

# Study on the Effects of Weights and Speed on Rolling Bearings in Belt Conveyor System

Abhishek George J<sup>1</sup>, Arun Kumar P.C<sup>2</sup>

<sup>1</sup>P.G student, Department of Mechanical Engineering, Ramaiah Institute of Technology, Bangalore, India

<sup>2</sup>Associate Professor, Department of Mechanical Engineering, Ramaiah Institute of Technology, Bangalore, India

**ABSTRACT:** In an industrial sector one of the most important component is the conveyor system. Belt conveyor is a commonly used equipment for continuous transport which has high efficiency, large conveying capacity and simple construction. The application of methods of technical diagnosis in the maintenance of belt conveyors is becoming an important issue for effective utilization of the machines. Any fault or damage in the system would result in complete shutdown of the operations depending on the extent of damage. Vibration analysis is proven to be an effective tool against machine failure, getting early signs of faults in moving parts. A study was carried out on a conveyor test rig to diagnose the vibrations developed on the rolling bearings of the head pulley. The rig was operated at various speed and weights placed at certain inter-distances. The vibrations along the x-axis was captured using FFT analyser and by performing ANOVA analysis, the parameter that influences the most on vibrations was determined. Further, FEA was applied to analyse the stress developed for the different working conditions.

**KEYWORDS:** Rolling Bearings, Vibration Monitoring, Design of Experiments (DOE), FFT Analyser, ANOVA, Finite Element Analysis (FEA)

## I. INTRODUCTION

A conveyor system is a material handling equipment that transports materials from one location to another. They are specifically used in applications involving the movement of heavy or bulky materials. There are many types of conveying systems available, and they are used according to the needs of different industries. A belt conveyor system is one of the types of material handling equipment under the many different categories of conveyor systems. The management will not introduce new technology until and unless they believe that the new technology will provide savings in operating costs or improve work safety which on the long run lowers the operating costs. The industry makes a high investment on getting the conveyor system to the industry [1] and failure to the system will incur high losses to the industry.

## II. LITERATURE SURVEY

There are many reasons for the breakdown of the conveyor system. Failures occur in pulleys, idlers, electric motors, gear-box [2] etc. All the machines manufactured tend to vibrate and these vibrations are caused due to the tolerances that are given by the machine designer while developing the machine, since some dimensional variations are certain in any machine's manufacture. Vibration is normally a natural product of dynamic and mechanical forces within a machinery, plant equipment and different process systems. Even during normal operating conditions, all machines tend to develop some level of vibrations [3-4]. Vibration Analysis when applied in an industrial sector or any condition monitoring facility, reduces the maintenance costs and downtime by detecting equipment faults at their initial stages. Vibration Analysis plays an important part in condition monitoring as it helps in preventive maintenance. According to RadoslawZimroz and Walter Bartelmus [5], by using adaptive filters while performing vibration monitoring on the shaft it cancels the noise and captures only the necessary vibrations – rolling bearing vibrations. According to David J. Kruse [6] there are different types of field measuring equipment that are used for data acquisition in a conveyor system – data acquisition system (daqs), magnetic pickup sensor and optical encoders. According to Jacek Dybala and RadoslawZimroz [7] empirical based decomposition (EDM) is the best method to acquire vibration

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signals from the rolling bearing. The acquired data from the vibration instruments can be analysed statistically by using analysis of variance (ANOVA) classifying and cross classifying the statistical results using which the tests are performed to check whether there is any difference in the means. From the test results ANOVA determines whether the classification made affects the given result or not. [8]. Finite element analysis plays an important role in determining the stress developed on the parts of conveyor system. Harshavardhan A. Kadam and Nilesh S. Hyalij [9] have used finite element analysis to determine the failure of the pulley shaft of the conveyor system when inclined at 17° and failure was observed on the shaft, end disks, bushes and gearbox.

### III. EXPERIMENTATION

The input parameters – weights (A), inter-distance (B) and speed (C) was developed according to 3<sup>3</sup> factorial design. Vibrations from the rolling bearings was considered as the output parameter.

Table 1: Input parameters along with their levels

Levels	Weights (A) (kg)	Inter-distance (B) (cm)	Speed (C) (RPM)
1.	20	40	24
2.	40	60	30
3.	60	80	36

The accelerometer was mounted on the plummer block casing which captures the vibration along the x-axis. It is connected to a FFT analyser, which receives the signal. The FFT analyser then converts the received signal into AC waveform and then displays it on to PC system consisting of the software to analyse the waveform and finally expresses it as the RMS value, forming the basis for vibration measurement in this study and the setup is shown in fig.1.



