DESIGN OF TORQUE TESTING SETUP FOR SHAFT HAVING SPLINES AT TWO ENDS

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Abstract - The shaft having splines at both ends is used in aircraft door, which is made up of AMS4928 one of Titanium-Aluminum alloy. A latch lock mechanism used to open and close a translating motion aircraft door. A lift lock mechanism that contains a lift lock cam and a follower which follows the cam, as well as a door drive linkage coupled to the cam follower, rotates the latch shaft, operated by a handle rotates the lift lock cam. When the handle is turned there is considerable torsional load applied on the shaft. The present work deals with the designing a rig for testing of a shaft ensuring that its splines are not getting damaged. The test requirement is to twist the rod about 25° and to monitor the torque with end results. This extreme torsional load is considered for those cases where there is no formal application of load but unexpected torsional thrust. The rig is designed in such a way that the rod tilted as per the required tilt by having simple setup. Setup includes adapters to hold the rod and a leverage bar for twisting the shaft.

***Key Words*:** Torque testing rig, 3D CAD modelling, FEA

1.INTRODUCTION

The doors are one of the systems where the electric drive will take the place of the already prevalent hydraulic technology. The Federal Aviation Administration's (FAA) circular CS25.783, which covers the subject "fuselage doors and hatches," reports the standards for cargo doors as well as passenger doors. The circular states that both container doors and passenger doors should have three primary sub-components: a lifting component that enables the removal of the entire door from the fuselage a locking component, which is a security component and a latching subsystem, which is utilized to secure the entrance to the fuselage and prevent unintentional opening during the flight. The principal lifting mechanism and the latching mechanism, in particular, have undergone electrification and automation interventions in recent years. However, in order to offer additional security, the locking mechanism is often left manually operable. A semi-automatic door is typically designed as shown in the patent [1] the latching and lifting phases are automated and electro-actuated, but the locking phase is manually operated due to safety concerns.

The shaft having splines at its both ends is used in aircraft door, which is made up of AMS4928 one of Titanium-Aluminium alloy. This alloy shows high strength to weight ratio and used in high strength lightweight applications. The present work deals with the designing a set-up for testing of a shaft, taking care of its splines without damaging. The test requirement is to twist the rod about 25° and to monitor the torque with end results. The test rig is designed such a way that the rod tilted as per the required tilt by having simple setup. Setup designed such a way that one end of the testing rod is fixed, and another end attached to the twisting end. At twisting end, torque is applied. Torque can be applied using motor or by leverage bar for twisting the shaft. The test Setup includes adapters with splines to hold the rod rigidly. In order to twist the shaft, a leverage bar is used, and bearings allow the adapter to rotate, and hydraulic cylinder is used to apply gradual loading, Hydraulic cylinders are actuation tools that generate force and linear motion using pressurized hydraulic fluid. They can be single- or double-action and are utilized in a few power transmission applications. Cast iron T-slot blocks were used to fix the components rigidly using fasteners. During the Torsion test for every 5° twist the applied torque is measured up to 25° and twisting to 25° for shorter length could permanently deform or break the part.

2. EXPERIMENTAL METHODS

2.1 Conceptual design of test rig.

One end of the testing shaft is fixed, and other end is connected to the long leverage, perpendicular to the axis of testing shaft which will create toque in the testing shaft. Torque depends on two quantities one is force and other one is perpendicular length of force acting and it is directly proportional to both the quantities, as length of the leverage increases the torque also increases. Leverage bar designed in such way that it can hold maximum loads without bending and failure.

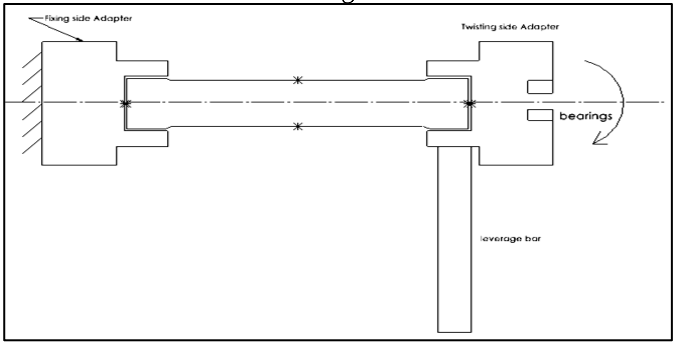

Fig -1: Leverage beam conceptual design

2.2 Calculations

consider basic torsional equation, given by

$$\frac{T}{J}=\frac{\tau}{r}=\frac{G\theta}{l}$$

Where,

T - Torque
J - Polar second moment of area of cross section
τ - Shear stress at outer fibres
r - Radius of shaft
G - modulus of rigidity
θ - Angle of twist in radians
l - Length of shaft
d - Diameter of shaft

Table -1: AMS4928 material properties

Properties	Values
Density	4.43 g/cc
Length of testing shaft	853.44 mm
Diameter of testing shaft	16.6 mm
Young's Modulus	113.8 GPa
Shear Modulus	44 GPa
Shear Strength	550 MPa

