FAILURE ANALYSIS OF SLEWING GEAR BOX AND BELT DRIVE DRUM ASSEMBLY OF SPREADER 116 AT NLCIL

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report **"FAILURE ANALYSIS OF SLEWING GEAR BOX AND BELT DRIVE DRUM ASSEMBLY OF SPREADER 116 AT NLCIL"** is the bonafide work of **"LEELAVATHI S, NIHIL MATHEW A, SANJAI RAMASAMY K, THALAPATHY S"** who carried out the project work under my supervision during the academic year 2021-2022.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

NLC INDIA LIMITED

(Formerly Neyveli Lignite Corporation Limited)

("Navratna"- A Government of India Enterprise)

CERTIFICATE

This is to certify that this project report on "**FAILURE ANALYSIS OF SLEWING GEARBOX AND BELT DRIVE DRUM ASSEMBLY OF SPREADER 116, MINE 1A**, **NEYVELI** is the bonafide record of work done by **LEELAVATHI S, NIHIL MATHEW A, SANJAI RAMASAMY K, THALAPATHY S from ALAGAPPA CHETTIAR GOVERNMENT COLLEGE OFENGINEERING AND TECHNOLOGY, KARAIKUDI,** during the period from 16-03-2022 TO 12-04-2022 at MINE 1A, NLC India Ltd., Neyveli, Tamil Nadu.

Office of the General Manager
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12 APR 2022
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ABSTRACT

Neyveli Lignite Corporation India Limited (NLCIL) is a leading public sector undertaking owned by a government of India. In NLCIL mines, open cast mining technology is adopted in which numbers of specialized mining equipment's (SME) are used. Spreader plays a vital role in mining of lignite. The excavated overburden is being refilled by using spreaders in the mined-out area. In Spreader there are many components and many mechanisms are present. Upon analysis a major problem has been raised from Spreader's slewing gear box, then the common failure is produced by the belt drive drum assembly's shaft due to shearing. Here all failures occurring in slewing gear box and belt drive drum assembly is studied and analysed based on FMEA analysis.

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NLC	-	NEYVELI LIGNITE CORPORATION
NLCIL	-	NEYVELI LIGNITE CORPORATION INDIA LIMITED
GOI	-	GOVERNMENT OF INDIA
MTPA	-	MILLION TONNES PER ANNUM
TPS	-	THERMAL POWER STATION
SME	-	SPECIALIZED MINING EQUIPMENT
BWE	-	BUCKET WHEEL EXCAVATOR
MTC	-	MOBILE TRANSFER CONVEYORS
RC	-	RECONDITIONING
MM	-	MACHINE MAINTENANCE
MRR	-	MAJOR REPAIRS AND RENEWAL
OH	-	OVER HAUL
FMEA	-	FAILURE MODE AND EFFECTS ANALYSIS
RPN	-	RISK PRIORITY NUMBER
GEO	-	GEO SYNCHRONOUS EQUATORIAL ORBIT
FEM	-	FINITE ELEMENT METHOD
FEA	-	FINITE ELEMENT ANALYSIS
TANGEDCO	-	TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED
NLCTNPL	-	NEYVELI LIGNITE CORPORATION TAMIL NADU POWER LIMITED

1. INTRODUCTION

1.1 INTRODUCTION OF NEYVELI LIGNITE CORPORATION:

NLC India Ltd (NLCIL) formerly, Neyveli Lignite Corporation Limited, a Navaratna enterprise of Government of India (GOI) is an existing, profit- making, public-sector enterprise engaged in mining of lignite and generation of power through lignite based thermal power plants. NLCIL was established by GOI in 1956, following the discovery of lignite deposits in Neyveli, Tamil Nadu. NLCIL comes under administrative control of Ministry of Coal, GOI serves as an important source of power generation to the states of Tamil Nadu, Andhra Pradesh, Karnataka, Kerala, Telangana, Rajasthan and Union Territory of Puducherry.

1.2 LIGNITE MINES:

NLCIL currently operates four opencast lignite mines with a combined capacity of 30.6 MTPA. The details of the existing operational mines are as shown in the table 1.1 below:

Table 1.1 Operating Mines

Location	Mine	Area covered (Sq.km)	Reserve (MT)	Capacity per annum(MT)	Commissioing
Neyveli, Tamil Nadu	I	31.78	365	10.50	May-1962
Neyveli, TamilNadu	II	42.00	613	15.00	Mar-1985
Neyveli, TamilNadu	IA	11.60	120	3.00	Mar-2003
Barisngsar,Rajasthan	Barsingsar	9.70	53	2.10	Oct-2009
TOTAL			1151	30.60	

1.2 THERMAL POWER STATION (TPS):

- In FY (Fiscal Year) 2017-18, NLCIL achieved an aggregate lignite production of 25.15 MT.

- NLCIL"s thermal power station (the units under TPS-I) is South Asia's first lignitefired and India's first pithead-based power station. From the lignite extracted from its mines, NLCIL operates five thermal power stations with an aggregate capacity of 3,240 MW in the states of Tamil Nadu and Rajasthan. Apart from lignite-based power plants, NLCIL also operates one coal based thermal power plant of 1,000 MW (2 X 500 MW) capacity through its joint venture with Tamil Nadu Generationand Distribution Corporation Limited (TANGEDCO), NLC Tamil Nadu Power Limited (NLCTNPL). It has also installed solar and wind-based power plants. The details of powerplants operated by NLCIL are as shown in the table 1.2 below:

Table 1.2 Thermal Power Station

Power Station	Location of Plant	Capacity (MW)	Commissioning
TPS I	Neyveli, Tamil Nadu	600.00	1962-1970
TPS II	Neyveli, Tamil Nadu	1,470.00	1986-1993
TPS I Expansion	Neyveli, Tamil Nadu	420.00	2002-2003
Barsingsar TPS	Bikaner, Rajasthan	250.00	2010-2011
TPS II Expansion (Unit-I& Unit-II)	Neyveli, Tamil Nadu	500.00	2015-2016
NTPL (Unit-I & Unit-II)	Tuticorin, Tamil Nadu	1,000.00	2015-2016
Wind	Tirunelveli, Tamil Nadu	51.00	2016-2017
Solar	Neyveli, Tamil Nadu	440.00	2017-2019
TOTAL		**4731.00**	

1.3 MINE 1A:

Figure 1.1 View Of Mine 1A

The Neyveli Mine IA coal mine is an opencast mine, operated by Neyveli Lignite Corporation (NLC) India Limited, the view of Mine 1A is shown in the figure 1.1 with a capacity of 3 million tons per year, and located near the town of Neyveli in Cuddalore district in Tamil Nadu, India. The mine IA has proposed expansion to 4 million tons per annum. The mine supplies the600- megawatt (MW) Neyveli Thermal Power Station and the 420MW Thermal Power Station I Expansion.

1.4 SPECIALIZED MINING EQUIPMENTS:

In NLC India limited specialized mining equipment's are used in the opencast mines Viz. Bucket Wheel Excavators, Mobile Transfer Conveyors, Conveyors, Tripper Cars and Spreaders.

1.4.1 BUCKET WHEEL EXCAVATORS:

- A bucket-wheel excavator (BWE) is a large heavy equipment machine used in surface mining. The image of BWE is shown in the figure 1.3.
- The primary function of BWEs is to act as a continuous digging machine in large-scale open-pit mining operations, removing thousands of tons of overburden a day. What sets BWEs apart from other large-scale mining equipment, such as bucket chain excavators, is their use of a large wheel consisting of a continuous pattern of buckets used to scoop material as the wheel turns. They rank among the largest vehicles (land or sea) ever produced, and the largest of the bucket-wheel excavators (14,200-ton Bagger 293 still holds the Guinness World Record forthe heaviest land-based vehicle ever constructed).

Figure 1.2 Bucket Wheel Excavator

1.4.2 MOBILE TRANSFER CONVEYORS:

Mobile Transfer Conveyors (MTCs) are "multi use" equipment that are used to both increase performance and flexibility of many mining operations. Mobile transfer conveyors work as a flexible connection between a mining machine and bench conveyors. Moreover, mobile transfer conveyors are easily relocatable and positionable, improving performance, flexibility and efficiency. The image of MTC is shown in the figure 1.3.

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Figure 1.3 Mobile Transfer Conveyor

1.4.3 SPREADER:

- Spreaders in mining heavy equipment used in surface mining and mechanical engineering/civil engineering.
- The primary function of a spreader is to act as a continuous spreading machine in large-scale open pit mining operations, Bucket-wheel excavators, BWEs, are used for continuous overburden removal in surface mining applications.
- They use their cutting wheels to strip away a section of earth (the working block) dictated by the size of the excavator. The overburden is then delivered to the discharge boom, which transfers the cut earth to another machine for transfer it to the central collection area where the material will be sorted. Then the remains of the overburden will be transported to the spreader which then scatters the overburden at the dumping ground. The view of spreader expressed below in figure 1.4.

Figure 1.4 Spreader

1.4.3.1 KEY DATA FOR THE SPREADER 116:

Table 1.3 Specification of Spreader 116

S.NO	DATA	UNIT	SPREADER 116
1.	Theoretical Capacity(loose)	Cum/hr	4420
2.	Width of track plates	Mm	4000/2000
3.	Safe ground width required for movement	M	41
4.	Working gradient	-	01:20
5.	Walking gradient		01:10
6.	Track ground pressure	Kg./Sq.cm	0.80
7.	Ground bearing area	m^2	102.8/27.2
8.	Travel speed	m/min	8
9.	Outreach of receiving boom	M	42
10.	Outreach of discharge boom	M	61
11.	Min & Max ht. of Rec. boom	M	3.2 to 3.7
12.	Min & Max ht. of Disc. boom	M	3 to 27
13.	Min & Max inclination range of receiving boom	degrees	15
14.	Min & Max inclination range of Discharging boom	degrees	-7 to 16

15.	Total length of machine	M	103
16.	No. of. Crawlers		2+2
17.	Belt speed	m/sec	4.2/4.2
18.	Belt width	Mm	1800
19.	Type of belt		ST 2250
20.	Troughing angle	degrees	40/15
21.	Dia of receiving boom hoist	Mm	Hydraulic
22.	Dia of discharging boomhoist	Mm	Hydraulic
23.	Length of discharging boomrope	M	200meach
24.	Slewing angle of super structure	degrees	360
25.	Slewing range of disc boom	degrees	105
26.	Ball race diameter	M	5.007
27.	Empty weight	T	918
28.	Service weight	T	987
29.	Max wind load in operation	l.Sq.mm	400
30.	Max wind load in idle	l.Sq.mm	800

1.5 MAIN DATA OF DRIVES:

The details of main data of drives are listed in the table 1.4,1.5 and 1.6

1.5.1 MAIN CRAWLER DRIVE:

Table 1.4 Main Crawler Drive

Description	Dimension	Main crawler
Rated power of motor	KW	110
Rated power of gear box	KW	130
No. of driver per crawler	Nos.	1
Rated speed	rpm	980
Type of the gear box		Worm planetary
Transmission ratio		1:638.4
No. of gear stages	Nos.	3

Lubrication		Splash
Coupling type		Cardan shaft
Brake type		Weight loaded double shoe
Diameter of brake drum	Mm	400

1.5.2 RECEIVING BOOM SUPPORT CRAWLER DRIVE:

Table 1.5 Receiving Boom Support Crawler Drive

Description	Dimension	Receiving boom support Crawler
Rated power of motor	KW	30
Rated power of gear box	KW	55
Number of drives per crawler	Nos.	1
Rated speed	rpm	980
Type of the gear box		Worm planetary
Transmission ratio		1:638.4
No. of gear stages	Nos.	3
Lubrication		Splash
Coupling type		Cardan shaft
Brake type		Weight operated Double shoe
Diameter of brake drum	Mm	400

1.5.3 SLEWING DRIVE:

Table 1.6 Slewing Drive

Description	Dimension	Receiving boom Supported crawler
Rated power of motor	KW	15
Rated power of gear box	KW	25

Number of drives per Crawler	NOS.	2
Rated speed	rpm	980
Type of the gear box		Planetary
Transmission ratio		1:796.8
No. of gear stages	NOS.	3
Lubrication		Splash
Coupling type		Flexible

1.6 SME YARD:

SME is split into four major zones they are,

- Reconditioning (RC)
- Machine Maintenance (MM)
- Major Repairs and Renewal (MRR)
- Over Haul (OH)

Major Repairs and Renewal (MRR), Machine Maintenance (MM) are the ones which deal with the work mostly done on site, while Reconditioning (RC) and Over Haul (OH) zones have separate yards to do the work which deals with machines part failures like gear boxes etc.

1.6.1 SME/RCYARD:

Reconditioning (RC) deals with over hauling gear boxes and reconstruction of pars for replacement during failure. NLC's mining equipment's work 24/7 all around the year. This leads to the major failures of parts under inevitable conditioned and may cause delay in excavating lignite which leads to loss for company. Reconstruction yard work around the clock to minor repairs, replacement for the parts and also over hauling of gear box BWE s while they run on standby replacement parts and return them to deal with next failure.

1.6.2 MACHINE MAINTENANCE (MM):

Maintenance is strictly connected to the utilization stage of the protector technical system, in which the concept of maintainability must be included. In this scenario, maintainability is considered as the ability of an item under stated conditions of use, to be retained in or restored to a state in which it can perform its required functions, using prescribed procedures and resources.

1.6.3 MAJOR REPAIRS AND RENEWAL (MRR):

1.6.3.1 PREVENTIVE MAINTENANCE:

Preventive maintenance is maintenance performed with the intent of avoiding failures, safety violations, unnecessary production costs and losses, and to conserve original materials of fabrications. The effectiveness of a preventive maintenance schedule depends on the RCM analysis which is was based on, and the ground rules used for cost efficiency.

1.6.3.2 CORRECTIVE MAINTENANCE:

Corrective maintenance is a type of maintenance used for equipment after equipment break down or malfunction is often most expensive - not only can worn equipment damage other parts and cause multiple damage, but consequential repair and replacement costs and loss of revenues due to down time during overhaul can be significant. Rebuilding and resurfacing of equipment and infrastructure damaged by erosion and corrosion as part of corrective or preventive maintenance programs involves conventional processes such as welding and metal flame spraying, as well as engineered solutions with thermoset polymeric materials.

1.6.3.3 PREDICTIVE MAINTENANCE:

More recently advances in sensing and computing technology have even rise to predictive maintenance. This maintenance strategy uses sensors to monitor key parameters within a machine or system, and use this data in conjunction with analyzed historical trends to continuously evaluate the system health and predict a breakdown before it happens.

1.6.3.4 OVERHAUL CONDITION:

Overhaul Condition of a part; overhaul refers to the process of maintaining the equipment or parts. It involves partial or full disassembly to restore equipment to its maximum level of function. Overhauling requires a thorough assessment and inspection of machine to check for defects and damage which may require repair or replacement. In machine, the term overhaul varies in meaning to an extent depending on the manufacturer's set limits or standard to meet the overhaul requirements. Overhaul is not merely intended to prevent the cataclysmic failure. Overhaul is required regardless of functionality and condition when the limit for flight cycles is reached.

2. LITERATURE REVIEW

FMEA is an important technique used to identify and eliminate known failures or have the potential to improve the reliability and security of complex systems and is intended to provide critical information for making decisions in risk management. The purpose of FMEA is to prioritize the failure modes of the product or system to assign limited resources to the most serious risk items. In general, the prioritization of failure modes for corrective actions is determined through the risk priority number (RPN), which is obtained by finding the multiplication of the Occurrence, Severity, and Detection of a failure.

Researchers proposed various methodologies in the field of the initial concept designing of the product. The remarkable work done by the various researchers in this field is discussed as follows:

- Lough et al. (2009) investigated the relationship between function and risk in early design, by presenting a mathematical mapping from product function to risk assessments that could be used in the conceptual design phase. They investigated a spacecraft orientation subsystem to demonstrate the mappings. The results from the study and its spacecraft application yielded a preliminary risk assessment method that could be used to identify and assess risks as early as the conceptual phase of design. They presented a preliminary risk assessment that may aid designers by identifying risks as well as reducing the subjectivity of the likelihood and consequence value from a risk element.

- S. Kahrobaee et al (2011) presents a quantitative approach called Risk-Based FMEA, based on the failure probabilities and incurred failure costs instead of rating scales. As a case study, this approach has been applied to a direct drive wind turbine. The results show that the definition of failure modes priorities based on their contribution to the total failure cost of the wind turbine is more realistic and practical than the common FMEA approach.

- F. Mozaffari et al (2013) gives a general procedure of failure modes and effects analysis (FMEA) for designing a GEO satellite payload has been implemented and it has been shown that this analysis serves as a useful tool to identify critical items of the product which leads to consider modifications for preventing or compensating failures and finally improving product reliability. The overall actions which have been done using FMEA technique and the design of a redundancy scheme with regard to cost, practical limitations, and system complications lead to an improvement in reliability from 79.15% to 97.52% for pre assigned lifetime which can satisfy the desired requirement for this kind of products.

- M. Molhanec et al (2012) gives an idea to improve FMEA method in the field of the free lead soldering process with employing a Model Based approach. This approach, a novelty of the Authors, contributes to more efficient risk management of a manufacturing process. It also increases quality, reliability and testing-capability of the process. Further, the Authors describe selected software tools and ontology editors suitable for the support of the introduced method.

- Bertan Beylergil (2020) presented the Design and discrete optimization of hybrid aluminum/composite drive shafts for automotive industry using FEM analysis. In this approach hybrid type of aluminum/composite drive shaft transmits the required torque, while the composite layer increases the bending natural frequency above the required frequency value of 9200 rpm.

2.1 OBJECTIVES:

Our project mainly entangles two objectives.

- To perform a failure analysis in a particular shaft. This shaft is the main component, used for rotating the drum in conveyor belt. It has been recorded that the shaft is failing for every 1-2 month. Varying impact load on belt is bringing failure to shaft.
- To prevent leakage oil from slewing gear so that the slewing drive can safely hold radial and axial loads. Hence the slewing gear box can used to turn the spreader (Mine)properly.

