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Effect of Eccentricity on Power Consumption of a Three Bolt Flange Coupling with Variation of Speed and Braking Torque

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Abstract - *Eccentricity is one of the most possible causes of vibration in machine components. Couplings with eccentricity error always cause more vibrations and generate excessive force in bearing area, hence ultimately increase power consumption by the machine components which are undesirable. Eccentricity error of coupling means the centerline of driving and driven shaft are not co-axial. A three bolt flange coupling was used to predict the values of power consumptions for no error condition and eccentricity error condition at a speed range of 800 rpm to 1800 rpm and braking torque of 1N-m to 3.2N-m. P-values and F-values are determined from ANOVA table by using Response Surface Methodology (RSM). The correlation among speed, braking torque and power consumption was analyzed from P-values. Power consumption values of three bolt flange coupling with no error and eccentricity error were compared.*

***Key Words*:** *Three bolt flange coupling, Eccentricity, ANOVA, Response Surface Methodology (RSM)*

1. INTRODUCTION

In fact, couplings are the most critical parts of any transmission system as they transmit power from drive to driven shaft smoothly .But to satisfy the above condition the two shafts must be aligned properly .However due to eccentricity effect of coupling the variation in speed of the drive and driven shaft is occurred which leads to severe vibration in the machine components .As a result of which the power consumption is increased by several times .Although eccentricity is a manufacturing defect in most of the cases, it is epidemic for the machine components .

1.1 Three Bolt Flange Coupling

The flange coupling is made up of two halves; one half with inset centring recess and one half with elevated centring collar. The two halves of the flange are held together by three bolts.

Fig.1

1.2 Literature Review

Effects of coupling misalignment on vibrations of rotating machinery which was performed by Sekhar AS et al.[1] suggested that the misalignment of shaft causes severe vibrations in the machine parts which ultimately affects the power consumption by the components. Flexible Coupling a New Approach by Deshmukh N.S et al.[6] gave some brief ideas about the accommodation of misalignment in couplings. Further Failure Analysis of Flange Coupling In Industry by Pasarkar M.D et al.[8] explained about the failure of flange coupling due to some design criteria like RPM, torque, misalignment, stiffness , inertia etc. Idea of implementation of surface response methodology was taken from Abidin A.R.Z et al.[10] and Nanda B.K et al.[11].

Failure Analysis of a Misaligned and Unbalanced Flexible Rotor by Haddar M. et al.[12] developed a generalized system equation for misalignment and unbalanced coupling. A Comprehensive Cause Analysis of a Coupling Failure Induced By Torsional Oscillations in a Variable Speed Motor by Whitney Robert et al.[9] warned about the coupling failure due to torsional resonance. In this paper general method of experiments were adopted in order to provide a comparative analysis of power consumption due to eccentricity effect in coupling. No error coupling was taken as baseline for this comparisons. All the analysis were done by using Response Surface Methodology. The value of power consumption can be significantly reduced by avoiding the eccentricity error in three bolt flange coupling.

2. EXPERIMENTAL

The experimental setup is shown in the fig.1.It consists of brake and load unit, elastic spare ring Coupling, bearing block with rigid bearings, reflective mark, short shaft, bearing block with elastic bearings, acceleration sensor, three bolt flange coupling, drive unit and reference sensor. The drive unit is fitted on the clamping plate and is connected to control unit .The control unit is connected to power supply. Three bolt flange coupling which is to be investigated is secured in between the drive unit and shaft. The bearing block with elastic bearing is loosely fitted onto the clamping plate and is flushed in front of drive unit .The short shaft is slid through the bearing block with elastic bearings. Then the first setting ring is slid onto the short shaft in such a way that the shaft can subsequently be fixed in place on the bearing block with rigid bearings. Setting ring is provided on each side of bearing block. The short shaft with both bearing blocks is slid on to the coupling so that the coupling can be connected to the shaft. The position of short shaft is secured to the bearing block with rigid bearings. Possible lateral misalignment is minimized to align and secure the drive unit and bearing blocks. The setting rings on the bearing block are aligned with rigid bearings. The brake and load unit is placed onto the clamping plate in such a way that the elastic spacer ring coupling can be used to offset the misalignment of the shafts. The short shaft and the brake and load unit are connected to the elastic spacer ring coupling. The acceleration sensors are attached to the bearing block with elastic bearing. The reflective mark for the reference sensor is attached on the shaft. Reference sensor is fitted with magnetic clamp and is roughly aligned with the reflective mark. Acceleration sensor and reference sensor are connected to the measuring amplifier. The measuring amplifier is connected to the PC via the USB measurement box.

Fig.2

For the above experiment speed and braking load are taken as input parameters in order to obtain power consumption as response .A speed range of 800 rpm to 1800 rpm and braking load 1N-m to 3.2N-m are taken to perform the experiments. Response Surface Methodology is applied in order to find out different speed and braking load values within the given range.

The brake control unit is connected to the power supply. Electrical connection is set up between the brake and load unit and brake control unit. The power supply for measuring amplifier is connected. The PC is switched on and pre-installed PT 500.04 software is started .The experiment is performed for thee bolt flange coupling with no error. The speed and braking load values which are obtained from RSM are feed by base unit and brake and load unit. The displayed speed value is checked on the PC whether it is same as the input value on base unit or not. Then braking load is provided from load unit .The value of power consumption is displayed on the base unit and is noted down. The same experiment is performed by taking three bolt flange coupling with eccentricity error.

