Analyze Different Taper Sized Assembly

Nilesh Vishwakarma[1], Dr. V.M.Phalle[2]

[1]M. Tech Student, Department of Mechanical Engineering, V.J.T.I Mumbai, Maharashtra, India
[2]Associate Professor, Department of Mechanical Engineering, V.J.T.I Mumbai, Maharashtra, India

***

Abstract - *The use of taper method for assembling components has its own advantages besides ease of assembly and disassembly. This paper gives an idea about the importance of taper fit method compared to straight fit in addition to different taper size analysis that can be used for assembly of components. An attempt to test straight fit and different taper size fitted component is carried out considering a simple shaft-disc assembly approach and the analysis is made with respect to stress and contact pressure. The analysis reveals that for the assembly with tapered bore, the stress reduces and a healthy contact pressure exists.*

Key Words: taper, turbomachine, taper interference fit, straight fit, taper fit, contact pressure, equivalent stress

1.INTRODUCTION

For every transmission system for instance shaft, enhancement of efficacy has always been a boundless quest. It is not just spinning, but how proficiently it spins is the decisive factor. As an example, if we want to connect a driving component like motor directly to the output end of the machinery, then there would hardly be any point in concerning about the efficiency loss. However, due to the constraint of space availability besides machine profile, translation of rotational speed, alteration in axial direction, etc., are inevitable in almost all machineries.

An innovative idea presented by L. Haugen, Robert King and Jeff Schmidt on Tapered Polygon Coupling for rotor [1], the shaft has a tapered bore having a polygonal cross-section. The rotor includes a corresponding tapered polygon plug configured to be placed in the bore of the shaft. Additionally, the rotor may include the tapered bore having a polygonal cross-section, and the shaft may include the tapered polygon plug configured to be placed in the bore of the rotor. The plug of the shaft is split so that when the fastener is inserted into the passage the plug expands against the side wall of the bore thereby creating an interference fit between the shaft and the rotor. This method gives an idea that the taper fit can be employed for coupling or assembly of components and an attempt to analyze the design parameters with respect to conventional straight fit method to have better understanding of its performance.

In turbo machines, the typical fit between the rotor and shaft using straight shrink fit method to provide interference may build up higher residual stresses throughout the component bore. Residual stress may be desirable or undesirable. For example, laser peening imparts deep advantageous compressive residual stresses into metal components such as turbine engine fan blades, and it is used in toughened glass to allow for large, thin, crack- and scratch-resistant glass displays on smartphones. However, accidental residual stress in a designed structure may cause it to fail prematurely [2]. For rotor assembly, undesirable residual stress is likely to happen if employed shrink fit is beyond the requirement. Such higher residual stresses can be curbed with use of taper fit method.

The mechanics of the tapered interference fits in dental implants and the analysis carried by Dincer Bozkay and Sinan Mueftue provides a reliable connection in addition to the stability of the implant-abutment. The analysis shows that plastic deformation in the implant limits the increase in the pull-out force that would have been otherwise predicted by higher interference values [3].

The tapered interference fit and its contact stress induce more and more relative study work. Stress variations of various configurations of the taper lock used to connect the turbine shaft to the turbine disk and when used in belt-conveyor systems are carried by V. Ramamurti and R. Karthikeyan [4]. Also, the effect of structures and pressure forces on the contact stress were studied and gives useful information [5,6].

For a turbomachinery applications if the stresses are reduced then the load carrying capacity can be increased and it would be able to run at higher speed to meet the requirements. Taper fit plays a better role to serve the purpose.

1.1 Straight Fit and Taper Fit

Typically, there are two different methods to connect axial parts i.e. straight fit and taper fit as shown in Fig -1. Also, we can eliminate the fittings if male and female parts are integrated i.e. made as a single unit, however, it would not only raise the cost of manufacturing, but also the maintenance cost can go up as the entire unit may need to replace.

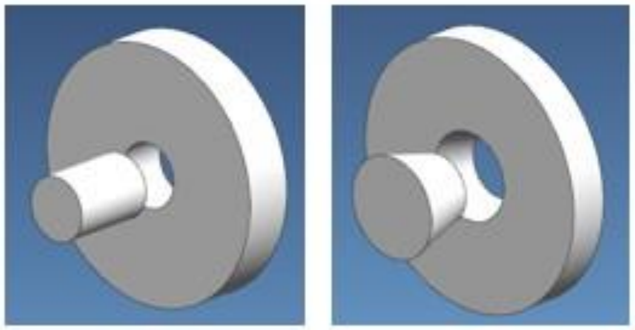


Fig -1: Straight fit and Taper fit

With the straight fitting method, a certain amount of clearance is required for the male and female parts to fit together, which could be a cause of rotational instability. Such instability is further amplified at the critical engaging portions such as rotor & shaft assembly, which could cause undesirable noise and fluctuations. When optimal fitting is achieved with taper fitting, undesirable noise and fluctuations could be minimized which emphasizes the importance of taper fit [7].

