

# Fatigue Life Prediction in Journal Bearing

Irsyadi Yani, Hasan Basri, Hafizd Ibrahim Marsil

Dept. of Mechanical Engineering

Faculty of Engineering, Sriwijaya University

Palembang, Indonesia

yani\_irs@yahoo.com, hasanbas1960@gmail.com, hafizdibrahim@gmail.com

**Abstract**— Failure of fatigue is damaged materials where caused frequent load. Fatigue owing to some factors, which is Stress concentration on fatigue, Stress life, Effect size and surface, and Change properties of surface. The fatigue failure of a material is dependent on the interaction of a large stress with a critical flow. In essence, fatigue is controlled by the weakest link of the material, with the probability of a weak link increasing with material volume. This phenomenon is evident in the fatigue test results of a material using specimens of varying diameters. From this research we can get effect of concentration stress on strength fatigue with S-N method. On this method only count fatigue life or endurance limit from Journal bearing housing. By Finite Element Analysis, it is not so easy to determine fatigue life. When we find the first yield point, it means this point is in the highest stress state. Then we can refer S-N curve. In this paper, the effect of bearing and housing elasticity on the stress field, which could result in surface fatigue in journal bearing, has been investigated. This condition is proved with occurred slip lines on surface of specimen. These slip lines are caused on some thousands stress cycles. Additional crack is happened immediately and finally long enough crack. So that formed unstable crack that caused fracture of brittleness or fracture of toughness because section of specimen cannot keep

**Index Terms**— journal bearing, numerical, fatigue life

## I. INTRODUCTION

While many parts may work well initially, they often fail in service due to fatigue failure caused by repeated cyclic loading. Characterizing the capability of a material to survive the many cycles a component may experience during its lifetime is the aim of fatigue analysis. In a general sense, Fatigue Analysis has three main methods, Strain Life, Stress Life, and Fracture Mechanics

According to independent studies carried out by the Battelle group in 1982, between 80-90% of all structural failures occur through a fatigue mechanism and the estimated annual cost of fracture and fatigue to the US was 4.4% of GDP.

Furthermore the Battelle Study concluded that this could be reduced by 29% by application of current fatigue analysis technology.

In the past, fatigue analysis was largely the domain of the development engineer, who used measurements taken from

prototype components to predict the fatigue behavior. This gave rise to the traditional “Build it, Test It, Fix It” approach to fatigue design. This approach is known to be very costly as an iterative design cycle is centered on the construction of real prototype components. This inhibits the ability to develop new concepts and reduces confidence in the final product due to a low statistical sample of tests. It is also common to find early products released with ‘known’ defects or product release dates being delayed whilst durability issues were addressed.

A more desirable approach is to conduct more testing based on computer simulations. Computational analysis can be performed relatively quickly and much earlier in the design cycle.

Confidence in the product is therefore improved because more usage scenarios can be simulated. It is not recommended, however, that these simulations completely replace prototype testing. It will always remain desirable to have prototype signoff tests to validate the analysis performed and improve our future modeling techniques. However, the number of prototype stages, and hence the total development time, can be reduced.

The following subsections are including: bearing in general, journal bearings, thrust bearing, other types of bearings, rotor-bearing system. Coupled thermomechanical non-linear finite element models have been developed to study 2D and 3D rolling, and rolling plus sliding contact problems. The various less or more realistic material constitutive models have been used to model behavior of bearing materials. The contact stress fatigue is considered as a primary wear mechanism. The damage process under contact loading such as, for example, is the cracking, spaling, and tribological reaction, can be study by the finite element method. We can study the mechanics of the sub-surface or near surface modes of rolling contact failure.

In this paper we overview the physical behavior responsible for fatigue stress from initiation to final component failure of journal bearing.

## II. JOURNAL BEARING

The bearings are important enough to be studied because if the shaft's orbit is not stable, or the bearing is not well designed, contact between the shaft and the bearing will appear.

The plain journal bearings are fully used in hydraulics due to their small size, low price, and its capability of carrying load.

The journal bearing appears in the finite element equations as a spring and damper. It appears at one node, linking the shaft to a rigid structure. It has 4 degrees of freedom.

