DESIGN ANALYSIS OF A KEYLESS COUPLING

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Abstract: **In a typical keyed shaft connection where shock or reversing loads are to be transmitted, the clearance between key and keyway required for fitting is a serious disadvantage. The impact loads, generate a continuous pounding between key and keyway. This pounding frequently leads to shaft failures. The present project work presents a Keyless coupling. The device provides an ultimate solution by incorporating all the advantages of interference fits, while eliminating mounting and removal problems. Analysis is carried using ANSYS. The obtained results are compared with standard values. The standard values are taken for RINGFEDER catalog. The keyless data is taken from RINGFEDER. Here it has made an attempt in analyzing keyless coupling. From the results it can be concluded that keyless coupling is most suitable.**

Keywords: **coefficient of thermal expansion, interference fit, virtual shrink, Contact surface, wedge principle.**

1. INTRODUCTION

In the transmission of power by means of shafting and pulleys or gears, the common method of fastening the pulley or gear to the shaft, so that the two will rotate together, is by means of a key inserted in a keyway cut in the shaft, and extending into a corresponding keyway cut in the hub of the pulley or gear. The keyway must weaken the shaft in which it is cut. We can see that the sharp corners of the keyway and its location at one side of the shaft might weaken the shaft more than the relatively small size of the keyway would lead us to expect. In view of the very extensive use of shafts with keyways and the small amount of information available on the subject, the effect of keyways on the torsional strength of shafts. If a shaft with a pulley keyed to it is given a permanent twist, the removal of the pulley is frequently a matter of great difficulty, while if a shaft carries a sleeve or gear with a key sliding in a keyway, any permanent twist practically ruins the shaft.

Various researchers have contributed to the field of coupling .In which N L Pedersen [3] using shape optimization and simple super elliptical shape, it shown that the fatigue life of a keyway can be greatly improved with up to 50 per cent reduction in the maximum stress. Vardi and Varghese [11] proposed uniform pressure distribution between the shaft and key and the key and the hub. Fred Seely and Thomas [1] demonstrate plaster-model shown satisfactory for the determining the maximum stress in a member .This method determine high localized stress. Frederick Lee Barber [8] proposed Vibrational analysis of rotating machinery. The Vibrational spectra can be used to determine the system abnormality, the degree of misalignment. Fred R Szenasi [13] has studied the torsional oscillations of rotating devices.

2. MODELING AND ANALYSIS OF KEY COUPLING

The key and the key seat for a particular application are usually designed after the shaft diameter is specified by methods commonly used for shafting. Then with the shaft diameter as a guide, the size of the key is selected from standards which give the key size for a range of shaft diameters, the only remaining variables are the length of the key and its material. The reason for this is the assumed uniform pressure distribution between the shaft and key and the key and hub at their respective contact surfaces. Instead of the uniform contact pressure along the keyway, in the shaft there is a non-uniform local contact stress distribution located at the top of the keyway in the shaft. Between the hub and the key the problem is similar.

3. SPECIFICATION OF KEY COUPLING

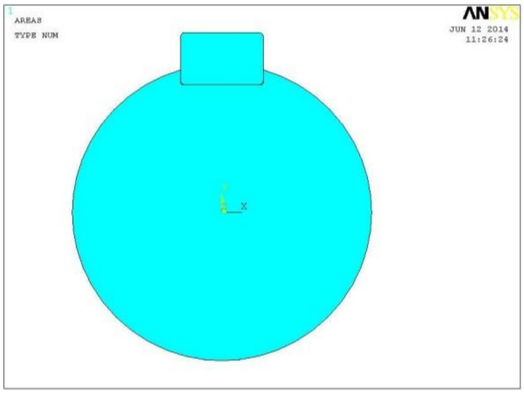
The shaft diameter as a guide, the size of the key is selected from standards which give the key size. Diameter of the shaft is 80 mm, with reference to diameter, key width is 22 mm and height is 14mm respectively. The material property is shown in table 1.

TABLE 1. Material properties for 15Ni2Cr1Mo15 of case hardened steels

Component properties	Specification
Ultimate Tensile Strength	1100 N/mm^2
Shear steady load	1560 N/mm^2
Varying load	104 N/mm^2
Alternative load	52 N/mm^2
Modulus of Elasticity	210000 N/mm^2
Poisson's Ratio	0.3

4. FINITE ELEMENT ANALYSIS OF KEY COUPLING

A key coupling is considered in the current study. The structural components shaft and key. Geometric modeling is carried out by using ANSYS software is shown in fig 2. Fine meshing is done to get the accurate results of contact stress. The fine mesh is done near the left side of the shaft is shown in fig 3. The stress concentration is more at the key way.



