Research Paper Engineering

Fatigue Analysis of Stepped Shaft Using Goodman Method

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ABSTRACT

Ball mill is generally used in ceramic industries, sanitary wares, tile industries and insulators industries. It is a cylindrical device used to grind materials like ores, chemicals, ceramics and paints. A failure of ceramic ball mill shaft has been analyzed. It was originated from stepped outer portion and gradually expands in circular direction toward inside because of multi axial stresses (axial, bending and torsion) produced on it. Endurance limit using Goodman's method, fatigue factor of safety and the theoretical no of cycles sustained by the shaft before failure is estimated.

Keywords : Fatigue, Stress analysis, Goodman diagram.

1. INTRODUCTION

Ball mills find their applications in ceramic industries, sanitary wares, tile industries, technical ceramics and insulators industries. The size of ball mill varies from 5"x5" to 300"x300". Ball mills are provided with v-ropes, a/c variable drives, triple stage helical reduction gearboxes, fluid couplings, inching devices etc. Ball mill is used for grinding raw material like ores, chemicals, ceramics and paints. Ball mill is cylindrical device generally used to grind ceramic industries, sanitary wares, tiles industries and insulators industries.

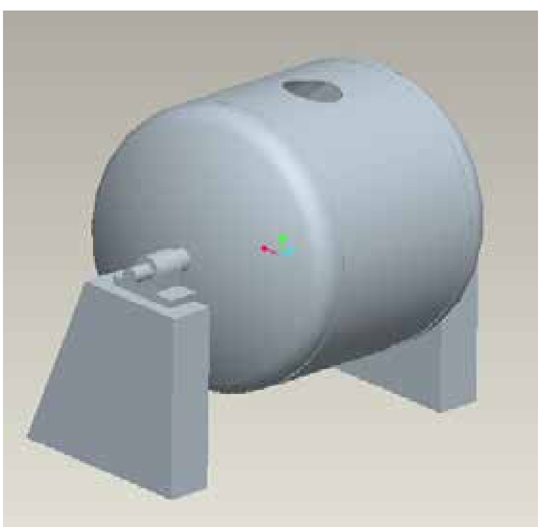

Fig. 1 Pro-E model of 8" x 8" Ball mill without drive arrangement

All the parts can be seen in above drawing (8" x 8" ball mill). Here, the specification of ball mill is given below;

- Grinding batch capacity- 5000kg
- Plummer block bearing-MATSA/USA make C.I. with grease nipple
- Gear box – KDN-280 size, gear ratio 100:1
- Motor – 25HP, 1460 rpm
- Fluid coupling-FCU 12.75
- Flexible coupling- H-type, make by love joy

2. Fatigue analysis

According to ASTM E 1150, fatigue is stated as "The process of progressive, localized, permanent structural change occurring in a material, subjected to conditions that produce fluctuating stresses and strains at some point or points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations". In fact, there are three stages of fatigue failure, fatigue-crack- initiation, fatigue-crack-propagation and sudden fracture due to unstable crack growth. The first stage can be of short duration, the second stage involves most of the life of the shaft and the third stage is instantaneous. The total fatigue life, N_t is the sum of the initiation and propagation lives that is,

$$N_t = N_i + N_p$$

3. Stress Analysis

From visual inspection of failure portion, we analyzed that failure occurred in circular direction and from outer stepped portion of shaft to center. Because of multi axial loads (axial, bending and torsion) are occurred on that stepped portion of shaft. We calculated multi axial stresses on that stepped portion of ball mill shaft. Drawing of ball mill shaft is given below;

Stress/load calculation:

- Minimum load (when ball mill is unloaded): 14200 Kg
- Maximum load (when is rotated with loading condition): 20200 + 0.05 (20200) = 21210 Kg

(Maximum loading can be taken from reference paper; it can conclude that weight of ball mill is increase 5% of starting load because of impact loading.)

4. Modified Goodman Diagram:

The components which are subjected to fluctuating stresses are designed by constructing the modified Goodman diagram. For the purpose of design, the problems are classified into two groups;

S-N curve:

The material is used in this shaft is C15 (low carbon steel). Its ultimate tensile strength, estimated strength and endurance limit stress are, Ultimate tensile strength, S_u = 414 MPa

Estimated strength, S_m =0.9 S_u =372.6 MPa

Corrected endurance limit,

$S_e = K_a \, K_b \, K_c \, K_d \, S_e'$

K_a Surface finish factor = 0.825

K_b Size factor = 0.75 (for d > 50mm)

K_c Reliability Factor = 1 (for R = 50%)

K_d Modified factor = 1/1.741 = 0.574

Endurance limit stress, S_e' = 0.5 S_{ut}

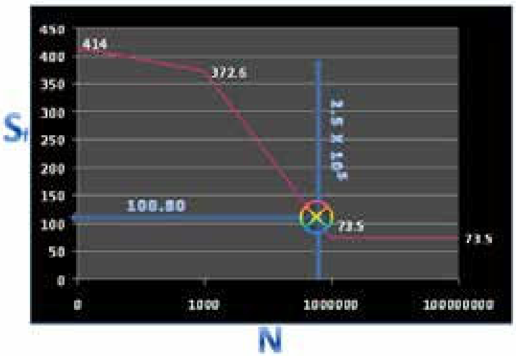

Fig.2 S-N curve for failed ball mill shaft

S_u = 414Mpa

S_m = 372.6Mpa

S_e = 73.5Mpa

From above data, we can generate S-N curve. Which indicate endurance strength for its failure life (2.5 x 10^5cycles) is 100.80Mpa

5. Conclusion

Failure analysis of the shaft is investigated in detail. Mechanical properties of the shaft are determined. After visual investigation of the fracture surface it is concluded that the failure occurred due to torsional-bending fatigue. Fatigue crack has initiated at the relief groove. Forces and torques acting on the shaft are determined; stresses occurring at the fracture surface are calculated. Endurance limit and fatigue safety factor is calculated, fatigue life of shaft is estimated. Fracture of the shaft occurred due to faulty design, causing a high notch effect. In conclusion effect of change in radius of curvature on stress intensity, effective placements of supports and precautions which have to be taken to prevent a similar failure is clarified.

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