

# Analysis of Blower Bearing Used In Dust Aspiration Unit of a Petrochemical Plant

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**Abstract:** *FACT diversified into petrochemicals in 1990 with the production of Caprolactum. The versatile petrochemical is the raw material in the manufacture of Nylon-6, which finds extensive application in textiles and engineering products. To its high quality the production have been acknowledge as among the best in the world. The finished product i.e Caprolactum is send to the bagging section. Here the problem identified is repeating compliant of the bearing in blower in bagging section. The blower is used to collect the dust particles from the caprolatum. It is found that the bearing problem an leads to serious quality problems. The main objective of this study is to find out the major causes of these problems and to find out remedies by which these defects can be reduced.*

**Index Terms**—Bearing Compliant, Cause and Effect Diagram, Pareto Diagram.

## I. INTRODUCTION

India's first large scale fertilizer unit industry was set up in 1944. The company's main business is manufacture and marketing of Fertilizers, Caprolactum and Engineering Consultancy, and Fabrication of equipment.

## II. PETROCHEMICAL DIVISION

Industry diversified into petrochemicals in 1990 with the production of Caprolactum. The versatile petrochemical is the raw material in the manufacture of Nylon-6, which finds extensive application in textiles and engineering products. To its high quality the production have been acknowledge as among the best in the world. The division is located adjacent to the Udyogamandal division. Co-product Ammonium Sulphate is transferred for processing to the fertilizer plant to Udyogamandal. The other plants present in the PD are Anyone Plant, Hyam Plant (Hydroxylamine), cyclohexane plant, captive power plant and RAP (Replacement Ammonia Plant). Products from these plants are essential for the production of caprolactum and Ammonium Sulphate.

## III. HYAM PLANT

Pure hydroxyl amine is an unstable product. When heated, it decomposes leading to an explosion. Hence it is used in the form of a salt and in fact, it is produced as hydroxyl amine sulphate (HYAM) solution having a concentration of 62 gpl. Hyam sulphate is prepared by "Raschig" process. The raw materials required for its production are ammonia, carbon dioxide, sulphur dioxide, air and water. The end reaction which gives hyam sulphate involves ammonium nitrite and sulphur dioxide. First, ammonia water is prepared by the absorption of ammonia in water, which will use at different

stages of hyam preparation. Ammonium carbonate/bicarbonate solution is prepared by absorbing gaseous carbon dioxide in ammonia water in an absorption column. Ammonia water and carbon dioxide are supplied so that the ammonia-carbon dioxide ratio is about 1.85 and the process water is also adjusted to obtain the desired concentration of ammonium carbonate/bicarbonate solution. The SO<sub>x</sub> in the form of off gases coming from the hyam preparation is reduced by scrubbing it with ammonia water. The ammonia sulphate thus obtained from scrubbing system is discharged to the hadsa reactor. The off gases from the scrubber are subjected to selective catalytic reduction of nitrogen in a reactor containing TiO<sub>2</sub> catalyst, where the NO<sub>x</sub> content is further reduced to 25 ppm. The off gases from the off gas reactor and the NO<sub>x</sub> removal system are discharged to the atmosphere through the stack. The gas going out to the atmosphere through the stack has a NO<sub>x</sub> content of 165 ppm and a SO<sub>x</sub> content of 25 ppm. The NO and NO<sub>2</sub> gases used in the production of Ammonium nitrite are prepared by the combustion of gaseous ammonia. A mixture of gaseous ammonia and air is fed to a reactor fitted with platinum/rhodium gauzes where the conversion to nitrogen monoxide takes place. Part of the NO is converted to NO<sub>2</sub> while the gases are being cooled in a cooler condenser. Some of the NO<sub>2</sub> gas formed is absorbed in the condensed reaction water to form nitric acid. The gas mixture leaving the cooler condenser is further cooled and oxidized in the first oxidation column. By this cooling water condenses and nitric acid is formed. This nitric acid together with acid from the cooler condenser is discharged to the storage tank. Before discharging to the storage tank, the dissolved gases are removed in the bleach tower and these gases are fed into the second oxidation column. The nitrous gas mixture from the first oxidation column is separated into two streams – one to ammonium nitrite preparation and the other to second preparation column. The nitrous gases leaving this column are mixed with off gases from nitrite reactor and fed into NO<sub>x</sub> absorber. From this the gases are sent to the atmosphere through a stack via a mist eliminator. The nitrous gas mixture and ammonium carbonate solution are sent to the nitrite reactor where ammonium nitrite is formed. The temperature in the reactor system is maintained at 3 degree Celsius by circulating the ammonium nitrate through cooler. This ammonium nitrite solution is further mixed thoroughly with ammonia water before coming in contact with SO<sub>2</sub> in Hadsa preparation section. The mixture of ammonium nitrite, ammonia water and sodium dioxide is fed into an absorption column known as Hadsa reactor in which hydroxyl amine

disulphonic ammonia is formed. This Hadsa solution is treated in two stages to get hyam sulphate. In the first stage the hadsa solution is heated in a heat exchanger after which spontaneous hydrolysis of hadsa to hydroxyl amine mono sulphonic ammonia takes place. This is further hydrolyzed to obtain hydroxyl amine sulphate. This neutralized hyam sulphate is sent for lactam preparation.

