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DIAGNOSIS OF THE UNBALANCE BY USING SHAFT DEFLECTION MEASUREMENT

KOLAGOTLA VENKATESWARAREDDY[1], G.DIWAKAR[2], P.RAVI KUMAR[3]
DEPARTMENT OF MECHANICAL ENGINEERING
[1,2,3] PVP SIDDHARTHA ENGINEERING COLLEGE, VIJAYAWADA, ANDHRA PRADESH

ABSTRACT: Till now Engineers use vibration transducer FFT (Fast Fourier Transform) to measure the Unbalance, Misalignment etc. But these are costly equipment and skilled persons are required to diagnose the problem.For diagnosis of machine engineers need to go near by the machine and has to take the readings for analysis and instruments need to contact with the machines.
Whereas, in the proposed techniquethe presence of unbalance can be measured by sitting in the control room. The condition monitoring can be converted in to a continuous monitoring.This paper inspects the unbalance at the overhang disk by analyzing the deflection curve. The unbalance in machines can cause decrease in efficiency and in the long-run it may cause failure because of unnecessary vibration, stress on motor, bearings and short-circuiting in stator and rotor windings. In this study, authors investigate the onset of deflection at different points on the shaft and overhang portion. From that deflection, the authors draw a curve through these deflection points and measure the how much amount of unbalance present at the disk. Verification of shaft alignment is done by precision laser alignment kit. Result shows that unbalance and misalignment is the parameter that is more responsible for the cause of instability.
Key words: Induction motor, Unbalance, Deflection, Continuous monitoring

INTRODUCTION

The studies of induction motor behavior during abnormal conditions due to presence of unbalance and the possibility to diagnose these abnormal conditions have been a challenging topic for many research engineers. Rotating machines cover a wide range of critical facilities and provide the backbone of numerous industries, from gas turbines used in the production of electricity to turbo-machinery utilized to generate power in the aerospace industry. It is vital that these machines run safely over time and under different operational conditions, to ensure continuous productivity and prevent any catastrophic failure, which would lead to extremely expensive repairs and may also endanger lives of the operating personnel.

The proposed technique called SHAFT DIFLECTION MEASUREMENT (SDM) is based on thedeflections at different positions of shaft; therefore it is not much expensive.

EXPERMENTAL SETUP

The shaft-disk system bearing test is shown in Figure. The shaft was fixed at one end to the test framesupport at one end and was continuous over the other frame support end in a cantilevered end, supporting thedisk. The disk has holes at different radii for supporting the unbalanced mass in experimental setup. The shaft was supported through ball bearings that were bolted to the two test frame supports. Themain objective of this experimental study was to investigate the effect of unbalance in the shaft system.

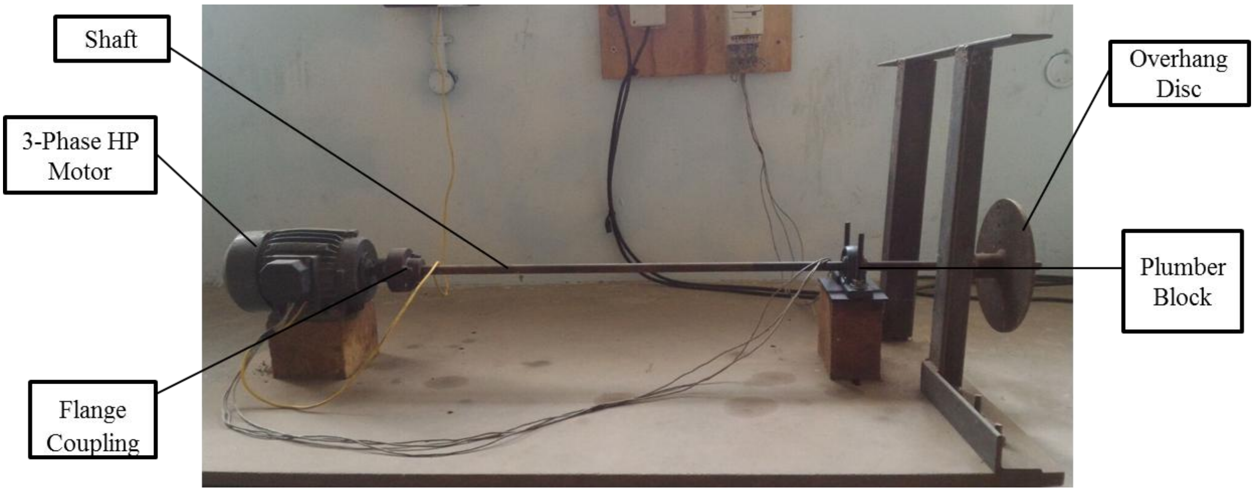


Figure 1.Experimental Setup

Test Rig Description

The shaft-disk system consisted of a shaft supported on two bearings, over two fixed steel supports, asshown in Figure 1(a). The length and the diameter of the shaft were,1250mm (to the end of the propeller) and16mm, respectively. It was supported on two mounted bearings with greased fittings and deep-groovedball-bearing inserts of type 5967k81.Twopairs of set screws were used to fix the shaft to the two bearings.Manually-made saw cuts (0.65mm wide) of different depths ratios (from 0% to 70% ratio) were made at adistance of 2cm to the right of bearing support 2(in the propeller end).