For required θ, torque to be applied is given by

$$T = \frac{J*G*\theta}{l}$$

$$= \frac{\pi*(16.6)^4*44*10^3*\theta*\pi}{32*180*853.44}$$

T= 6707.942 * θ ……. N-mm

To calculate leverage beam length, consider the below Fig- 2

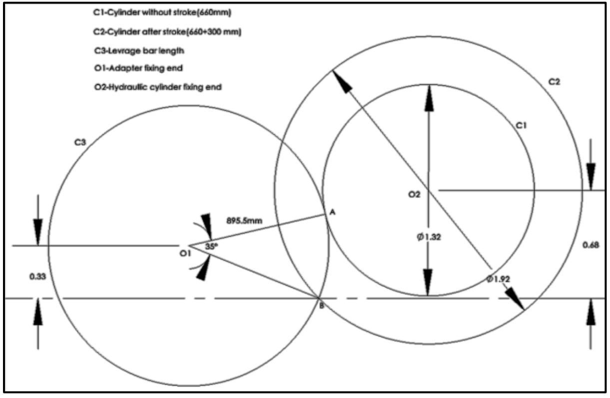

Fig -2: Leverage length calculation

From the above figure to get 35° angle of twist, 895.5 mm leverage beam is required, force applied on the leverage beam to get desirable torque is

T = F X L
F = T/ 895.5
F = 6707.942 X θ/ 895.5 …. N

Below Table- 2 explains amount of force applied to the leverage to get required angle of twist.

Table -2: Force v/s angle of twist variation

θ in degrees	Torque to be applied(N-mm)	Force applied(N)
5	33522.71	37.43
10	67045.41	74.87
15	100568.12	112.30
20	134090.83	149.74
25	167613.53	187.17

2.3 Material selection for test set-up

Material used for setup of test rig are EN24 and EN36, which are the alloy steels used in manufacturing.

Table -3: EN24 Material properties

Tensile Strength N/mm²	Density g/cm3	Young's modulus GPa	Yield Stress N/mm²	Hardness HB
850-1000	7.85	210	680 Min	248-302

Table -4: EN36 Material properties

Tensile Strength N/mm2	Density g/cm3	Young's modulus GPa	Yield Strength N/mm2	Hardness HB
1230	15.7	200	1100	341

EN36 is used in manufacturing of leverage beam which will take more impact loads compare to EN24. Material and critical parts are heat treated up-to 42-45HRc to get desirable strength.

2.4 CAD modelling

From the draft design, the torque testing rig mainly consist of following components, Fixed side adapter and twisting side adapter which are having female splines it will hold the testing shaft. Bearing and bearing cover helps to twist the twisting side adapter. leverage beam is used to apply force, which will apply torque to the testing shaft. Eye end Support cylinder to block support fixture cast Iron block were used to fix rig. Components. Hydraulic cylinder and hydraulic hand pump used to apply force at leverage beam. Fasteners were used to mount all the components. Detailed CAD modelling assembly is shown in the Fig -3 below.

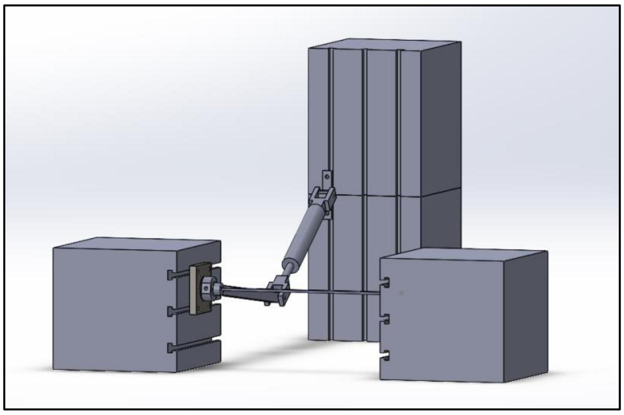

Fig -3: CAD assembly of test rig.

2.4 Simulation study

FEA analysis was carried on by taking critical parts, the entire setup was made to simulate the real-world test setup. Then, these equations and boundary conditions are 'projected' into the nodes, yielding a finite (though frequently huge) number of nodes. The computer solves the linear equations, and the set of derived variables for every node and element is saved to files. The generated data is utilized to perform numerical analysis, visualize data, and make design decisions.

Meshing for critical and non-critical components were carried out. For both critical and non-critical components element size was specified to be 5mm. Tetrahedral mesh is applied after meshing, boundary conditions must be applied. For fixed side adapter and rotating side adapter holes fixed boundary conditions were applied. And constant force of 190 N or 175 Nm in negative Y direction was applied at hole in the leverage bar. Below series of figures portray maximum stress and maximum stress location in critical parts of the test set-up.

3. RESULTS AND DISCUSSION

Final results of the FEA analysis for the critical parts are as shown in below. Each individual critical component out of assembly was taken separately for better visual understanding, and critical data is presented in the following Table -5.