3. BACKGROUND STUDY

3.1 STUDY OF GEARS:

- Gears are used to transmit motion from one shaft to another or between a shaft and a slide. This is accomplished by successively engaging teeth. Gears use no intermediate link or contact and transmit the motion by direct contact.
- In this method, the surfaces of two bodies have either a rolling or a sliding motion along the tangent at the point of contact.

3.1.1 LAW OF GEARING:

The fundamental law of gearing states “The common normal to the tooth profile at the point of contact should always pass through a fixed point, called the pitch point, in order to obtain a constant veloc ity ratio”

3.1.2 TERMINOLOGY OF SPUR GEARS:

The terminology of spur gear is expressed in the figure 3.1

Pinion:

A pinion is a round gear usually the smaller of two meshed gears used in several applications, including drive train and rack and pinion systems.

Gear:

A gear is the larger of the two mating gears.

Velocity Ratio:

Velocity ratio is the ratio of angular velocity of the driving gear to the angular velocityof the driven gear. It is also called the speed ratio.

Transmission Ratio:

The transmission ratio (i) is the ratio of the angular speed of the first driving gear to the angular speed of the last driven gear in a gear train.

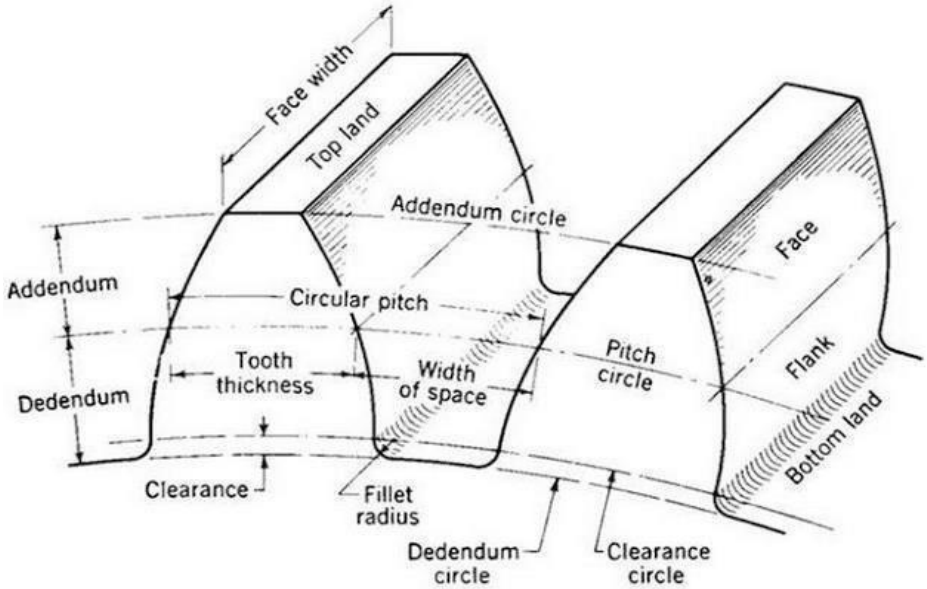


Figure 3.1 Terminology of Spur Gears

Pitch Circle:

The pitch circle is the curve of intersection of the pitch surface of revolution and the plane of rotation. It is an imaginary circle that rolls without slipping with the pitch circle of a mating gear. The pitch circles of a pair of mating gears are tangent to each other.

Pitch Circle Diameter:

The pitch circle diameter is the diameter of the pitch circle. The size of the gear is usually specified by the pitch circle diameter. It is also called pitch diameter. The pitch circle diameter is denoted by ‘d’.

Addendum Circle:

The addendum circle is an imaginary circle that borders the tops of gear teeth in the cross section.

Addendum (h_a):

The addendum (h_a) is the radial distance between the pitch and the addendum circles. Addendum indicates the height of the tooth above the pitch circle

Dedendum Circle:

The dedendum circle is an imaginary circle that borders the bottom of spaces between teeth in the cross section. It is also called root circle.

Dedendum (h_f):

The dedendum (h_f) is the radial distance between pitch and the dedendum circles. The dedendum indicates the depth of the tooth below the pitch circle.

Centre Distance:

The center distance is the distance between centers of pitch circles of mating gears. It is also the distance between centers of base circles of mating gears.

Pressure Angle:

The pressure angle is the angle which the line of action makes with the common tangent to the pitch circles. The pressure angle is also called the angle of obliquity. It is denoted by α.

3.1.3 CLASSIFICATION OF GEARS:

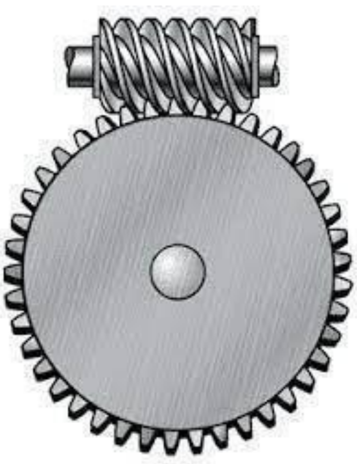
Gears are broadly classified into

- Spur Gears
- Helical Gears
- Rack
- Bevel Gears
- Worm Gear
- Internal gear

The classification of gears with feature and applications are expressed in table 3.1

Table 3.1 Classification of Gear

Types of Gears	Diagram	Features	Applications
Spur gear		Easy to manufacture. There will be no axial force. Relatively easy to produce high qualitygears. The commonest type.	Transmission components
Helical Gear		It has higher strengthcompared with spurgear, Effective in reducing noise and vibration compared with spur gear. Gears in mesh produce thrust forces in the axial directions.	Transmission components, automobile, speed reducers etc.
Rack		Changes a rotary motion into a rectilinear motion.	A transfer system for machine tools, printing press, robots, etc.

Bevel Gear		Relatively easy to manufacture. Provides reduction ratio up to approx. 1:5. Allows a higher reduction ratio.	1. Machine tools, printing Press, etc. Especially suitable for a differential gear unit. 2. Automobile, tractor, Vehicles, final reduction gearing for ships.
Worm Gear		The primary benefit of worm gears is their ability to provide high reduction ratios and correspondingly high torque multiplication.	Packaging equipment, small machinery, and conveyors.
Internal gear		Low vibration, high speed reduction ratio, and the low cost for the entire train layout.	Internal gears are used in planetary gear box applications, but can also be applied in other situations

3.2 STUDY OF BEARINGS:

- Bearings are the most essential mechanical component used in all machines and mechanism. Production, productivity, performance, reliability and many other aspects are mostly based on the bearing used in the machine. A machine will run successfully only when a correct bearing is applied in the machine along with its proper care and maintenance during working of the bearing.
- When there is relative motion between two machine parts, one of which supports the other, the supporting member is called bearing.

3.2.1 FUNCTIONS OF BEARING:

- It bears the load. Bearing must be capable of bearing dead as well as the live load of the machine.
- It minimizes unnecessary motion of the shaft by keeping clearance between bearing and shaft.
- It provides free motion to the moving part by reducing friction. More friction consumes more power, which generates more heat and more wear and tear in bearing.

3.2.2 NOMENCLATURE:

The sectional view of bearing expressed below in figure 3.2.

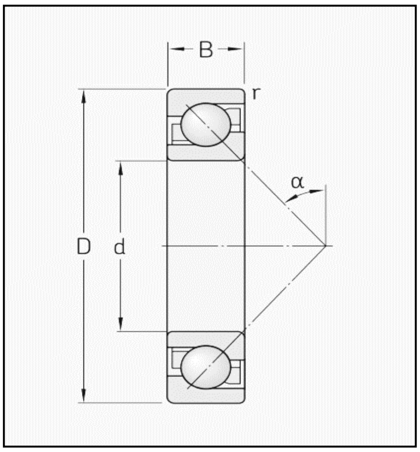


Figure 3.2 Nomenclature of Bearing

The most common symbols are:

d - Bore diameter

D - Outside diameter

B - Bearing width

H- Bearing height

r - Chamfer dimension

α - Contact angle

3.2.3 SHAFT-BEARING-HOUSING SYSTEM:

The Shaft bearing housing system expressed in below figure 3.3

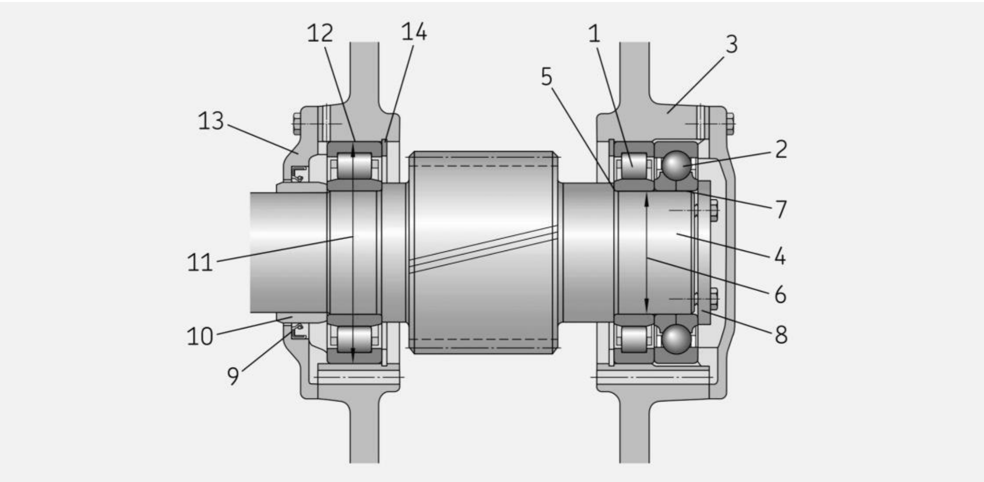


Figure 3.3 Shaft-Bearing-Housing System

1	Roller bearing	8	End plate
2	Ball bearing	9	Radialshaft seal
3	Housing	10	Seal wear ring
4	Shaft	11	Housing bore diameter
5	Shaft abutment shoulder	12	Housing seat
6	Shaft diameter	13	Housing cover
7	Shaft seat	14	Snap ring

The components inside the bearings are expressed in the figure 3.4

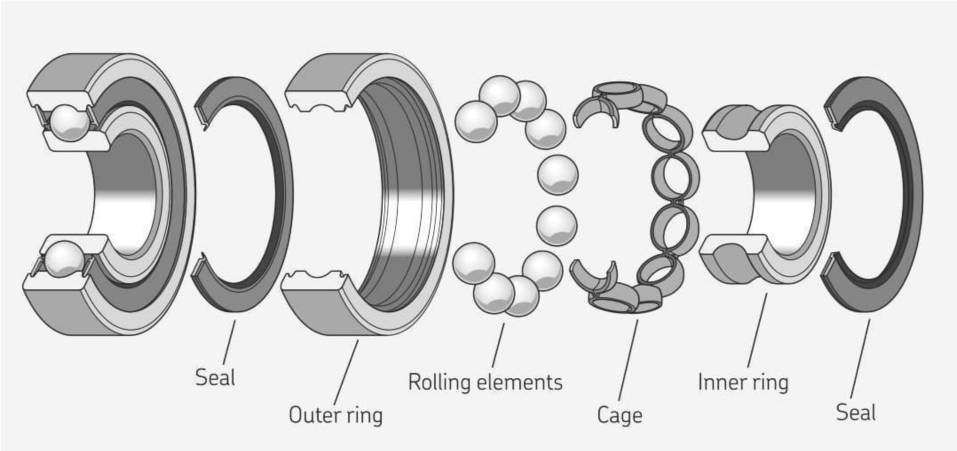


Figure 3.4 Layers of Bearing

3.2.4 TYPES OF ROLLING CONTACT BEARING:

3.2.4.1 CYLINDRICAL ROLLER BEARING:

Suitable for heavy radial load and in some case, few amounts of thrust load. It has numbers of steel rollers in series between two races. The open type can be withdrawn from both sides and bears only radial load. The held closed type can be withdrawn only from one side and take some amount of thrust load only in one direction. The close type is a rigid type and can take thrust load in both directions. These bearings may be of single row, double rows or four rows type. Cylindrical Roller Bearing is expressed in below figure 3.5.

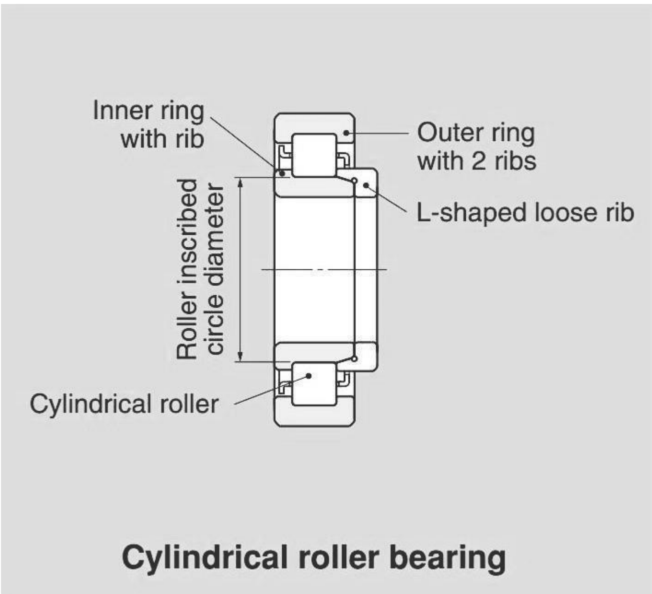


Figure 3.5 Cylindrical Roller Bearing

3.2.4.2 SPHERICAL ROLLER BEARING:

The axis of rollers will meet at one point on the bearing axis. The track on the inner race mostly fitted in the housing is spherical and thus allows self- aligning of the bearing. This special feature of the bearing is its capacity to carry a light radial load and heavy thrust load. Spherical Roller Bearing is expressed in below figure 3.6

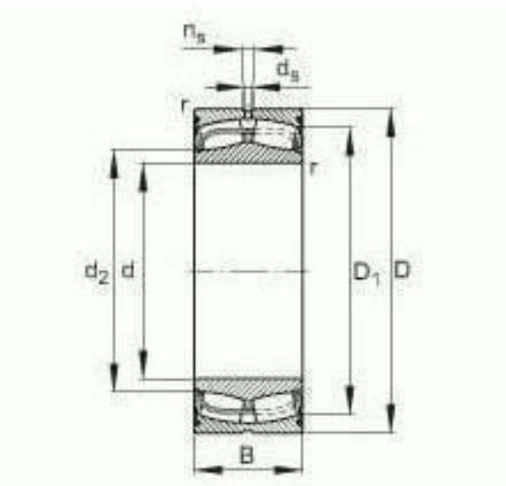


Figure 3.6 Spherical Roller Bearing

3.2.4.3 TAPER ROLLER BEARING:

It is a combined load bearing, which takes heavy radial and thrust load under moderate speed. According to load, it may be of single row, double rows or four rows type. These bearings are of separable type, which are fitted in pairs. The details of taper roller bearing is expressed in below figure 3.7.

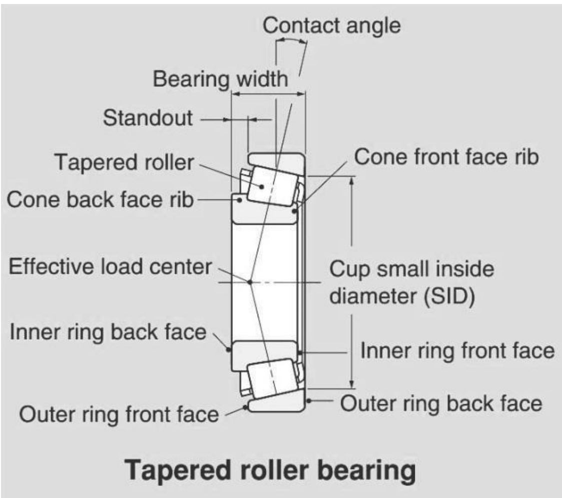


Figure 3.7 Taper Roller Bearing

3.3 STUDY OF LIMITS, FITS, TOLERANCE:

3.3.1 TERMINOLOGY:

The terminology used in fits and tolerances is shown in Fig 3.8 below. The important terms are:

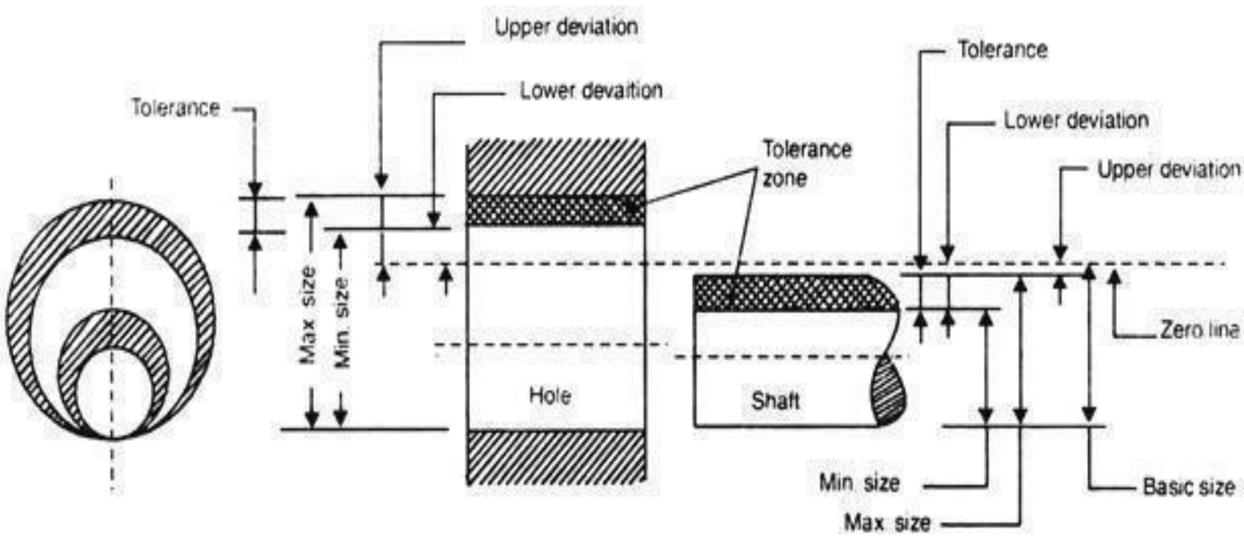


Figure 3.8 Terminology

Allowance:

It is an intentional difference between maximum material limits of mating parts. It is a minimum clearance or maximum interference between mating parts.

