Static and Dynamic Simulation of a new High Deflection Constant-velocity U-joint (Persian Joint)

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This paper simulates statically and dynamically a new universal joint (Persian joint) which newly has been invented by M. Yaghoubi. The intersecting angle range of this joint is up to 100 degrees and even more and can transmit power at constant angular velocity at all angles. Because of its complex design, it can not be designed by analytical analysis. To solve this problem, the joint is designed with initial dimensions and by simulation of components statically and dynamically at a specified torque a new safety factor according to a component which has maximum stress was determined. By this safety factor all components can be designed. [Report and Opinion 2010;2(5):41-44]. (ISSN:1553-9873).

Keywords: Dynamic; Intersecting angle; Persian joint; Safety factor; Static; Stress

1. Introduction

The objective of this study is calculation of static and dynamic stresses on a joint (Persian joint) which was designed by M. Yaghoubi (2009) at Tehran university. This joint has intersecting angle up to 100 degrees and even more and can transmit power at constant velocity at all angles [Yaghoubi, 2009].

Universal joint is a coupling which can transmit power between intersecting shafts [Shirkhorshidian, 2004]. SAE separates U-joints into three categories: nonconstant-velocity, near-constant-velocity and constant-velocity. But all joints during rotation because of their intersecting angles are under variable forces and torques [Hojjati, 2000]. To design of U-joints components we must calculate the all forces and torques on joints both statically and dynamically. But because of load fluctuations during rotation at different angles, the calculation of all forces and torques is very difficult and time-consuming [Erdmanetal, 1991; Behroozi Lar, 2003]. So because of high intersecting angle of Persian joint, the force and torque fluctuations on its joints are very high. One of the torque equations on input shaft of Persian joint is shown in equation (1).

$$T_{1x} = K.T_{1z}(1+\cos(2\alpha))/(\cos(2\alpha).K.\sin(2\alpha) - \cos^2(2\alpha).K.\sin(2\alpha) + \cos(2\alpha).K.\sin^2(2\alpha).T_{1z} + \cos(2\alpha).S.\sin(\alpha).\cos^2(2\alpha).S.\sin(\alpha) + \cos(2\alpha).S.\sin(\alpha).T_{1z}.\sin(2\alpha) + S.\cos(\alpha).K.((S.\cos(\alpha).K\cos(2\alpha) + S.\cos(\alpha).K.T_{1z}.\sin(2\alpha) - K.\sin(2\alpha) \quad (1)$$

Where: T_{1x}= Torque in x direction of input shaft
T_{1z}= Input Torque
K= Length of Input coupling
2α= Intersecting angle

As shown in equation (1) calculating the all equations are very difficult and complex. Thus by these equations the strength of components can not be estimated. Then to optimize time and initial construction costs, this mechanism must be simulated with initial dimensions to be determined how much torque can be transmitted [Yaghoubi, 2009].

1. Materials and Methods

Persian joint consists of one drive coupling and one driven coupling which are coupled to input and output shafts respectively, six guide arms, and three connecting arms.

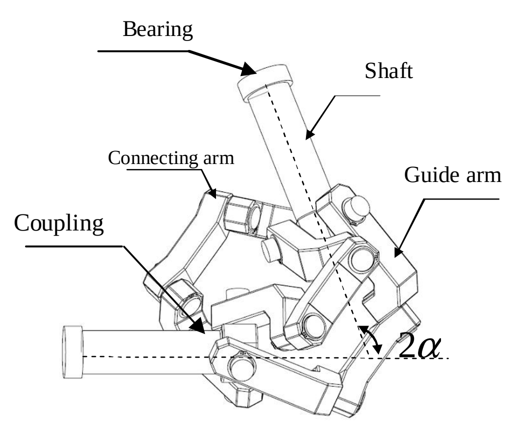


Figure 1. A schematic of Persian joint

Because of non-constant angular displacement of connecting arm during rotation (2), variable forces and torques occur in its joints [Yaghoubi, 2009].

$$\theta = Sin^{-1}\left(\frac{Sin(\beta).Sin(\gamma)}{Sin(\beta + Tan^{-1}(Cos(\gamma).Tan(\alpha)))}\right) \qquad (2)$$

Where: $\beta(rad) =$ Slope of connecting arm with respect to the vertical line on its surface

$\theta(rad) =$ Displacement of connecting arm

$2\alpha(rad) =$ Intersecting angle between two shafts

$\gamma(rad) =$ Displacement of input shaft

As shown in Figure 2 in initial design following dimensions is considered for Persian joint. All dimensions are based on millimeters.