Test Instrumentation System

The test instrumentation system used to measure the unbalance ofthe rotating shaft system, . For the experimental portion of the study, the EngineeringInnovation (ANSYS) software package was used. Modal testsshow the experimental setup to measure unbalance of the rotating shaft. In the deflection measurement system three strain gages were fixed atthree locations, one placed near the bearing support 1, the second placed at the middle of the supported span, andthe last one placed near propeller as shown in Figure 1. Five data acquisition channels were usedin this study, viz., three for torsional strain measuring gages, one for accelerometer channel, and the fifth for impact load with a maximum mass of 22kg.

Modeling of Shaft-bearing Support

The shaft was supported over two roller bearings supported by two fixed steel supports; the fixed steel supportswere fixed-welded to the large steel base plate as shown in Figure 1. The steel base plate was fixed to thetable at bottom.The bearing model used for the present study wasthe Flange Mounted McMaster-Carr Ballbearing (5967k81) shown in Figure 1. It contains two main parts,viz., the inner and outer housing bearing surfaces connected together through some balls; and two tightscrewsthat connected the shaft to the inner bearing.

Elements Used in Analysis

In this paper, the Finiteelement software program ANSYS 13 was used to create 3-D analyticalmodels of the disk-shaft system. The element type used for the 3-D model was chosen SOLID45 from the element library by the ANSYS according to the types of the structuralbodies used in the analysis.
SOLID45 is used for the three-dimensional modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. A reduced integration option with hourglass control is available.

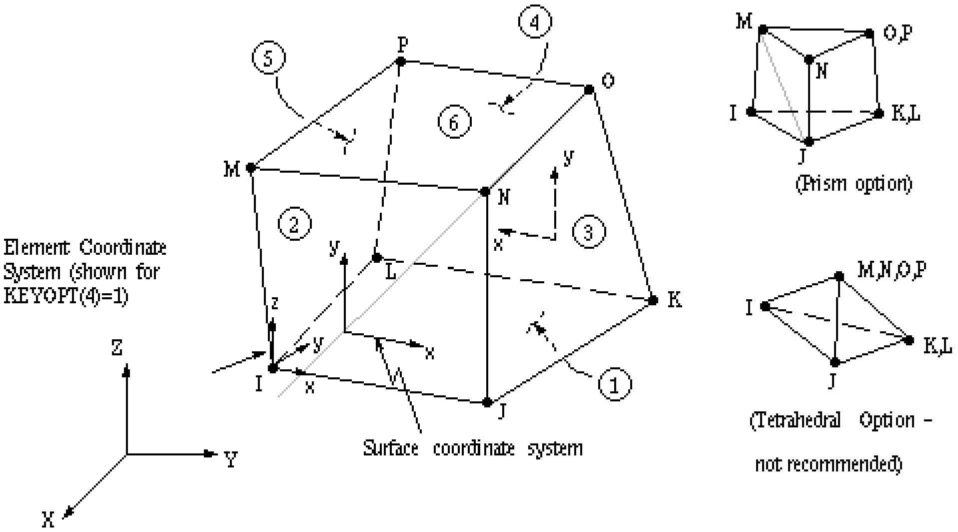


Figure 2SOLID45 3-D Structural Solid

Mesh Convergence Study and Geometry

Commercial FE software ANSYS with Workbench was utilized to carry out the modeling and frequency analysisof circular shafts supported on bearings. A mesh convergence study was carried outearlier so as to ensure that thevalues of the experimental convergent with numerical results.Several mesh sizes (with maximum element dimensions varying from 0.7cm to 2.0cm) of the model wereutilized in this study. The shaft-disk-bearing configuration and mesh generation are shown in Figure 3.The mesh convergent study carried out showed that the unbalance responses werevery close to the experimentalresults for a mesh size of 1.0 cmfor the shaft system. The model had 22784 elements and 32915 nodes for theshaft.

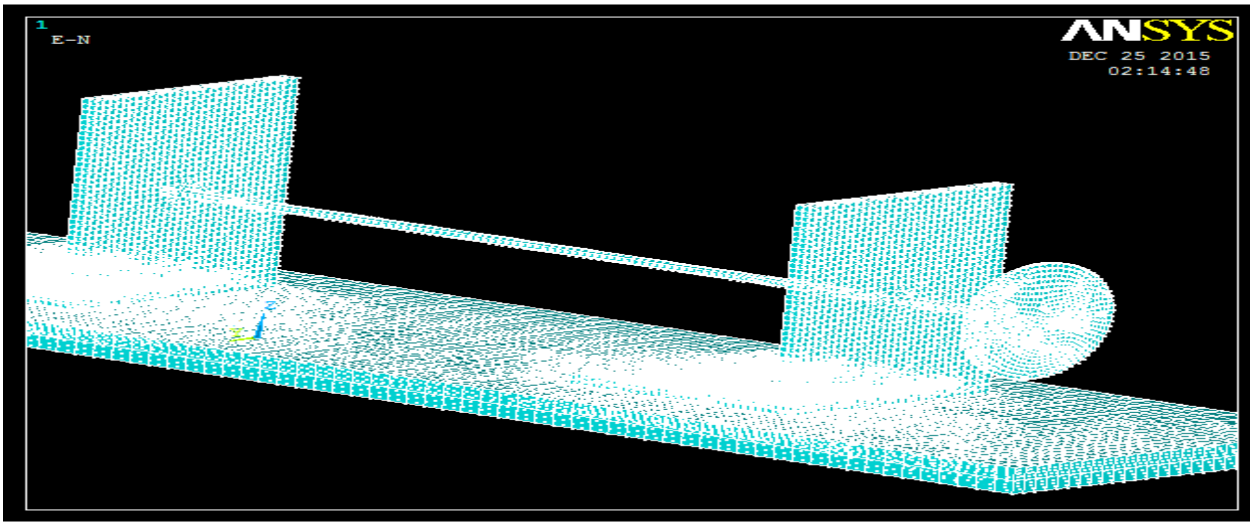


Figure 3 Meshed Model

Procedure for test: for determining the unbalance in the shaft and disk the arrangement is as shown in figure.For determining the unbalance, first we have to calculate the deflections at some specific points from that deflection points we have to draw a deflection curve. For obtaining the different types of defection curves we run the motor with different operating conditions. From the all deflection curves we can determine the unbalance.

