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RESEARCH ARTICLE OPEN ACCESS

A SCHEMATIC DESIGN AND ANALYSIS OF A HINGE IN AEROSPACE STRUCTURES USING DIFFERENT MATERIALS

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Abstract:

On an aircraft, the hinge is one of the important directional control surface along with the rudder-like elevator (attached to the vertical stabilizer) and ailerons (attached to the wings) that control pitch and roll, respectively. The components of hinge assembly are hinge Arms, Fork Head, Spar and Panel, hinge Arms are to be designed to take loads from rudder. The scope of the present work is to detailed design of hinge to meet strength and stability requirements and modeling done by using CATIA V5 software. The static stress analysis carried out to find the stresses like Von misses, Maximum Principal, shear stresses for different materials using ANSYS.

Keywords — **Hinge, CATIA, ANSYS.**

1.0 Introduction:

Hinges have been widely used in applications such as gyroscopes, accelerometers, balance scales, missile control nozzles and multiplying linkages. Furthermore, micromanipulation has emerged as an important technological advancement in the past decade that increases the use of flexure hinges. Hinge consists of a flexible, slender region between two adjacent rigid parts that undergo relative limited rotation in a mechanism and is the important constituent of lumped compliant mechanisms. Flexure hinges have several advantages over conventional rotational joints due to being monolithic with the rest of the mechanism. In these solid-state mechanisms, the flexibility is achieved only by flexure hinges, which fulfill the function of conventional revolute joints but are limited to small angular deflections of a few degrees. For guiding and transfer tasks in ultra precision systems of Microsystems technology, precision engineering or metrology, mostly prismatic flexure hinges with basic cut-out geometries are used as material coherent revolute joints realizing a plane motion. Because of the material coherent pair, flexure hinges have a small motion range, which is limited by the allowable stress. In addition, the load-dependent shift of its axis of rotation is disadvantageous. The demand for larger angular deflection and a low shift of the rotational axis results in very complex flexures or an increased number of joints in the mechanism. With a few exceptions, the contour optimization of flexure hinges with regard to both of the opposed criteria is not yet the subject of research.

In practice, both aileron and hinge control input are used together to turn an aircraft, the ailerons imparting roll, the rudder imparting yaw, and also compensating for a phenomenon called adverse yaw. A hinge alone will turn a conventional fixed-wing aircraft, but much more slowly than if ailerons are also used in conjunction. Use of hinge and ailerons together produces co-ordinate turns, in which the longitudinal axis of the aircraft is in line with the arc of the turn, neither slipping, nor skidding. Improperly hinge turns at low speed can precipitate a spin which can be dangerous at low altitudes.

2.0 Literature review:

1. **K. Michalczyk (2017)** the analysis of elastomeric coating influence on dynamic resonant stresses values in spring is presented in this paper. The appropriate equations determining the effectiveness of dynamic stress reduction in resonant conditions as a function of coating parameters were derived. It was proved that rubber coating will not perform in satisfactory manner due to its low modulus of elasticity in shear. It was also demonstrated that about resonance areas of increased stresses are wider and wider along with the successive resonances and achieve significant values even at large distances from the resonance frequencies.
2. **B. Pyttel , I. Brunner, et al. (2017)** Long-term fatigue tests on shot peened helical compression springs were conducted by means of a special spring fatigue testing machine at 40 Hz. Test springs were made of three different spring materials – oil hardened and tempered SiCr- and SiCrV-alloyed valve spring steel and stainless steel. With a special test strategy in a test run, up to 500 springs with a wire diameter of d = 3.0 mm or 900 springs with d = 1.6 mm were tested simultaneously at different stress levels. Based on fatigue investigations of springs with d = 3.0 mm up to a number of cycles N = 109 an analysis was done after the test was continued to N = 1.5 _ 109 and their results were compared. The influence of different shot peening conditions were investigated in springs with d = 1.6 mm.
3. **Touhid Zarrin-Ghalami, Ali Fatemi (2016)** Elastomeric components have wide usage in many industries. The typical service loading for most of these components is variable amplitude and multiaxial. In this study a general methodology for life prediction of elastomeric components under these typical loading conditions was developed and illustrated for a passenger vehicle cradle mount. Crack initiation life prediction was performed using different damage criteria. The methodology was validated with component testing under different loading conditions including constant and variable amplitude in-phase and out-of-phase axial–torsion experiments. The optimum method for crack initiation life prediction for complex multiaxial variable amplitude loading was found to be a critical plane approach based on maximum normal strain plane and damage quantification by cracking energy density on that plane. Rain flow cycle counting method and Miner's linear damage rule were used for predicting fatigue life under variable amplitude loadings.
4. **Wei Li, Tatsuo Sakai , et al. (2015)** Very high cycle fatigue (VHCF) properties of a newly developed clean spring steel were experimentally examined under rotating bending and axial loading. As a result, this steel represents the duplex S–N property only for surface-induced failure under rotating bending, whereas it represents the single S–N property for surface-induced failure and interior inhomogeneous microstructureinduced failure under axial loading. Surface small grinding defect-induced failure is the predominant failure mode of

