International Journal of Industrial Engineering and Technology.
ISSN 0974-3146 Volume 5, Number 2 (2013), pp. 37-46

http://www.irphouse.com

Design and Analysis of Oil Pump Performance Inspection Fixture Using Archad's Equation and ANSYS

S.A. RoshanFarid[1] and N. Ashwin Kumar[2]

[1](B.E. in Mechanical Engineering, Sri Ramakrishna Engineering College (Affiliated to Anna University), Coimbatore, India)
[2](B.Tech in Mechanical with Specialization in Energy Engineering, VIT University, Vellore, India)

ABSTRACT

The oil pump performance checking fixture indigenously designed and manufactured by Ashok Leyland is used to check the performance of the lubrication circuit used in automobiles. The constant wear and tear of the Cast Iron fixture leads to inconsistent oil circulation, which caused several problems in the engine. The objective of this industrial project is to carry out analysis and to reduce the wear volume of the fixture theoretically using Archad's equation and simulate the results using ANSYS v14.5. As a part of analysisthe author suggested a change in material to class 1 Work Hardened Steel in order to reduce the wear volume considerably. Analysis was carried out on both, the existing Cast Iron fixture as well as the Work Hardened steel fixture. Theoretically using Archad's equation the new material reduced the wear volume. To verify the results of the theoretical calculations, Finite Element Analysis (FEA) was carried out on the existing Cast Iron fixture and the suggestedWork Hardened Steel fixture. The results of FEA not only supported the theoretical calculations but also showed the magnitude to which the efficiency of the fixture could be improved on using the work hardened steel fixture.The project yielded valuable results to enhance accurate checking of the oil pump circuit thereby preserving the reputation of the company.

INTRODUCTION

The oil pump in an internal combustion engine circulates engine oil under pressure to the rotating bearings, sliding pistons and the camshaft of the engine. Efficient lubrication of bearings allows the use of higher-capacity fluid bearings, which reduces the heat generated in the engine. For checking the performance of the oil pump, a separate fixture is used in machiningshop floor of Ashok Leyland.

Engines have varying oil needs,for example high performance enginesneed large quantities of oil in comparison with the conventional automobile engine. On road most car engines reach a maximum of 5000- 6000 rpm,whereas high performance engines reach speeds up to 9000 rpm. In this case, the lubrication system must be highly robust in order to meet the engine's needs.In performance engines the oil must circulate at rapid speeds else it would lead to air mixingwith oil.To enhance power, some enginesuselower weight oil, which requires less power to run the oil pump. Oil grades commonlyused in engines are usually either 5w30 or 10w30 oil, whereas high performance engines use 0w20 oil, which is less viscous.

The oil pump fixtureis a simulation of the oil pump. This checking fixture is composed ofdriving flange, oil pump cover and driven gears. The driving flange is driven externally by separate Induction motor. The design of oil pump cover must be rigid to check the oil performance effectively, at present the oil pump cover material used is Cast Iron that wears off on continuous usage and has to be changed frequently.

Analysis plays a major role indetermining the wear resistance of the fixture. Work hardened steel with Rockwell hardness of58-60Cwas selected after conducting studies on material properties of several materials.Work hardened steel hassuperior wear resistance properties over cast iron. The superiority of work hardened steel over cast iron can be proved theoretically using Archad's Equation and simulated using ANSYS v14.5 software.

EXPERIMENTAL PROGRAMME

Material Properties of the fixtures

The fixture is manufactured by the process of metalcasting; the contours and holes in the fixture are machined usingwire cut Electrical discharge method. The properties of Cast Iron are mentioned in Table 1.The properties of Work hardened steel are mentioned in Table2. The Cast iron used complies with Ashok Leyland standards.

Table 1: Physical Properties of Cast iron used in the fixture

Sl No	Property	Value
1.	Density	7100kg/m^3
2.	Young's Modulus	150000MPa
3.	Poisons ratio	0.3
4.	Bulk Modulus	100000MPa
5.	Shear Modulus	60000Mpa
6.	Yield Strength	130 MPa
7.	Ultimate Tensile Strength	800 MPa
8.	Elongation	0.5%
9.	Rockwell Hardness	A63.6

Table 2: Physical Properties of Work Hardened steelsuggested by the author

Sl No	Property	Value
1.	Density	8000kg/m^3
2.	Young's Modulus	210000 MPa
3.	Poisons ratio	0.3
4.	Bulk Modulus	175000 MPa
5.	Shear Modulus	80769 MPa
6.	Yield Strength	493MPa
7.	Ultimate Tensile Strength	925MPa
8.	Elongation	15%
9.	Rockwell Hardness	B104