Deviation:

The algebraic difference between a size (actual, maximum, etc.) and the corresponding basic size.

Upper deviation:

The algebraic difference between the maximum limit of size and the corresponding basic size.

Lower deviation:

The algebraic difference between the minimum limit of size and the

Corresponding basic size.

Upper deviation = Lower deviation + Tolerance

Clearance:

It is the positive difference between the hole size and the shaft size.

Maximum clearance:

The positive difference between the maximum size of a hole and the minimum size of a shaft.

Minimum clearance:

The positive difference between the minimum size of a hole and the maximum size of a shaft.

3.3.2 STUDY OF LIMITS:

The maximum and minimum permissible sizes within which the actual size of a component lies are called limits.

- Limits are fixed with reference to the basic size of that dimension.
- Upper limit (The high limit) for that dimension is the largest size permitted and the low limit is the smallest size permitted for that dimension.

3.3.3 STUDY OF TOLERANCES:

- The permissible variation in size or dimension is tolerance. The difference between the upper limit (high limit) and the lower limit of a dimension represents the margin for variation to workmanship, and is called a tolerance zone.
- Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service . It is expressed below figure 3.9.

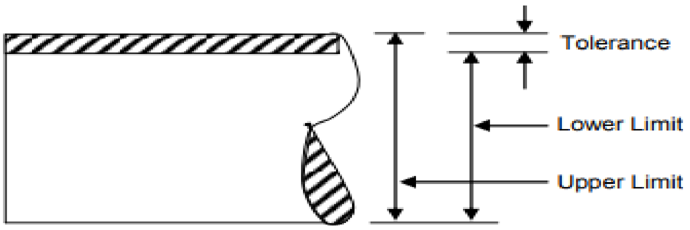


Figure 3.9 Tolerances

There are two ways of writing tolerances:

i) Unilateral Tolerance:

In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e., tolerance lies only on one side of the basic size either above or below. It is expressed in below figure 3.10

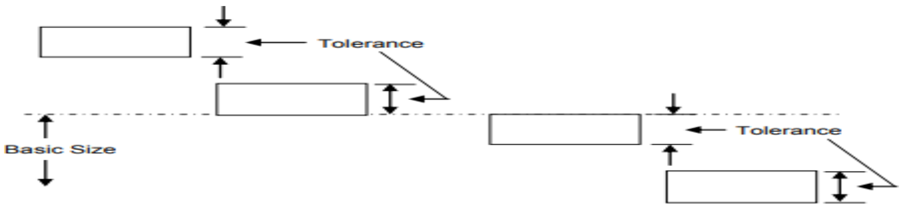


Figure 3.10 Unilateral Tolerance

ii) Bilateral Tolerance:

In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e., the limits of tolerance lie on either side of the basic size, but may not be necessarily equally disposing about it. This is expressed in below figure 3.11.

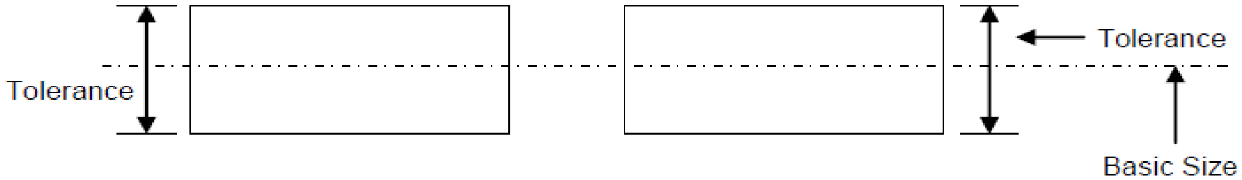


Figure 3.11 Bilateral Tolerance

3.3.4 STUDY OF FITS:

When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a fit. A fit may be defined as the degree of tightness and looseness between two mating parts.

i) Clearance Fit:

- This means there is a gap between the two mating parts. The schematic representation of clearance fit. Clearance fit is expressed in below figure 3.12

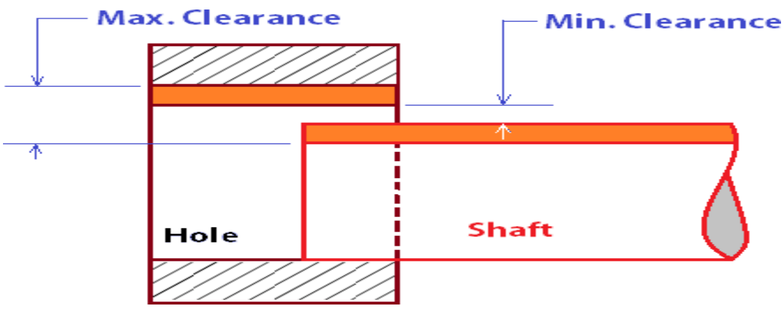


Figure 3.12 Clearance Fit

ii) Interference Fit:

- There is no gap between the faces and there will be an intersecting ofmaterial will occur . It is expressed in figure 3.13.

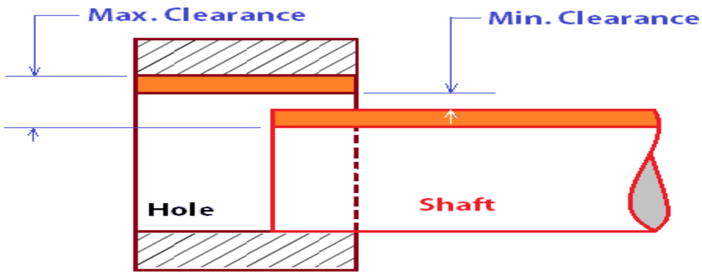


Figure 3.13 Interference Fit

iii) Transition Fits:

- A transition fit encompasses two possibilities. The shaft may be a little bigger than the hole, requiring some force to create the fit. At the other end of the spectrum is a clearance fit with a little bit of room for movement . It is expressed in figure 3.14.

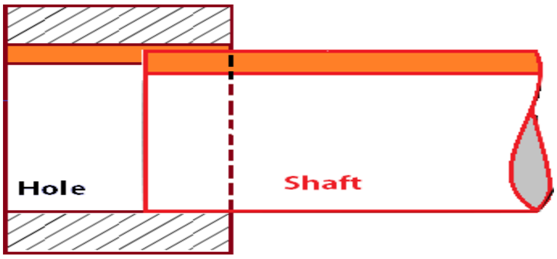


Figure 3.14 Transition Fits

The type of fits and symbols and applications of fits are detailed in table 3.2

Types of fits with symbols and applications Symbol of fit

Table 3.2 Types of fits

Type of fit	Symbol of fit	Applications
Interference fit		
Shrink fit	H8/u8	Wheel sets, tyres, bronze crowns on worm wheel hubs, couplings under certain conditions, etc. Coupling on shaft ends, bearing bushes in hubs, valve seats, gear wheels.
Heavy drive fit	H7/s6	
Press fit	H7/r6	
Medium press fit	H7/p6	
Transition fit		
Light press fit	H7/n6	Gears and worm wheels, bearing bushes, shaft and wheel assembly with Feather key.
Force fit	H7/m6	Parts on machine tools that must be changed without damage, e.g., gears, belt pulleys, couplings, fit bolts, inner ring of ball Bearings.
push fit	H7/k6	Belt pulleys, brake pulleys, gears and couplings as well as inner rings of ball bearings on shafts for average loading Conditions.

Clearance fit		
Precision sliding fit	H7/h6	Sealing rings. bearing covers, milling cutters on milling mandrels, other Easilyremovable parts.
Close running fit	H7/g6	Spline shafts, clutches, movable gears in change gear trains, etc.
Normal running fit	H7/f7	Sleeve bearings with high Revolution, bearings on machine tool spindles.
Easy running fit	H8/e8	Sleeve bearings with medium revolution, grease lubricated bearings of wheel boxes, gears sliding On shafts, sliding blocks.
Loose running fit	H8/d9	Sleeve bearings with low Revolution, plastic material bearings.
Slide running fit	H8/c11	Oil seals (Simmering's) with metal housing (fit in housing and contact surface on shaft), multi-Spline shafts.

3.4 INTERNAL CLEARANCE:

- Internal clearance is the distance which the two rings of a non-installed bearing can move when they are pushed in opposite directions. A distinction is made between radial and axial clearance
- Radial clearance is measured perpendicular to a bearing's central axis, while axial clearance is measured along the central axis. The distance between one final position and the other is measure. The various internal clearance are expressed in table 3.3

Table 3.3 Internal Clearance

Operating conditions	Examples	Internal clearance
Severe shaft deflection	Semi-floating wheel bearings in cars	C5
Steam flow through hollow shafts or pressure bars exposed to heat	Dry end of paper machines Conveyor rollers in rolling mills	C3, C4
High impact loads and vibrations, or both inner and outer rings with an interference fit	Traction motors for trains Vibrating screens Hydraulic clutches gear boxes for tractors	C3 C4 C3, C4
Loose-fitting inner and outer rings	Roll Tenon's for rolling mills	C2
Very quiet, vibration-free running	Small motors with special specifications	C1, C2, CM

C0 - Referred to as “standard clearance”. Normally, there are no markings on a bearing with a C0 clearance value.

C1 - offers the least extra clearance

C2 - Refers to a “less than standard clearance”. Bearings with this type of clearance are uncommon and have very limited uses.

C3 - Refers to a “greater than standard clearance”. This is the most common type of bearing, and is the correct choice for the majority of applications.

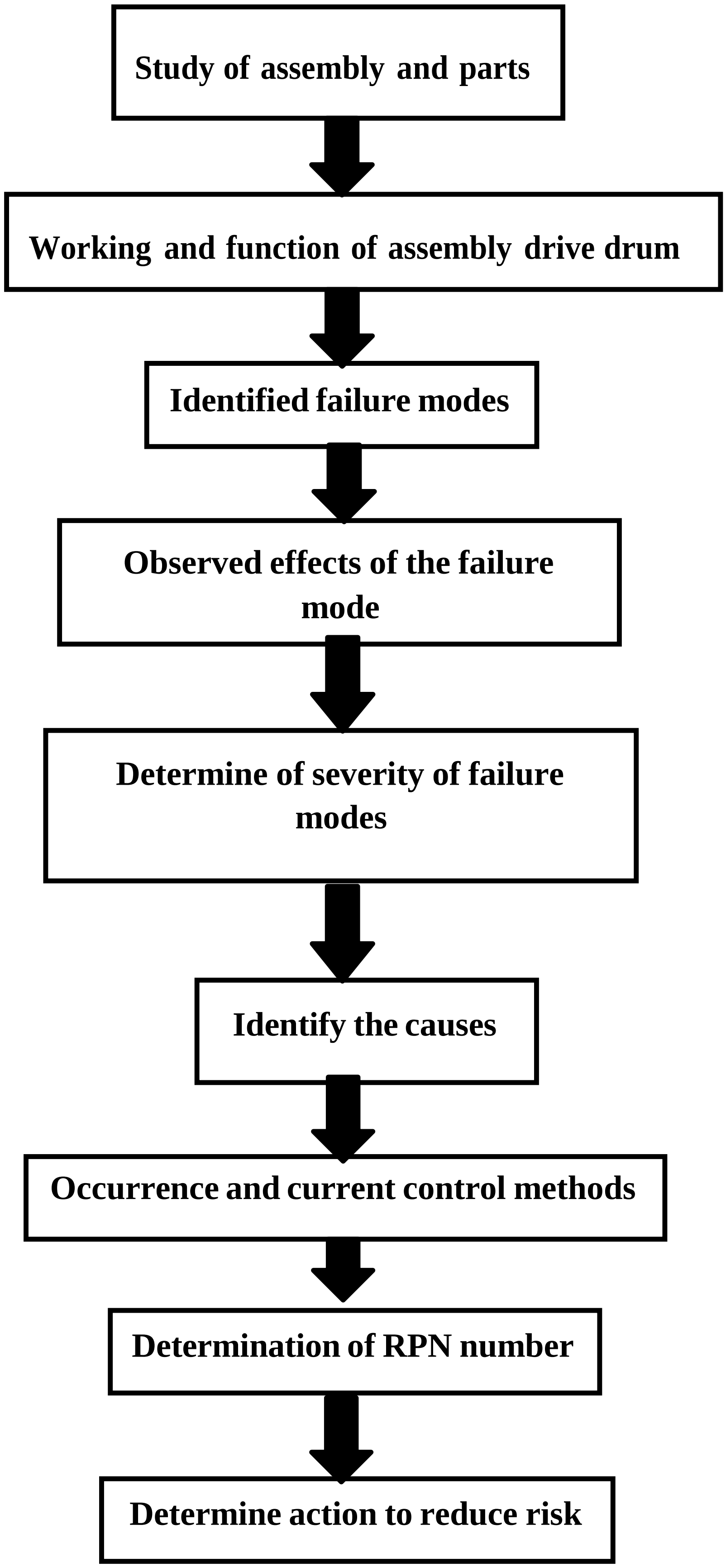
C4 - Refers to “greater than C3 clearance”. Not as common as C3, but often specified in small engine crankshaft bearings.

C5 - offers the most extra clearance.

CM - clearance is specified by some motor manufacturers where closer radial internal clearance helps reduce noise.

4. METHODOLOGY OF FAILURE ANALYSIS

4.1 WORKING METHODOLOGY:



4.2 BRIEF SUMMARY & WORKING OF SPREADER:

- Spreaders in mining are heavy equipment used in surface mining and mechanical engineering/civil engineering. The primary function of a spreader is to act as a continuous spreading machine in large-scale open pit mining operations. BWEs,are used for continuous overburden removal in surface mining applications. Theyuse their cutting wheels to strip away a section of earth (the working block) dictated by the size of the excavator. The overburden is then delivered to the discharge boom, which transfers the cut earth to another machine for transfer it to the central collection area where the material will be sorted. Then the remains of the overburden will be transported to the spreader which then scatters the overburden at the dumping ground.
- The purpose of the spreader is to receive overburden from the system conveyor of mined carrying/conveying and dump it in an orderly and efficient manner in the mined-out area. System conveyor of mine area and dump
- Spreaders are able to dump the overburden and sand in low-dump operation under or directly onto the current driving level. The freshly filled soil forms the new driving level during the further advance of the landfill area. Spreaders with a lift able discharge conveyor can also operate in high-dump operations to backfill the soil. Depending on the application and customer specific use case, high-dump and low-dump operation can be combined for enhanced capacity with less effort in relocation of the shift able dump conveyors.
- With the focus on application- and specific use cases, spreaders can be realized with a single conveyor boom, as a conventional machine with receiving boom and discharge boomconveyors with top-mounted counterweight boom.
- Crawler–based travel mechanisms below the center enable an enhanced flexibility in operation and a minimization of relocation-downtimes. A slewable central superstructure connects the conveyor booms and provides the operator’s cabin in apposition with an optimal view over the equipment.

- The discharge conveyor boom is designed as a lifetable structure to achieve a controlled dumping process during high-dump and low-dump operations. The bridge conveyor transports the material from the upstream equipment and can be designed with or without a support traveler below the bridge structure. A counterweight boom contains the electrical equipment of the machine and further smaller equipment-units

ADVANTAGES:

- Highest efficiency in handling large amounts of overburden.
- Maximized flexibility in dumping activities at a mine's landfill area.
- Tailor-made solutions for any application and demands.
- Sophisticated machine control concepts for operation assistance.
- Improved environmental impact of the mines by controlled recultivation.

4.3 FAILURE MODES AND EFFECTS ANALYSIS (FMEA):

Failure Mode and Effect Analysis (FMEA) is a bottom-up qualitative dependability analysis method. It is particularly suited to the study of material, component and equipment failures and their effects on the next higher functional system level. FMEA lends itself to the analysis of systems of different technologies with simple functional structures.

FMEA procedure involves examining each item, considering how that item can fail and then determining how that failure will affect the operation of the entire component or system. The process of identifying possible component failure modes and determining their effects on the system operation helps the analyst to develop a deeper understanding of the relationship among the different system components and to make any necessary changes to either eliminate or mitigate the possible undesirable effects of a failure.

FMEA is used to identify potential failure modes, determine their effect on the operation of the product and identify actions to minimize the failures.

The early and consistent use of FMEAs in the design process allows the engineer to design out failures and produce reliable, safe and customer pleasing products. FMEAs also capture the historical information for the use in future product improvement.

4.3.1 TYPES OF FMEA

There are several types of FMEAs. Among them, some are used much more often than others. FMEAs should always be done whenever failures would mean the potential harm or injury to the user of the end item being designed. The types of FMEA are given below:

(i) System-focuses on global system functions.

(ii) Design-focuses on components and subsystems.

(iii) Process-focuses on manufacturing and assembly processes.

(iv) Service-focuses on service functions.

4.3.2 STEPS INVOLVED IN FMEA

The major steps involved in performing a FMEA include the following:

Step 1: Identify all item failure modes.

Step 2: Determine the effect of failure for each failure mode both locally and on the Overall system being analyzed.

Step 3: Classify the failure by its effects on the system operation and mission.

Step 4: Determine the failure probability of occurrence.

Step 5: Identify how the failure mode can be detected.

Step 6: Identify any compensate provisions or design changes to mitigate the failure effects.

Step 7: Calculate the Risk Priority Number (RPN).

After each of these steps, actions are developed. Next, Risk Priority Numbers (RPN) are calculated which is the product of the numerical severity, occurrence and detection ratings. RPN = (S) x (O) x (D). Note that RPNs are calculated after three possible action opportunities have occurred.

Step 8: Develop recommended actions, assign responsible persons and take actions.

Step 9: Assign the predicted severity, occurrence and detection levels and compare RPNs.