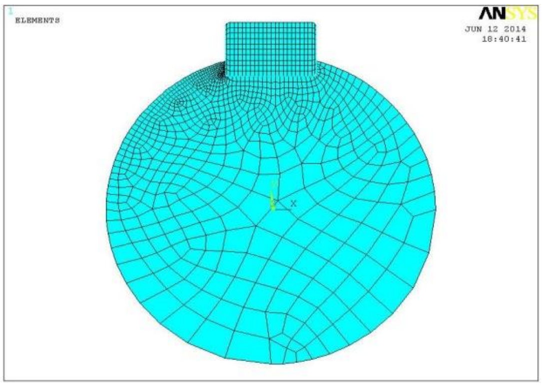
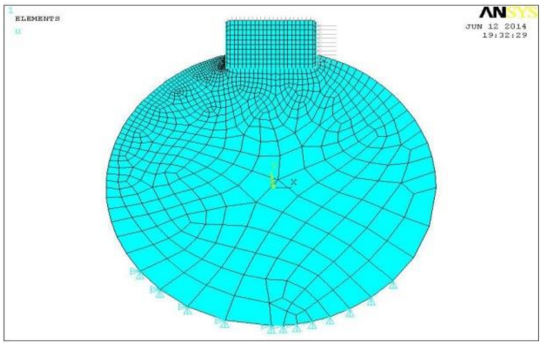


Fig. 2 Geometric configuration of key coupling

Fig. 3 Finite element mesh of shaft and the key

Load and Boundary conditions and loads are applied for the meshed shaft and the key. The lower surface of the shaft is constrained. The pressure load of is applied on right side of key surface. The finite element model with loads and boundary condition is shown in fig 4.



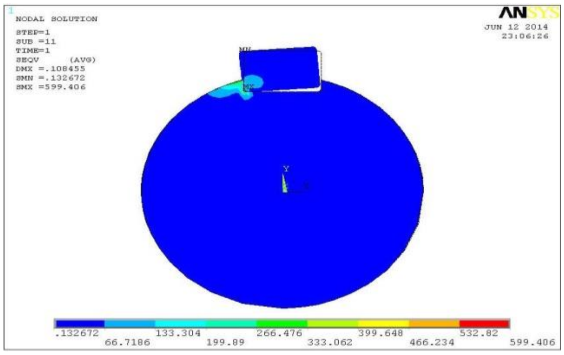


Fig . 4 Loads and boundary conditions of key coupling

Fig. 5 Von Mises stress

5. MODELING AND ANALYSIS OF KEYLESS COUPLING

In Keyless Locking Devices all operate using the simple wedge principle. An axial force is applied by either a hex nut or a series of annular screws to engage circular steel rings with mating tapers. In the case of keyless bushings, the resulting wedge action creates a radial force on the tapered rings, one of which contracts to squeeze the shaft while the other expands and presses into the component bore.

For keyless coupling standard dimension are taken from RINGFEDER catalog

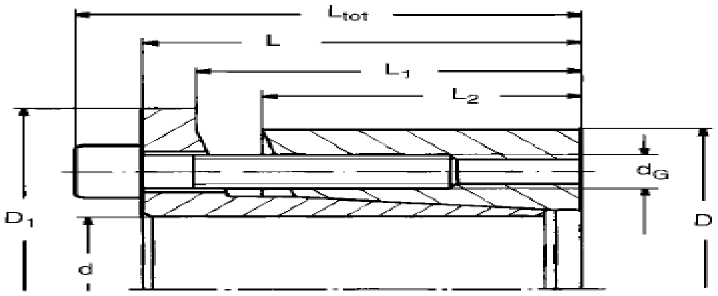


Fig. 6 Keyless coupling

TABLE 2 . Standard dimension from RINGFEDER catalog [2]