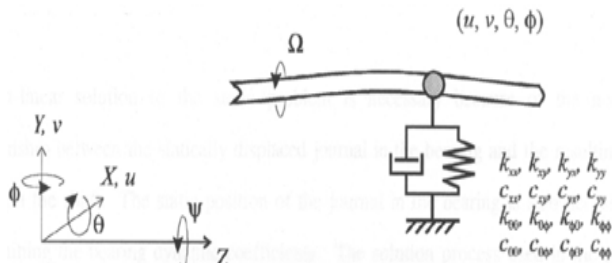


Fig 1. FE Equation of Journal Bearing

The first thing we need to do is determine the static (mean) position of the shaft in the bearing

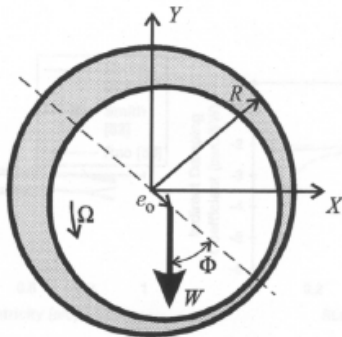


Fig 2. Static Bearing Calculation

Two important parameters are obtained from the bearing test: (i) bearing yield ( $S_{b,yield}$ ) and (ii) bearing ultimate ( $S_{b,ult}$ ) of the material; where bearing stress is defined with the following relation:  $S_b = P/(Dt)$ . The yield parameter is defined as the stress at a 2% permanent hole deformation, which is a definition comparable to the tensile yield. Bearing ultimate is defined as the first maximum load peak, which generally was the maximum stress reached.

For the material model, it is assumed that it behaves as an isotropic material with isotropic hardening. Uniaxial tensile test data are simplified into a trilinear behavior, consisting of (i) an elastic part, (ii) plastic part up to necking (15% plastic strain) with stiffness equal to 1467.67 MPa, which is followed by (iii) a description of the necking behavior.

Fatigue is defined as 'Failure under a repeated or otherwise varying load which never reaches a level sufficient to cause failure in a single application.' Fatigue cracks always develop as a result of cyclic plastic deformation in a localized area. This plastic deformation might arise through the presence of a small crack or pre-existing defect on the surface of a

component, for both cases it is practically undetectable and unfeasible to model using traditional Finite Element techniques.

The fatigue life prediction follows the strain life approach used for notched geometries. Surface grooves are treated as microscopic notches, where elastic stresses and strains are converted to local plastic stresses and strains in the notch root. Different methods can be used for this conversion, depending on the stress state in the notch root and the applied loading. The most well-known approach is that due to Neuber which relates nominal elastic values to notch root stress and strain as  $\epsilon\sigma = K_t \epsilon_n E = C$ , where C is a constant and  $\epsilon_n$  is nominal elastic strain. Plane stress is assumed in this analysis, which can be shown not to be the case for a circumferentially notched bar. A method for general stress states is outlined later.

The fatigue strength of a welded component is defined as the stress range which fluctuating at constant amplitude causes failure of the component after a specified number of cycles (N). The stress range is the difference between the maximum and minimum points in the cycle. The number of cycles to failure is known as the endurance or fatigue life.

The expression linking N and  $R^m$  can be plotted on a logarithmic scale as a straight line and is referred to as an S-N curve. The relationship holds for a wide range of endurance. It is limited at the low endurance end by static failure when the ultimate material strength is exceeded. At endurances exceeding about 5-10 million cycles the stress ranges are generally too small to permit propagation under constant amplitude loading. This limit is called the non-propagating Stress.

Finite element technique involves element-modeling discretion, which is defined through a displacement function of each node.

$$\{F\} = [k]\{D\} \quad (1)$$

Handling Finite Element Analysis stress requires a good understanding of the stress-concentration effect, quantified as a factor  $K_t$ . The theoretical stress-concentration factor is based on a theoretical elastic, homogeneous, isotropic material and can be expressed as:

$$k_t = \sigma_{max} / \sigma_{nom} \quad (2)$$

Handling FEA fatigue stresses correctly also requires good understanding of fatigue stress-concentration factor

By Finite Element Analysis, it is not so easy to determine fatigue life. When we find the first yield point, it means this point is in the highest stress state. Then we can refer S-N curve.

### III. RESULT AND DISCUSSION

From this research we can get effect of concentration stress or  $K_t$  on strength fatigue with S-N method. On this method only count fatigue life or endurance limit from Journal Bearing. The lubricant was assumed to supply at ambient pressure via a full width line groove in the upstream groove. The Reynolds equation was solved using the Gauss-Seidel iterative method with over relaxation factor. The boundary conditions required were at the bearing edges and at the lubricant supply line. The lubricant was assumed to capitated at ambient pressure. Thus, it can be clarified that  $P_{cavitation} = P_{atmofer} = 0$ . For use with the Reynolds equation and full-width film applied, the following boundary conditions adapted were,

- a)  $P = 0$  at  $\phi = 0$ .
- b)  $P = 0$  at  $\phi = \pi/2 - \phi$ , and  $P = 0$  at  $\phi = 3\pi/2 - \phi$
- c)  $P = dP/dX = dP/dZ = 0$  at  $\phi = \phi/2 = \pi + \alpha$
- d)  $P = 0$  at  $z = \pm b/2$ .