4.4 FMEA OF BELT DRIVE DRUM ASSEMBLY

For FMEA analysis of belt drive drum assembly, first the assembly and the parts of the system are studied in order to understand the working process and importance of eachcomponent.The FMEA table is expressed in the table 4.1

4.4.1 ASSEMBLY DIAGRAM OF BELT DRIVE DRUM ASSEMBLY:

The belt drive drum assembly of the spreader is used for the linear motion of theconveyor. The conveyor takes the sand to fill the overburden. The sand is coming fromthe receiving doom. The motor power is transmitted to the shaft the shaft transmit the rotation motion to the drum which in turn move the conveyor. The assembly diagram of belt drive drum assembly is shown in the figure 4.1.

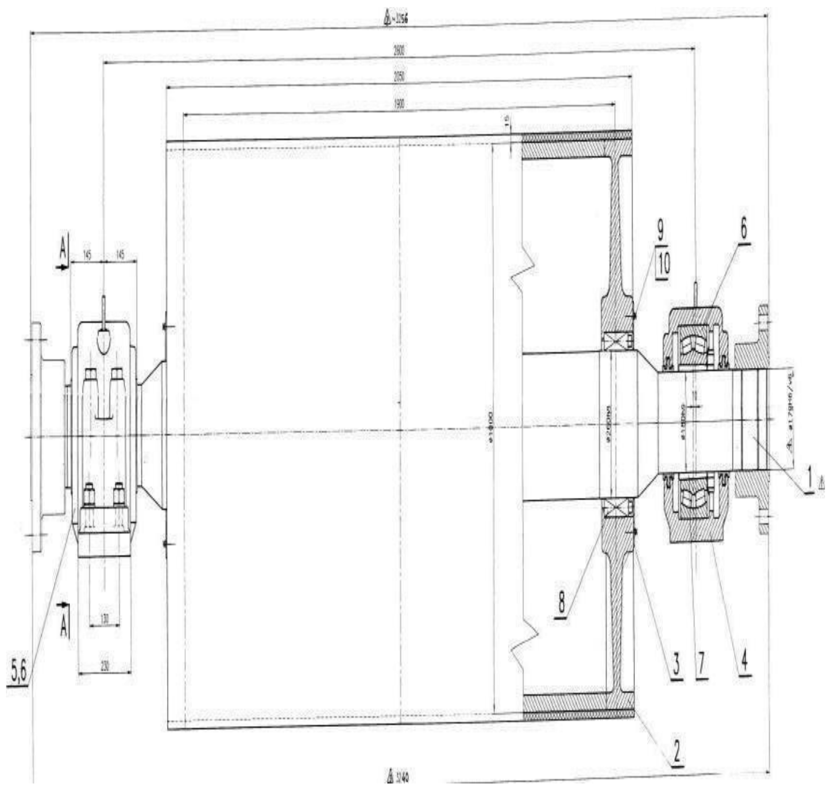


Figure: 4.1 Assembly Diagram of Belt drive drum assembly

4.5 STUDY OF PARTS

PLUMBER BLOCK

Plummer block is a pedestal which is used to provide support for a rotating shaft with the help of compatible bearings & different accessories. Housing material for a Plummer block is typically made of cast iron or cast steel. A Plummer block may contain spherical roller bearing. The Plummer block of belt drum is shown in the figure 4.2

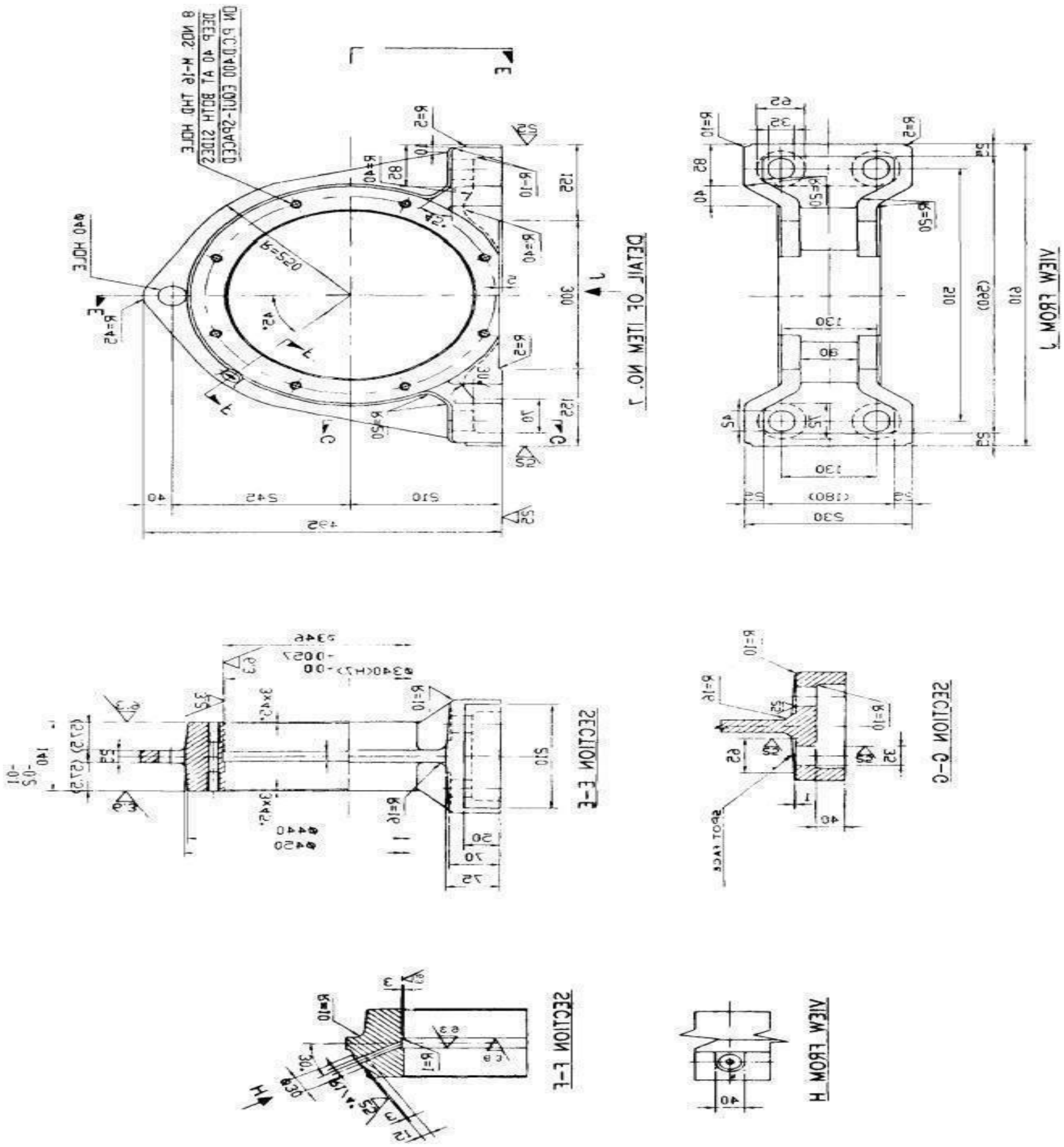


Figure: 4.2 Plumber block

1. FLANGE COUPLING

A flange is a method of connecting pipes, valves, pumps and other equipment to form a closed system. Flanges are usually welded or screwed. Bolt connections and high thread count nut are used to securing the flange coupling place. These bolts and nuts are usually made from tempered alloys or steel to provide the enduring strength and ability to tighten to the utmost level and ensure that the system doesn't leak at any flanged junction. The flange coupling in belt drive drum assembly is shown in the figure 4.3.

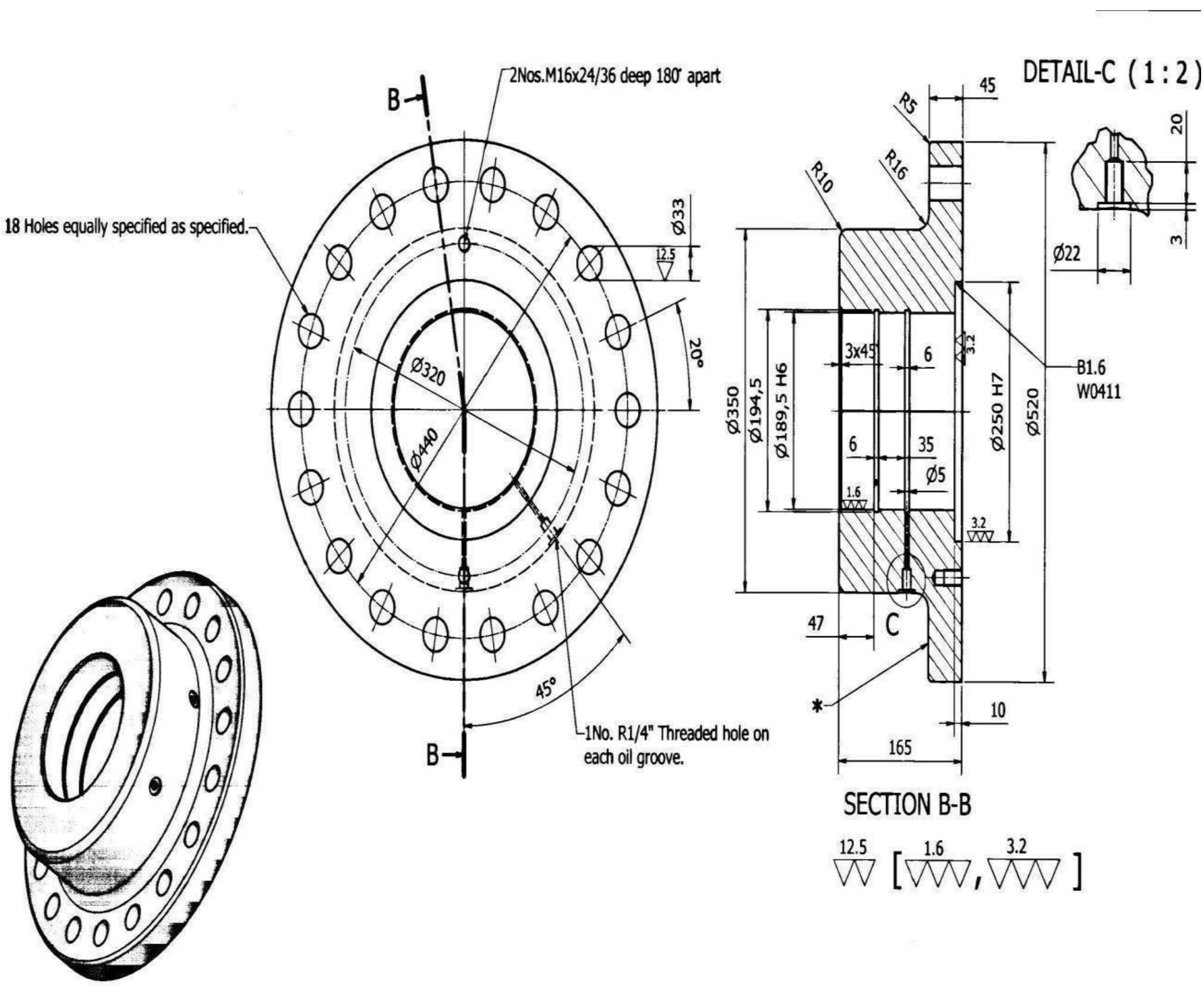


Figure: 4.3 Flange coupling

2. LABYRINTH FLANGE

The labyrinth flange is made of steel and have two radially arranged labyrinth stepsthat form a narrow sealing gap with the housing grooves. Labyrinth flange allow for some misalignment, high speeds, a wide temperature range, and do not limit axial movement due to thermal expansion. The labyrinth flange in belt drive drum assembly is shown in the figure 4.4.

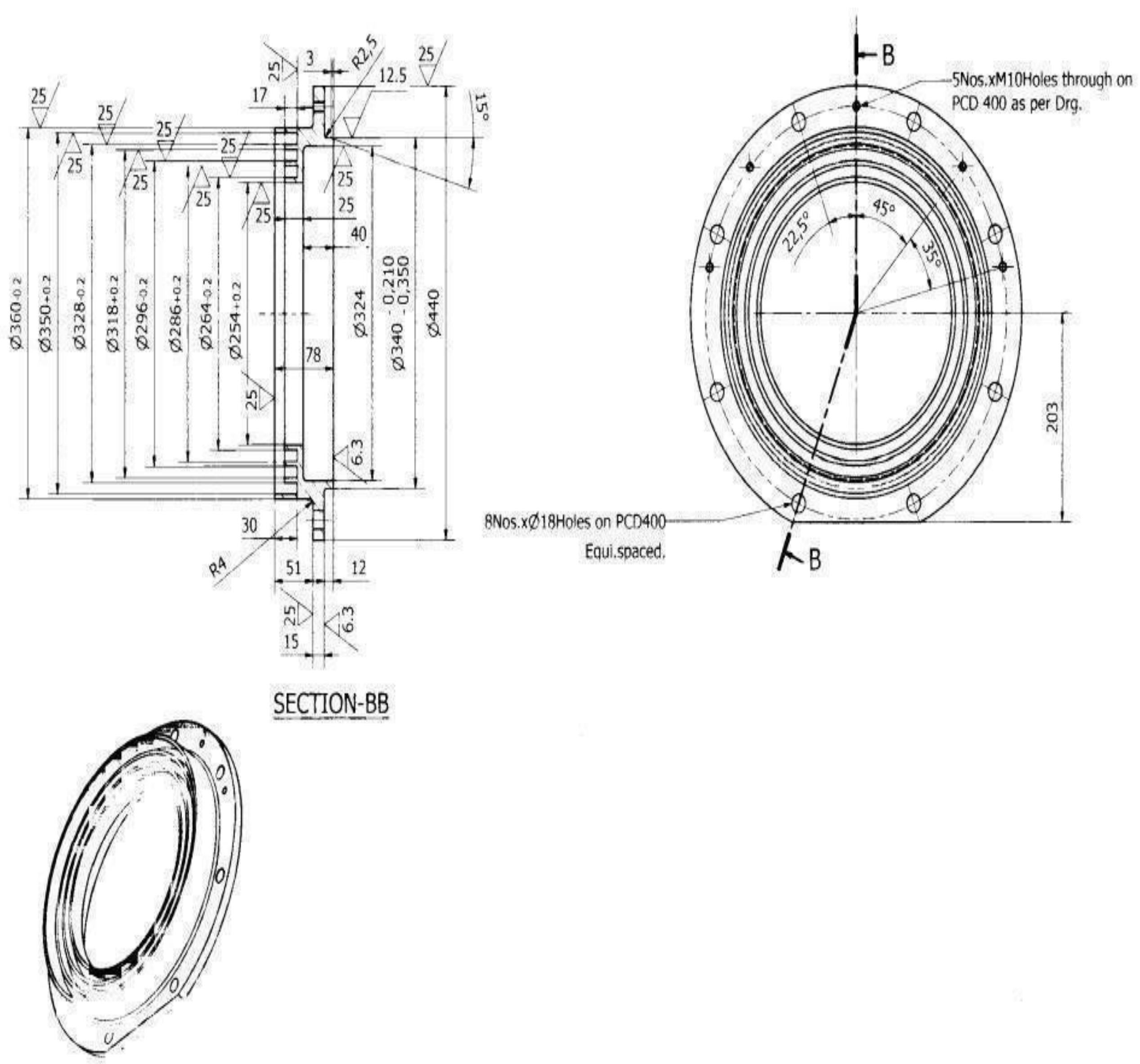


Figure: 4.4 Labyrinth flange

3. DRUM

A Conveyor Drum Pulley is a mechanical device similar to a conveyor roller/idler which is used to change the direction of the belt in a conveyor system or to drive thebelt or to put tension on the belt. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley. Pulley lagging increases the traction between the belt and the pulley, which in turn reduces load and wear on the drive, belt, and pulleys. The drum conveyor in belt drive drum assembly is shown in the figure 4.5.