this steel in VHCF regime. The surface morphology of the interior inhomogeneous microstructure with distinct plastic deformation is much rougher than that of the ambient matrix, which means the stress concentration resulted from the strain inconsistency between the micro structural in homogeneity as soft phase and the ambient matrix as hard phase plays a key role in causing interior crack initiation.

5. **Sid Ali Kaoua a, Kamel Taibi a, et al. (2014)** This paper presents a 3D geometric modelling of a twin helical spring and its finite element analysis to study the spring mechanical behaviour under tensile axial loading. The spiralled shape graphic design is achieved through the use of Computer Aided Design (CAD) tools, of which a finite element model is generated. Thus, a 3D 18-dof pentaedric elements are employed to discrete the complex ‘‘wired-shape” of the spring, allowing the analysis of the mechanical response of the twin spiralled helical spring under an axial load. The study provides a clear match between the evolution of the theoretical and the numerical tensile and compression normal stresses, being of sinusoidal behaviour.
6. **B. Pyttel , D. Schwerdt, et al. (2013)** The paper gives an overview of the present state of research on fatigue strength and failure mechanisms at very high number of cycles (Nf > 107). Testing facilities are listed. A classification of materials with typical S–N curves and influencing factors like notches, residual stresses and environment are given. Different failure mechanisms which occur especially in the VHCF-region like subsurface failure are explained. There micro structural in homogeneities and statistical conditions play an important role. A double S–N curve is suggested to describe fatigue behaviour considering different failure mechanisms. Investigated materials are different metals with body-centred cubic lattice like low- or highstrength steels and quenched and tempered steels but also materials with a face-centred cubic lattice like aluminium alloys and copper.
7. **Stefanie Stanzl-Tschegg (2012)** Ever since high-strength steels were found to fail below the traditional fatigue limit when loaded with more than 108 cycles, the investigation of metals’ and alloys’ very high cycle fatigue properties has received increased attention. A lot of research was invested in developing methods and machinery to reduce testing times. This overview outlines the principles and testing procedures of very high cycle fatigue tests and report’s findings in the areas of crack formation, non-propagating small cracks, long crack propagation and thresholds. Furthermore, superimposed and variable amplitude loading as well as frequency effects are reported.
8. **Yuxin Penga, Shilong Wangb, et al. (2011)** a stranded wire helical spring (SWHS) is a unique cylindrically helical spring, which is reeled by a strand that is formed of 2~16 wires. In this paper, a parametric modeling method and the corresponding 3D model of a closed-end SWHS are presented based on the forming principle of the spring. By utilizing a PC + PLC based model as the motion control system, a prototype machine tool is designed and constructed, which improves the manufacturing of the

SWHS. Via the commercial CAD package Pro/Engineering, numerical simulation is carried out to test the validity of the parametric modeling method and the performance of the machine tool.

