Increasing the Efficiency of the TurntableSystem

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Abstract- *It is very important in Steel and Metal Industries to transfer ingots from one place to another. The turntable system is such a mechanism that assists the transfer and provides direction to the trolleys which contain heavy machinery and raw materials (ingots) to various parts of the plant. The maintenance and servicing of this system is very complex and expensive due to its design and weight. The weight concentration is also an important factor while considering the efficiency of the turntable system. The current system uses a hexagonal formation of wheel positioning. Due to this the load is not equally concentrated on all the wheels of the turntable system. This leads to failure of some of the bearings that are used to rotate the wheels while the rest are not fully used. Thus in this paper we have got a new idea of wheel positioning which can distribute loads on almost all the bearings and increase the life of the turntable system. Also the current system is open to the surrounding and thus during monsoons in direct contact to rain water. The water flows into the foundation of the turntable system and accumulates inside the system. As there is no way for the water to go out it keeps accumulating under the system. This accumulated water leads to formation of mud and comes in contact with the wheels. This creates an obstruction in the movement of wheels and in-turn requires more input from the motor to rotate the wheels which also decreases the efficiency of the entire turntable system. Thus in this paper we have focused on the drainage system which can help seep the water out from the turntable system and lead to smooth and efficient running of the system. Moreover the abstract idea is to find out the various factors that affect the efficiency and working of the turntablesystem.*

Keywords- Turntable, Bearings, Wheel Positioning, Drainage.

I. INTRODUCTION

Turntables are devices which are used for turning railroad rolling stock, usually locomotives, in order to change their direction. These devices are usually installed in industries and railway plants in order to turn a very heavy railroad vehicle from one direction to another. In certain industries like steel industries, there are items that are so heavy, that involving another vehicle to carry it increases the cost of operation. Also at times when heated elements are to be transferred it becomes quite difficult to perform the task. Hence railroad non-engine vehicles are made, which when pulled over by another vehicle, like tractor or a jeep, can be transferred to another location with ease. The heavy railroad vehicles have to be turned in order to change their direction and send them to the appropriate location where required. Hence in order to achieve this, Turntables are designed. This mechanism ensures safe transfer of material, however heavy, according to the load carrying capacity of the turntable system.

A. Mechanism of turntable system:

The turntable system is used to change the direction of the oncoming trolleys. It rotates with the help of a rope-drum mechanism which is driven by a motor. The motor is run by AC mains and is operated manually by the operator using power switches. Once the motor starts the force is transmitted through the rope drum with the help of wire ropes to turn the table. The wire ropes are wound around the circumference of the table. The rotation of the table is assisted with the wheels that are placed beneath the table. Generally six wheels are used in a turntable system. Each wheel contains a set of two bearings which helps the wheel to rotate and in-turn leads to turning of the table. The turntable rotates and after it reaches a predefined stop, the operator stops the rotation with the help of the switch and he manually puts the hydraulic locks on the turntable. The trolley carrying ingots is then transferred on the turntable with the help of a tractor by pulling action and the direction of the trolley can be changed using the turntable system for the trolley to go from one place toanother.

B. Working of turntable system:

The turntable system used in Steel Industries is an important mechanism which is used to change the direction of the oncoming trolleys or wagons carrying hot metal ingots and they are then further transferred from one place to another. The hot steel ingots are placed in the metal ingots which are then placed on the trolley/wagon. A tractor is used to pull the trolley carrying ingots and it places the trolley exactly at the center of the turntable. After the wagon is placed in the center of the system, hydraulic locks are applied to lock the system which prevents further or unnecessary movement of the wagon. The turntable is then rotated with the help of a motor which is used to drive the wheels for the rotation of the turntable. The motor is handled by switches and is operated manually by the worker. This rotation is used to change the direction of the wagon. After the specified location is achieved the rotation of the turntable is stopped manually and then the tractor pushes the wagon in a forward motion and takes it to its nextstop.

C. **Turntable Specifications**:

The given table no.1 is the detailed specifications of the turntable system as obtained from the company Mahindra Sanyo Special Steels Pvt. Ltd. (MSSSPL).

Table 1: Detailed Specifications of Turntable system [MSSSPL].