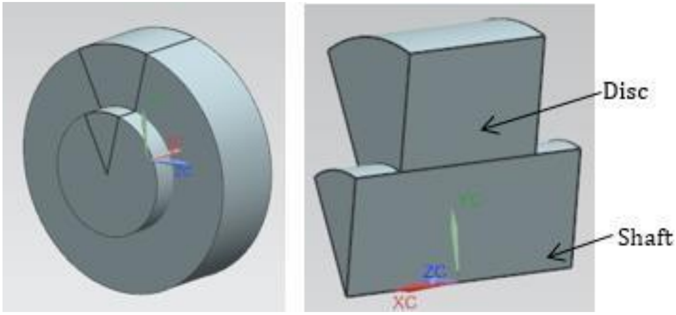
Tapered joint can be considered as a power transmission component which transfers rotational power. Tapered joint hardly induces any stress concentration because of no use of key or cotter to prevent rotational slip in addition to advantage of ease in assembly or disassembly.

Tapered interference fits can avoid the impact of keyways on the parts strength and transfer huge torques. The study done on the influence of taper on the interference fit between a propeller hub and a shaft reveals improved stress distribution of the propeller hub and an effective approach to increase the connection strength [8].

Having conferred to various benefits of tapered interference fit method the limitation of different taper size is equally important since higher taper may reduce the stress but at the same time it may lead to very weak contact pressure between the component assembled and likely to lose the connection completely. An attempt to present the analysis of various taper sizes and their effect on the components is analysed with respect to stresses and contact pressure.

2. MODELING

A simple shaft and disc approach is modeled for analysis. Shaft and disc with suitable size and an initial straight fit, is modelled using NX™ software and for swift results a slice model (one sector) is considered as shown in Fig -2.



A B

Fig -2: Assembled shaft and disc Model
A. Full Model B. Slice Model

3. ANALYSIS

ANSYS® software package is used for analysis. Static structural analysis in workbench is carried out wherein, the material generally used for rotor (disc in this case) and shaft in turbo machine is considered for analysis. For most applications, high-strength alloy steel is selected for the rotor material, the similar material is used for disc material having higher strength and suitable yield strength is considered for shaft material. The straight fit slice model shown in Fig -2 is then imported in static structural environment. Contact constraints with respect to shaft and disc besides uniform geometric interference is applied using add offset, rammed effects. Cyclic symmetry is applied so that the program solves for the full cyclically symmetric model using the basic sector model as shown in Fig -2 B. Fine meshing is used as shown in Fig -3 for better accuracy of results.

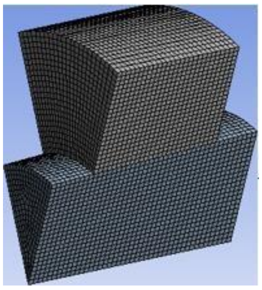


Fig -3: Fine meshed straight fit assembly (slice model)

Boundary conditions and loadings for shaft and disc are applied and the model is solved. The flowchart shown in Fig -4 presents the steps followed for analysis.

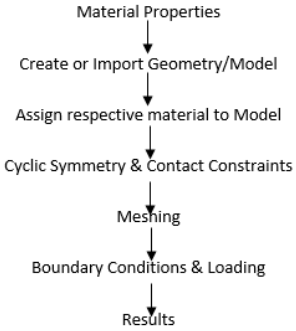


Fig -4: Steps for analysis in Ansys

In the similar manner, the procedure as conferred is applied to various tapered geometry as carried for straight fitted assembly i.e. modelling the various tapered geometry using NX™ and performing the analysis using ANSYS® software package. Straight fitted model besides different taper size is tested to check the feasibility of the design constraints. Different tapered geometries having the taper size of 1/50, 1/40, 1/30, 1/20, 1/15, 1/10, 1/7, 1/5, 1/3 and 1/1 is modeled and analyzed. Fig-5 depicts one of such tapered slice model.

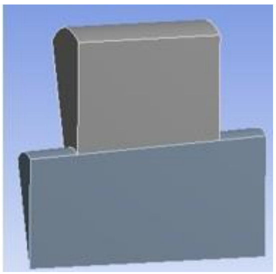


Fig -5: Taper Fitted Shaft-disc assembly (slice model)

4. RESULTS & DISCUSSIONS

Table-1 shows the result of straight fitted assembly and various taper geometries considered for analysis.