2.2 Fixture 1.0

The original fixture made of Cast Iron class 3 is designated as fixture 1.0.The process of metal casting is employed to manufactures the fixture; the contours and holes in the fixture are machined using wire cut Electrical discharge method. The geometry of fixture 1.0 is shown in Fig 1

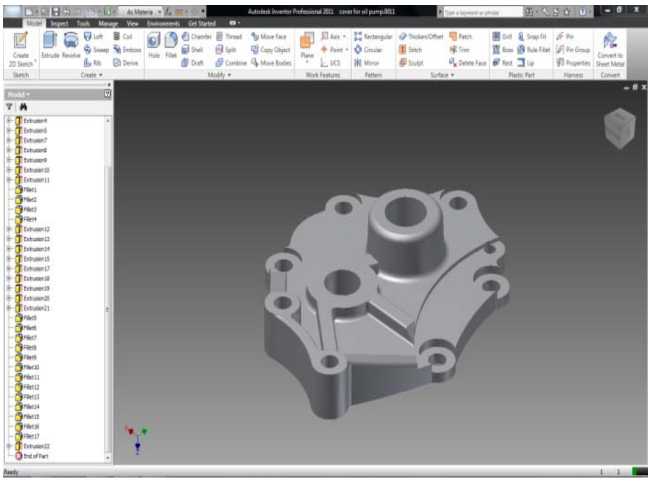

Fig 1: Geometry of fixture 1.0

2.3 Fixture 2.0

The fixture made of Work Hardened Steel suggested by the author is designated as fixture 2.0. Work hardening is done by nitriding process. Since the hardness and the material properties of Work hardened steel vary largely from Cast Iron the manufacturing process may also vary. The geometry of fixture 2.0 is shown in fig 2

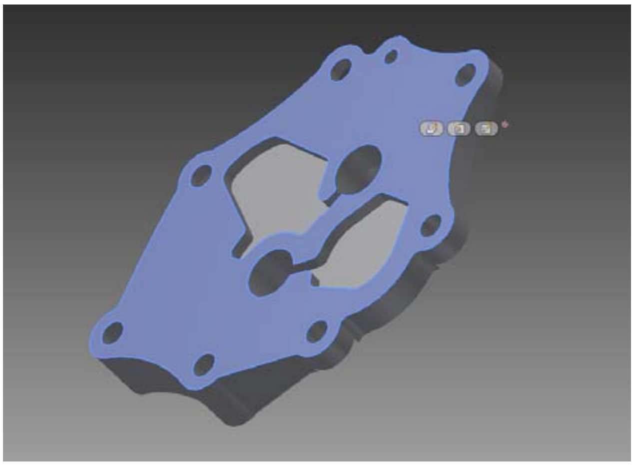

Fig 2: Geometry of fixture 2.0

3.1 ARCHAD's EQUATION

The Archard's wear equation is a simple model used to calculate wearvolume, it is based on the theory of asperity contact. The Archad equation is denoted as follows:

$$V = \frac{KWL}{H}$$

Where,
V = Volume of wear in cubic inches
K = Wear co-efficient in m^3/Nm
W = Normal load in pounds
L= Sliding distance in feet
H = Penetration hardness of softer material in psi

From design point of view the wear displacement H is more convenient than V. With $h_i = \frac{V_i}{A}$, the contact pressure $p = \frac{F}{A}$ where A is the area subjected to wear then$h_i = k_i$ p s. The sliding distance s can be replaced by s=v.t where v is the mean value for the slide rate and t the running time because the k-value varies just like the friction coefficient on a lot of parameters this factor is to be found experimentally.

3.2 CONVERSION OF SLIDING WEAR TO LINEAR WEAR

Calculation of sliding wear involves over 25 variables, some of which are difficult or impossible to measure. Thus, there is no general applicable equation; only simulative testing should be performed using analysis software like ANSYS. However theoretically the shaft can be assumed as a linear surface and the Archad's equation can be used calculating the wear volume. The conversion of the cylindrical shaft to a linear surface is shown in Fig3.