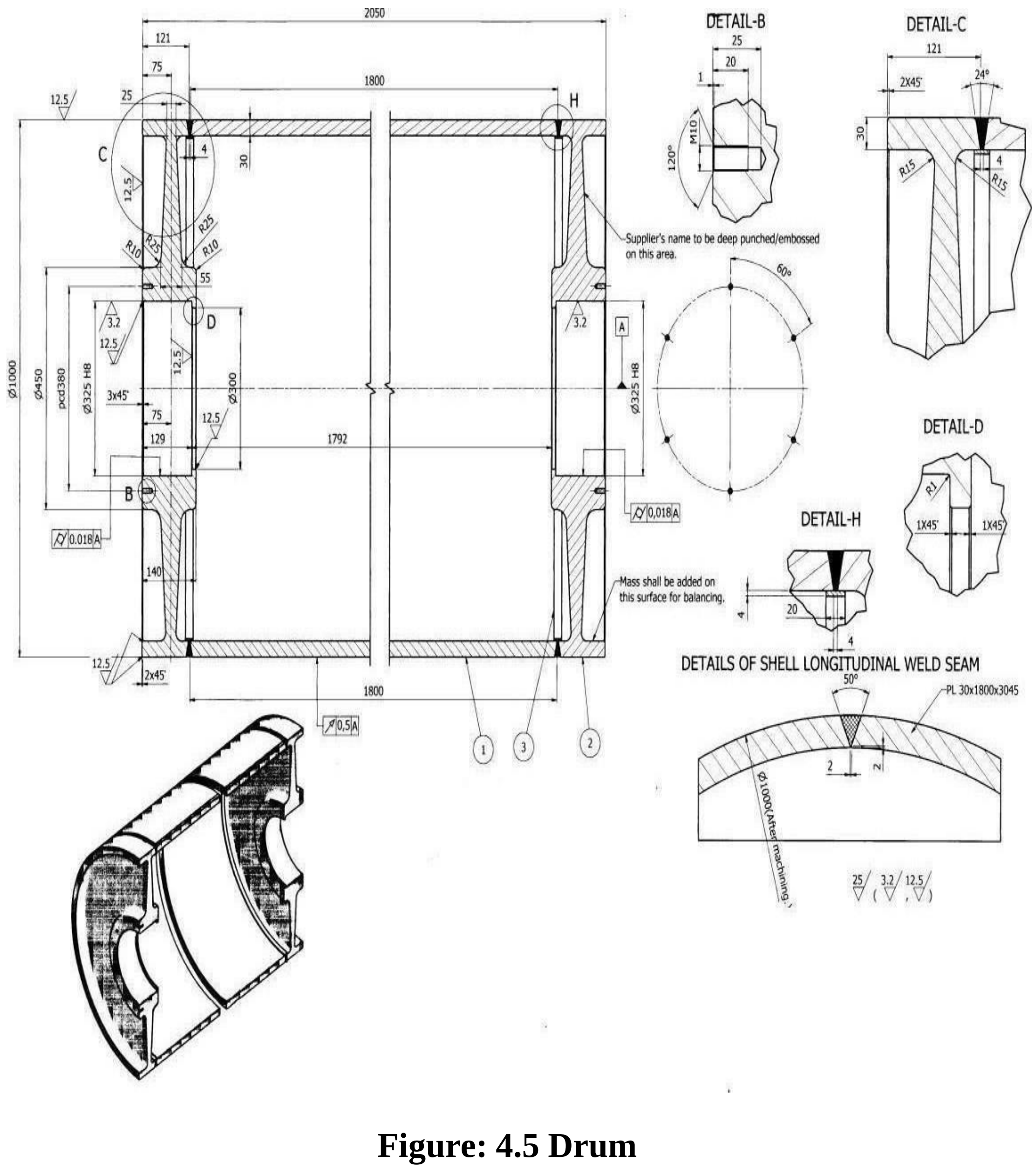


Figure: 4.5 Drum

Table 4.1 FMEA of Belt drive drum assembly

ASSEMBLY	FUNCTION	PARTS	FAILURE MODE	EFFECTS	SEV	CAUSES	PREVENTION CONTROL	OCC	DET	RPN
Belt Drive Drum assembly	It is used for linear movement of conveyor Belt which result in carrying the sand	Drum	Breakage of drum	Stoppage of production	4	No of cyclic loads	Manually	1	1	4
		Shaft	Shaft breakage Shear shaft Cut due to torsion	It leads to stoppage of production level	8	Less strength Less toughness	Manually and Sensor	7	7	392
		Bearing	Lubrication failure, Misalignment fatigue	It increases wear and reduce efficiency, Breakage of bearings	2	Rise in temperature, Excessive rotary bending	Manually	4	4	32
		Plummer block	Lubrication failure	It increases wear and reduce efficiency	2	Insufficient lubricant	Manually	1	1	2
		Flange coupling	Excessive speed or load	Causes wear and breakage	2	Over load on conveyor	Manually	1	1	2

4. BELT DRIVE DRUM ASSEMBLY FAILURE DATA

The failure that are occurring in the belt drive drum assembly are listed below in thetable 4.2 from the year 2017 to 2020

Table 4.2 Belt drive drum assembly Failure Data

SI.NO	DATE	UNIT NO	ASSEMBLY DATA
1.	13-11-2017	A/232	Shaft got cut near coupling.
2.	24-11-2017	A/552	Shaft got cut in-between shaft taper Step bearing assembly.
3.	02-12-2017	A/552	Shaft got cut at bearing seating.
4.	14-08-2018	A/552	Shaft got cut near coupling.
5.	15-09-2018	A/552	Shaft got cut near coupling.
6.	19-03-2019	A/200	Shaft got cut in-between shaft taper Step bearing assembly.
7.	07-11-2019	A/650	Shaft got cut in-between shaft taper Step bearing assembly.
8.	16-11-2019	A/650	Shaft got cut near coupling.
9.	27-01-2020	A/271	Shaft got cut in-between shaft taper Step bearing assembly.
10.	11-04-2020	A/271	Shaft got cut near coupling.

5.SEVERITY:

Severity is a ranking number associated with the most serious effect for a given failure mode, based on the criteria from a severity scale. From the failure data of belt drive drum assembly, the severity of each failure modes are identified. It is observed that shaft has been cut which resulting in the stoppage of the process of the spreader. The severity rank is givenaccording to the table 4.3

Table: 4.3 Severity

RANK	EFFECT	DESIGN FMEA SEVERITY	PROCESS FMEA SEVERITY
10	Hazardous no warning	Affects safe operation without warning	May endanger machine or operator without warning
9	Hazardous warning	Affects safe operation with warning	May endanger machine or operator with warning
8	Very High	Makes product inoperable	Major disruption in operations (100% scrap)
7	High	Makes product operable at reduced performance (customer dissatisfaction)	Major disruption in operations (may require sorting and some scrap)
6	Moderate	Results in customer discomfort	Minor disruption in operations (no sorting but some scrap)
5	Low	Results in comfort and convenience at a reduced level	Minor disruption in operations (portion may require rework)
4	Very Low	Results in dissatisfaction by most customers	Minor disruption in operations (some sorting and portion may require rework)
3	Minor	Results in dissatisfaction by average customers	Minor disruption (some rework but little affect on production rate)
2	Very Minor	Results in dissatisfaction by few customers	Minor disruption in operations (minimal affect on production rate)
1	None	No effect	No effect

6.DETECTION:

Detection is a ranking number associated with the best control from the list of detection-type controls, based on the criteria from the detection scale. The detection ranking considers the likelihood of detection of the failure mode/cause, according to defined criteria listed in the table 4.4

Table: 4.4 Detection

RANK	LIKELIHOOD OF DETECTION	CRITERIA: LIKELIHOOD OF IN-SERVICE DETECTION BY DESIGN CONTROL
10	Absolute Uncertainty	Failure mode/cause are not detectable in-service
9	Very Remote	Failure mode/cause is possibly detected during offline unplanned testing or inspection
8	Remote	Failure mode/cause is most likely detected during offline unplanned testing or inspection
7	Very Low	Failure mode/cause is possibly detected by offline planned periodic testing or monitoring
6	Low	Failure mode/cause is most likely detected by offline planned periodic testing or monitoring
5	Moderate	Failure mode/cause is possibly detected by online planned periodic testing or monitoring
4	Moderately High	Failure mode/cause is most likely detected by online planned periodic testing or monitoring
3	High	Failure mode/cause is possibly detected by online automatic continuous testing or monitoring
2	Very High	Failure mode/cause is most likely detected by online automatic continuous testing or monitoring
1	Almost Certain	Failure mode/cause detected by online automatic continuous testing or monitoring

7. OCCURRENCE

Occurrence is a ranking number associated with the likelihood that the failure mode and its associated cause will be present in the item being analysed. From the failure data of belt drive drum assembly the occurrence of each failure modes are identified. The occurrence rank is given from 0 to 10 based on the frequency of occurrence. From the FMEA table the shaft failure occurrence is high.

8. RPN NUMBER

The Risk Priority Number, or RPN, is a numeric assessment of risk assigned to a process, or steps in a process, as part of Failure Modes and Effects Analysis (FMEA)

Rpm number of the shaft = S x O x D

= 7 x 7 x 7

= 343

4.6 RECOMMENDED ACTIONS

Table 4.5 Summary Data

Shaft cut near taper	**4**
Shaft cut near coupling	**5**
In between the shaft	**1**
Total	**10**

- The sumary data of failure data is shoen in the table 4.5. The failure data of the spreader 115/116 in belt drive drum assembly for the past four years are studied.
- Shaft shear after taper step and before bearings are found to be 4 time
- Shaft shear after bearing and before coupling step 5 times
- one time the shat got cut in between the bearings

- For the given maximum load(1600KN) data by NLC India limited/SME/Mine I A
- The bearing withstands the load and no bearing failure reported and the dynamic load of bearing found matching
- Shaft re modification work with the given load was undertaken
- Shaft size for the given load is found to be 180 mm
- Taking into consideration the shaft failure increase in the factor of safety was suggested
- When the factor of safety increased the shaft size got increased to 200 mm
- Without changing the 260 diamter step increase the diameter of 180mm diameter to 20 mm diameter
- Bearing size with bearing sleeve 23140 CCK/W33 and H3140 was altered to23144CCK/W33 and H3144
- Use of suitable Plummer block suggested
- The output coupling (flanged coupling) too suitably modified
- New shaft drawing with suggested modification is made.

4.7 CALCULATIONS:

Two belt drive gear boxes are used to drive the belt drive drum assembly

The sectional view of shaft is shown in the figure 4.6

Power of one belt drive gear box is 240KW Power = P = 2×240 KW = 480 KW

Limiting Load of the bearing 23140 (F) = 1600 KN

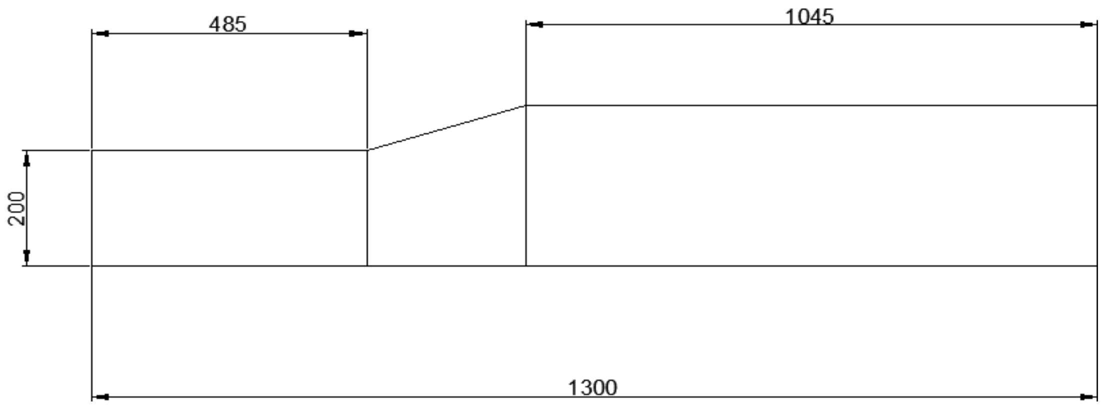


Figure: 4.6 Sectional view of shaft

Length of the shaft (L) = 1300 mm

= 1.3m

Safe stress for shaft material = 850×10^{6} N/m^2

From the NLC spreader catalogue

Speed (N) = 80.25 rpm

Belt Speed (V) = 4.2 m/s

Factor of safety (FOS) = 1.25 to 1.5

To find the diameter (D)

$$\boldsymbol{P} = \frac{\boldsymbol{2\pi NT}}{60}$$

$$480 = \frac{2\times 80.25\times T}{60}$$

$$\boldsymbol{T} = \boldsymbol{57.11\ KN\ m}$$

$$\boldsymbol{Moment} = \boldsymbol{F} \times \boldsymbol{d}$$

$$= 1600 \times 1300 \times 10^{-3}$$

$$\boldsymbol{Moment} = \boldsymbol{2080\ KN\ m}$$

$$T = \sqrt{M^2 + T^2}$$

$$= \sqrt{2080^2 + 57.11^2}$$

$$\boldsymbol{Te} = \boldsymbol{2080\ KN\ m}$$

$$\boldsymbol{FOS} = \frac{\boldsymbol{Allowable\ Load}}{\boldsymbol{Maximum\ \ Load}}$$

$$1.5 = \frac{Allowable\ load}{850 \times 10^6}$$

$$\boldsymbol{Allowable\ Load} = \boldsymbol{1275} \times \boldsymbol{10^6 N/m^2}$$

$$\boldsymbol{T_{eq}} = \frac{\boldsymbol{\pi \times\ D^3 \times A.L}}{\boldsymbol{60}}$$

$$D^3 = \frac{2080 \times 10^3 \times 16}{\pi \times 1275 \times 10^6}$$

$$D = 0.202\ m$$

$$\boldsymbol{D = 202\ mm}$$

For the dynamic load shaft diameter is found to be 202 mm

As per the standard dimension standards shaft diameter reduced to 200mm.

4.8 SELECTION OF BEARING:

As per the SKF/FAG bearing catalogue the bearing number found to be 23144CCK/W33

Bearing sleeve found to be H3148

4.9 OLD DESIGN SHAFT OF 180 DIAMETER:

The 2D diagram of old shaft of belt drive drum assembly is shown in the figure 4.7

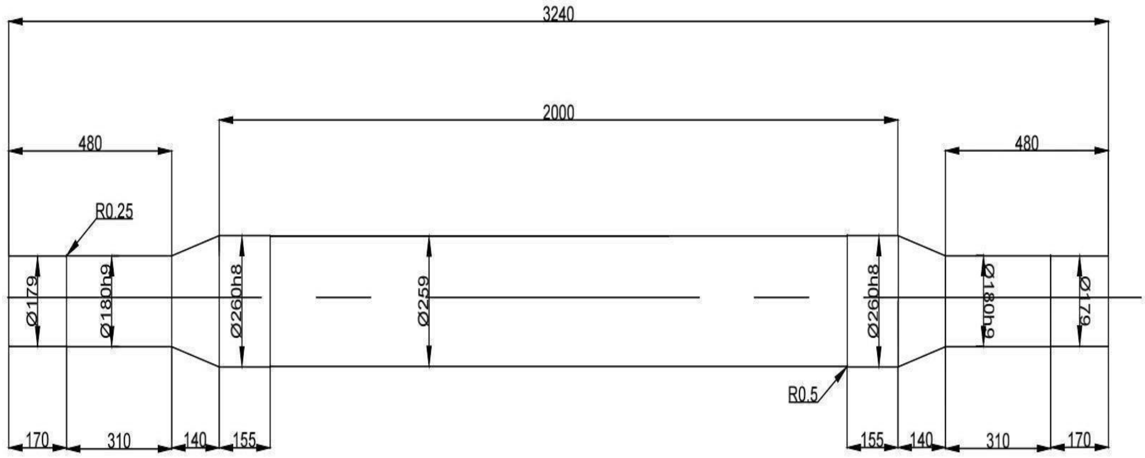


Figure: 4.7 Old design shaft of 180 diameter

4.10 REDESIGNED SHAFT OF 200 DIAMETER:

The 2D diagram of modified shaft of belt drive drum assembly is shown in thefigure 4.8

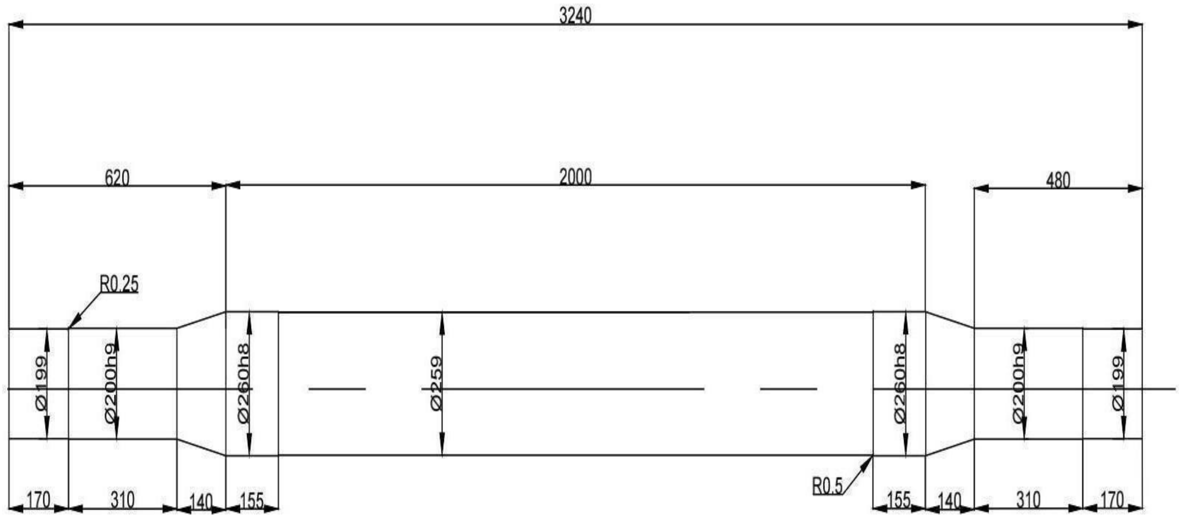


Figure: 4.8 Redesign shaft of 200 diameter

4.11 SLEWING GEAR BOX IN SPREADER:

Slewing gear box is used in specialized mining equipment (SME). Slewing gear box is used to slew the boom of the spreader. It rotates up to 180 degrees. The slew gear box having sun pinion and planetary gears arrangement to reduce the initial input speed. The slew gear box is powered by using electrical motor. The electrical motor coupled with clutch with claw. Clutch is connected with brake drum with claw. The brake drum is connected with slew gear box input couplingclaw. The slew gear box input shaft is connected with worm wheel gear drive. The worm wheel gear drive is rotating the planetary gear drive. This is the first stage of slew gear box. The output of first stage planetary gear drive is input to second stage of planetary gear drive. The second stage of planetary gear drives coupled with ring gear. The three planetary wheels are rotating the ring gear. Thering gear is connected to output shaft with pinion and to the bull gear.