Size inches	Locking Assembly dimension d	T_1	D	T_2 inches	L_{tot}	L	L_1	L_2	D_1	max. M_t lb-ft	p psi	p' psi	Locking screws Qty 1)	Qty 2)	Size d_G	s mm	M_A lb-ft	D_N inches
1	1.000	+0	1.969		1.456	1.220	1.012	.854	2.205	323	40 170	15 070	5	7	M 6x20	5	12.5	2.875
1-3/16	1.1875	−.0013	2.165		1.456	1.220	1.012	.854	2.441	385	33 800	13 650	5	7	M 6x20	5	12.5	3.000
1-1/4	1.250		2.362		1.456	1.220	1.012	.854	2.677	531	38 560	15 070	6	9	M 6x20	5	12.5	3.375
1-3/8	1.375		2.362	−0	1.456	1.220	1.012	.854	2.677	585	35 055	15 070	6	9	M 6x20	5	12.5	3.375
1-7/16	1.4375		2.559	+.0018	1.456	1.220	1.012	.854	2.874	620	33 495	13 935	6	10	M 6x20	5	12.5	3.625
1-1/2	1.500	+0	2.559		1.456	1.220	1.012	.854	2.874	647	32 100	13 935	6	10	M 6x20	5	12.5	3.625
1-5/8	1.625	−.0016	2.953		1.811	1.496	1.193	.996	3.267	1 234	43 870	19 055	6	9	M 8x25	6	30	4.750
1-3/4	1.750		2.953		1.811	1.496	1.193	.996	3.267	1 329	40 740	19 055	6	9	M 8x25	6	30	4.750
1-7/8	1.875		3.150		1.811	1.496	1.193	.996	3.464	1 426	38 070	17 915	6	9	M 8x25	6	30	4.875
1-15/16	1.9375		3.150		1.811	1.496	1.193	.996	3.464	1 473	36 840	17 915	6	9	M 8x25	6	30	4.875
2	2.000		3.150		1.811	1.496	1.193	.996	3.464	1 521	35 690	17 915	6	9	M 8x25	6	30	4.875
2-1/8	2.125		3.346		1.811	1.496	1.193	.996	3.740	1 803	39 125	19 625	7	10	M 8x25	6	30	5.500
2-3/16	2.1875		3.346		1.811	1.496	1.193	.996	3.740	1 856	38 005	19 625	7	10	M 8x25	6	30	5.500
2-1/4	2.250		3.543		1.811	1.496	1.193	.996	3.937	1 908	36 875	18 485	7	10	M 8x25	6	30	5.500
2-3/8	2.375		3.543	−0	1.811	1.496	1.193	.996	3.937	2 014	34 935	18 485	7	10	M 8x25	6	30	5.500
2-7/16	2.4375	+0	3.740	+.0022	1.811	1.496	1.193	.996	4.134	2 466	38 965	20 050	8	12	M 8x25	6	30	6.125
2-1/2	2.500	−.0018	3.740		1.811	1.496	1.193	.996	4.134	2 530	37 990	20 050	8	12	M 8x25	6	30	6.125
2-9/16	2.5625		3.740		1.811	1.496	1.193	.996	4.134	2 593	37 065	20 050	8	12	M 8x25	6	30	6.125
2-3/4	2.750		4.331		2.362	1.968	1.590	1.315	4.724	3 680	34 770	18 200	7	10	M10x35	8	60	6.750
2-7/8	2.875		4.528		2.362	1.968	1.590	1.315	4.921	3 845	33 300	16 920	7	10	M10x35	8	60	6.875
2-15/16	2.9375		4.528		2.362	1.968	1.590	1.315	4.921	3 929	32 590	16 920	7	10	M10x35	8	60	6.875
3	3.000		4.528		2.362	1.968	1.590	1.315	4.921	4 012	31 910	16 920	7	10	M10x35	8	60	6.875
3-3/8	3.375		4.921		2.362	1.968	1.590	1.315	5.315	5 434	32 430	18 345	8	12	M10x35	8	60	7.625
3-7/16	3.4375		5.118		2.362	1.968	1.590	1.315	5.512	5 543	31 810	17 630	8	12	M10x35	8	60	7.875
3-1/2	3.500	+0	5.118	−0	2.362	1.968	1.590	1.315	5.512	5 644	31 240	17 630	8	12	M10x35	8	60	7.875
3-3/4	3.750	−.0022	5.315	+.0025	2.362	1.968	1.590	1.315	5.709	7 180	36 450	21 190	10	15	M10x35	8	60	9.000
3-15/16	3.9375		5.709		2.677	2.283	1.882	1.606	6.102	7 957	27 300	16 210	10	15	M10x35	8	60	8.500
4	4.000		5.709		2.677	2.283	1.882	1.606	6.102	8 083	26 870	16 210	10	15	M10x35	8	60	8.500

6. FINITE ELEMENT ANALYSIS OF KEY COUPLING

The axi-symmetric geometry of shaft, bushes and bolt is shown in fig 7. The element type is solid 4 nodes 182. It is defined by four nodes having two degrees of freedom at each node. The element has large deflection, and large strain capabilities.