Fig.1 Accelerometer mounted on plummer block casing

The weights of 20kg (5kg plates x4) as shown in fig.2 were placed on the belt of the rig at 40cm apart (end to end distance) and with the help of the control panel the speed was set at 24RPM. The vibrations developed from the bearings were captured by the FFT analyser with the help of accelerometer mounted on the casing of the plummer block. The experimentation was conducted likewise for the remaining 26 trails where for 40kg – 10kg plates x4 and 60kg – 15kg plates x4 was used and the results were obtained.

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Fig.2 Weights on the belt

### 3.1 Geometric Modelling

The cad model of the head pulley along with the plummer block was developed according to dimensions as shown in table.2 using Solid Edge ST8.

Table.2 Pulley and Rolling Bearing Dimensions

Cylinder diameter	800mm
Cylinder thickness	37mm
Disc diameter	753mm
Shaft diameter	183mm
Shaft length	1581mm
Cylinder length	668mm
Ball diameter	37mm
Number of balls	32
Outer diameter of bearing cage	259mm
Inner diameter of bearing cage	213mm

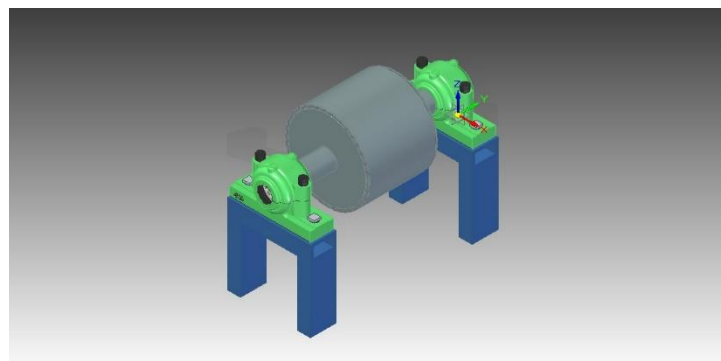


Fig.3 CAD model of the pulley assembly

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The Fig.3 shows the CAD model of the pulley assembly developed using the software.

### 3.2 Finite Element Analysis

The cad model developed was extracted into Ansys R18 software to carry out linear static analysis for different working conditions (weights and speeds) of the test rig. The principle axis was taken along the x-axis.

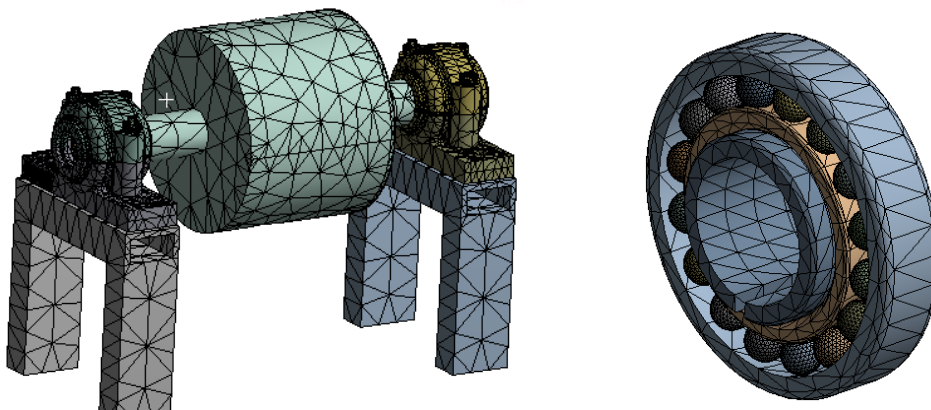


Fig.3 Meshed model of the pulley assembly and the bearing

The model was refined meshed with tetra mesh element. The total number of nodes were 424684 and elements were 269043 having an element size of  $4 \times 10^{-3}$  m. The balls of the rolling bearings were the main object of interest and there were 64 balls in both the rolling bearings as shown in fig.3.