4.12 FMEA OF SLEWING GEAR BOX

For FMEA analysis of slewing gear box, first the assembly and the parts of the system are studied in order to understand the working process and importance of each component. The FMEA table is expressed in the table 4.6

Table 4.6 FMEA of Slewing Gear box

ASSEMBLY	FUNCTION	PARTS	IDENTITY FAILURE MODE	EFFECTS	SEV	CAUSES	PREVENTION CONTROL	OCC	DET	RPN
Slewing Gear Box	It uses the electric power and transfer motive for the movement of all gear	Flange	Corrosion	It causes breakage of flange	4	Low resistance to corrosion	Manually	2	2	16
			Wear	It detached from original position	3	Cyclic loads	Manually	1	1	3
		Locking nut	Vibration	It causes misalignment	2	Unbalanced force	Manually	1	1	2
		Output pinion	Surface fatigue	Surface material has broken away from the tool	4	Improper selection of lubrication	Manually	2	2	16
		Bolts	Thread failure	It causes breakage in bolt	4	Due to in load	Manually	1	1	4
			Shear	It leads to oil leak	6	Unwanted vibration	Manually	7	7	294
		Oil seals	Excessive gaps	It leads to oil leak	4	Improper alignment	Manually	4	4	64

4.13 ASSEMBLY OF SLEWING GEAR BOX:

Slewing gear box is used in specialized mining equipment (SME). Slewing gear box is used to slew the boom of the spreader. It rotates up to 180 degrees. The slew gear box having sun pinion and planetary gears arrangement to reduce the initial input speed . The assembly diagram of slewing gearbox is shown in figure 4.9

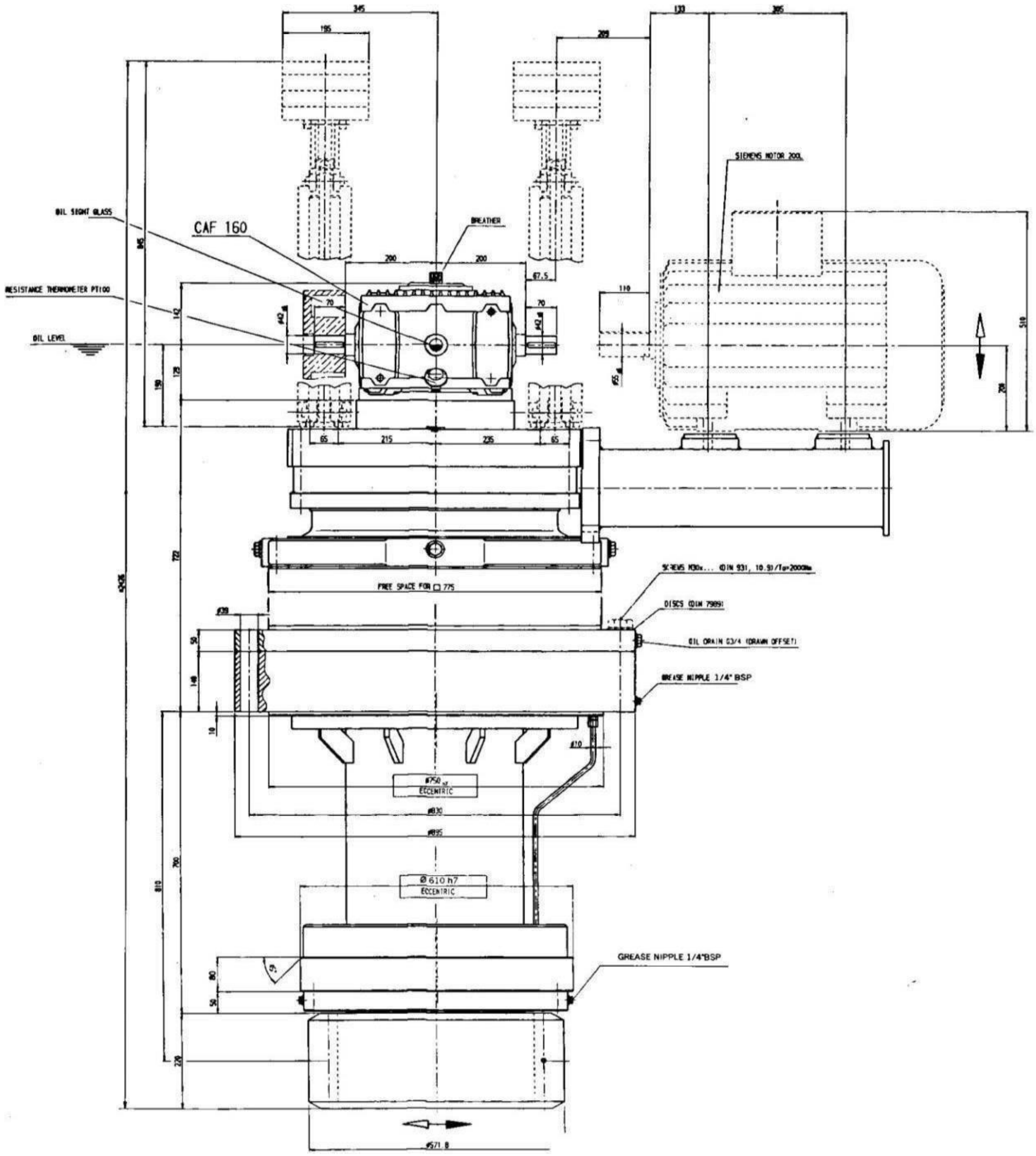


Figure: 4.9 Assembly of Slewing Gear Box

4.14 SLEWING GEAR BOX SETUP

The slew gear box is powered by using electrical motor. The electrical motor coupled with clutch with claw. Clutch is connected with brake drum with claw. The brake drumis connected with slew gear box input coupling claw. The slew gear box input shaft is connected with worm wheel gear drive. The worm wheel gear drive is rotating the planetary gear drive. This is the first stage of slew gear box. The output offirst stage planetary gear drive is input to second stage of planetary gear drive. The second stage of planetary gear drives coupled with ring gear. The three planetary wheels are rotating the ring gear. The ring gear is connected to output shaft with pinion and to the bull gear. The interior arrangement of slewing gearbox is shown in figure 4.10

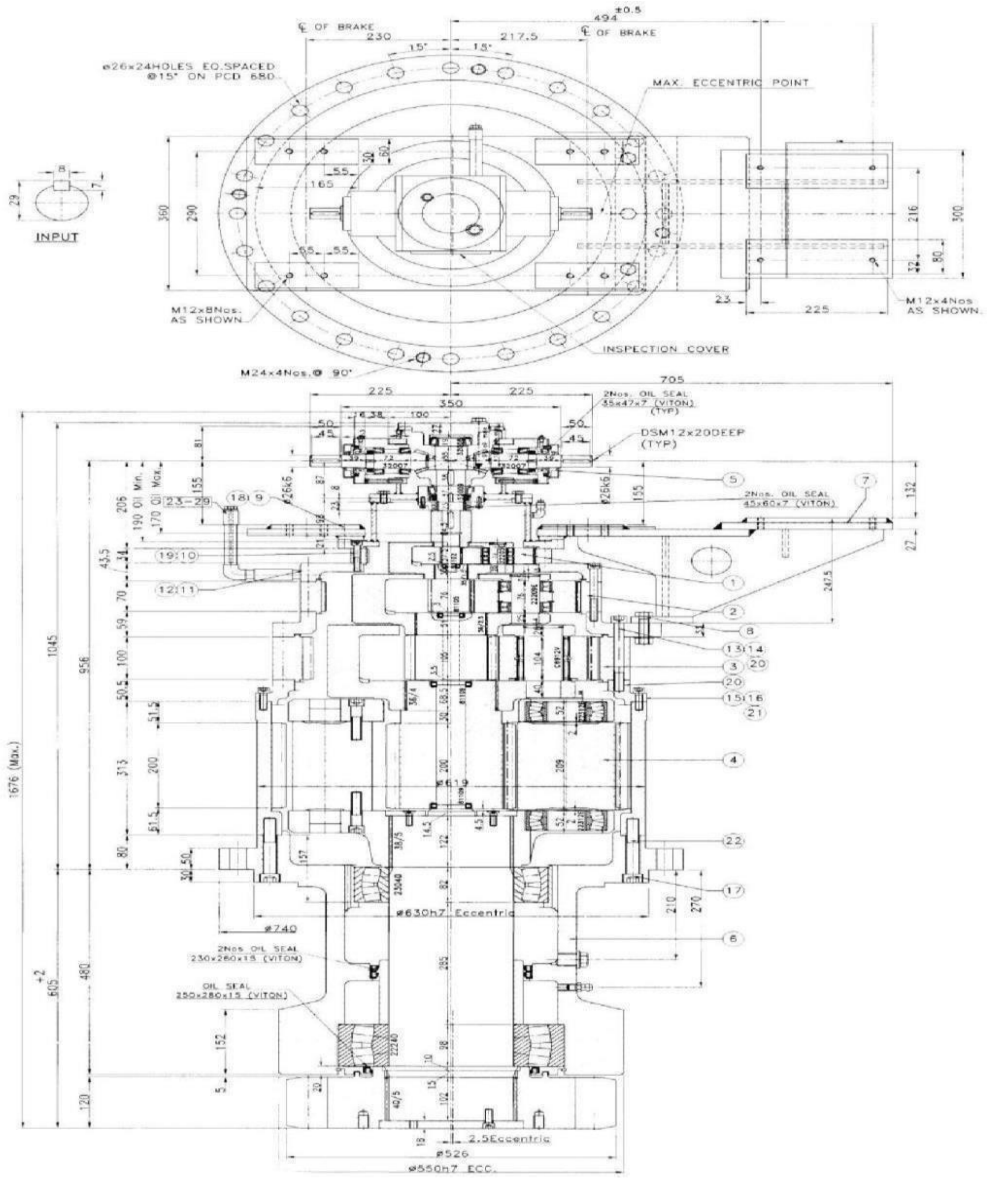


Figure: 4.10 Slewing Gear Box Setup

4.15 SLEWING GEAR BOX PART DRAWING

1. INTERMEDIATE FLANGE

The intermediate flanges are custom fit precisely according to the distance between the encoder flange and the application interface. In this way it guarantee the safety integrated mechanical attachment of the encoder to the machine housing. Individually sized spacer rings ensure the right mechanical interface between the flange and the machine housing. The intermediate flange diagram is shown in figure 4.11

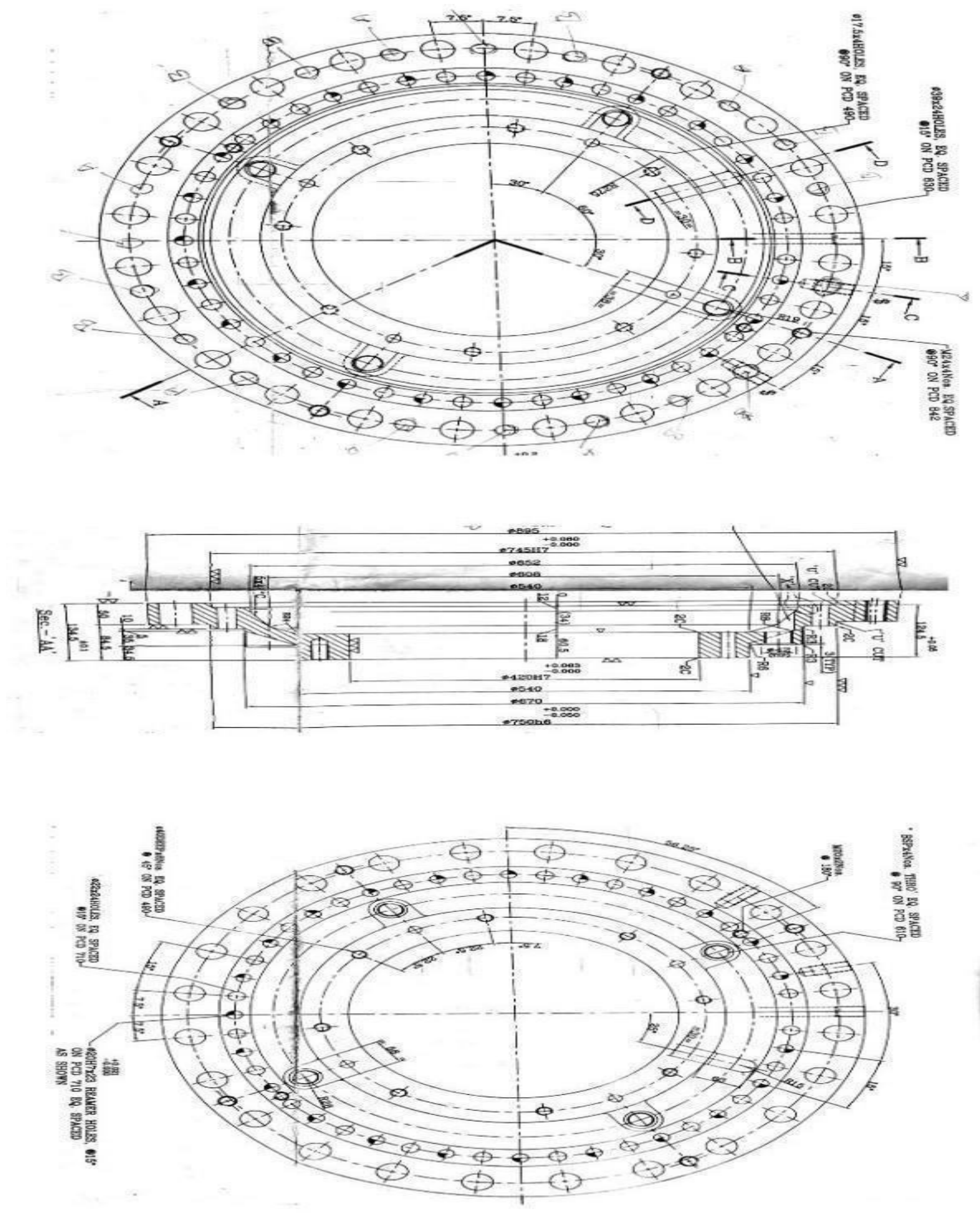


Figure : 4.11 Intermediate Flange

2. MOTHER HOUSING

The mother housing has the output pinion and which is attached with the gear housing. The mother housing and gear housing are locked with the bolt and nuts and the leakage is prevent by the application of Sealant. The figure of mother housing is shown in the figure 4.12 and the respective parts are mentioned in the table 4.7

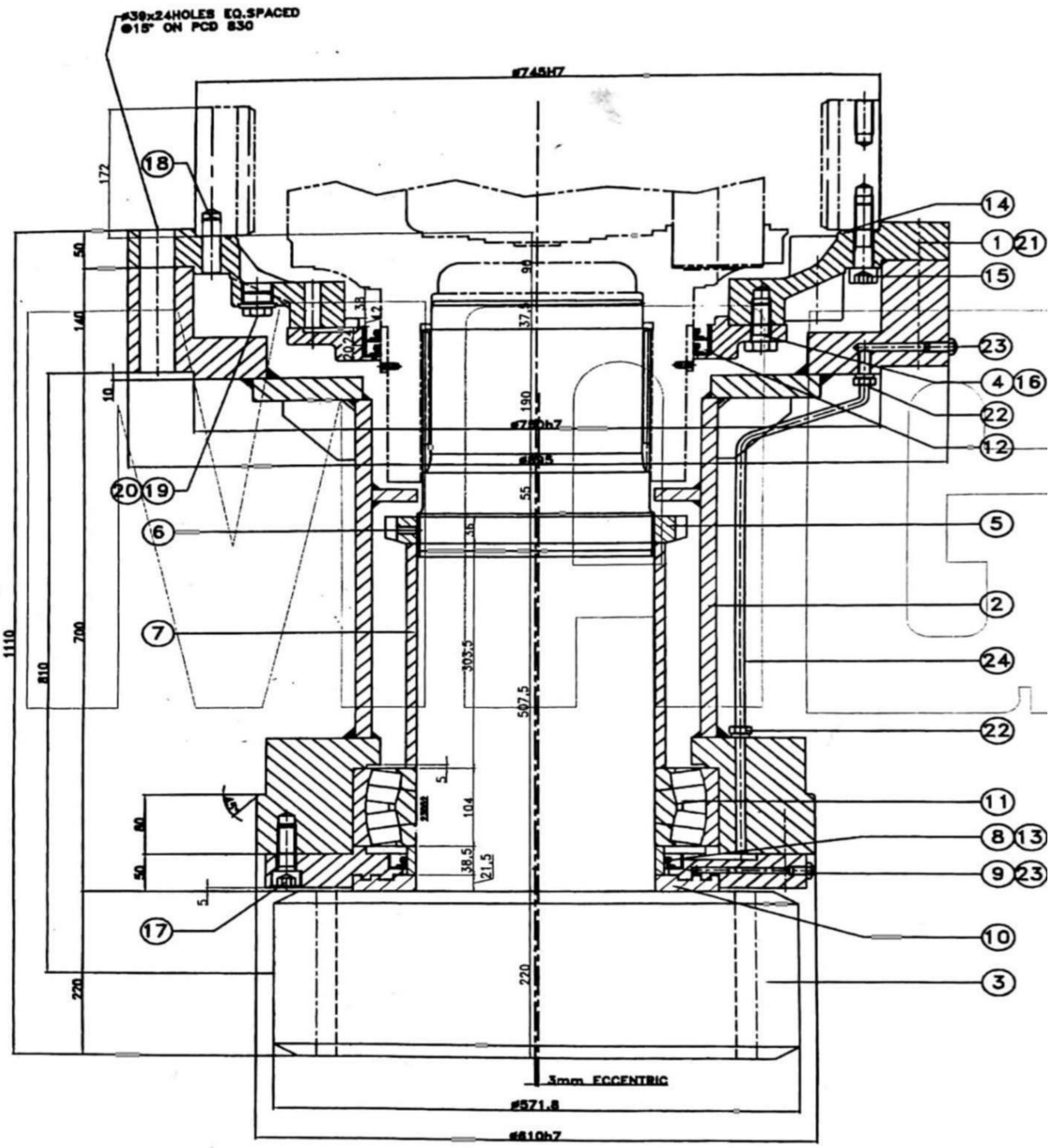


Figure: 4.12 Mother Housing

Table: 4.7 Mother Housing

ITEM NO	QTY	DESCRIPTION
1.	1	FLANGE BRACKET
2.	1	OUTPUT BRACKET
3.	1	OUTPUT SHAFT WITH PINION
4.	1	BEARING COVER
5.	1	LOCK NUT
6.	1	HEX. SOCKET SET SCREW WITH DOG POINT
7.	1	SPACER
8.	1	SPACER
9.	1	EXT. LABYRITH
10.	1	INT. LABYRITH
11.	1	SPERICAL ROLLER BEARING
12.	2	OIL SEAL
13.	1	OIL SEAL
14.	1	RUBBER RING
15.	24	HEX. SOCKET HEAD CAP SCREW
16.	6	HEX. BOLT
17.	12	HEX. SOCKET HAED CAP SCREW
18.	23	DOWEL PIN WITH TAP HOLE
19.	1	MAGNETIC OIL DRAIN
20.	3	BLANKING PLUG
21.	1	PLUG
22.	2	STRAIGHT MALE STUD COUPLING
23.	4	GREASE NIPPLE
24.	1	10mm O/D HY. PIPE

3. SLEWING GEAR BOX FAILURE DATA:

The failure that are occurring in the slewing gear box are listed below table 4.8 from the year 2019 to 2020

Table: 4.8 Slewing Gear Box Failure Data

S.NO	DATE	UNIT NO	ASSEMBLY DATA
1.	11-05-2020	U/485	Bolts got loosen results in oil leak
2.	21-10-2019	U/485	Bolts got loosen results in oil leak
3.	12-10-2019	A/200	Bolts got loosen results in oil leak
4.	08-10-2019	A/200	Bolts got loosen results in oil leak
5.	28-05-2019	A/135	Bolts got loosen results in oil leak
6.	19-03-2019	A/200	Bolts got loosen results in oil leak
7.	25-02-2019	A/200	Bolts got loosen results in oil leak
8.	24-02-2019	A/200	Bolts got loosen results in oil leak
9.	24-02-2019	A/140	Bolts got loosen results in oil leak
10.	14-02-2019	A/140	Bolts got loosen results in oil leak

4. SEVERITY

It is observed that oil leak which resulting in the stoppage of the process of the spreader. The severity rank is given according to the table 4.9. Severity of bolts is 6.