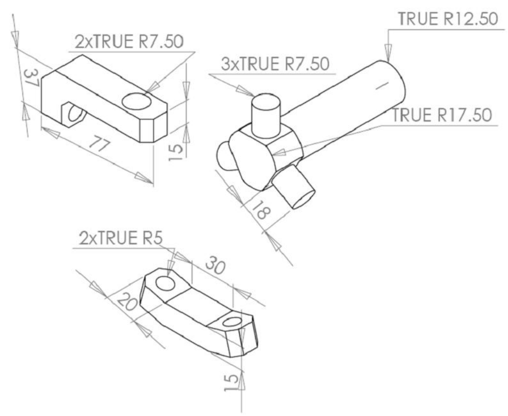


Figure 2. Initial dimensions of components

Because of the most components under heavy load are made of 18CrNi8, this materials is chosen for all components. The properties of 18CrNi8 are shown in Table 1 [Yaghoubi, 2010].

Table 1. Properties of 18CrNi8

General	Mass Density	217.3 g/cm^3
	Yield Strength	800 MPa
	Ultimate Tensile Strength	1200 MPa
Stress	Young's Modulus	210 GPa
	Poisson's Ratio	0.38 ul
	Shear Modulus	76.087 GPa

To prevent abrasion, all components must be hardened.

2.1. Static Analysis

After initial design, the joint was transferred to COSMOSWorks software for static analysis. In static analysis the intersecting angle of the joint is 100 degrees and input torque without rotating is 1000 N.m. As shown in Figure 3, maximum stress occurs in input shaft with safety factor 0.7 but in other components safety factor is more than 2.

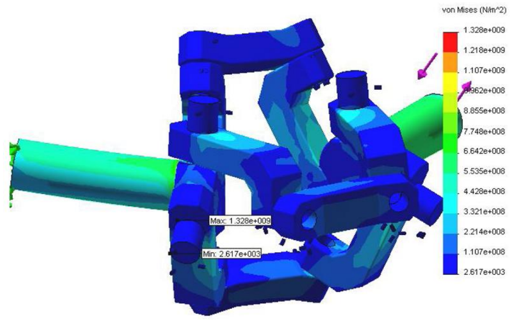
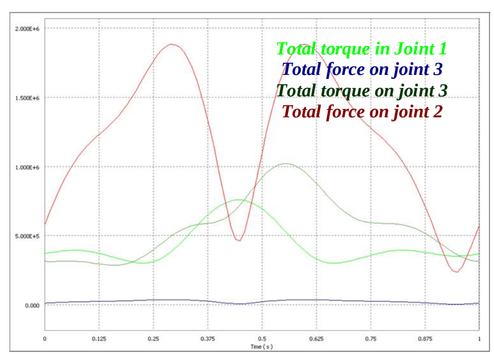


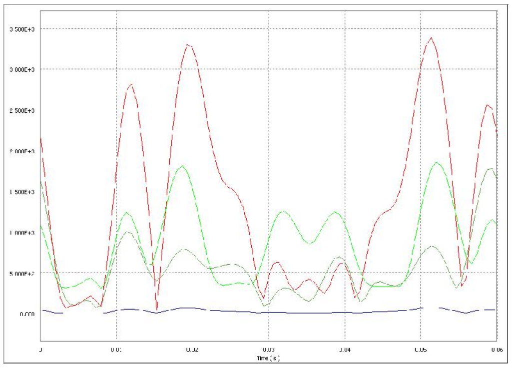
Figure 3. Stress counter of all components

2.2. Dynamic Analysis

As explained in introduction, because of intersecting angle between shafts during rotation, force and torque fluctuations occur on components. After static analysis, the joint was transferred to Autodesk Inventor software and simulates under two dynamic simulations one with input angular velocity 1 deg/s, torque 300 N.m and another with high angular velocity without input torque.