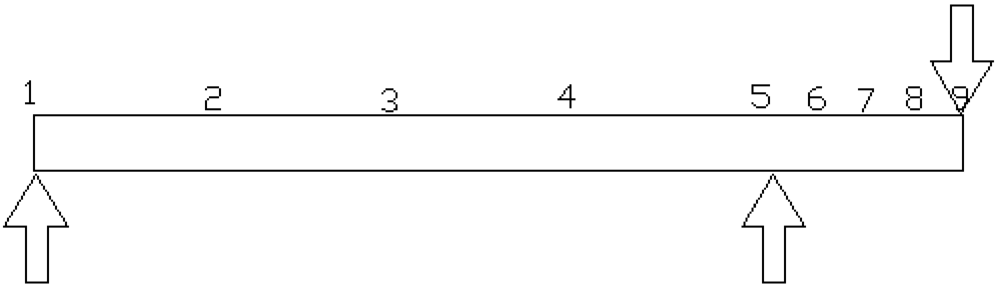


Fig 4(a)

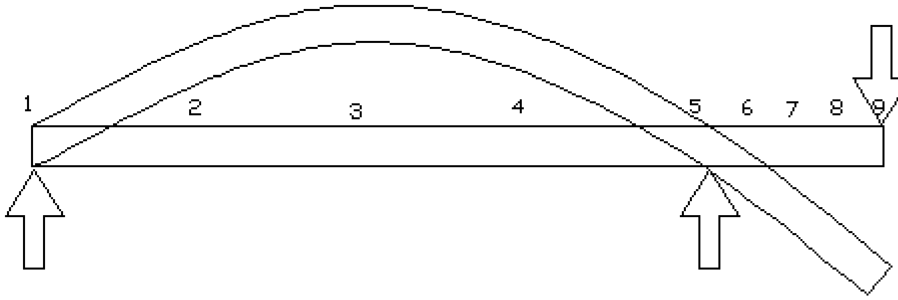


Fig 4(b)

The figure 4(a) shows the overhanging beam and the point load at the end of the beam. By the application of the point load acting at the free end, the beam can be deflected as shown figure (b). Now the simply supported portion can be divided into 4 equal parts as well as the cantilever part too. Now the deflections can be measured at each point to measure the unbalance at the support.

Mainly there are three cases we are using to determine the deflections at different operating conditions. They are

- (i) Keeping the unbalanced mass, radius constantand changing the angular velocity of the shaft.
- (ii) Keeping the unbalanced mass, angular velocity of the shaft constant and changing the radius.
- (iii) Keeping the radius, angular velocity of the shaft constant and changing the unbalanced mass.

From the above calculations and observations we have to develop a deflection curve. By using that deflection curve we can measure the unbalance at the disk.

RESULTS AND DISCUSSION:

Case-1: Keeping the unbalanced mass, radius constant an changing angular velocity of the shaft:

In this case the unbalanced mass attached to the disk is constant and the radius of the unbalanced mass attached to the disk from center is constant.by varying the speed of the shaft we can calculate the deflections at different points i.e 0mm,250mm,500mm,750mm,1000mm,1062.5mm,1125mm,1187.5mm,1250mm. Here we are considering again two cases by varying the angular velocity 2000 rpm and 1500 rpm

(a) The unbalanced mass200gm is attached at radius of 96.75mm from center. The shaft is rotates at 1000 rpm the following are the deflections observed at above distances.