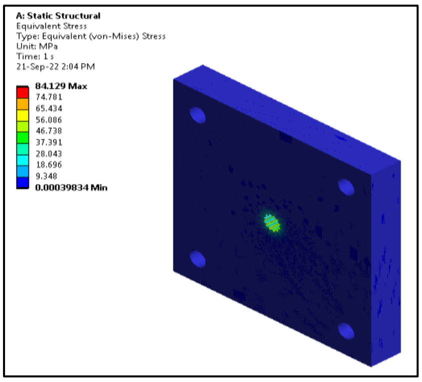

Fig -4: Fixed side adapter analysis and Max. stress location

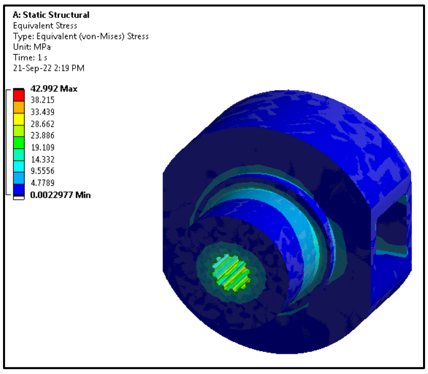

Fig -5: Twisting side adapter analysis and Max. stress location

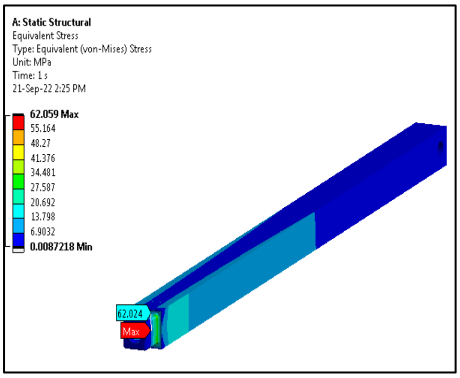

Fig -6: Leverage beam analysis and Max. stress location

Table -5: Analysis results summary

	Fixing side Adapter	Twisting side Adapter	Leverage beam
Load	172 N-m	172 N-m	190 N
Element size	5 mm	5 mm	5 mm
No. of nodes	79809	71286	43825
No. of elements	17478	47439	30121
Yield stress	680 N/mm2	680 N/mm2	1100 N/mm2
Max. stress	84.129 N/mm2	42.992 N/mm2	62.059 N/mm2
FOS	Greater than 6	Greater than 6	Greater than 6
Results	Design is safe	Design is safe	Design is safe

Among the critical components, maximum stress is observed in the fixing side adapter. But all the critical parts are considered safe because none of the maximum stress values cross yield limits. Hence drawing of the components will be next step in the design process.

Below fig -7 shows amount of force required to get required angle of twist

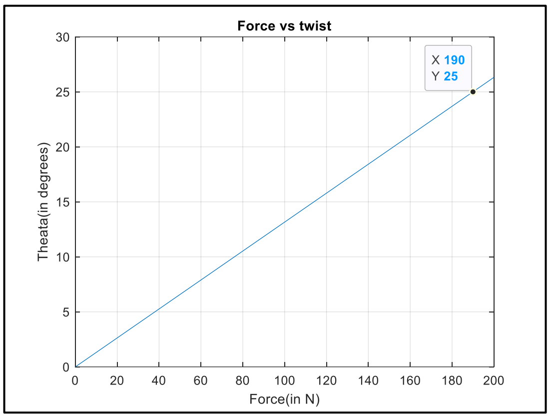

Fig -7: Force v/s angle of twist variation

4. CONCLUSIONS

The main intent of the current work is to design and develop a prototype for testing of the shaft with splines made of material AMS 4928. For this work began with considering appropriate mechanism post literature survey, followed with appropriate material selection for the test rig. Then conceptual model was developed and same was modelled and assembled in SOLIDWORKS.

For the CAD model Finite Element Analysis was performed. Critical parts which are subjected to heavy loads are concentrated on the analysis. Mesh convergence test was performed for optimum mesh size to avoid residual errors in the calculations. Mesh refinement was done at critical sections such as holes in the adapter. For high torsion angles (near to the material rupture stage), a considerable stress localization was found in the specimen's centre area, necessitating numerical modelling for interpretation. Results were analysed and critical sections were noted. Fixed adapter went through maximum stresses which are below the critical limits, hence the adapter design was considerably safer and hence, can be forwarded to manufacturing. Before that manufacturing drawings were prepared. Appropriate surface roughness and tolerances are supplied wherever they are required. Heat treatment methods were suggested based on the literature survey of the material properties to achieve the required strength.

Finally, post manufacturing of the components, tolerance testing, mating testing and surface hardness testing was performed, followed with the assembly of the components. Final testing of the prototype rig has to be carried out as future scope of this work. Convergence of numerical and analytical results with the actual testing has to be verified carefully.

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