Parameters	Type/Material	Dimensions
Turntable plate	Iron	Self-weight – 7 tons Diameter –6m
Bearing	22220 spherical rollerbearing	OD x ID x t = 80 x 100x 46mm
Trolley	Iron	Weight = 35tons
Ingots	-	Weight = 3 tons/mould (8-10 moulds used)
Pneumatic Cylinder valve	Schrader valve	Bore diameter = 8in Stroke = 330mm Pistonrod diameter=45mm
Wirerope	High tensile fiber	D x I = 20 x 24000mm

II. FACTORS AFFECTING EFFICIENCY OF THE TURNTABLE SYSTEM

1. Bearing Failure

Failure of bearing is a very important aspect to be considered while talking about the efficiency of the turntable system. The failure of bearing can be due a number of ways such as Improper Mounting, Bearing Misalignment, Vibrations, Wear Rate, Improper Bearing Lubrication and Corrosion. Some of these factors are elaborated as givenbelow.

Due to Wear: As the period of use of the turntable increases, the bearing life starts reducing i.e. the more the use of the bearing more is the wear of the bearing. The anti-wear coating on the bearing begins to wear out with time, leading to a very low heat transfer capacity and increased friction leading to increased metal to metal contact. This leads to physical wear of the bearing. Also as the coating reduces with time the reaction of the metal of the bearing with various impurities such as chemicals and reagents that are very commonly found in industries, increases and also leads to wear [1]. Due to Unequal Load: Six wheels are used in the turntable system and they are placed in a hexagonal position. The trolley carrying ingots weights approximately 50 Tons. This trolley comes from one specific side of the rail on the turntable system and leaves through another specific side. Thus the load acting on these sides of the wheel is more as compared to the rest of the wheels. Thus these bearings tend to fail faster than the other bearings. The diagram below shows the hexagonal arrangement of the wheels in the turntable system. Fig 1 shows a schematic of the hexagonal wheel position which is being used currently in thesystem.

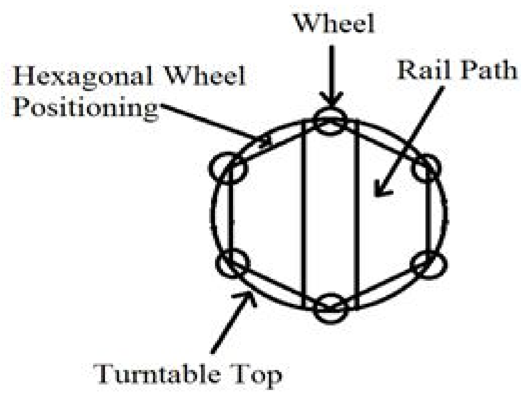


Fig 1: Schematic Diagram of Wheel Positioning [MSSSPL].

Due to Corrosion: Corrosion isanimportant factor leading to failure of bearing. As the turntable system is placed underground and there are always unavoidable crevices for the water over the ground to enter into the turntable pit. This water comes in contact with the bearing material and prolonged contact in presence of air leads to corrosion of the bearing materials and also removal of coating. Thus the smooth and efficient running of the bearing ishampered.

2. Drainage System

The water entering into the turntable system by any means travels into the foundation of the turntable system. As the system is placed below the ground, the water when comes in contact with the ground leads to formation of mud. This mud formation enters into the turntable system and comes in contact with the wheels. This mud obstructs the rotation of the wheels which leads to more use of the motor power. More power is needed to drive the turntable system which reduces theefficiency of the system. Also, the mud enters into the wheels and comes in contact with the bearings. This mud carries out the lubrication from the bearings which leads to increased friction of the bearings. This leads to reduction in the life of the bearings and in-turn affects the efficiency of the turntable system. Thus the water entering from the rains or by any other means needs to be drainedout.

III. AREAS OFIMPROVEMENT

Considering the failures of bearings and other areas of failure of the turntable system as mentioned earlier, there are some suggestions to overcome these failures and in-turn maintain and increase the efficiency of the turntable system. They are as follows:

1. CHANGE IN THE TYPE OFCOATING

A coating is a covering that is applied to the surface of the object, usually referred to as a substrate. The purpose of applying the coating is to reduce friction of the bearings and in-turn increase the life ofbearings.

DLC Coating:

DLC means Diamond like Carbon coating which has properties of both diamond and carbon which can be used for bearings. The composition of the coating is optimized on a flat AISI 52100 steel substrates based on ball-on-disc tribotest results in air, vacuum and dry nitrogen environments. The developed DLC coatings can be tailored to yield ultra-low friction values in vacuum (u=0.008). The average friction coefficient range obtained in humid air, dry nitrogen and vacuum for the range of applied loads were, respectively, 0.22 to 0.27, 0.02 to 0.03, and 1.7 to 0.013. Torque and life tests were conducted on pairs of angular contact bearings (type ED20) lubricated with DLC coating formulation 2 in vacuum as well as in air. It was observed that for the DLC coated bearings in air, relatively high bearing torques were generated that increase with running time, while the amount of coating wear generated during in-air operation appeared relatively light. In vacuum, low torques were generated after a prolonged running-in period, while low torque life exceeded that observed for MoS2 by a factor of abouttwo [2].