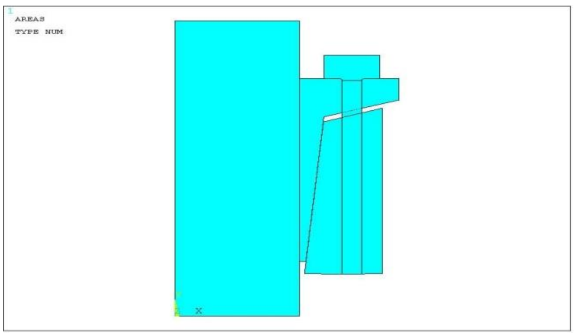


Fig. 7 Keyless coupling

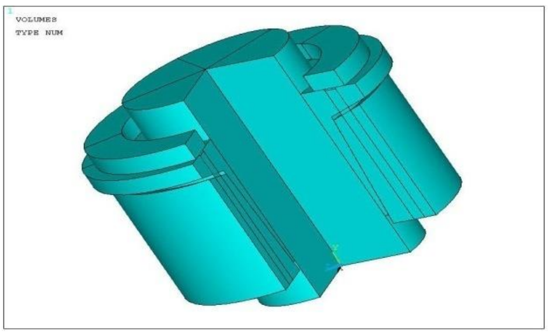


Fig. 8 3D Expanded view of keyless coupling

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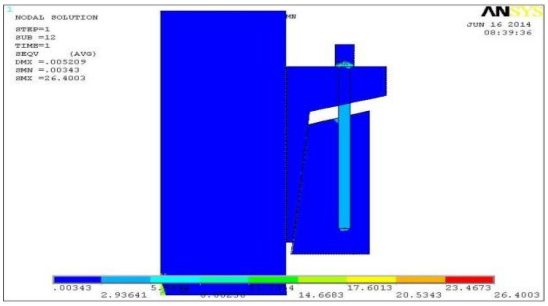
7. DESIGN VARIANTS OF KEYLESS COUPLING

Non- linear analysis is carried out with shaft lower edge is fixed. A negative temperature load is applied. This will cause the bolt material to shrink due to the coefficient of thermal expansion while the other parts remain unchanged. Thermal load is applied it result in bolt virtual shrinking and thereby giving rise in bolt load.



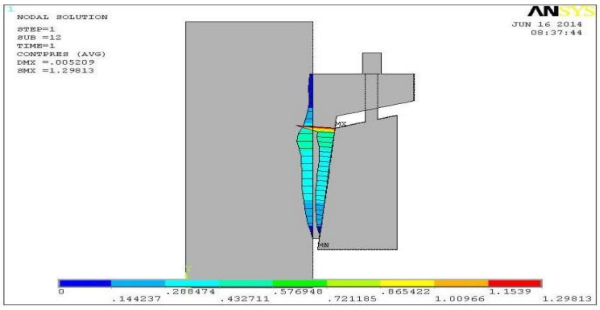
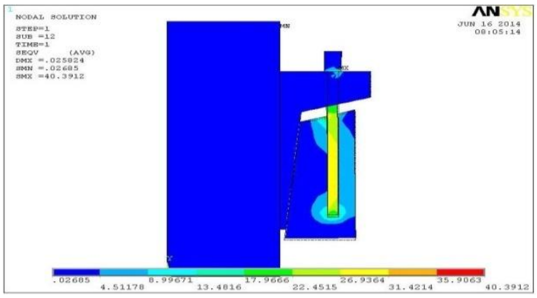


Fig. 9 von Mises stress in bolt **Fig. 10 Contact pressure in between shaft, and bush**

Design variant 2:



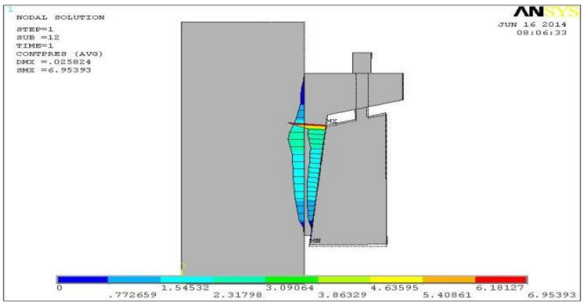
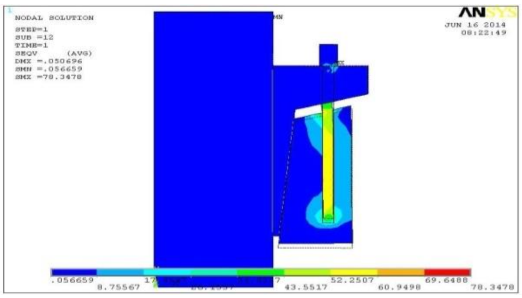