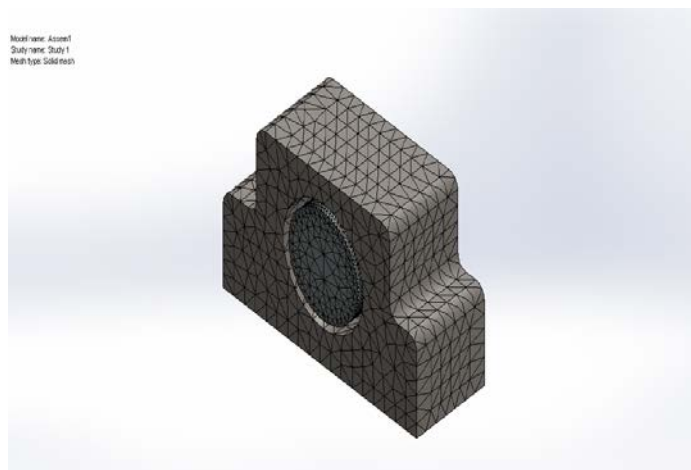


Fig 3. FEA Modelling for Journal Bearing

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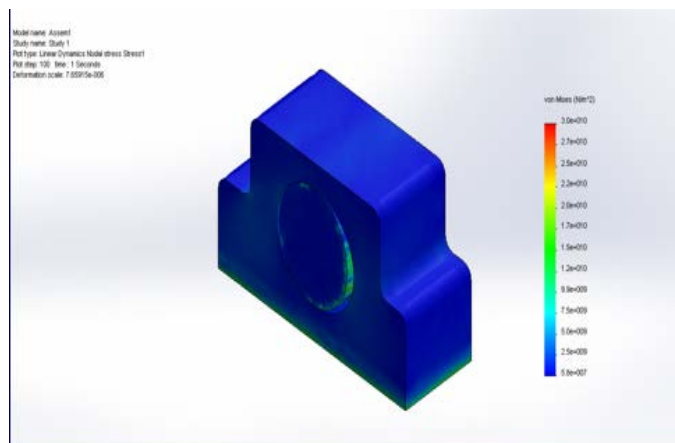


Fig 4. F Stress Concentration for Journal Bearing

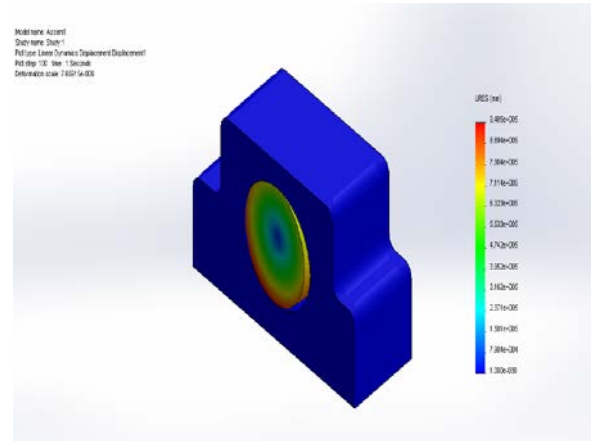


Fig 5. Fatigue for Journal Bearing

Table 1. Fatigue Test for Journal Bearing

Stress (Mpa)	Fatigue life (cycle)
13,872	48671
21,047	20518
27,728	15191
35,312	10513
40,128	5732

From the data we can draw S-N curve for j ournal bearing.

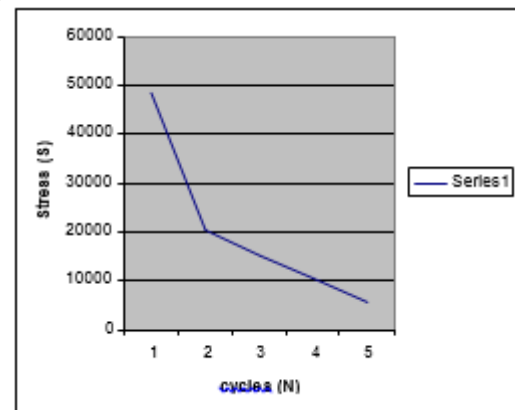


Fig 6. S-N curve

### IV. CONCLUSION

A general approach to modelling the durability of Journal Bearing has been developed. The approach removes the requirement of rebuilding FEM models in order to capture the important stress raising features which significantly affect fatigue life predictions.

The method is ideally suited for predicting data for fatigue life calculations in Journal Bearing.

Example applications have been presented demonstrating some of the capabilities of the method. The most important point addressed in this work is that the method, which uses, can be implemented easily to predict fatigue life of journal bearing by Finite Element Analysis. Moreover, the algorithm provides robust and fast results because the proposed method avoids the extra computational burden for

preprocessing since only stress concentration of the components are used to predict the fatigue stress of the journal bearing. The proposed method can identify stress concentration, fatigue stress and calculate the fatigue life of the journal bearing.

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