PVD Coating:

Table shows the properties of the PVD-coatings, which were deposited on the rolling bearings with the help of the magnetron- sputter-ion-plating (MSIP) process. The process temperature was held below the tempering temperature of the substrate (180– 220◦C). The loss of hardness is here less important than the change in accurate dimension. The bearings were coated by Lugscheider and Möller the companies Balzers (WC/C) and MetaplasIonon (W-C:H). The thickness of the coatings was between 2 and 3m. Moreover, some characteristic quantities of the coatings are stated in Table 2. A Berkovich diamond indenter tip was used to determine the hardness HV and the Young's modulus E of the coatings. The critical load Lc2 was determined in a scratch test, in which a Berkovich-indenter is moved over the coated surface with a discontinuous increase in the applied load. The critical load Lc2 is the test load, at which adhesion failures could be observed for the first time. The adhesive strength ("Haftklasse") of the coatings (1 = very good, 5 = insufficient) was measured with the method that is standardized in VDI 3198. A deep Rockwell-indentation with plastic deformation of the substrate is evaluated with regard to coatingfailure. The below Table 2 shows the mechanical properties of various coating [3].

Table 2: Mechanical Properties of the Examined Coatings [3].

Coating	Hardness (GPa)	Young's Modulus (GPa)	Critical Load (N)	Adhesiv e Strength
TiAIN	25	340	25	5
CrAIN	19	320	40	2
ZrN	14	320	25	3
ZrC	15	200	30	2-3
WC/C	12	150	70	1
W-C-H	12	169	40	1

2. Change in the type of bearing

A bearing is a machine element that constrains relative motion to only desired motion and reduce friction between moving parts. The design of bearing is such that it provides free linear movementof the moving parts or free rotation around a fixed axis, in our case thewheel, and it may also prevent a motion by controlling vectors of the normal forces that bear on the moving parts.

Spherical Roller Bearing:

This is the most traditional type of bearing that is currently being used. A spherical roller bearing is a rolling-element bearing that permits rotation with low friction, and permits angular misalignment. Typically these bearings support a rotating shaft in the [bore] of the inner ring that may be misaligned in respect to the outer ring. The misalignment is possible due to the spherical internal shape of the outer ring and spherical rollers. Despite what their name may imply, spherical roller bearings are not truly spherical in shape. The rolling elements of spherical roller bearings are mainly cylindrical in shape, but have a profile that makes them appear like cylinders that have been slightly over- inflated.

Some common materials for bearingcages:

- Sheet steel (stamped or laser-cut)
- Polyamide (injection moulded)
- Brass (stamped ormachined)
- Steel (machined)

The choice of material is mainly done by the manufacturing volume and method. For large-volume bearings, cages are often of stamped sheet-metal or injection molded polyamide, whereas low volume manufacturers or low volume series often have cages of machined brass or machined steel. For some specific application, special material for coating (e.g. PTFE coated cylindrical bore for vibratory application) is adopted.

Hydrodynamic Foil Bearing:

Hydrodynamic Foil bearings, also known as foil-air bearings, are a type of air bearing. A shaft is supported by a compliant, spring-loaded foil journal lining. Once the shaft is spinning fast enough, the working fluid (usually air) pushes the foil away from the shaft so that there is no contact. The shaft and foil are separated by the air's high pressure which is generated by the rotation which pulls gas into the bearing via viscosity effects. A high speed of the shaft with respect to the foil is required to initiate the air gap, and once this has been achieved, no wear occurs. Unlike aero or hydrostatic bearings, foil bearings require no external pressurization system for the working fluid, so the hydrodynamic bearing is self-starting. Fig 2 shows a schematic of a hydrodynamic foil bearing [4].