Table: 4.9 Severity

RANK	EFFECT	DESIGN FMEA SEVERITY	FMEA SEVERITY
10	Hazardous nowarning	Affects safe operation without warning	May endanger machine oroperator without warning
9	Hazardous warning	Affects safe operation with warning	May endanger machine oroperator with warning
8	Very High	Makes product inoperable	Major disruption in operations(100% scrap)
7	High	Makes product operable at reduced performance (customer dissatisfaction)	Major disruption in operations (may require sorting and somescrap)
6	Moderate	Results in customer discomfort	Minor disruption in operations(no sorting but some scrap)
5	Low	Results in comfort and convenience at a reduced level	Minor disruption in operations(portion may require rework)
4	Very Low	Results in dissatisfaction by most customers	Minor disruption in operations (some sorting and portion mayrequire rework)
3	Minor	Results in dissatisfaction by average customers	Minor disruption (some reworkbut little affect on production rate)
2	Very Minor	Results in dissatisfaction by few customers	Minor disruption in operations (minimal affect on productionrate)
1	None	No effect	No effect

5. DETECTION

. From the detection table the detection ranking is given from 0 to 10 which is listed in the table 4.10 The detection of bolt failure is 7

Table: 4.10 Detection

RANK	LIKELIHOOD OF DETECTION	CRITERIA: LIKELIHOOD OF IN-SERVICE DETECTION BY DESIGN CONTROL
10	Absolute Uncertainty	Failure mode/cause are not detectable in-service
9	Very Remote	Failure mode/cause is possibly detected during offline unplanned testing or inspection
8	Remote	Failure mode/cause is most likely detected during offline unplanned testing or inspection
7	Very Low	Failure mode/cause is possibly detected by offline planned periodic testing or monitoring
6	Low	Failure mode/cause is most likely detected by offline planned periodic testing or monitoring
5	Moderate	Failure mode/cause is possibly detected by online planned periodic testing or monitoring
4	Moderately High	Failure mode/cause is most likely detected by online planned periodic testing or monitoring
3	High	Failure mode/cause is possibly detected by online automatic continuous testing or monitoring
2	Very High	Failure mode/cause is most likely detected by online automatic continuous testing or monitoring
1	Almost Certain	Failure mode/cause detected by online automatic continuous testing or monitoring

6. OCCURRENCE

. From the failure data of slewing gear box the occurrence of each failure modes are identified. The occurrence rank is given from 0 to 10 based on the frequency of occurrence. From the FMEA table the oil leakage to shear occurrence is high. The occurrence of the oil leaks 7.

RPN Number

Rpm number of the oil leakage due to bolts = S x O x D

= 6 x 7 x 7

= 294

4.16 CALCULATION:

Rpm of the slewing gear box = 950 rpm

Operating frequency = 950/60

= 15.83

The operating frequency (approx.) = 16 Hz

$$P = \frac{2\pi NT}{60}$$

The power of the slewing gear box = 25kW

The input torque is calculated as 251.73 Nm

From the **NLC catalogue**,

The output torque of slewing gear box = 103 K Nm

4.17 RECOMMENDED ACTIONS

1. Slewing pipe housing joints, ring gear and preceding joint of the slewing gear box and its mounting secured by one fixing bolt.
2. The fixing bolt size is M36 × 220.
3. During operation in machine chance of the mounting bolts to get open become more often.
4. As reported by NLCIL to the joints getting opened even after bolts were tightened using double nut to the required torque of the bolts
5. The bolt size is M36 × 220, 10:9 grade as per is 2102.
6. As bolt size replacement to higher size ruled out the following suggestion were made.
7. Introduction of keyed ring plated on mounting plate. The diagram is shown in the figure 4.13 and diagram of bolts and nuts is shown in the figure 4.14

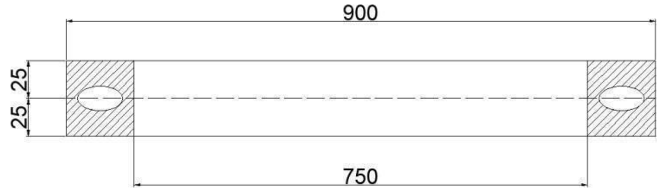


Figure 4.13 ring plate

- ➢ Key size 40 × 22 × 50mm - 2 no's
- ➢ Key way size 40 × 12 × Depth 50mm - 2 no's

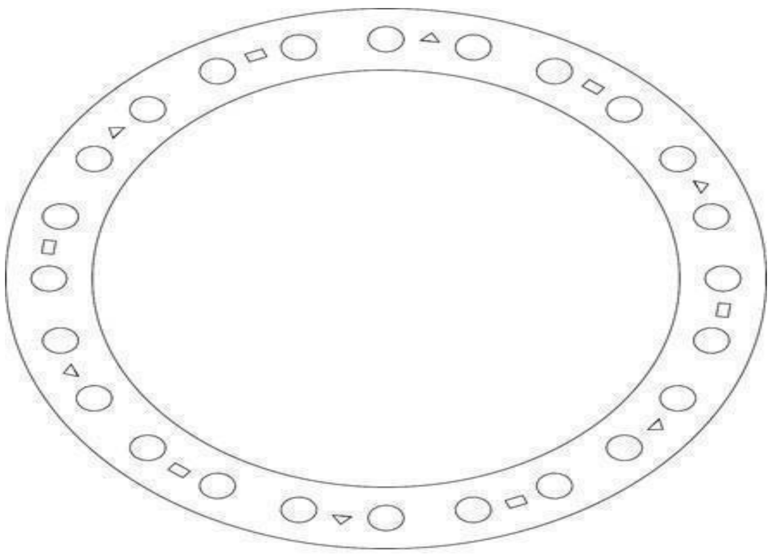
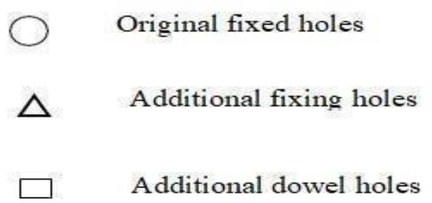


Figure 4.14 Bolts and Nuts



6 nos × m20

6 nos x Φ20

8. Torque arresting/transmitting rings plate 2 no's with key be introduced to thein between mounting mother plate and the gear box fixing joint.
9. The torque arresting in mother plates to be stretch well to
    - ➢ Mother plate
    - ➢ Gear box mounting seat
10. The joint between ring gear and its preceding joint to be drilled for additional fixing holes and dowel holes.It is shown in the figure 4.14
    - ➢ Additional fixing holes 6 no's × M20 size

- Additional dowel holes 6 no’s - Ø20 & dowel holes

11. By drilling additional holes ring gear and preceding joints are secured relatively apart from original fixing bolts.

5. FINITE ELEMENT ANALYSIS

5.1 INTRODUCTION

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It is also referred to as finite element analysis (FEA). FEM subdivides a large probleminto smaller, simpler, parts, called finite elements.

The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses vibrational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

5.1.1 GENERAL DESCRIPTION OF FEM:

In engineering problems there are some basic unknowns. If they are found, the behavior of the entire structure can be predicted. The basic unknowns or the field variables which are encountered in the engineering problems are displacement in solid mechanics, velocities I fluid mechanics, electric & magnetic potentials in electrical &temperature in heat flow problems. In a continuum, these unknowns are infinite. The finite element procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements & by expressing the unknowns' fieldvariables in terms of assumed approximately functions within each element. The approximating functions are defined in terms of field variables of specified points called nods or Nodal points. After selecting elements and nodal unknowns, next step in finite element analysis is to assemble element properties for each element. Mathematically the relationship is of the form then the boundary conditions are imposed. The solution of their simultaneous equations gives the nodal unknowns. Using these nodal values additional calculations are made to get the required values e.g.: stresses, strains etc.

5.1.2 STEPS INVOLVED IN FEA:

- Discretization into the element
- Selection of the displacement models
- Derivation of the element stiffens matrix.

- Assembling
- Solution for the unknown displacement
- Computations of the element stresses and strains at the nodal points

5.1.3 DISCRETIZATION INTO THE ELEMENT:

The given footing is divided into an equivalent system of finite elements, by a process known as Discretization. The equivalent system may consist of triangular or quadrilateral and/or tetrahedron or hexahedron based on whether the problem is solved as in 2-D or 3-D plane.

5.1.4 SELECTION OF THE DISPLACEMENT MODELS:

It is generally not possible to select a displacement function that can represent exactly the actual variation of displacement in the element. Hence, the basic approximation of the finite element method is introduced at this stage. There are three interrelated factors, which influence the selection of a displacement model. The type and degree of displacement model must be chosen. The particular displacement magnitude that describes the model must be selected. These are usually the displacement at nodal points, but they may also include the derivation of the displacement at some or all of the nodal points. The displacement model must specifycertain requirements, which ensure that the numerical result approach the correct solution.

5.1.5 DERIVATION OF THE ELEMENT STIFFENS MATRIX:

The stiffness matrix consists of the co-efficient of the equilibrium equations derived from the material and properties of an element and obtained by the use of minimum potential energy. The stiffness relates the displacements at the nodal points (the nodal forces) to the applied forces at the nodal points. The distributed forces applied to the structure are converted into equivalent concentrated forces at nodes. The equilibrium relates the stiffness matrix [K], nodal force vector [F], and the nodal displacement vector [d] is expressed as a set of simultaneous linear algebraic equations.

5.1.6 ASSEMBLING:

This process includes the assemblage of the overall or global stiffness matrix for the entire body from the individual element stiffness matrices and the overall or global forces or load victor from the element nodal vectors. The most common assemblage technique used is called as the direct stiffness matrix [K].

5.1.7 APPLYING OF BOUNDARY CONDITION:

A problem is incomplete unless boundary conditions are specified. In fact without imposition of boundary condition, the element and global stiffness matrix becomes singular. Thus boundary conditions are applied.

5.1.8 SOLVE FOR THE UNKNOWN NODAL DISPLACEMENT:

Solving the unknown displacement in global equilibrium equations by using elimination method, penalty, multi-constrain method etc.

5.1.9 SOLVE FOR ELEMENTAL STRESS AND STRAIN:

The quantities of strains and stresses in each element can be obtained by using the relationship between strain displacement and stress-strain.

5.2 FEA OF SHAFT

ANSYS workbench was chosen to create mesh and perform the analysis. The version used is 2018 R1. We performed a stress analysis to confirm the strength of the material. However, the solid modelling is drawn from the SOLIDWORKS 2020. The model used is stored in the format of an IGES file.

5.2.1 PREPROCESSOR

MATERIAL SPECIFICATION

The material which is used in the shaft is alloy steel which has a chemical composition of 34CrNiMo6. Highly hardenable steel (more than 36HNM) that does not show tempering brittleness, which enables them to create very strong and ductile parts which have a density: 7.78 g/cm3 and a specific heat capacity: 0.46

BOUNDARY CONDITIONS

In the shaft, the two ends are assumed to be fixed. A fixed support is given at both ends of the shaft. The load is given in the center in order to solve the problem. The torque of 2080 kNm is applied at the center of the shaft. The torque is applied in the rotation of the X axis

MESHING

Meshing is the process of turning irregular shapes into more recognizable volumes called elements. The mesh used in the analysis is fine mesh which has a surface area of 8.3432e-003 m^2. The number of elements is 43878

5.2.2 FEA RESULTS

STATIC STRUCTURAL

The stress and deformation analysis are carried out to ensure the strength of the shaft. The equivalent stress and total deformation of the existing model and modified are discussed below figure 5.1 and 5.2

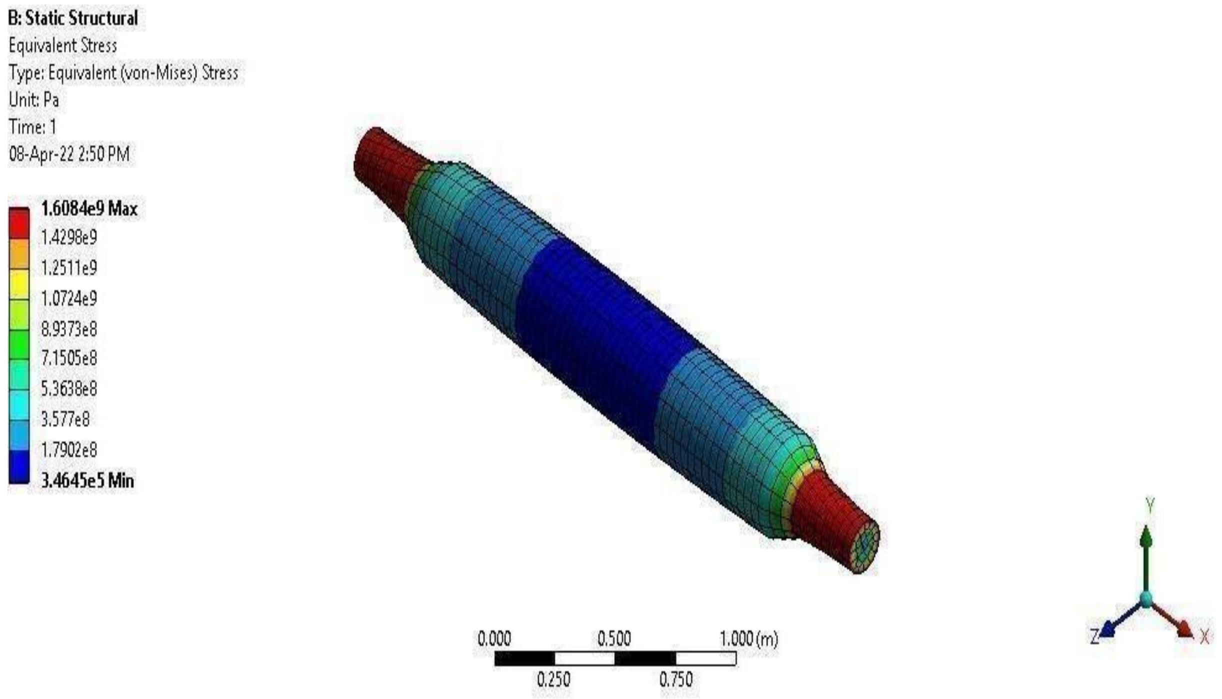


Figure: 5.1 Internal Stress of 180 Diameter Shaft

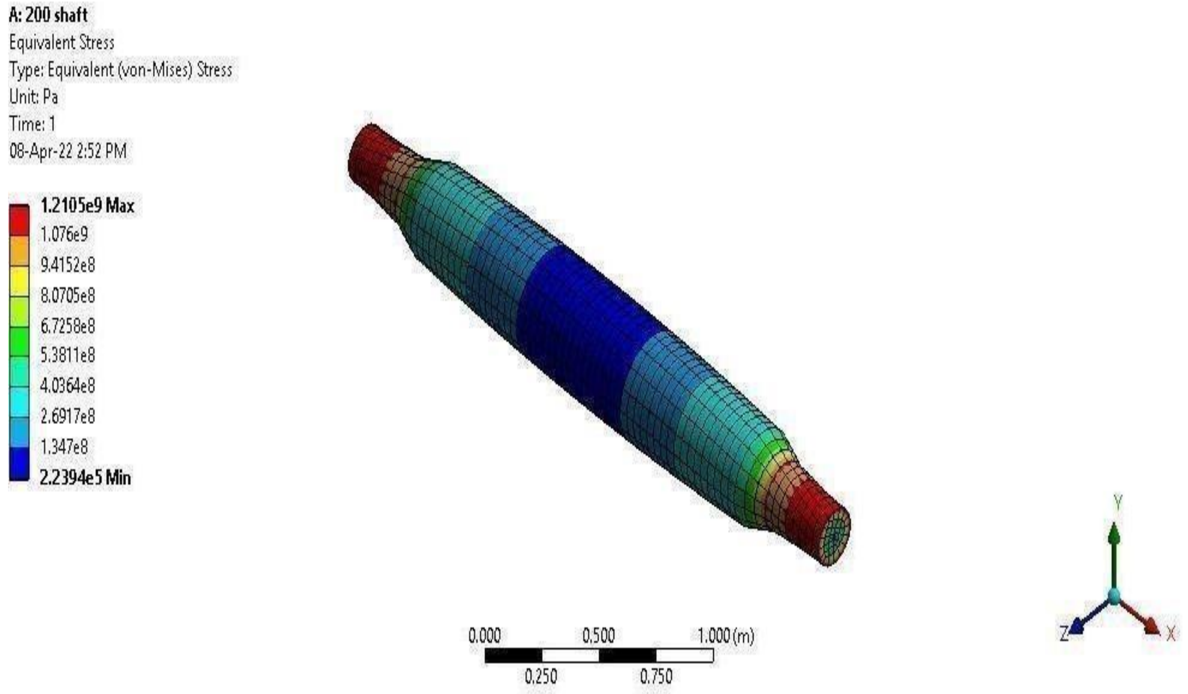


Figure: 5.2 Internal Stress of 200 Diameter Shaft

It is observed that the stress in the modified model is lower than in the existing model. The failure occurs at the end of the shaft, the stress in the existing model at the end of the shaft is 1.6e9 Nm and stress in the modified model is 1e9 Nm.