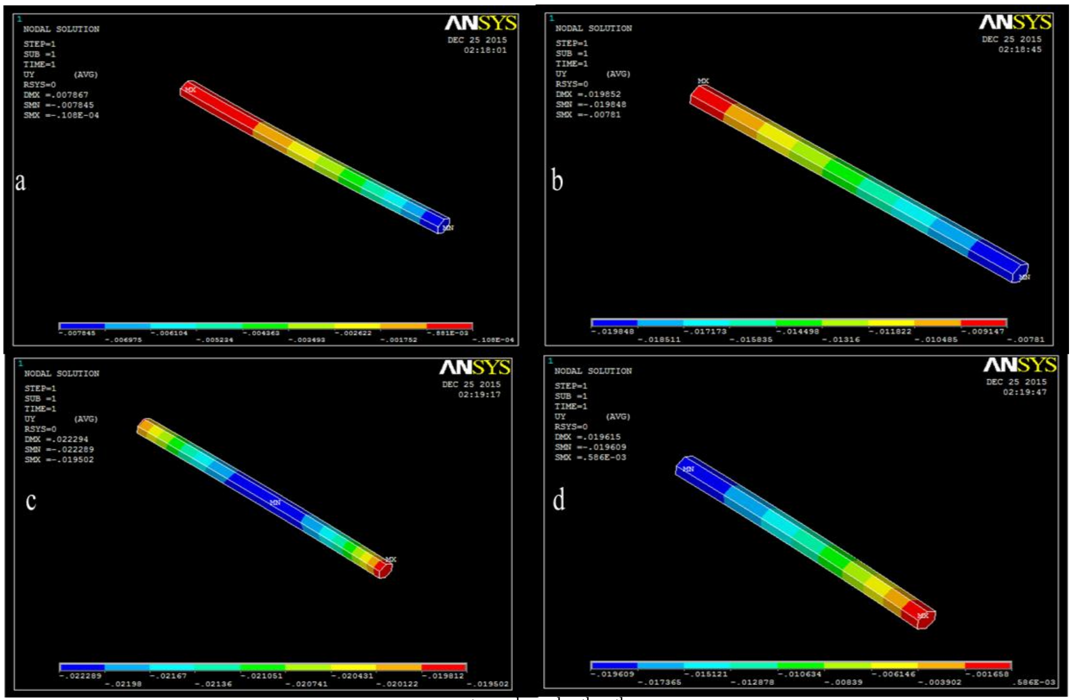


Fig5 deflections at 1st, 2nd, 3rd,4th,5th positions of shaft

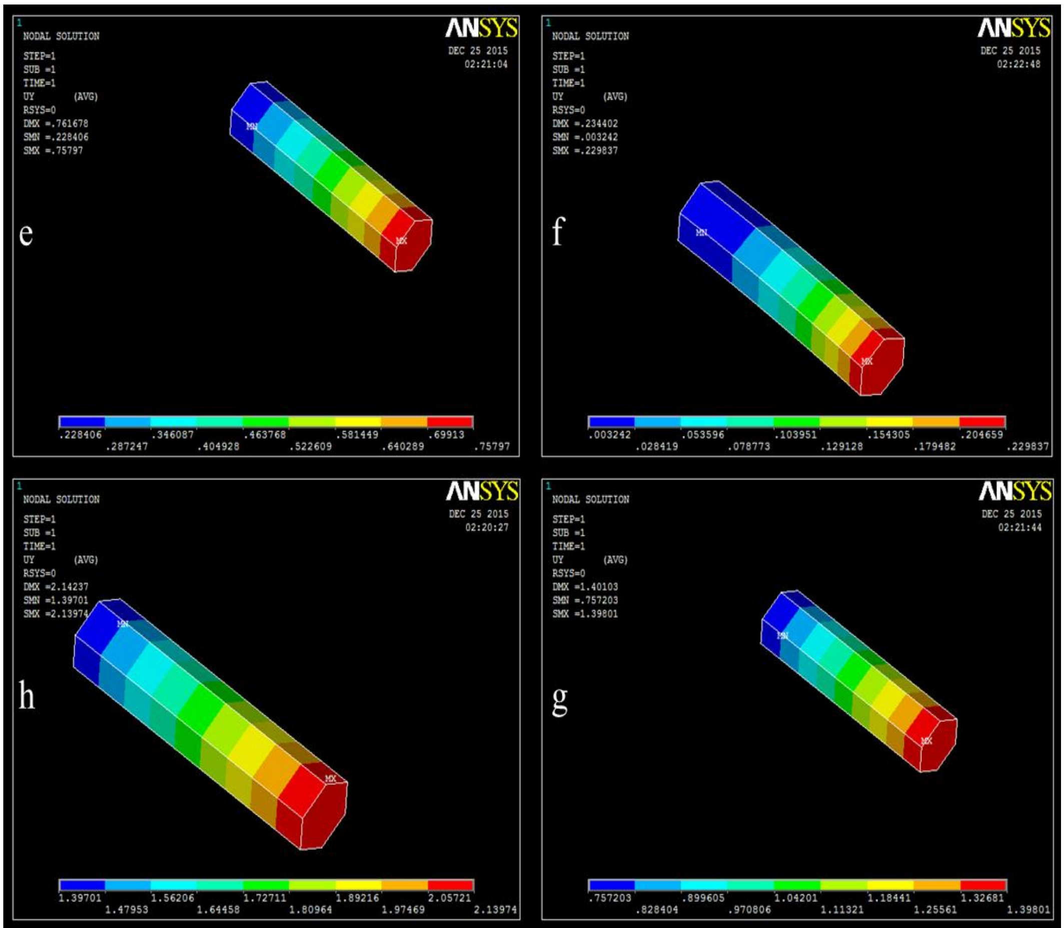


Fig6. Deflections at 6th, 7th, 8th,9th positions of shaft

The same procedure followed for experimental and the deflections are observed by deflection sensors and are tabulated below.

s.no	Shaft Length	Deflection	
		Simulated Results	Experimental Results
1	0	-1.08E-05	0
2	250	-0.0078	-0.008
3	500	-0.0198	-0.02
4	750	-0.0222	-0.025
5	1000	5.86E-04	0
6	1062.5	0.229	0.25
7	1125	0.75	0.8
8	1187.5	1.39	1.45
9	1250	2.139	2.25

(b) the unbalanced mass200gm is attached at radius of 96.75mm from center.. The shaft is rotates at 1500 rpm the following are the deflections observed at above distances.