3. RESULTS AND DISCUSSIONS

The experimental values of power consumption were obtained for three bolt flange coupling with no error and with eccentricity error which is shown on table1. A correlation among power consumption, speed and braking torque was obtained in terms of coded equation for both the couplings with no error and with eccentricity error which are given in equation 1 and 2 respectively. The equation in terms of coded factor can be used to make predictions about the response for given levels of each factor. The coded equation is useful for indentifying the relative impact of the factors by comparing the factor coefficients. The coded equation was developed by using Response Surface Methodology.

Power consumption=$190.68+52.7*A+85.50*B+19.75*AB+5.75*A^2+31.29*B^2$ (Equation 1)

Power consumption=$208.21+66.33*A+94.00*B+26.25*AB+14.68*A^2+26.68*B^2$ (Equation 2)

Where, A indicates speed and B indicates braking load.

ANOVA tables were derived by applying RSM for both three bolt flange coupling with no error and eccentricity error which are shown in table 2 and 3 respectively. There is only 0.01% chance that an F-value this large could occur due to noise .P-values less than 0.0500 indicate model terms are significant. In this case A, B, AB, A^2, B^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Table1: Value of Power Consumption of Three Bolt Flange Coupling

Speed (rpm)	Braking Torque(N-m)	Power Consumption (Watt) with No Error	Power Consumption (Watt)with Eccentricity Error
1300	1	130	142
800	3.2	243	260
1800	2.1	248	290
800	1	114	118
1300	2.1	192	210
1300	2.1	192	210
1300	3.2	306	317
1300	2.1	192	210
1800	3.2	385	439
1300	2.1	192	210
1300	2.1	192	210
800	2.1	137	145
1800	1	177	192
1300	2.1	192	210

Table 2: ANOVA for No Error Coupling

	Sum of Squares	df	Mean square	F-value	P-value	
Model	66055.26	5	13211.05	799.63	<0.0001	significant
A-Speed	16642.67	1	16642.67	1007.34	<0.0001	
B-Braking Torque	43861.50	1	43861.50	2654.82	<0.0001	
AB	1560.25	1	1560.25	94.44	<0.0001	
A^2	95.12	1	95.12	5.76	0.0432	
B^2	2774.75	1	2774.75	167.95	<0.0001	
Residual	132.17	8	16.52			
Lack of Fit	132.17	3	44.06			
Pure Error	0.0000	5	0.0000			
Cor Total	66187.43	13				

Table3: ANOVA for coupling with Eccentricity Error

Source	Sum of Squares	df	Mean square	F-value	P-value	
Model	86469.93	5	17293.99	341.61	<0.0001	significant
A-Speed	26400.67	1	26400.67	521.50	<0.0001	
B-Braking Torque	53016.00	1	53016.00	1047.24	<0.0001	
AB	2756.25	1	2756.25	54.45	<0.0001	
A^2	610.30	1	610.30	12.06	0.0084	
B^2	2016.30	1	2016.30	39.83	0.0002	
Residual	405.00	8	50.62			
Lack of Fit	405.00	3	135.00			
Pure Error	0.0000	5	0.0000			
Cor Total	86874.93	13				

The variation of power consumption with changing value of speed and braking torque were analyzed for three bolt flange coupling with no error and with eccentricity error which are shown on the figure 3 and 4 respectively.

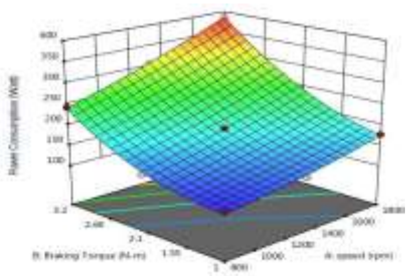

Fig.3

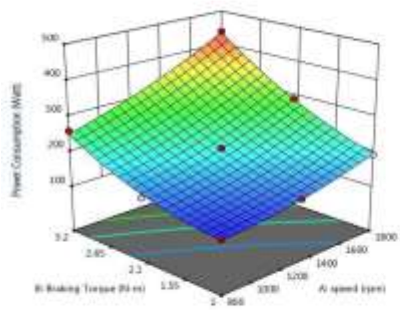

Fig.4

4. Conclusion

The model of a three bolt flange coupling with eccentricity error was analyzed with experimentation. Throughout the experiment the validity of the setup was checked thoroughly and was succeeded. The experimental values of power consumption were obtained. The maximum value of power consumption was recorded at a speed of 1800rpm and braking torque of 3.2N-m for eccentricity condition. It has been noticed that the value of power consumption in case of coupling with eccentricity error is always greater than that of coupling with no error, which indicates that the experimental analysis is in good agreement with maintenance and condition monitoring techniques. A correlation among speed, braking torque and power consumption was obtained in terms of quadratic equation. The validity of the equation was checked from the P-values of ANOVA table which was obtained by using Response Surface Methodology. It was found that the correlation is 99.99% valid with the experimental values. Based on this experiment the value of power consumption of flange coupling in industries in different speed range and braking torque can be evaluated and the stability of the components can be checked pretty easily.

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