Fig. 11 von Mises stress in bolt **Fig. 12 Contact pressure in between shaft, and bush**

Design variant 3:



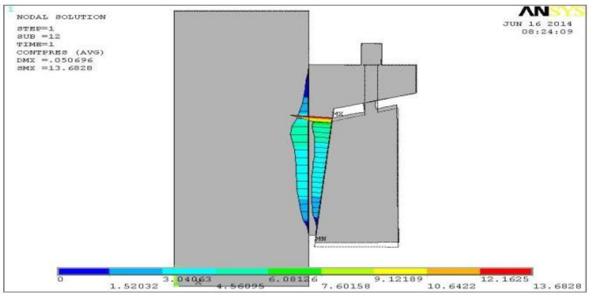
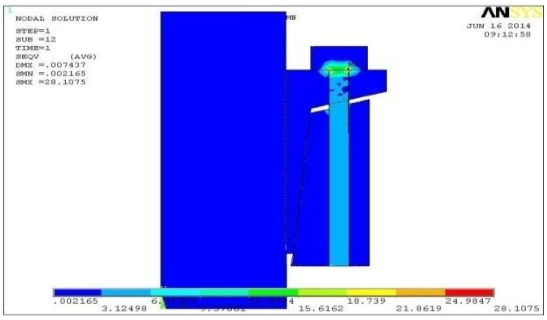


Fig. 13 von Mises stress in bolt **Fig. 14 Contact pressure in between shaft, and bush**

Design variants 4:Non linear analysis is carried out.The bolt length is increased upto end.



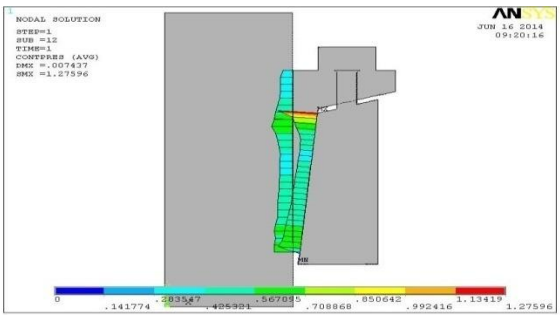


Fig. 15 von Mises stress in bolt **Fig. 16 Contact pressure in between shaft, and bush**

Design variant 5:

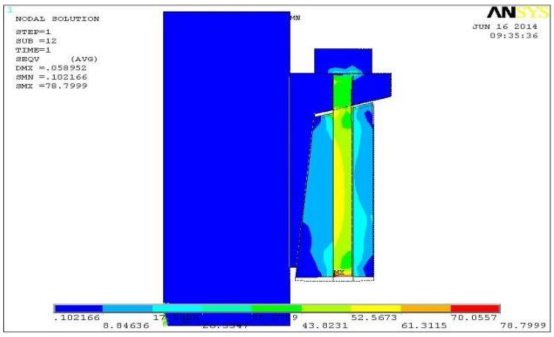


Fig. 17 von Mises stress in bolt

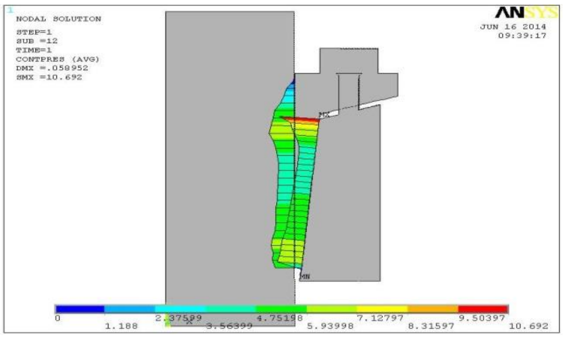


Fig. 18 Contact pressure in between shaft, and bush

Design variant 6:

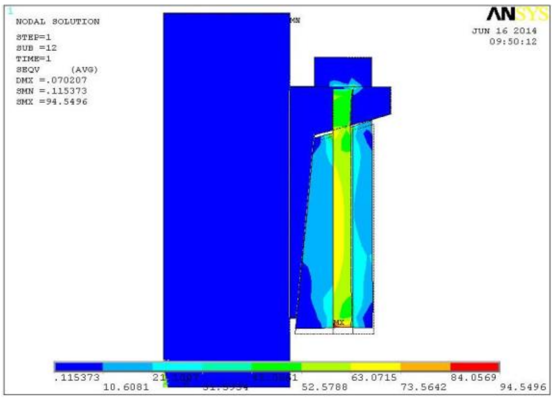


Fig. 19 von Mises stress in bolt

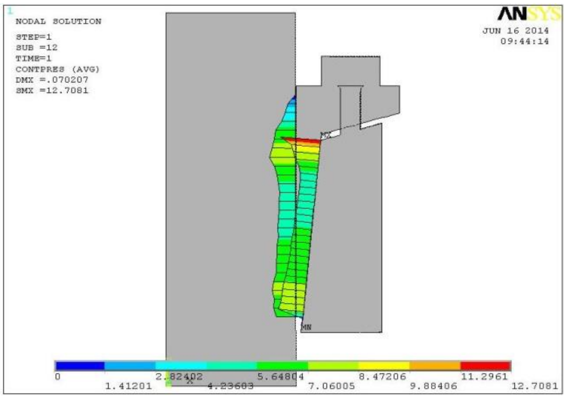


Fig. 20 Contact pressure in between shaft, and bush

7. RESULT AND DISCUSSION

Analysis is carried out for key coupling. The stress concentration in shaft is. 49.25N/mm^2 .For fluctuating load this can cause a crack initiation at the stress concentration point. This leads to shaft failure. In this case diameter of the shaft and weight is more. Because of this reason keyless coupling is suggested. Interestingly the diameter will be much small and same power is transmitted with decrease shaft diameter.

A non-linear analysis is carried out for keyless coupling. Negative thermal load is applied the bolt material to shrink and develops a constant pressure distribution over the shaft and near the bushes.

The standard torque from catalog **1839967.3.**

TABLE 3. Results of design variants

Design varaint	**Temp/°C**	**Bolt load N**	**Stress N/mm^2**	**Contact pressure N/mm^2**	**TorqueN-mm**
1	-17.24	173000.1	52.6	0.6733	23173.8
2	-100	52180.5	260.3	1.344	46288.6
3	-200	208722.3	567	2.624	924052.9

By varying the bolt, bush length analysis is carried out. Here there are design variant, temperature of the bolt is varied it result in, bolt virtual shrinking and thereby giving rise in bolt load. The torque value is calculated for design variants. The torque values are compared with standard values. Torque value is calculated for another set of design variant whose bolt length is increased up to bush end. The analysis is carried is carried out for each design variant and stress and pressure distribution are find out. The average pressure values are used in torque calculation. The von Mises and pressure distribution are obtained in ANSYS and tabulated in table respectively.

TABLE 4. Results of design variants

Design varaint	Temp/°C	Bolt load N	Stress N/mm^2	Contact pressure N/mm^2	TorqueN-mm
4	-17.24	173000.1	63.4	2.321	23173.7
5	-100	52180.5	593.4	4.551	1566500.8
6	-200	208722.3	633.5	5.455	1807696.9

In design variant 6 obtained torque value 1807696.9 N-mm is nearer to standard value 1839967.3 N-mm.

8. CONCLUSION

In present work key and keyless coupling are modeled and simulated using FEA approach. By using ANSYS software. Non linear analysis is carried out with appropriate material constant. Using FEA stress and pressure are obtained for different bolt load. In key coupling power transmitting is 24.4 KW at 100 rpm, the stress concentration in shaft is 49.25 N/mm^2.

For fluctuating load this cause a crack initiation at the stress concentration point. In this case the same power is transmitted with lesser diameter by keyless coupling. The keyless coupling is operated at same power 24.4 KW and speed is 200 rpm. The obtained torque values are compared with standard torque. In design variant 6 obtained torque value 1807696.9 N-mm is nearer to standard value 1839967.3 N-mm.

Keyless coupling is more suitable compared to key coupling, and diameter of the shaft can be reduced. It provides completely tight fit around shaft no backlash. It can transmit high torque and axial loads. In keyless coupling it can transfer more power when compare to key coupling.

9. FUTURE SCOPE OF THIS WORK

The keyless coupling is most efficient when compared to key coupling. The future works are identified as follows:

- Analysis is carried out by considering different material property, that keyless coupling is made stronger so that it can transmit more power.
- Larger taper angle permits tightening with less displacement along the shaft.
- Full length bushes support the shaft correctly.

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