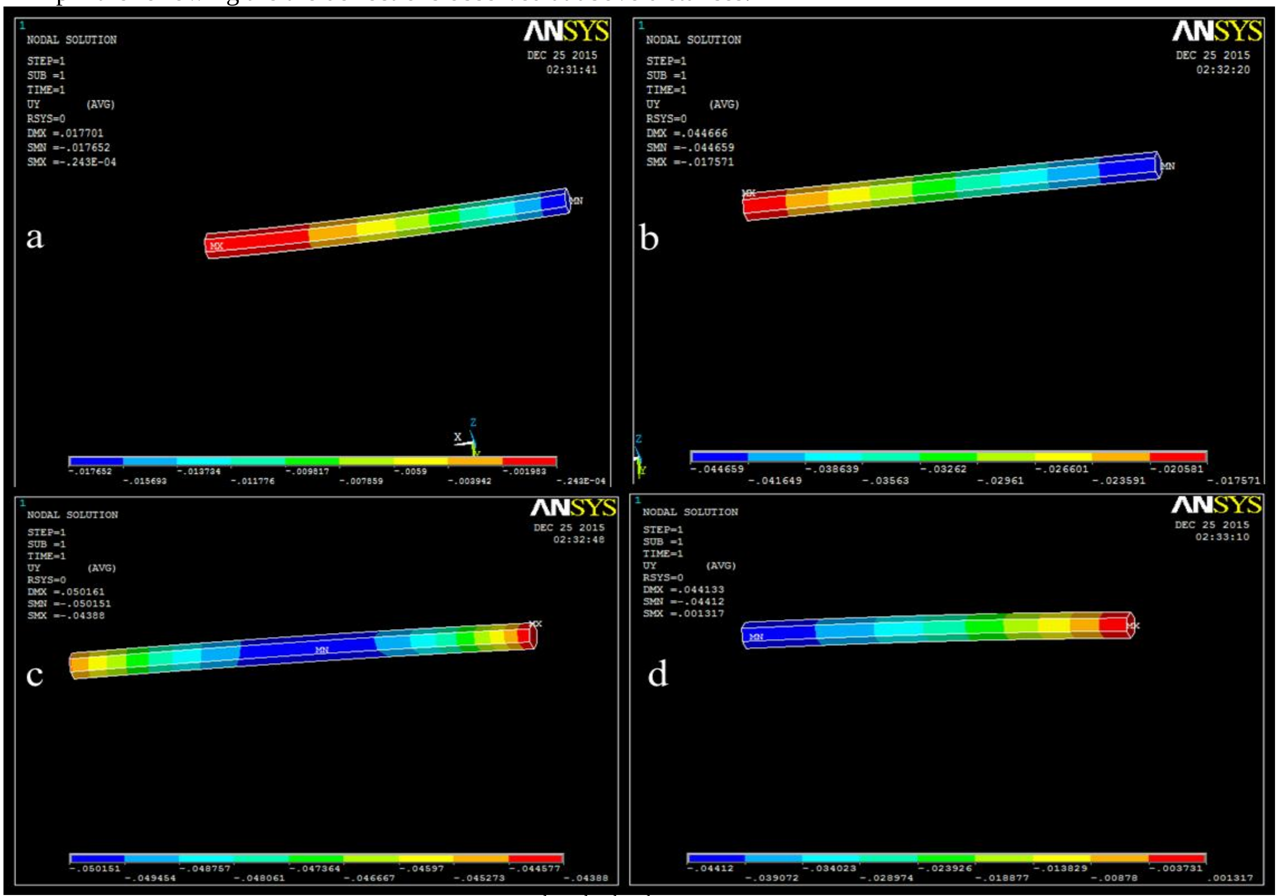


Fig7. Deflections at 1st, 2nd, 3rd,4th,5th positions of shaft

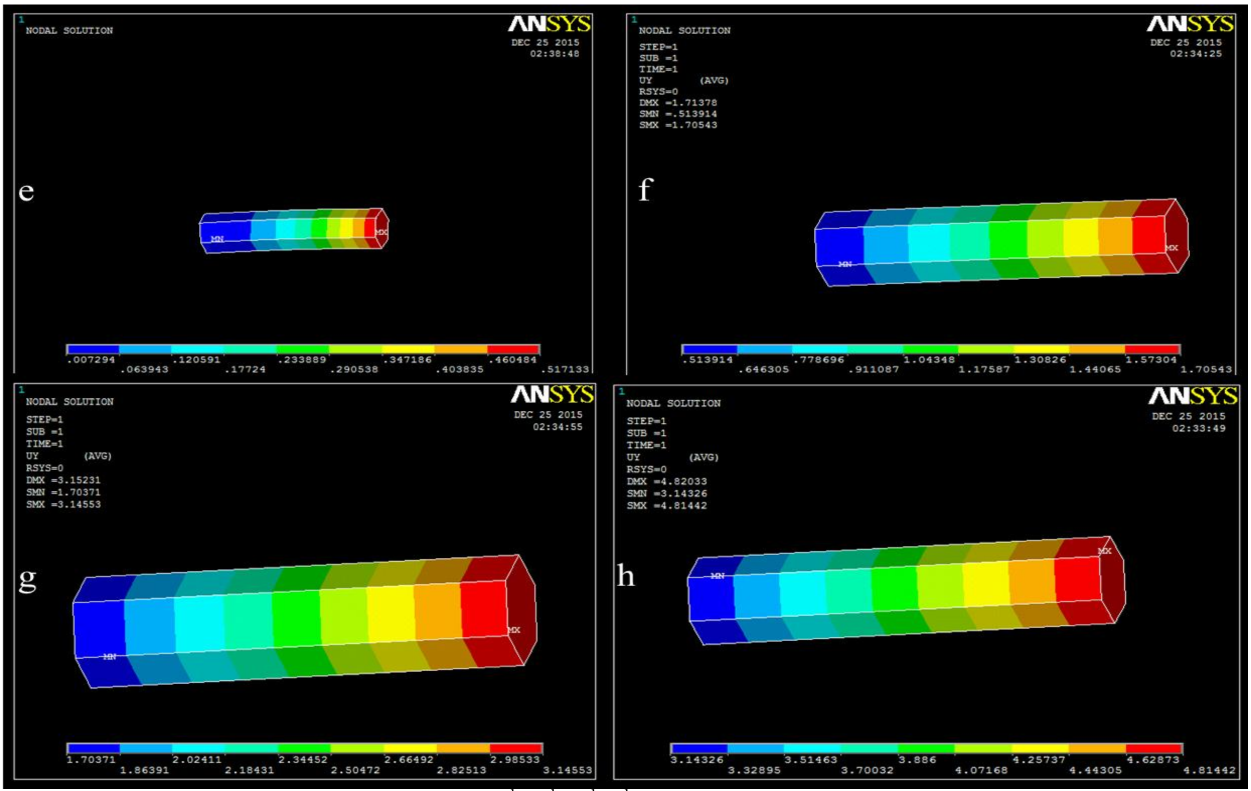
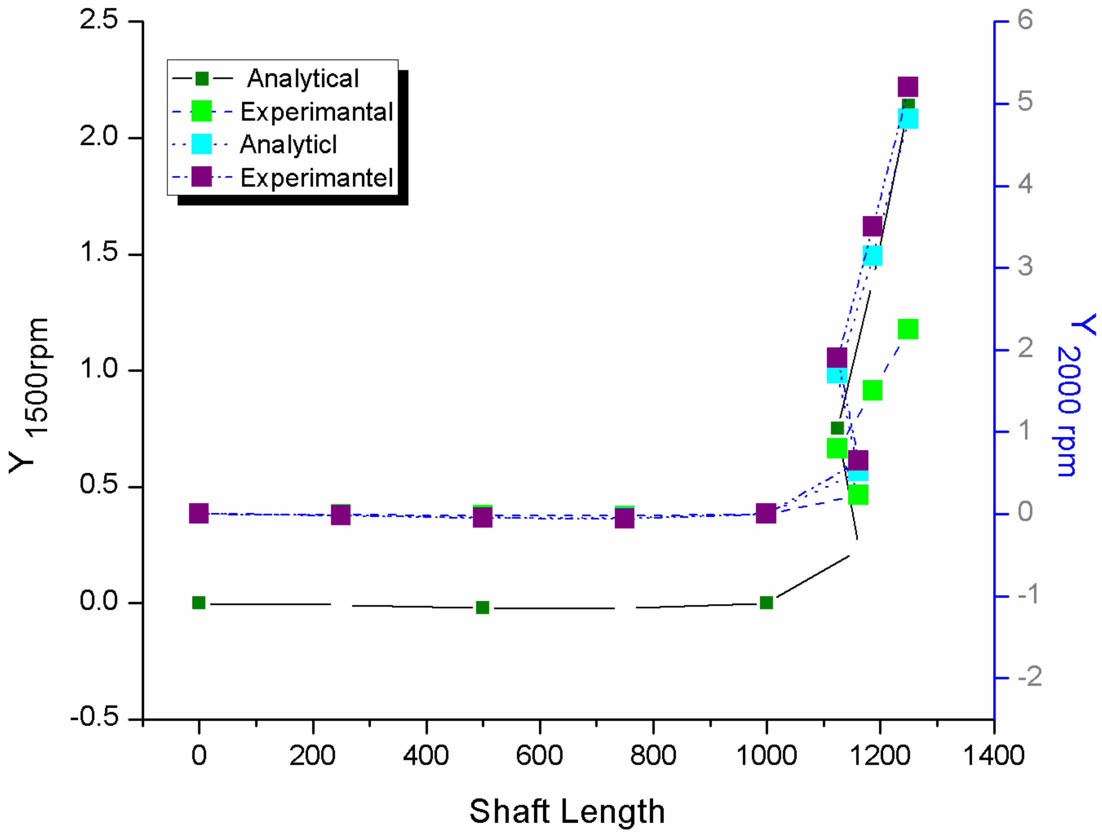


Fig8. Deflections at 6th, 7th, 8th,9th positions of shaft

The same procedure followed for experimental and the deflections are observed by deflection sensors and are tabulated below

S.NO	Shaft Length	Deflection	
		Simulated Results	Deflection results
1	0	-2.43E-05	0
2	250	-0.017	-0.02
3	500	-0.044	-0.045
4	750	-0.0501	-0.0505
5	1000	0.00131	0.00
6	1062.5	0.517	0.52
7	1125	1.705	1.8
8	1187.5	3.145	3.4
9	1250	4.814	5.1

The graph drawn between above two cases as shown figure. In the graph the green colour represents the analytical part of the shaft rotates at 1500 rpm acting at the disk. Where as the cyan colour represents the analytical part ofthe shaft rotates at 2000 rpm. The deflection values are in between the supports are very less as compared to cantilever part as shown on the graph.