#### IV. ANONE PLANT

Benzene is one of the raw materials used for the production of cyclohexane which is an intermediate in the production of caprolactam. The production of cyclohexane involves two major steps. Hydrogenation of Benzene to Cyclohexane In this step, benzene is hydrogenated in a reactor using platinum over alumina as catalyst. Since water causes sintering of alumina, the benzene is to be dried so that the water content is less than 100ppm. Water is removed as a benzene water azeotrope. Hydrogenation of benzene is an exothermic reaction taking place on the surface of the catalyst at a temperature of around 350 – 400 degree Celsius. This reaction heat is removed by circulating thermal oil. Minor amounts of sulphur which is present in the benzene and hydrogen feed-stocks in an after reactor containing a lower bed of ZnO catalyst and an upper bed of platinum on alumina catalyst. Sulphur is removed in the lower bed. After the sulphur removal, complete conversion of benzene to cyclohexane is attained in upper bed hydrogenation catalyst. Before hydrogenation, benzene is preheated in a heat exchanger by heat exchange with hot reaction mixture coming out of after reactor. This preheated benzene is evaporated in an evaporator by the hydrogen-nitrogen feed to the hydrogenation reactor. The cyclohexane thus formed is liquefied by condensation. After condensation, cyclohexane and the reaction gas are separated. The liquefied cyclohexane is sent to the heptane distillation column to remove heptane as bottom product. This bottom product is further utilized in the purge incineration plant. Part of the recirculation gas from the separator is recycled to hydrogenation section. To avoid the accumulation of inerts a purge stream is drawn from the separator. Purge gas is cooled to reduce a cyclohexane concentration and this is further reduced to less than 0.1% wt in absorption unit containing active carbon. This is then sent to hyam plant to be used as fuel. Oxidation of Cyclohexane On oxidation, cyclohexane becomes cyclohexyl hydro peroxide (CHHP). For this, oxygen is supplied as air at 13 kg/cm<sup>2</sup> and 165 degree Celsius. This CHHP decomposes to anol and anone. The oxidation of cyclohexane to CHHP is carried out in a number of reactors arranged in a cascade. In each of these reactors, air is passed through cyclohexane via concentric circular spargers at the reactor bottom. The cyclohexane liquid from the last oxidation reactor flows by gravity into a decomposition reactor. Aqueous solution of sodium hydroxide and small amount of cobalt acetate solution are also fed to this reactor. In this aqueous alkaline environment, the CHHP decomposes to cyclohexane and cyclohexanol. Neutralization of acidic by-products of the

oxidation as well as decomposition reactions takes place in the decomposition reactor. After decomposition of CHHP and neutralisation of the acids present, the organic phase and aqueous phase are separated in a combination of three separators. Part of the aqueous layer formed is recycled to the decomposition reactor and the remaining is discharged to the Soda Ash recovery unit. The aqueous layer contains sodium salts resulting from the neutralisation of organic acids and the excess sodium hydroxide fed in for complete decomposition of CHHP. The organic layer from the separator is discharged into the cyclohexane distillation system. In this, the unconverted cyclohexane is separated from the higher boiling oxidation product, i.e. anone, anol, esters, aldehydes and other organic products. The aldehydes in the oxidation products are converted into heavier components by aldol condensation in the saponification process step by addition of aqueous NaOH solution. The esters present in the oxidation product are also saponified. After saponification, cyclohexane is supplied to separate the saponification product into an organic top layer and an aqueous bottom layer. The organic top layer is washed with water in an extraction column to extract sodium salt and sodium hydroxide that are dispersed in the organic state. The organic too layer of the extraction column is discharged to drying column were cyclohexane and water are stripped from the rest of the anone-anol mixture. The purification of the crude oxidation products takes place in three fractional columns. In the first column (fore run column), low boiling impurities are removed as top product which is used as fuel in the boiler plant. In the second column (anone column), pure anone is obtained as top product. In the third column, the anol is separated as top product from the higher boiling impurities. The bottom product (heavy residue) is used as fuel in boiler plant (Soda Ash recovery section). The top product anol is converted into anone by dehydrogenation, using Cu-Mg oxide as catalyst in a dehydrogenation reactor. The unconverted anol forms a recycle stream.

