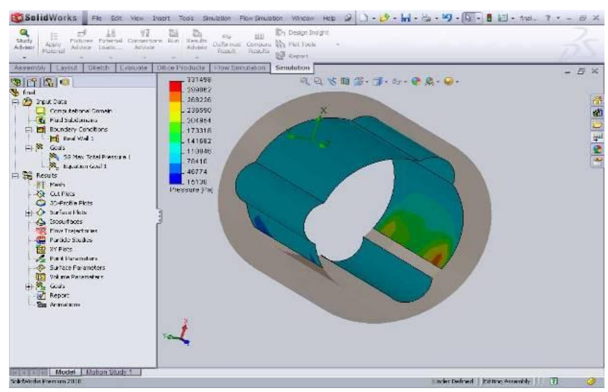

Figure 1.6 Surface plot indicating Bearing pressure

So, from this analysis we get the bearing pressure p=0.38 or 0.4 N/mm$^2$. We will use this value in the design of our journal bearing as follows:

We will consider the case for the design of the Journal bearing for a 1.5 hp or 1.1 kW submersible motor which rotates with a constant speed of 2800 rpm or 293 rad/s.

We need to find the Radial load $F_N$ which is given by,

$$F_N = \frac{9550 \ x \ kW}{N \ X \ R} \qquad \ldots(1)$$

Where R is the radius of the journal. In this case it is 0.01299 m

$= \frac{9550 \times 1.1}{2800 \times 0.01299}$

= 288.82 N

Now, Area A = l x d

= l x 25.98

We already know that,

$p=w/ld$ …(2)

taking value of p= 0.4 N/mm$^2$ and

w= $F_N$=288.82 N

so,

$0.4 = \frac{288.82}{l \times 25.98}$ …(3)

Thus, l= 27.79 mm which is the bearing length. At present the bearing length used for 1.5 hp or 1.1 Kw motor is 24 mm. The recommendation made here is that the bearing length must be changed to 27.79 mm.

Let us check this by using a bearing pressure of 0.7 N/mm$^2$ is used as per Table 1.0

From (3),

$0.7 = \frac{288.82}{l \times 25.98}$

The length comes out to be 15.9 mm which is very less. Again if the value of bearing pressure is increased say in steps till 1.4 then it is quite obvious that we will get an in correct length of the bearing bush.

## IV. RESULTS AND DISCUSSIONS

The specified bearing pressure for this particular application was 0.7 N/mm$^2$ to 1.4 N/mm$^2$ as per Table 1.0 above. Using these values it is found that the bearing lengths obtained are very short and may be not sufficient for that specific power rating. Thus, a precise bearing pressure has to be used to get accurate results. It has been found that by implementing the bearing pressure obtained by CFD results gives a more accurate length of the bearing. The same technique can be used for various diameters of the journal or the bearing bush and for various power ratings which ultimately help in achieving an optimum journal bearing length can be achieved.

The manufacturer is an ISO 9001 Certified organization. The basic objective of the organization is to control rejection below 3 %. The new design was implemented in October 2009. The results were collected in May 2011 i.e. after 17 months as shown in figure 1.7

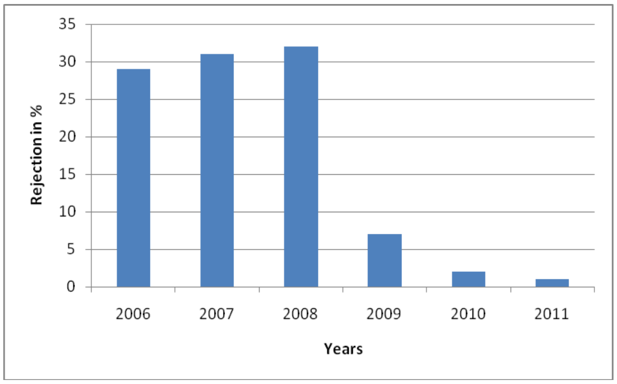


Figure 1.7 Rejection percentage

This new method and design changes were communicated to all potential customers and practical demonstrations of the pump sets were done in presence of customers. This boosted confidence of the customer that the failure reasons have been removed and product is updated. Slowly the customer response gone up and we observed stiff rise in quantum of sales of this product which is graphically represented in Figure 1.8 This is very much fruitful achievement of the research undertaken and completed which was related to Bearing bush of the Submersible motor.

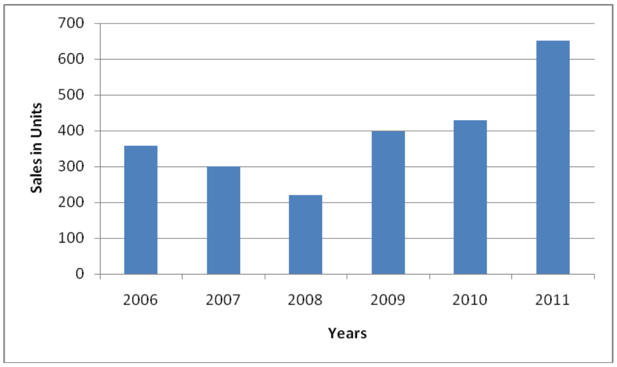


Figure 1.8 Increase in Sales

## V. CONCLUSION:

This paper thus demonstrates how CFD Technique can be effectively used to sort out design lacunas in existing designs and make the product free from complaints. This saves sizable amounts of effort and money. The manufacturing organizations who are engaged in design and development of own products must establish a system which will keep consistent focus on field operation of the product through immediate corrective and preventive actions to improve upon the product life cycle through harnessing available advanced and most suitable technologies.

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