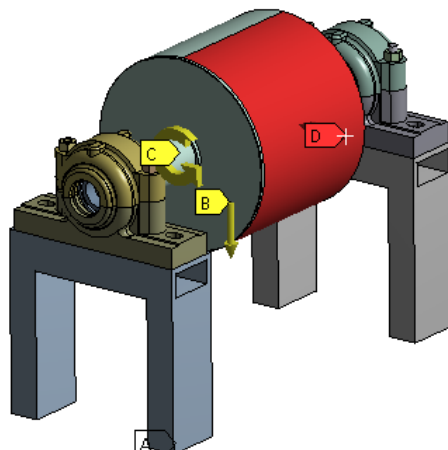


Fig.4 Loading and boundary conditions

The stand on which the rolling bearings are mounted was set as a fixed support, represented as “A” in the figure. The next consideration was the standard earth’s gravity acting on the pulley represented as “B”. The rotational movement of the pulley, represented as “C” defines the speed at which the pulley is rotating. The loading condition was given along the x-axis wherein one half of the pulley was taken into consideration. This is due to the fact that as the pulley rotates at a certain speed having a particular weight on the belt, the pulley gets pulled along the x-axis because of the weight. As the shaft has to remain straight, stresses and deformation on the shaft occur which in turn affects the bearings.

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## IV. RESULTS AND DISCUSSIONS

ANOVA analysis and FEA analysis was carried out for the study.

### 4.1 ANOVA

Statistica software was used to perform the ANOVA analysis to determine the influence of weights, inter-distance and speed on vibrations produced from the rolling bearings along x-axis.

Table.3 ANOVA results for vibration in x-axis

Factor	SS	df	MS	F	p
(A) Weight	0.0002919	2	0.000109	1.172335	0.333461
(B) Distance	0.000123	2	0.000062	0.662212	0.528515
(C) Speed	0.001307	2	0.000654	7.011891	0.006017
A*B	0.000169	1	0.000169	1.816716	0.195393
A*C	0.000122	1	0.000122	1.309291	0.268379
B*C	0.000020	1	0.000020	0.210912	0.651871
Error	0.001585	12	0.000093		
Total SS	0.003545	26			

The analysis which has been carried out indicates the influence of the input parameters on the vibrations along x-axis. Table.3 indicates the analysed values and the ‘f’ and ‘p’ values are mainly used in determining the most significant influencing parameter on vibration. From the analysis, ‘f’ maximum and ‘p’ minimum values are the highest for speed thus making it the most influencing parameter than the other two input parameter.

### 3D Scatter Plots for vibration along X-axis

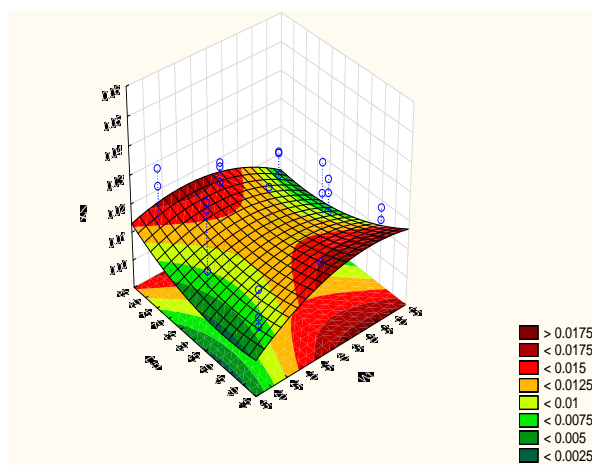


Fig.5 3D scatter plot for speed 24RPM

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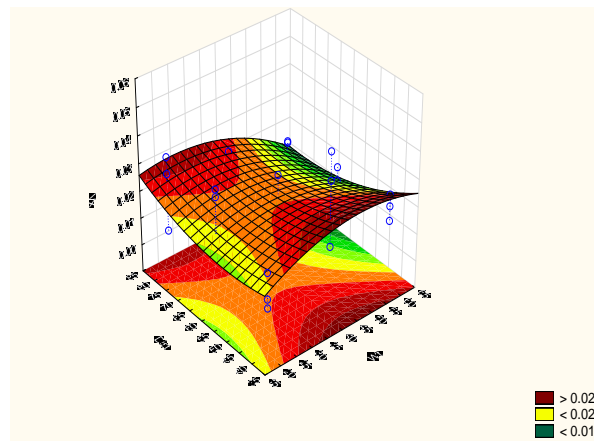