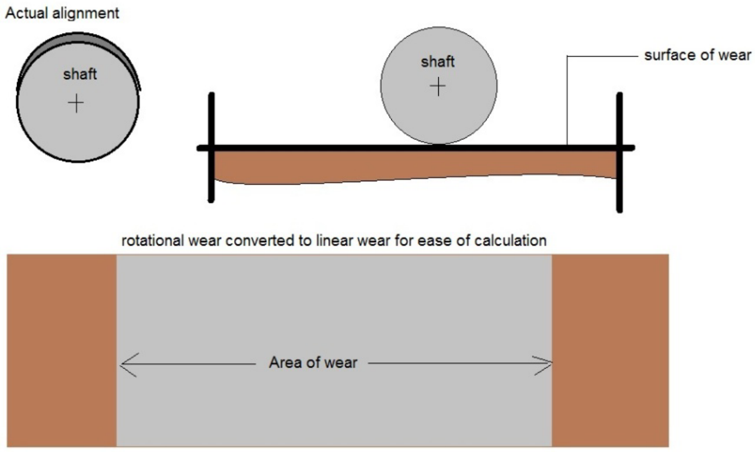

Fig3: Conversion of sliding wear to linear wear.

3.3 CALCULATION OF WEAR VOLUME IN CAST IRON

The class of the cast iron used in fixture	= 3
The wear co-efficient for class 3 CI (k)	= 0.5
Radius of hole (r)	= 7.5 mm
Sliding distance (L)	= 0.1546 feet
Penetration hardness of Cast iron in psi (H)	= 260
Normal load (W)	= 1450.3774 psi
Wear volume (V)	= 0.43121 cubic inches

3.4 CALCULATION OF WEAR VOLUME IN WORKHARDENED STEEL

The class of the work hardened steel used in fixture	= 1
The wear co-efficient for class 1 work hardened steel (k)	= 0.005
Radius of hole (r)	= 7.5 mm
Sliding distance	= 0.1546 feet
Penetration hardness of work hardened steel in psi (H)	= 270
Normal load (W)	= 1450.3774 psi
Wear volume (V)	= 0.0014751 cubic inches

3.5 RESULTS OF THEORITICAL CALCULATION

The calculation of the wear volume using Archad's equation was carried for Cast iron and Work hardened steel, the results of calculation yielded results as 0.43121 cubic inches for the former and 0.0014751 cubic inches for the latter. Clearly a large variation occurs between wear volume of the two chosen materials. The theoretical calculations emphasize the fact that Work hardened steel is superior to Cast iron. In order to support these calculations FEA is to be carried out to both the metal fixtures.

4. RESULTS OF FINITE ELEMENT ANALYSIS

4.1 Boundary and Loading Conditions

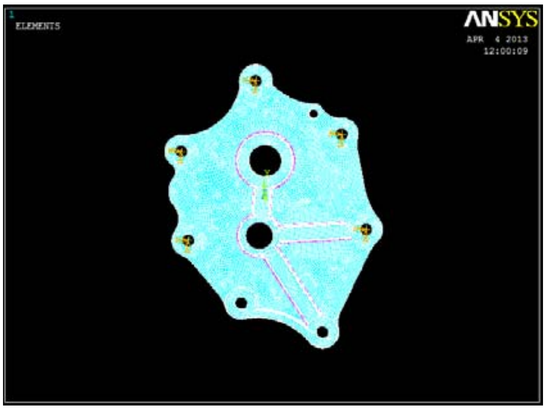

Fig 4a: Constrain of DOF

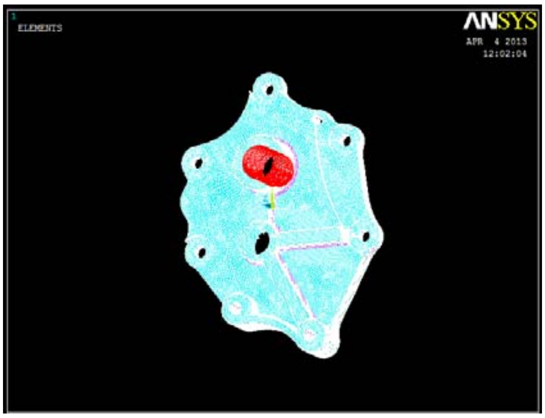

Fig 4b: Load Application

The fixture is held in position by screwing it through the five holes in the edges of the fixtures as shown in figure 4a. All degrees of freedom (DOF) are constrained in the selected 5 holes. A rotational force of 1450.3774 psi is applied along the XZ plane in the anticlockwise direction to the central hole as shown in figure 4b. The same boundary and loading conditions are applied for both the Cast iron and the Steel fixtures.