#### V. LACTAM PLANT

Caprolactam is prepared by the reaction of cyclohexanone and hyam sulphate. In the first step, cyclohexanone and hyam sulphate is reacted with simultaneous supply of ammonia water to form cyclohexanone oxime and ammonium sulphate. In the second step, hyam get converted forming a mixture of anone/oxime and ammonium sulphate. After separation anone/oxime mixture is discharged in to the first step in which all this anone will react with fresh hyam now in excess, forming a mixture of oxime, hyam sulphate and ammonium sulphate. After separation oxime is discharged to the rearrangement, while hyam/ammonium sulphate mixture is discharged to this second step to react with fresh anone. After second step, the separated ammonium sulphate is discharged to a stripper to remove small amount of anone which it contains. This ammonium sulphate is discharged to the new ammonium sulphate plant for further processing. Chemically both cyclohexanone oxime and caprolactam have the same

molecular structure. So the separated oxime from the first step is rearranged to caprolactam by mixing it with oleum. This process is known as Beckman's Rearrangement. This reaction product is mixture of lactum and oleum. This mixture is neutralized with ammonia water, forming two layers – one ammonia sulphate solution in water and the other crude lactam in water. The ammonium sulphate solution which contains small amount of caprolactam is extracted with benzene. The benzenic lactum is sent to lactam extraction. The small amount of benzene present in the ammonium sulphate solution is stripped off before the ammonium sulphate is discharged to ammonium sulphate tank. The crude lactam is extracted with benzene – fresh lactam as well as benzenic lactam from the ammonium sulphate extraction. The benzenic lactam thus formed is re-extracted with process condensate to remove benzene soluble impurities. The benzene dissolved in aqueous lactam solution is stripped off before the lactam is fed to ion exchangers. The benzene which contains impurities from recirculation step is purified in a distillation column and reused along with fresh feed of benzene in these ammonium sulphate and lactam extraction sections. The ionic impurities – mainly ammonium sulphate ions – in aqueous lactam are removed in a set of ion exchangers (2 anion and 1 cation unit). Cation unit is double the capacity of anion unit. In an ionic exchanger, the sulphate ions are replaced by 20 H ions. In a cation exchanger the NH<sub>4</sub> ions are replaced by H<sup>+</sup> ions. The unsaturated impurities present in lactam which cannot be removed by distillation, are converted into saturated ones by means of hydrogen and Raney (Nickel catalyst), so that they can be removed by distillation. The aqueous lactam of 30% wt. concentration is concentrated to 100% wt. in two steps – in the first step it is concentrated to about 90% wt. in a triple effect evaporator. In second step it is increased to about 100% wt. In the flacking section, lactam is solidified on internally cooled rotary drum. This solidified lactam is scrapped from the drum by scrapper blades and is send to the bagging section.

**VI. EXPERIMENTAL DETAILS**

Caprolactam is produced in Petrochemical division of FACT. The finished product i.e Caprolactam is send to the bagging section. Here the problem identified is repeating compliant of the bearing in blower in bagging section. The blower is used to collect the dust particles from the caprolatum. The data for the study were collected from maintenance department of the company. And major defects in blower were identified. Root causes for these defects were found out from cause and effect diagram and remedies were suggested.

**VII. RESULTS AND DATA COLLECTION**

*Details of Blower*

BLOWER NUMBER	K7801
TYPE	HV-65J-7-16-2-1
SERVICCE	EXHAUST BLOWER

SPEED	3120 rpm
RATED BHP	9.07HP
ROTOR TYPE	IMPELLER, BACKWARD SLOPPING
MOTOR POWER	12.5 HP
POWER TRANSMITION	SHEARED PULLEY WITH 'V' BELT
MANUFACTURER	FLAKT INDIA LTD

**Table 1 Shows the Details Of Blower BEARING SPECIFICATIONS**

*Table II*

SINGLE ROW DEEP GROOVE BALL BEARING	6211
INNER DIAMETER	55mm
OUTER DIAMETER	100mm
BREADTH	21mm
DYNAMIC LOAD	43.350kN
STATIC LOAD	29.397kN

**Table 2 Shows the Details of the Bearing**

**VII. CAUSES OF THE FAILURE OF BEARING**

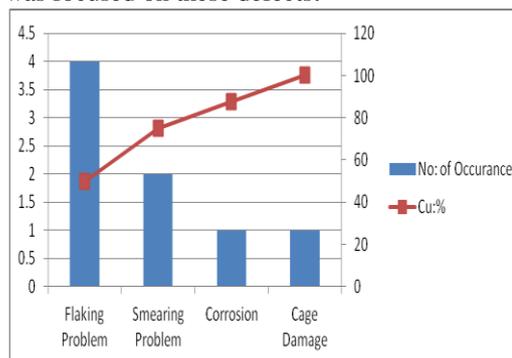
In order to identify the causes of the bearing problem, cause and effective diagram was drawn and the main causes was categorized in to different categories as shown below.