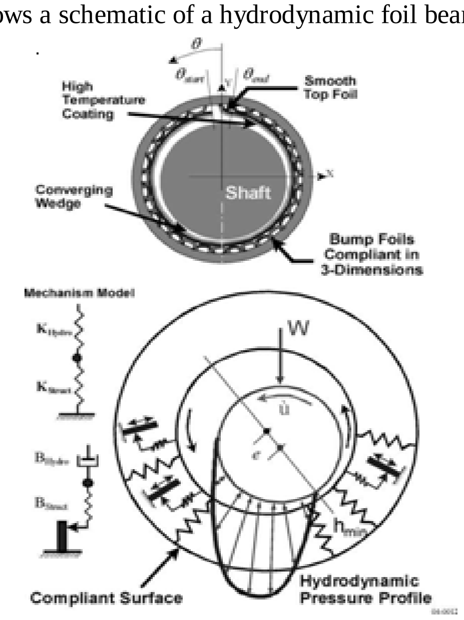
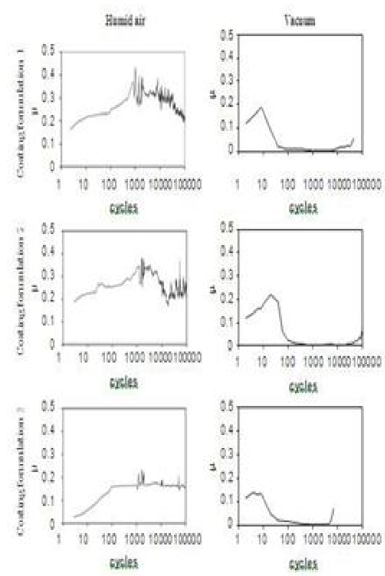


Fig. 2: Schematic of Hydrodynamic Foil Bearing[4].

The figure above is a schematic of a Hydro-dynamic Foil Bearing which shows the Hydrodynamic pressure profile and all the mechanism models about the bearing. The figure shows that the high temperature coating such as Korolon 700, Korolon 800 or Korolon 1350 A can be used in the inner side of the top foil of the bearing whereas a DLC coating can be used to cover the outer top foil of the bearing as a coating. While the tribological behavior of Korolon coatings was determined to be a function of temperature, in most cases a minimum coefficient of friction less than 0.1 was observed during start-up/shutdown periods.

Based on the measured coefficient of friction and post-test visual inspection of the mating surfaces, the hard chrome coating proved unacceptable for high-temperature applications due to extensive surface cracking. The other disk coatings exhibited excellent tribologicalperformance.

The following results were obtained for number of cycles considering 3 types of formulations for Hydrodynamic Foil Bearings in Humid air and Vacuum:



Graph 1: life cycle of different coating formulations[4].

In Graph 1 we can observe that the graph is on Coating Formulations which was being prepared by the researchers in the paper observed. The test was based on coating formulations vs. the number of cycles which states that for what coating formulation the applied on the Hydrodynamic Foil Bearing how many cycles will the bearing withstand without getting worn out.

After the tests performed on the Hydrodynamic Foil Bearing it was observed that all the three formulations have a lifetime of over 100,000 cycles in air. For coating formulation 1 & 2, the coefficient of friction was varying considerably during the entire test being performed whereas the coating formulation 3 had a very stable coefficient of friction of 0.17.

None of the coating formulations never showed a wear track depth of 0.6um which constitutes half the amount of the coatingthickness.

3. Change in the BearingMaterial

Bearings made of Chrome Steel – SAE 52100 is the most common material used to produce the load carrying components in precision ball bearings, roller bearings, and tapered roller bearings is 52100 chrome steel. These components are the bearings inner and outer rings, balls androllers.

Use of Silicon Nitride Balls andRollers:

Use of nitride balls instead of traditional steel balls used in bearings and the found out that there is a cross over between the life obtained with the silicon nitride materials and the bearing steels, at lower stress level the Silicon Nitride Bearings will produce longer life than bearing steel. The following conclusions were obtained viz. an all-steel bearing under the same load will have a longer life than the equivalent hybrid bearing under nominal operating speeds and similar environments [5]. Life factors derived for hybrid bearings based upon the Lundberg- Palmgren equations are dependent on the bearingtype. The following equation is used to find the life span of a bearing in 10,000 rotations [6].

$$L_{10} = [C_D/P_{eq}]^P$$

Where

C_D– Dynamic Load
Capacity (N) L10 – 10
Percent Life
P_{eq} – Equivalent Radial Load
P – Load LifeExponent

The life factors for deep-groove, angular-contact, and cylindrical roller hybrid bearings are 0.42, 0.59, and 0.72, respectively [7]. These life factors are multiplied by the calculated life of an all- steel bearing using the Lundberg-Palmgren formula to obtain the hybrid bearing life. 3. The Lundberg-Palmgren equations under predict bearing life. Under nominal operating speeds, the resultant calculated lives of the deep-groove, angular-contact, and cylindrical roller hybrid bearings with races made of post-1960 bearing steel increased by factors of 3.7, 3.2, and 5.5, respectively, from those calculated using the Lundberg-Palmgren equations.

4. Implementation of DrainageSystem

Drainage is the natural or artificial removal of surface and sub- surface water from an area. The water gets drained out from the area and doesn’t allow accumulation of water in thatarea.