4.2 Finite Element Results of Fixture 1.0

4.2.1 Displacement Vector sum

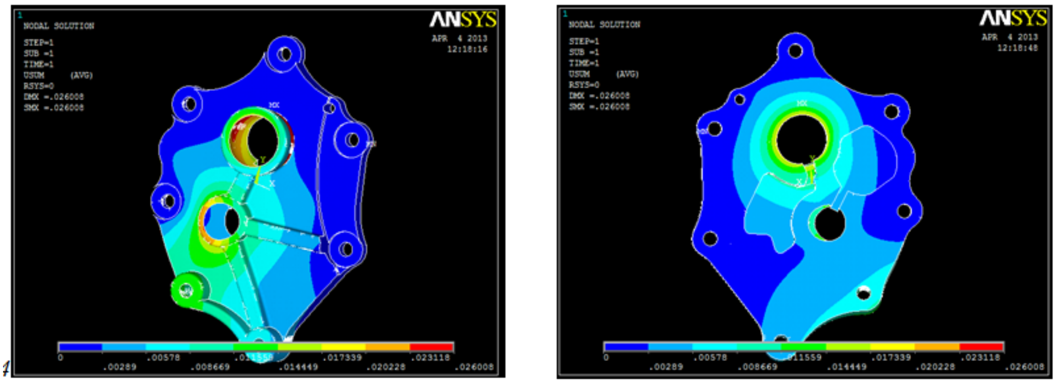

Fig 5: Displacement vector sum for fixture 1.0

On applying the rotational force of 1450.3774 psi, Fixture 1.0 had a maximum displacementof 0.026008 mm. It may beobserved from fig 5 that the maximum deformation occurred along the inner circumference of the largest hole. The hardness of the material plays a vital role in determining the displacement caused. Preliminary conclusions suggest that a harder material would reduce the deformation caused.

4.2.2. Stress Intensity

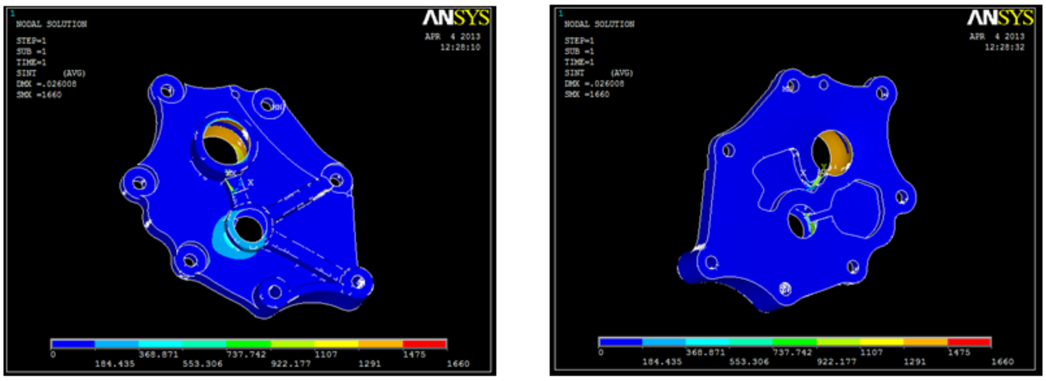

Fig 6: Stress intensityfor fixture 1.0

Fixture 1.0 had the highest stress intensity of 1660 Pa concentrated along the circumference of the largest hole in the fixture for the applied load. The value of maximum stress is well within the yield stress. A stress intensity of this measure would increase the wear volume of the hole. As a resultreducing the number of cycles for which this fixture can be used.