The deformation of the shaft is relatively less for the modified shaft (0.0057 m) than for the existing shaft (0.00779 m) which is shown in the figure 5.3 and 5.4. From the two analyses, the modified shaftis stronger than the existing one.

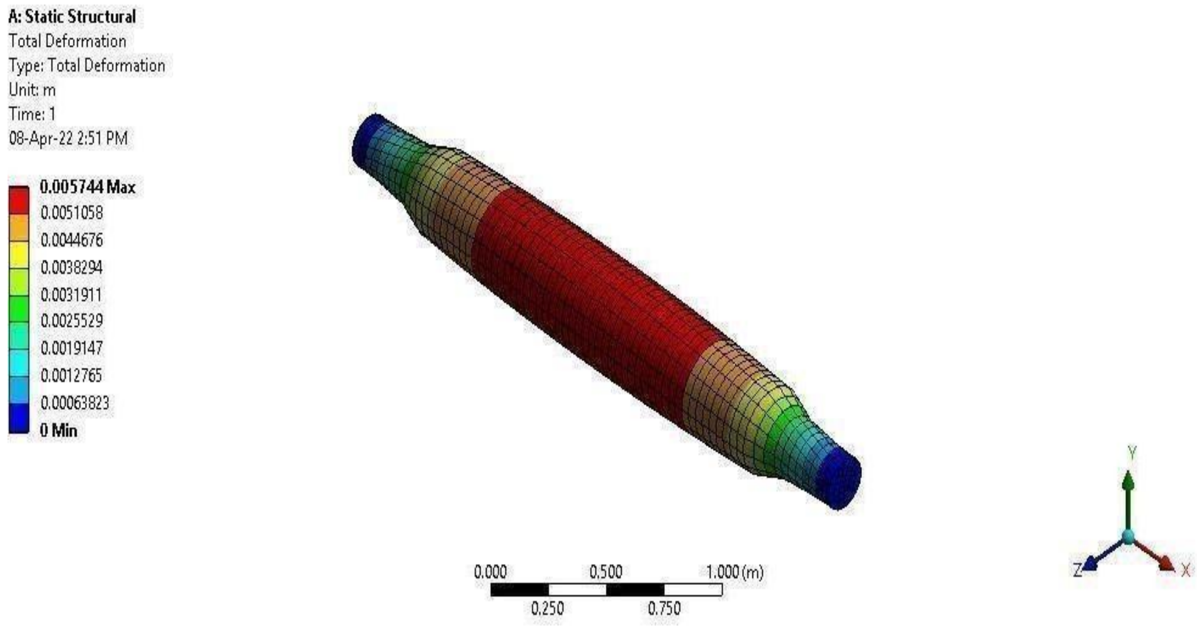


Figure: 5.3 Displacement of 180 Diameter Shaft

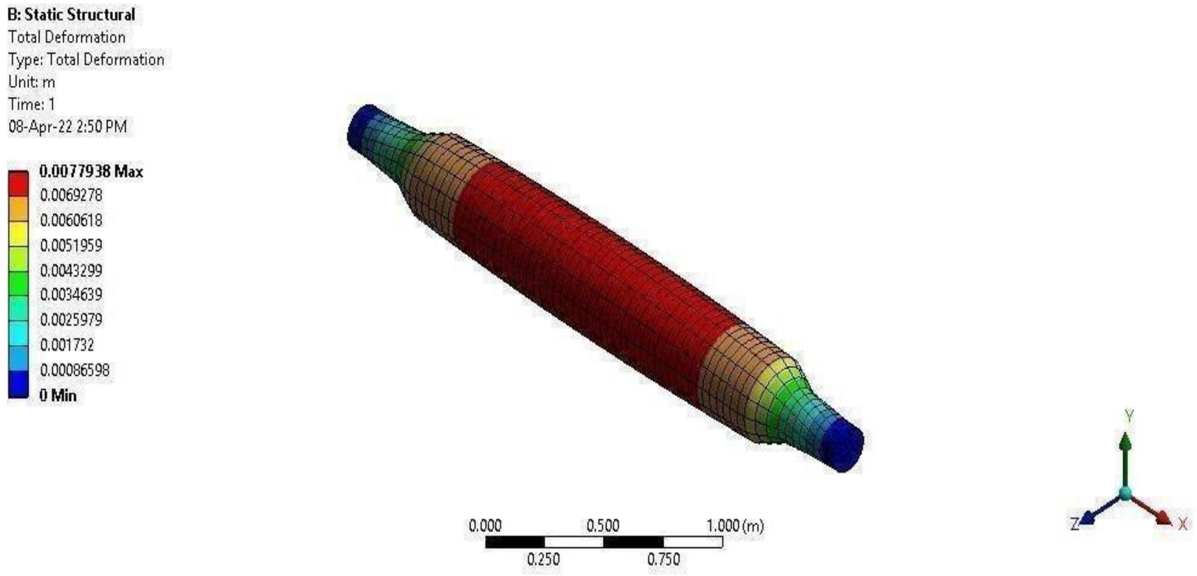


Figure: 5.4 Displacement of 200 Diameter Shaft

5.3 FEA ANALYSIS OF SLEWIMG GEAR BOX

MATERIAL SPEICIFICATIONS

The material which is used for housing is alloy steel which has a chemical component of 42crmo4.After being quenched and tempered, It obtains high strength, good low-temperature impact toughness with a typical tensile strength of 900 -1200 N/mm2. The 42CrMo4 alloy material also has high fatigue strength. The bolts and nuts are made of alloy steel EN24 and 10.9 grade. The chemical composition is 34CrNiMo6.

BOUNDARY CONDITIONS

In the housing of the slewing gear box the two fixing ends are taken into consideration. A fixed support is given at the end of the mother housing. The load is acting inside of the housing. The torque of 103 kNm is applied to the inner surface of the housing in the z direction

MESHING

The mesh used in the analysis is fine mesh which has a surface area of 8.35e-003 m^2. The number of elements is 44000. The bolts and nuts are meshed in hexagonal meshing

5.3.1 FEA RESULTS

MODAL ANALYSIS

Modal analysis is the process of determining the inherent dynamic characteristics of a system in the form of natural frequency, damping and modal shapes. Modal analysis is carried out to find the modal shapes and the natural frequency of the slewing gear box.

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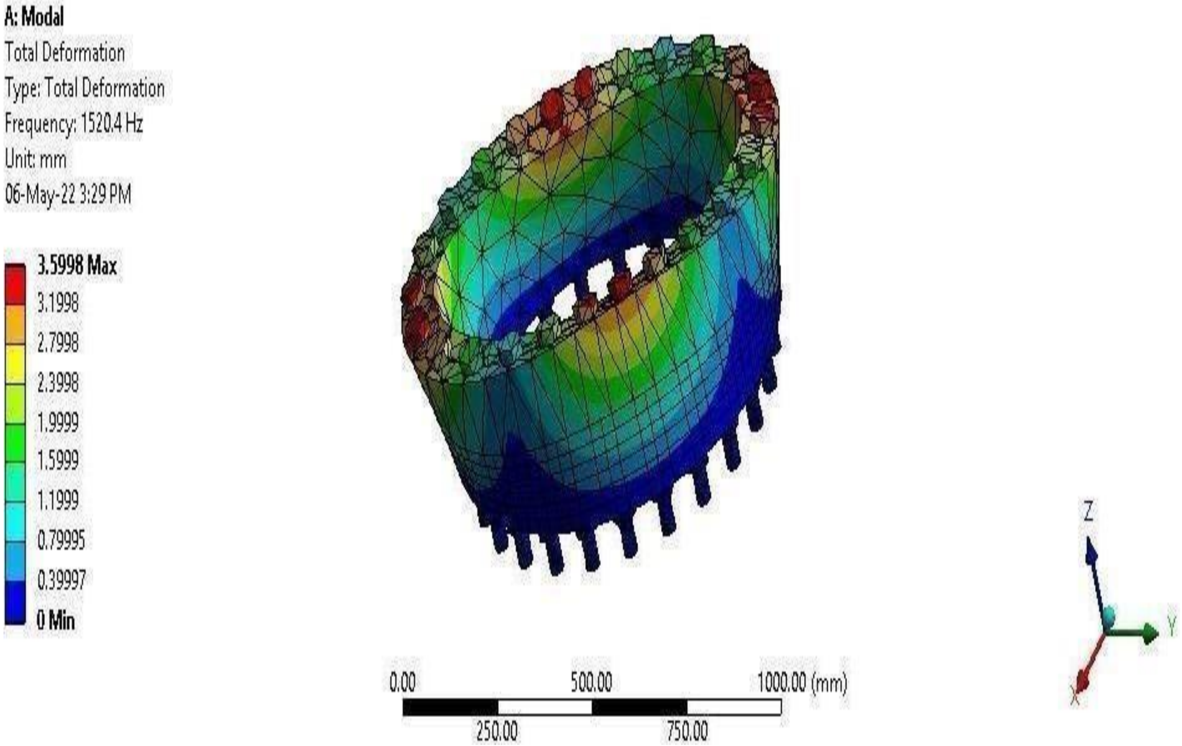

Figure: 5.5 Modal for Existing Model

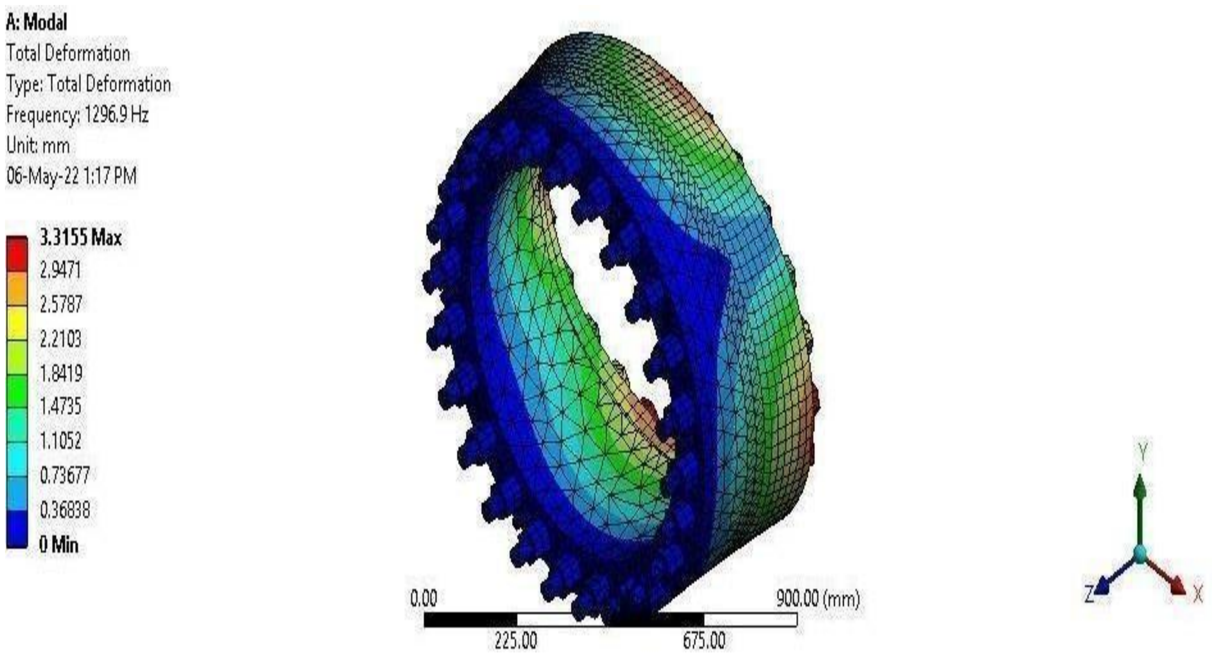

Figure: 5.6 Modal for Modified Model

The modal analysis existing model and modified model is shown in figure 5.5 and figure 5.6.

From the modal analysis it is observed that the modified model (1269.3 Hz) has higher frequency than the operating frequency, so there is no resonance occurring in the modified model.

STATIC STRUCTURAL

The stress analysis is carried out to ensure the strength of the housing. The equivalent stress of the existing model and modified are discussed below in the figure 5.7 and 5.8

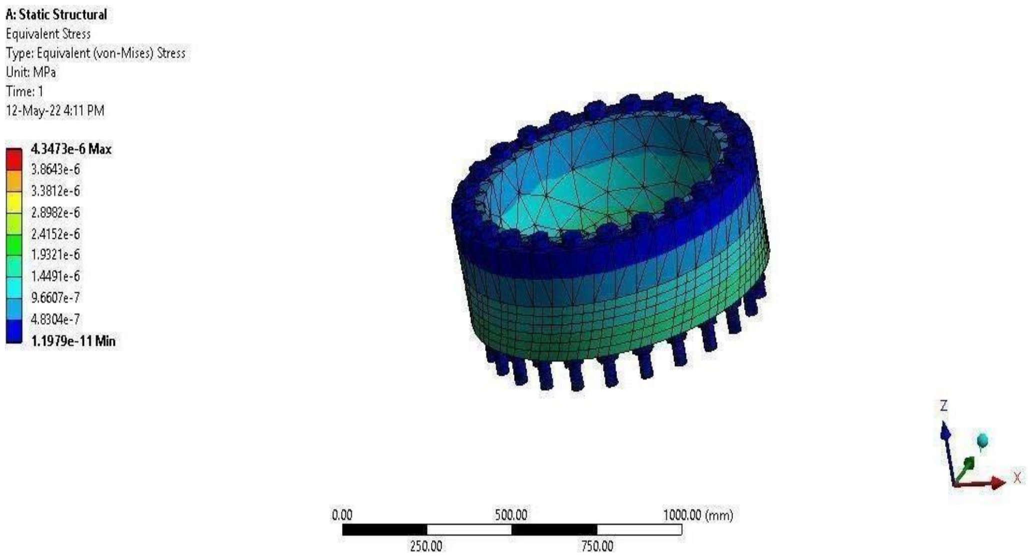

Figure: 5.7 Stress of Existing Model

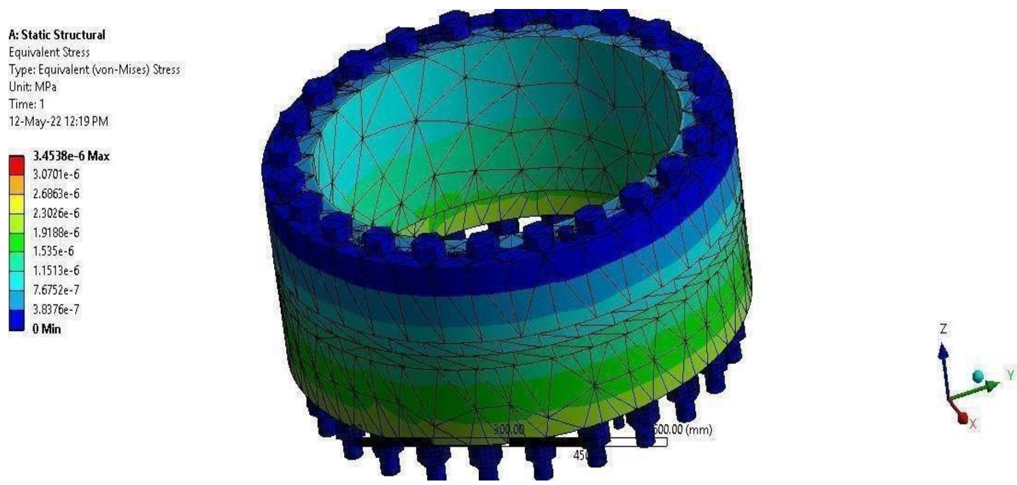

Figure: 5.8 Stress of Modified Model

From the two images, it is observed that stress does not damage the housing because the induced stress in both models is very much less than the safe stress. But in the modified model, the distribution of stress to the bolts is low because of the introduction of keyways. Hence, the bolts do not get loosened.

6. COST ANALYSIS:

Existing shaft and modified shaft manufacturing cost expected to be remained same or with marginal difference is obtained from NLCIL executives

The Bearing Cost For 23140 Cck/W33 = 38940 Rs

The Bearing Cost For 23144 Cck/W33 = 52815.17 Rs

The new plummer block cost is same as the previous plummer block (data given by department).

Output coupling manufacturing cost may remain the same/orwith marginal increase by considering the increase in bearing and Plummer block purchase value the cost involved is Rs 13875.17/-

7. CONCLUSION

- One of the main problems in spreader 116 is failure in belt drive drum assembly. The shaft cut was a major cause for the failure of belt drive drum assembly and hence suggestions are made to rectify the shaft failure with considering the weight of the drum and bearing. The diameter of the shaft at both ends has been increased from 180mm to 200mm. From the FEA analysis, it is found that the internal stress in the suggested model is 25% less than in the existing model. Hence the failure will be eliminated.
- Another main problem in spreader 116 is failure in the slewing gear box.The failure of the slewing gear box was oil leakage due to shearing of the bolts. To overcome this problem, suggestions are made. Torque arresting/transmitting ring plates (2 no’s) with keys are introduced. The joint between ring plates for the diameter of 900mm and its preceding joint had to be drilled for Additional fixing holes 6 no’s (diameter 20mm) for M20 bolts and Additional dowel holes 6 no’s (diameter 20 mm) for dowel pins diameter 20mm. From that, the loosening of bolts due to shear will get arrested. Hence, there is no leakage of oil intothe slewing gear box of the spreader.

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