Table -1: Straight fit vs different tapered fit results

Taper Size	Eq. Von-Mises Stress (Mpa)	Average Contact Pressure (Mpa)
Straight Fit-No Taper	446.98	33.9
1/50	439.4	32.9
1/40	438.1	31.6
1/30	437.8	31.4
1/20	436.5	31.3
1/15	435.8	30.1
1/10	430.6	29.2
1/7	425.1	27.8
1/5	413.1	25.1
1/3	59.3	2.99
1/1	10.1	0

The foremost attention is to analyze the equivalent Von-Mises stress and contact pressure between shaft and disc for safe operations. Lower stress and healthier contact pressure is the deciding criteria. From the Table-1, the straight fitted assembly shows higher stress compared to any of the tapered assembly. Fig -6 shows the von-mises stress for straight fit and a tapered fit having 1/20 taper size. However, comparison with respect to various tapered geometry reveals that as the taper size increases, the stress decreases continuously. Also, minimum contact pressure should be present to ensure healthier connection. With increase in taper size the contact pressure also keeps on decreasing and completely vanishes for 1/1 taper size as seen in table-2 and chart-1. Hence, suitable taper size for healthier contact pressure should be confined as per need.

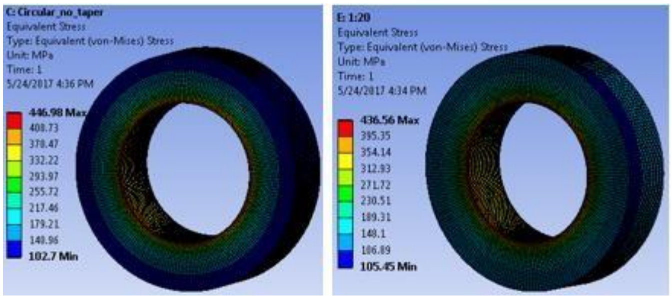


Fig -6: Von-Mises Stress for Straight Fit and a Taper Fit

Based on the stress levels and contact pressure, taper size of 1/20 and the size in its vicinity seems to give results at par with straight fit considering good contact pressure and lower stress echelons. Here it may appear that the stress levels and contact pressure are similar for many of the tapered geometries because of the lighter geometry considered for analysis, however its impact can only be understood if it is applied for heavy duty operations wherein the rotor analysis can give better understanding of the conferred results.

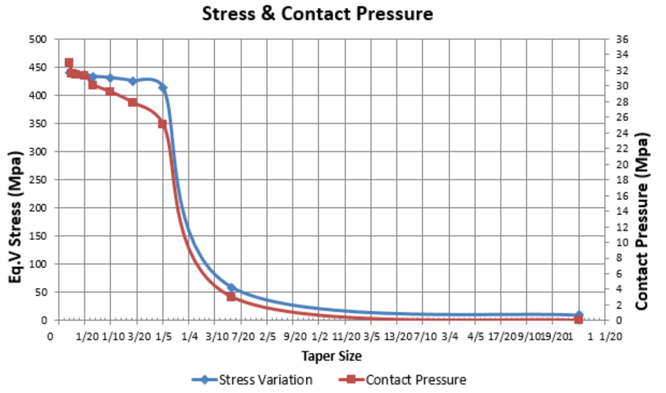


Chart -1: Von-mises Stress and Contact Pressure vs Taper

4. CONCLUSION

The analysis of the straight modeled assembly and the tapered assembly model shows that the stress levels for taper fit can be reduced in comparison with straight geometry and maintaining healthier contact pressure at par with straight fit assembly. If the stresses are reduced while sustaining the contact pressure higher than the requirement, then it can be inferred that the application can withstand higher loads keeping the design parameters safe. With the above results and discussions, it can be concluded taper fit method of assembly helps to achieve better results.

ACKNOWLEDGEMENT

The author expresses sincere gratitude to Dr. V.M.Phalle, for his inspiring thoughts throughout the academics for research activities and to come up with out of box thinking ideas. Also, the author thanks Avinash Renuke, Design Engineer for motivating towards research activities and emphasizing the zeal for learning.

REFERENCES

[1] Ronald L. Haugen, Robert King, Jeff Schmidt. “Tapered Polygon Coupling.” US Patent Pub. No.: US 2002/0164252

[2] Wikipedia contributors. “Residual stress.” Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 26 Mar. 2017. Web. 26 May. 2017.

[3] Dincer Bozkay and Sinan Mueftue, “Mechanics of the tapered interference fit in dental implants”, Journal of Biomechanics, Vol.36, pp.1649~1658, 2003

[4] V. Ramamurti, R. Karthikeyan, “Stress analysis of taper locks”. Computers & structures 62(1997), Vol.62, Issue 4, pages 721-736

[5] A. Ozel, Ş. Temiz, M. D. Aydin, et al. “Stress analysis of shrink-fitted joints for various fit forms via finite element method”. Materials & design 26(2005): 281-289.

[6] I. T. Cook, H. Fessler, T. H. Hyde, et al. “Assembly stresses in taper-locking shaft couplings Part 1: Photoelastic work.” Journal of Strain Analysis for Engineering Design 36(2001) : 25-34.

[7] "Advantages of Taper Fitting." High Precision Taper Grinding Products : M1 Seiko Co., Ltd. N.p., n.d. Web. 26 May 2017.

[8] “Exact Solution of Stresses of Tapered Interference Fit”, Applied Mechanics and Materials, Vol.556~562, pp.4284~4287, 2014