**Fig 1. Cause and Effect Diagram**

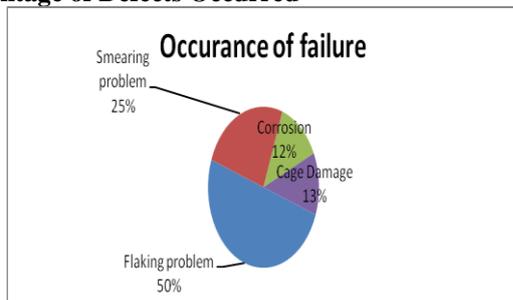
**VIII. DATA ANALYSIS**

Pareto chart was plotted based on the data collected is shown in figures given below. It is found that these defects were responsible for about 80% of the problem and hence study was focused on these defects.



**Fig 2: Shows the No of Times the Defect Occurred For the Last Four Years**

**Percentage of Defects Occurred**



**Fig 3: Shows the Percentage of Defects Occurred For the Last Four Years**

**IX. RESULTS AND DISCUSSION**

**A. CAGE DAMAGE**

After collecting and analyzing the data, cause and effect diagram was drawn to identify the causes of Cage damage. The major cause of the defect was identified as wear. Cage wear may be caused by inadequate lubrication or by abrasive particles. The idea with rolling bearings is of course to avoid sliding friction. However, where the cage is concerned; sliding cannot be eliminated in the contacts with the other components of the bearing. This explains why the cage is the first component to be affected when the lubrication becomes inadequate. The cage is always made of softer material than the other components of the bearing and consequently it wears comparatively quickly.[6] As the cage pockets increase in size, due to wear, the rolling element guidance deteriorates and this also applies to the cage in cases where the cage is centered on the rolling elements. The resultant forces may lead to cage failure within a short space of time.[1] Other causes of damage are If the rings of a deep groove ball bearing are fitted out of alignment with each other, the path of the balls has an oval configuration. If the cage is centred on the balls, it has to change shape for every revolution it performs. Fatigue cracks then form in the material and sooner or later they lead to fractures. There is a similar case when a thrust ball bearing is fitted together with radial plain bearings. If clearance arises in the plain bearings, the washers of the thrust bearing become displaced in relation to each other.[5] Then the balls do not follow their normal path and heavy stresses may arise in the cage. Cages in bearings subject to severe acceleration and retardation, in conjunction with fluctuations in speed, are affected by forces of inertia. These give rise to considerable pressure between the contacting surfaces, with consequent heavy wear. These damages can be overcome by care full handling of bearing, i.e do not unpack the bearing until just before it is to be mounted. Keep workshop clean and use clean tools. Check and possibly improve the sealing. Always use fresh, clean lubricant .Wipe the grease nipples. Filter the oil. Check that the lubricant reaches the bearing. More frequent relubrication. Secure the bearing during transport by radial preloading. Provide a vibration-damping base.[1]

**B. CORROSION**

Presence of water or water droplets was identified as the root cause for the corrosion defect. Rust will form if water or corrosive agents reach the inside of the bearing in such quantities that the lubricant cannot provide protection for the steel surfaces. This process will soon lead to deep seated rust. Another type of corrosion is fretting corrosion.[1], [7]. This can be reduced by improved sealing. Use lubricant with better rust inhibiting properties.

**C. SMEARING PROBLEM**

Sliding under heavy axial loading and with inadequate lubrication is the main cause of the Smearing problem. When two inadequately lubricated surfaces slide against each other under load, material is transferred from one surface to the other. This is known as smearing and the surfaces concerned become scored, with a “torn” appearance.[5] When smearing occurs, the material is generally heated to such temperatures that rehardening takes place. This produces localized stress concentrations that may cause cracking or flaking. In rolling bearings, sliding primarily occurs at the roller end-guide flange interfaces. Smearing may also arise when the rollers are subjected to severe acceleration on their entry into the load zone. If the bearing rings rotate relative to the shaft or housing, this may also cause smearing in the bore and on the outside surface and ring faces. In thrust ball bearings, smearing may occur if the load is too light in relation to the speed of rotation.[2] This defect can be reduced by applying More suitable lubricant. Reduce bearing internal clearance. Rotate the inner or outer ring during entry. Lubricate the surfaces well. Use a mounting ring when fitting a series of bearings.[2]