(a)



(b)

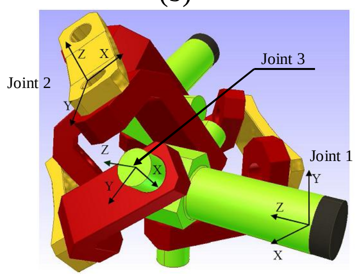
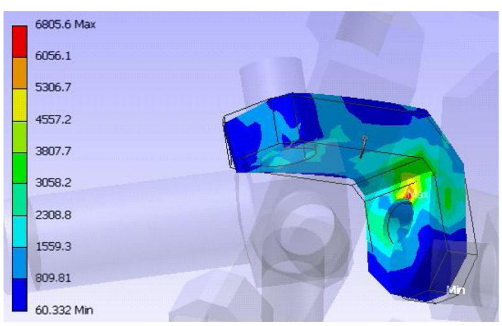
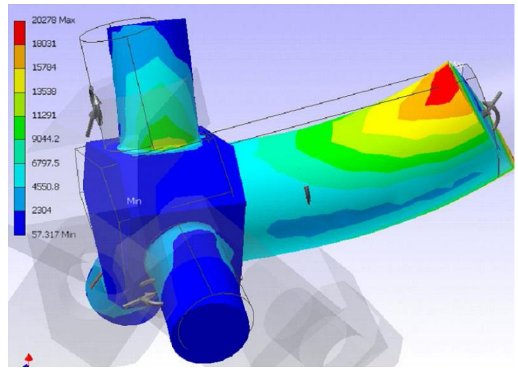


Figure 4. Diagram of forces and torques in joints a) high torque and low angular velocity b) High angular velocity and low torque

As Shown in Figure 4, maximum stress in Figure 4 (a) is more than Figure 4 (b). Therefore the forces and torques in Figure 4 (a) were transferred to ANSYS software and all components were simulated. All stress counters were shown in Figure 5.





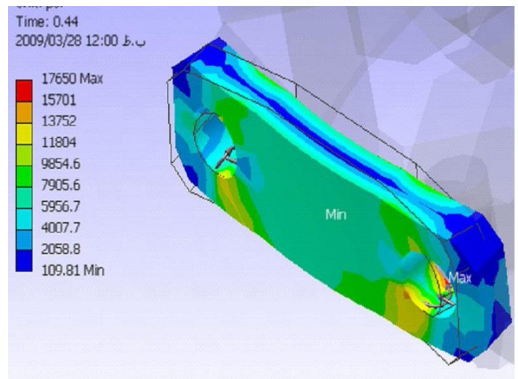


Figure. 5. Stress analysis of components

As shown in Figure 5, maximum stress occurs in shafts. The shafts safety factor was 0.57. For comparison between static and dynamic stresses of shaft (high stress component) only this component was simulated statically with torque 300 N.m. After simulation safety factor was 4.5.

3. Results

As shown in Figures 3, maximum stress occurs in shafts and safety factor of all components of the joint is more than 1.5. Thus the joint under high static torque is resistant and for initial design first shafts must be designed.

By dynamic analysis was determined that the joint can transmit power at high angular velocity but for low torque; thus to design of the joint we must focus on the input torque value.

Also in the dynamic analysis, highest forces occur in shafts. With comparison between safety factors of the shafts at 300 N.m statically and dynamically, was determined, to specify the dimensions of the shafts for each torque rating, almost safety factor 8 (4.5/0.57) × desired safety factor value must be considered and dimensions of other components must be determined in proportion of new dimensions of the shafts and Figure 2.

Conclusion

By simulation statically and dynamically was determined that because of high intersecting angle of Persian joint, torque rating of the joint at high intersecting angles is low and because of high the maximum stress occurs in shafts therefore to design of the joint first shafts must be designed with a high safety factor which was determined in results part. The dimensions of other components are related to the new dimensions of the shafts. For comparison of the joint with other joints such as Rzeppa joint, the joint should be analyzed in the range of their intersecting angles.

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