4.2.3. Von Miss Stress

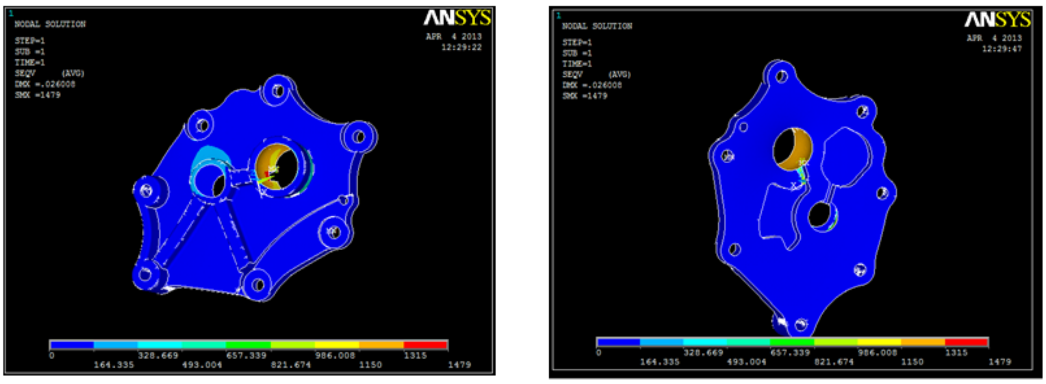

Fig7: Von miss stress for fixture 1.0

The Von miss stress of fixture 1.0 is analyzed as 1479 Pa. Although this value is withinthe yield stress value, in order to increase the life of the fixture the stress value needs to be lower. The results of analysis indicate the need to bring down the value of the principal stress in order to increase the life of the fixture.

4.3 Finite Element Results of Fixture 2.0

4.3.1 Displacement Vector Sum

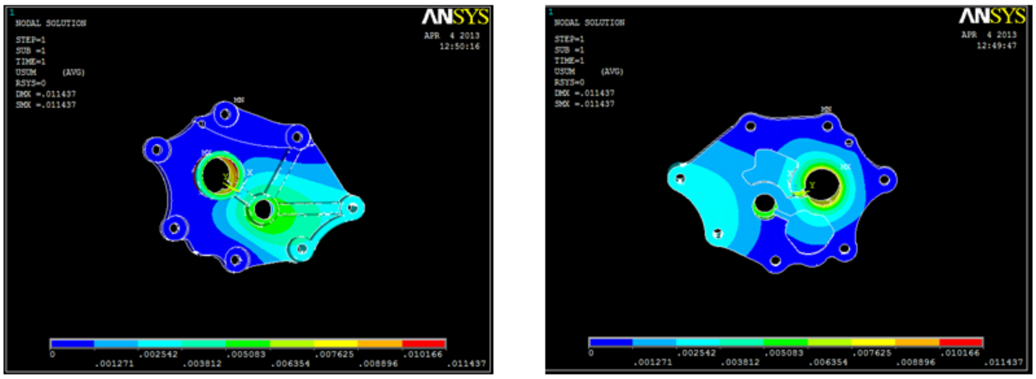

Fig 8: Displacement vector sum for fixture 2.0

On applying aload of 1450.3774 psi, Fixture 2.0 had a maximum displacementof 0.011437mm. It is noted that the maximum deformation of fixture 2.0 is much lesser than0.026008mm that of fixture 1. It may beobserved from fig 8 that the maximum deformation occurred along the inner circumference of the largest hole identical to that of fixture 1.0 but the intensity varies largely.

4.3.2 Stress Intensity

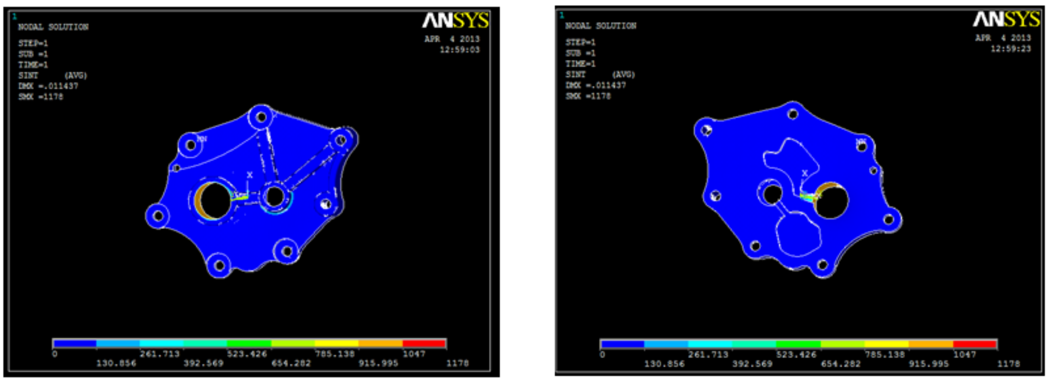

Fig 9: Stress intensity for fixture 2.0

Fixture 2.0 had the highest stress intensity of 1178Pa concentrated in the circumference of the largest hole. The steel fixture experiences a lower value of stress intensity in comparison to the stress intensity of 1660 Pa experienced by the Cast Iron fixture. Stress causes the fixture to experience cracks, weakness in the material. Thus when the stress experienced by the fixture is reduced automatically the number of usable cycles of the fixture can be increased.