Radially Outward Drainage System:

Radially Outward Drainage Pattern consists of streams that extend radially from a central zone. It is typical of the patterns developed on freshly constructed landforms and on areas of domed uplift. In our case, Radial Drainage System suits the best. The water that gets accumulated under the turntable leads to mud formation and obstructs the rotation of wheels. This wheel obstruction leads to decrease in the efficiency of the turntable. Also the bearings inside the wheels are obstructed and thus they wear out quickly[8]. Thus more power is used by the motor to drive the wheels which leads to decreasing the efficiency of the turntable system. Thus radial type drainage system can be used. A Radially outward type of drainage system is shown in Fig 3.

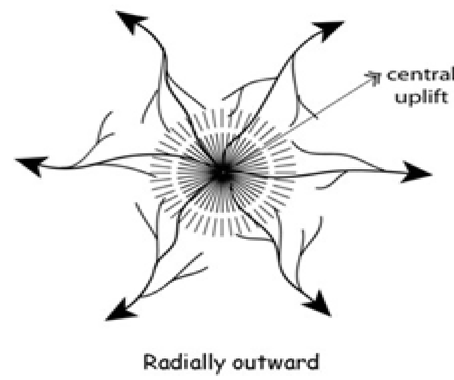


Fig 3: Radially Outward Drainage System[8].

The water will seep through the sides of the of the center point under the turntable system. This water can be drawn out from the system with the help of pipes or hoses using manually controlled motor. The motor will help suck the water out from the system with the help of a pipe and drain it out from the system. As it is manually worked, it can be done at any point of time thus leaving the turntable system and its components free and keeping it away from the contact of water or mud. This will in-turn increase the efficiency and allow smooth working of the turntable system.

Dendritic Drainage System:

In Dendritic Drainage System shown in Fig 4, there are many contributing streams (similar to the twigs of a tree), which are then joined together into the tributaries of the main river (the branches and the trunk of the tree, respectively) [9]. They develop where the river channel follows the slope of the terrain. This type of drainage system can also be used in the current application of the turntable system.

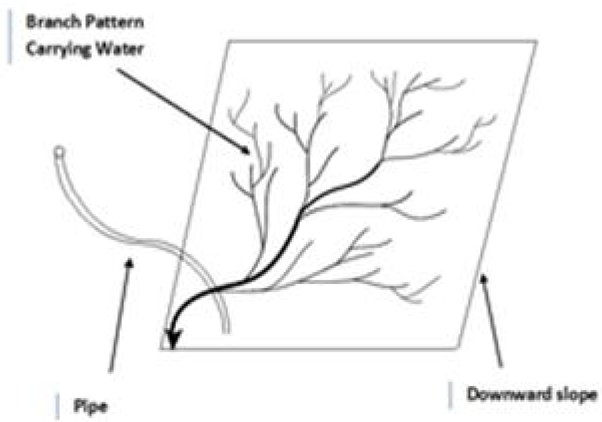


Fig 4: Dendritic Drainage System[9].

Dendritic Drainage pattern forms a slope of land and the side to which it is tilted can be used to drain the water out. The water can never come in the reach of the turntable or its components due to the slope. The collected water at the end of the slope can be drained out the same way as in radial type of drainage system i.e. with the help of motor and suction pipe leaving the turntable system free ofwater.

V. CONCLUSION

In this paper we have given a brief detail about the Turntable System, its mechanism and working. We have also specified the specifications of the turntable system on which the work is being carried. Moreover, we have discussed about the causes that lead to reduced efficiency of the turntable system. We have also selected and detailed on the areas of improvement which we are going to work on to increase the overall efficiency of the Turntable System.

From the above information provided, we can see that the main reason for decreased life and efficiency of the bearing is due to failure due to wear, unequal loading and corrosion. We have also given the effects on the turntable efficiency due to the absence of drainagesystem.

Considering these reasons of reduced efficiency of the turntable system we have suggested various fields of improvement such as Change in the type of coating, change in the type of bearing, change in bearing material and implementation of drainage system.

From these above suggestions we can see that the use of DLC and PVD Coating helps to reduce wear and creates smooth rotation of the bearings. Also change of bearing from 22220 Spherical Roller Bearing to Hydrodynamic Foil Bearing can increase the life of the turntable system by a considerableamount. Moreover, the implementation of drainage system either Radial type or dendritic type can eradicate the problem causing due to accumulation of water and formation of mud which obstructs the rotation of wheels. Using any of the drainage systems can be used to drain the water out of the system and in-turn increase the efficiency of the turntablesystem.

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