**D. FLAKING**

The reason for the flaking problem is the Flaking occurs as a result of normal fatigue, i.e. the bearing has reached the end of its normal life span. However, this is not the commonest cause of bearing failure. The flaking detected in bearings can generally be attributed to other factors. If the flaking is discovered at an early stage, when the damage is not too extensive, it is frequently possible to diagnose its cause and take the requisite action to prevent a recurrence of the trouble. The path pattern of the bearing may prove to be useful.[6] When flaking has proceeded to a certain stage, it makes its presence known in the form of noise and vibrations, which serve as a warning that it time to change the bearing. The causes of premature flaking may be heavier external loading than had been anticipated, preloading on account of incorrect fits or excessive drive-up on a tapered seating, oval distortion owing to shaft or housing seating out-of-roundness, axial compression, for instance as a result of thermal expansion. Flaking may also be caused by other types of damage, such as indentations, deep seated rust, electric current damage or smearing.[7] This problem can be reduced by Preloading on

account of fits being too tight. Excessive drive-up on a tapered seating. Single row angular contact ball bearings or taper roller bearings adjusted to give excessive preload. Temperature differential between inner and outer rings too great.[4]

### E. SELECTION CALCULATION FOR BALL, ROLLER AND ANGULAR CONTACT BALL BEARINGS

#### Calculation for Ball Bearing

Required life of the bearing in million revolutions

$$L = (T \times n \times 60) / L_c$$

$$L = (6 \times 30 \times 24 \times 3120 \times 60) / 10^6$$

$$L = 808.704 \text{ million revolution}$$

$$C = 3400 \text{ kgf (From Design data book)}$$

$$L = 808.704 \text{ million revolution}$$

Applying the value of C and L in the equation, we get the equivalent load

$$C = \left(\frac{L}{L_{10}}\right)^{1/k} \times P$$

$$34000 = \left(\frac{808.704}{1}\right)^{1/3} \times P,$$

Therefore P = 3649.351 kgf

#### Calculation for Taper Roller Bearing

$$P = 3649.351$$

From Design Data Book we get the Dynamic Capacity of Taper Roller Bearing having inner radius 55mm and outer radius 100 mm is 8900kgf, applying in the equation, we get the actual time,

$$C = \left(\frac{L}{L_{10}}\right)^{1/k} \times P$$

$$89000 = \left(\frac{L}{1}\right)^{3/10} \times 3649.351$$

$$\left(\frac{L}{1}\right)^{3/10} = 24.387 \times 10^6$$

$$L = (24.387 \times 10^6) / (3120 \times 24 \times 30 \times 60)$$

$$L = 31.2 \text{ months}$$

#### Calculation for Angular Contact Ball Bearing

$$P = 3649.351$$

From Design Data Book we get the Dynamic Capacity of Angular Contact Ball Bearing having inner radius 55mm and outer radius 100 mm is 3600kgf, applying in the above equation, we get the actual time,

$$36500 = \left(\frac{L}{1}\right)^{1/3} \times 3649.351$$

$$\left(\frac{L}{1}\right)^{1/3} = 10.001 \times 10^6$$

$$L = (10.001 \times 10^6) / (3120 \times 24 \times 30 \times 60)$$

$$L = 7.4 \text{ months}$$

### COST CALCULATION OF BEARINGS

#### Cost Calculation for Ball Bearing

Cost of each Ball Bearing = 4600/-

Labour Charge = 500/-

Lubrication = 100/-

Total cost = 5200/- for 6 months

Total cost for 2 years = 20800/-

#### Cost Calculation for Taper Roller Bearing

Cost of Taper Roller Bearing = 9813/-

Labour Charge = 500/-

Lubrication = 100/-

Total cost = 10413/-

#### Cost Calculation for Angular Contact Ball Bearing

Cost = 6180/-

Labour Charge = 500/-

Lubrication = 100/-

Total Cost = 6780/-

Total cost for 2 years = 20340/-

### X. CONCLUSION

Industrial training included a case study. The major problem faced was a bearing complaint in the blower of packing section of caprolactum plant. This was observed and taken up as case study. The major causes and the root causes for bearing failure were identified along with due consideration for technical feasibility and economic viability. The solution for the causes were found out and the current ball bearing is proposed to be replaced by the taper roller bearing SKF 32211A.

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