Case-2: Keeping the unbalanced mass, angular velocity of the shaft constant and changing the radius:

In this case the unbalanced mass attached to the disk is constant and the angular velocity of the unbalanced mass attached to the disk from center is constant.by varying the radius of unbalanced mass of the shaft. we can calculate the deflections at different points i.e 0mm,250mm,500mm,750mm,1000mm,1062.5mm,1125mm,1187.5mm,1250mm. Here we are considering again two cases by varying the radius of unbalanced mass of the shaft.

(a) the unbalanced mass200gm is attached at radius of 70 mm from center. The shaft is rotates at 2000 rpm the following are the deflections observed at above distances.

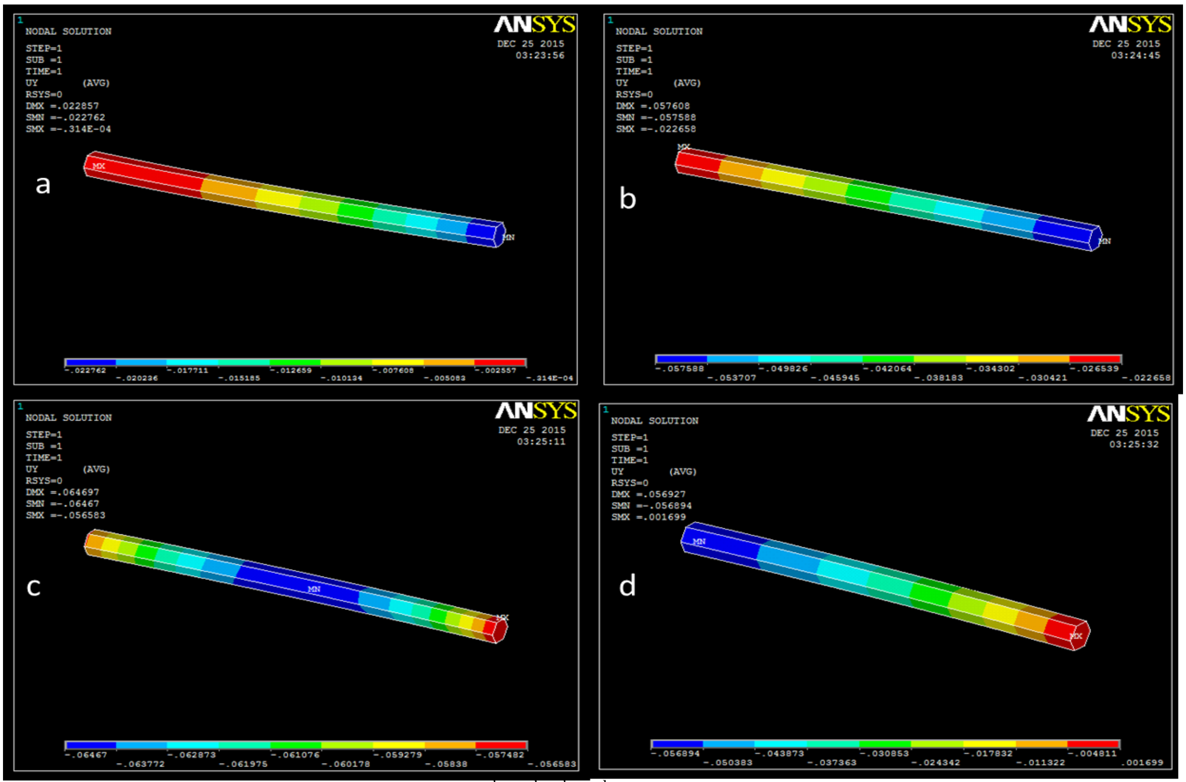


Fig 9 deflections at 1st, 2nd, 3rd,4th, 5th positions of shaft

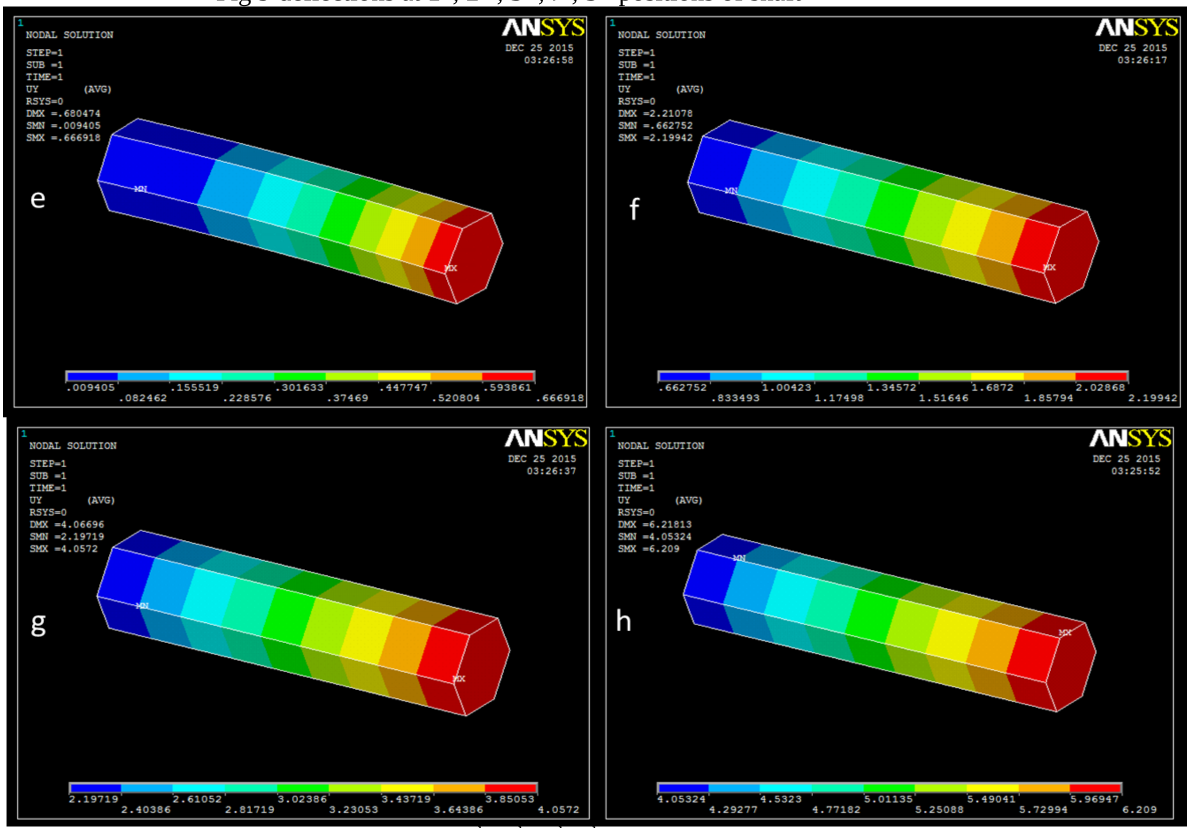


Fig10. Deflections at 6th, 7th, 8th,9th positions of shaft

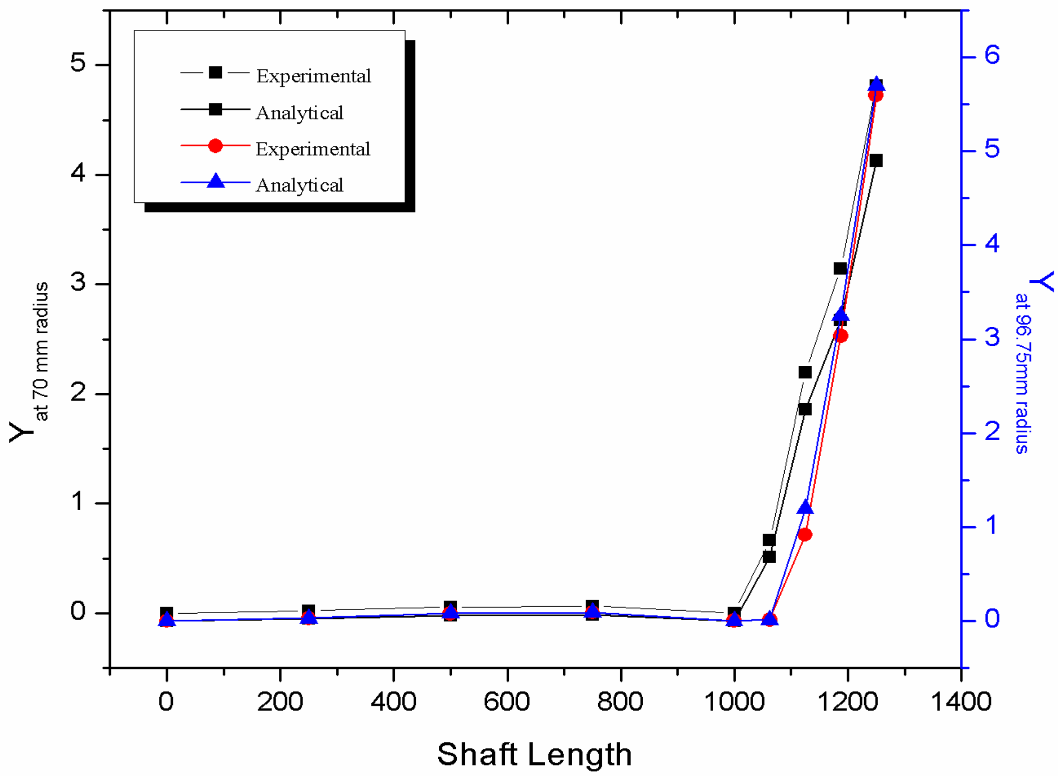
The same procedure followed for experimental and the deflections are observed by deflection sensors and are tabulated below

S.NO	Shaft Length	Deflection	
		Simulated Results	Deflection results
1	0	-3.14E-05	0
2	250	0.022	0.025
3	500	0.057	0.058
4	750	0.064	0.067
5	1000	0.001	0.00
6	1062.5	0.666	0.68
7	1125	2.199	2.25
8	1187.5	3.145	3.2
9	1250	4.814	4.9

(b) The unbalanced mass200gm is attached at radius of 96.75 mm from center. The shaft is rotates at 2000 rpm the following are the deflections observed at above distances.

S.NO	Shaft Length	Deflection	
		Simulated Results	Deflection results
1	0	0.432E-4	0.00
2	250	0.0313	0.032
3	500	0.0793	0.082
4	750	0.0891	0.091
5	1000	0.00234	0
6	1062.5	0.0129	0.013
7	1125	0.919	1.2
8	1187.5	3.031	3.25
9	1250	5.592	5.7

The graph drawn between above two cases as shown figure. In the graph the green colour represents the analytical part of the shaft rotates at 2000 rpm acting at radius 70mm of the disk. Whereas the cyan colour represents the analytical part of 2000 rpm acting at radius of 96.75mm from center of the disk. The deflection values at the shaft rotates at the in between the supports are very less as compared to cantilever part as shown on the graph.



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