Fig.6 3D scatter plot for speed 30RPM

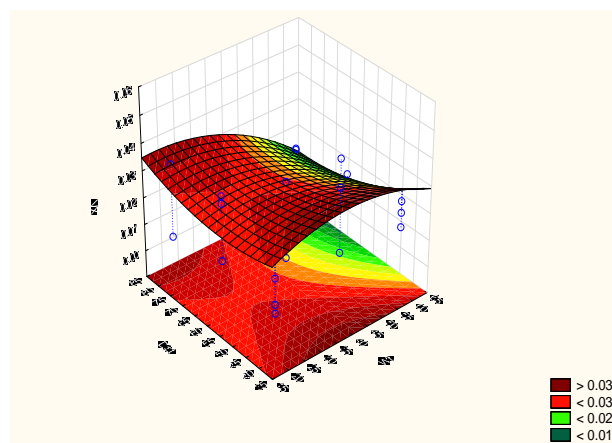


Fig.7 3D scatter plot for speed 36RPM

The fig.5, fig.6 and fig.7 shows the plots between weight and inter-distances and their corresponding response on vibration for three speeds – 24RPM, 30RPM and 36RPM of the conveyor test rig. For lower weights on the belt placed at small inter-distances vibrations tend to increase. As the speed is increased from 24RPM to 30RPM, there was an increase in vibration on the bearings and similarly an increase in vibration at speed 36RPM for the same condition. The vibrations are developed due to looseness on the belt causing an increase in belt tension which affects the pulley which in turn affects the bearings. When the weights are placed evenly on the belt, the belt tension is reduced thus reducing vibrations on the bearings.

## 4.2 FEA Analysis

Linear static analysis was carried out on the model for a working condition where the speed of the rotating shaft was set at 30RPM and the belt carrying a weight of 60kg by applying a force of 24032N along x-axis. The deformation and stress developed on the rolling bearings were found out along x-axis as the deformation and the stress on the bearings are more due to weights and the rotating speed of the pulley.

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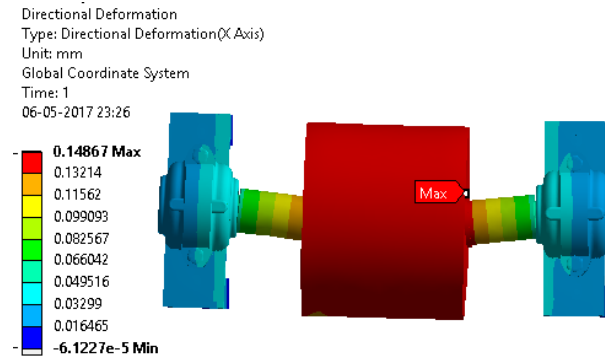


Fig.8 top view of stress along x-axis

Fig.8 shows the directional deformation along the x-axis. As the test rig continues to operate under speed 30RPM and 60kg weight, the pulley tends to move along the x-axis due to the force acting on it. The deformation is very much negligible but on continued operation will cause damage.

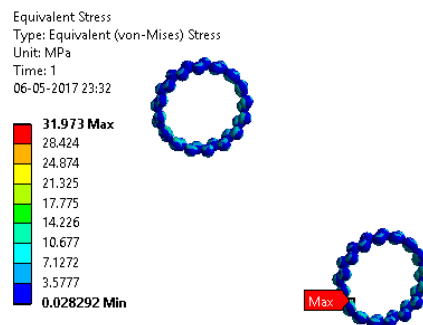


Fig.9 Von mises stress on the bearings

The maximum von-mises stress developed on the bearings was about 31.97MPa. This was formed at the side of the unit. The reason is that the weights exert a pull force on the pulley. The shaft also gets pulled which in turn exerts force on the bearings.

The DOE was developed in ansys to determine the stresses developed on the bearing for different weights and speed as show in fig.10. The force and speed are used as input parameters and the resulting stress on the bearings forms the output parameter thus predicting the stress for different working condition.

Outline of All Parameters				
	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	Gravity (B1)			
4	P2	Rotational Velocity Magnitude	25	rev min <sup>-1</sup>
5	P4	Force X Component	24032	N
*	New input parameter	New name	New expression	
7	Output Parameters			
8	Gravity (B1)			
9	P3	Equivalent Stress Maximum		MPa
*	New output parameter		New expression	
11	Charts			

Fig.9 DOE for different working conditions

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## V. CONCLUSION

Anova analysis shows that speed is the most influencing parameter affecting vibrations than the other two inputs and by using the DOE developed in analysis, the stresses on the bearings for different working conditions – weights and speed can be predicted for optimal usage of the system.

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