4.3.3 Von Miss Stress

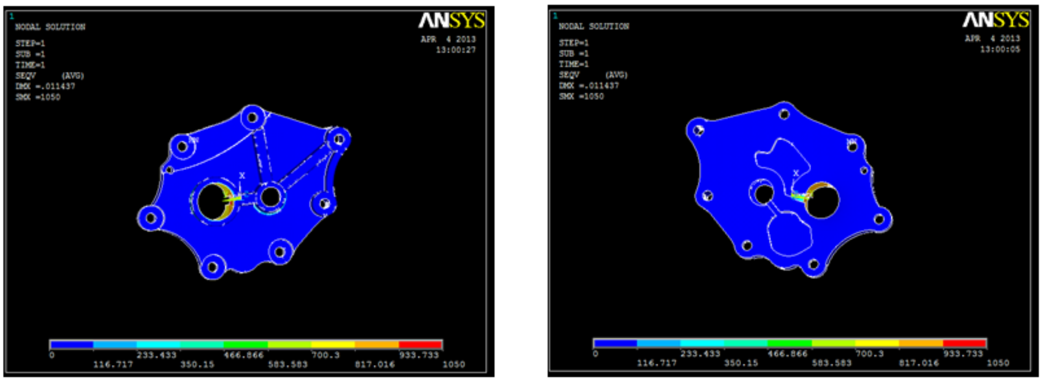

Fig 10: Von miss stress of fixture 2.0

The Von miss stress of fixture 2.0 is analyzed as 1050 Pa. Thus there is a greater difference between the yield stress and the principal stress with regards to fixture 1.0. The first step to increase the life expectancy of the product would be to increase the intensity of the principal stress. With the vast reduction in the principal stress in the steel fixture indicates a guaranteed increase in the usable cycles of the new fixture.

5. CONCLUSION

5.1 Results and Discussions

Table 3: Results of Analysis

Description	Load Applied (psi)	Wear volume (cubic inches)	Displacement Vector Sum (mm)	Stress intensity (Pa)	Von miss stress (Pa)
Fixture 1.0	1450.3774	0.43121	0.026008	1660	1479
Fixture 2.0	1450.3774	0.0014751	0.011437	1178	1050

From the theoretical calculations it is evident that Fixture 1.0 has the maximum wear volume, which means it, will undergo a wear of 0.43121 cubic inches for every cycle. This abruptly reduces the number of cycles it can be used and its lifetime.

Fixture 2.0 has a wear volume of only 0.0014751 cubic inches thereby increasing the number of cycles it can be used while checking the oil pump assembly.

The theoretical calculations were based on the material properties of the chosen materials. The success of the theoretical calculations can be accepted by simulation. The results obtained from ANSYS not only simulate the working condition of the fixture with precision but also indicates that Fixture 2.0 is superior to Fixture 1.0.

The three tests used to authenticate the superiority of Fixture 2.0 over Fixture 1.0 include Displacement vector sum, Stress intensity and Von Miss stress. All the tests indicate that Work Hardened Steel Fixture is a better substitute over Cast Iron. The results of ANSYS show the magnitude to which the life of the fixture can be improved by employing the new fixture. Most importantly by increasing the number of cycles to which the fixture can be used necessarily indicates using a more economic substitute.

5.2 Scope of Future Work

The aim of this industrial project was to suggest solutions to increase to increase the usable cycles of the fixture. The project suggested one such method to enhance the life of the fixture. Several other methods can be employed to reach the goal.

An alternate analysis can be carried out by increasing the size of the holeup to 4 mm in diameter in order to incorporate a steel bushin the hole of the fixture where maximum wear occurs. In this method when maximum stress or wear occurs it does not effect the hole of the fixture but the full impact is taken by the bush which alone can be replaced after it is worn out rather than changing the fixture itself.

A vibration damping analysis can be carried out using ANSYS Work bench and thus analyze the precise number of cycles for which the fixture can be used.

REFERENCES

[1] N. P. Suh. “An overview of the delamination theory of wear”

[2] Archard, J. F. and Hirst, W. “Wear of metals under unlubricated conditions.” Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences, Vol. 236, No. 1206. (Aug. 2, 1956), pp. 397-410.

[3] Kauzlarich and Willams. “Archard wear and component geometry.” Proc. Instn. Mech. Engrs. Vol 215 Part J.

[4] Hegadekatte et al. “Finite element based simulation of dry sliding wear.” ModellingSimul. Mater. Sci. Eng. 13 (2005) 57-75

[5] Podra, P. and Andersson, S. “Simulating sliding wear with finite element method.” Tribology International 32 (1999) 71-81.