3.0 Methodology:

- Suitable elements are used for metallic and composite parts of hinge in FEA.
- Aircraft loads and loads arising from rudder rotation are according to aircraft standards.
- Stress-Strain and Stiffness based approach are used for the design of individual parts of hinge.

DESIGN SPECIFICATIONS:

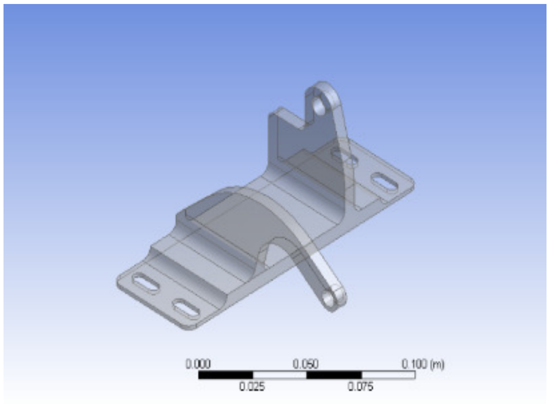
- Length of Hinge arms = 831.11mm
- Thickness of hinge arms = 10.2mm
- Radius of Fork head R1 = 25.05mm
- Radius of fork head R2= 25.95mm
- Skin thickness (t) = 3.5mm

The investigations in this contribution are based on the first approach with the following steps:

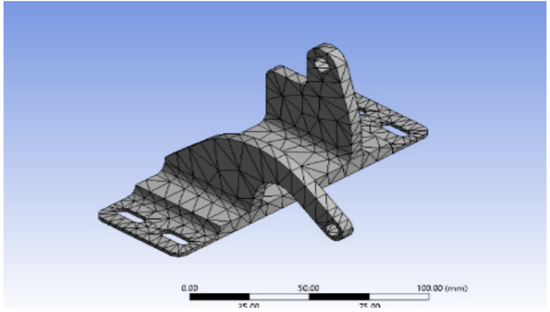
1. Determining the kinematic parameters of the rigid-body mechanism,
2. Modeling of the compliant mechanism,
3. Modeling of the flexure hinges with different cut-out geometries,
4. FEM analysis of the compliant mechanism, verification of results and, if necessary, iterative improvement.

Materials used for analysis:

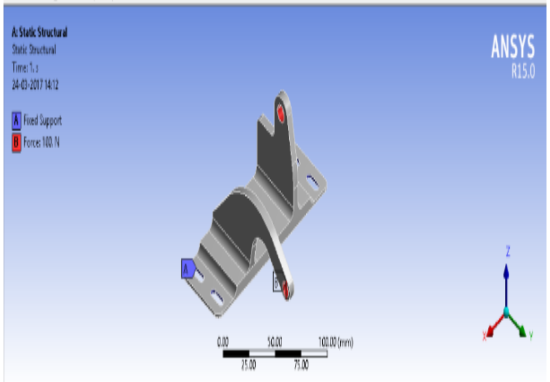
- Structural steel
- Grey cast iron
- Aluminium alloy



Modeling of the hinge



Meshing of the hinge



Static structural view of the hinge with fixed support

4.0 RESULTS AND DISCUSSIONS:

Case 1 Hinge made of material structural steel:

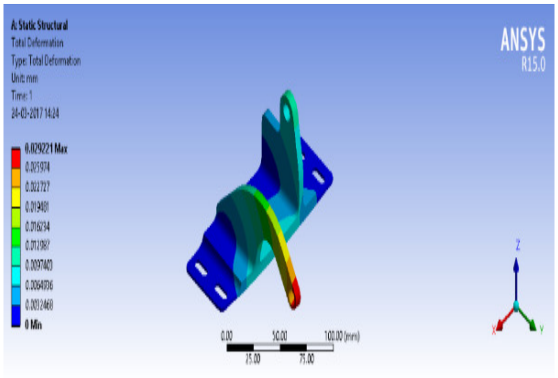


Figure shows total deformation of the hinge

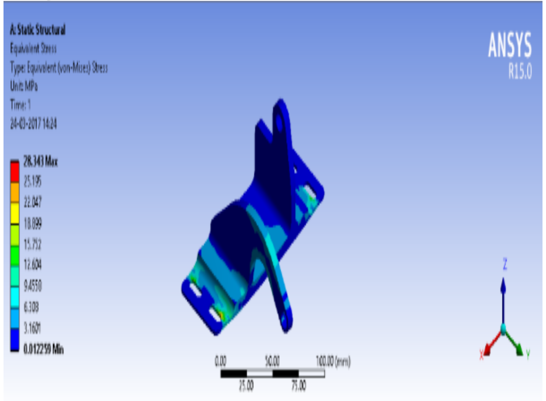


Figure shows equivalent stress of the hinge

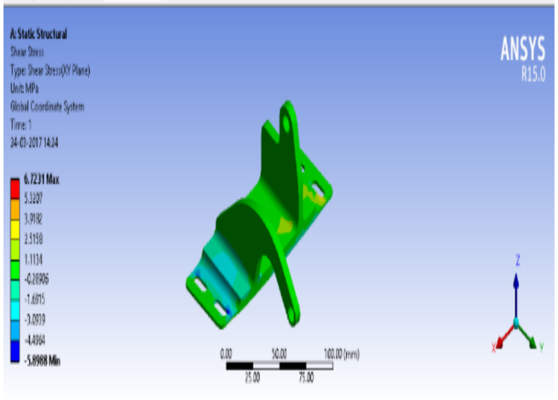


Figure shows shear stress of the hinge

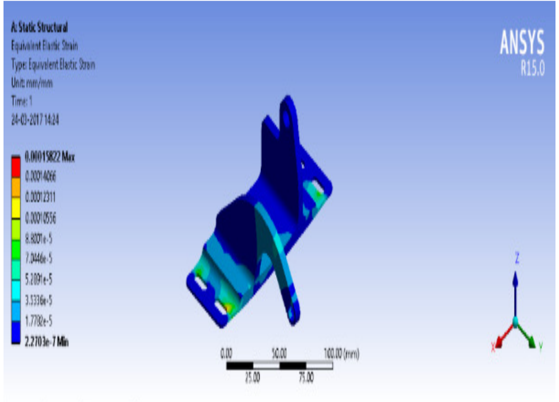


Figure shows equivalent elastic strain of the hinge

Case 1 Hinge made of material Grey cast iron:

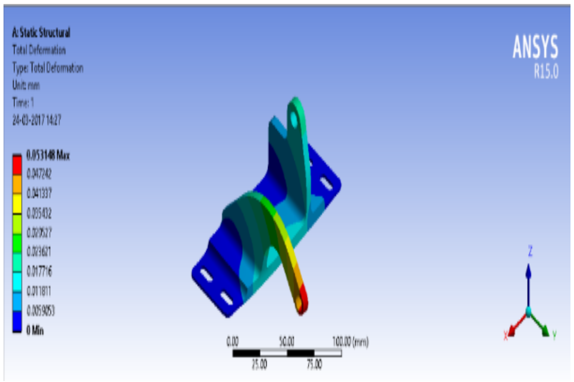


Figure shows total deformation of the hinge

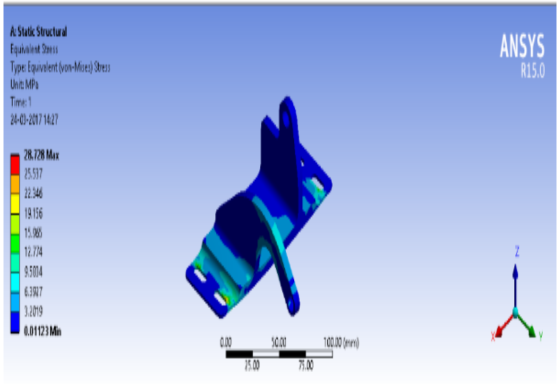


Figure shows equivalent stresses of the hinge

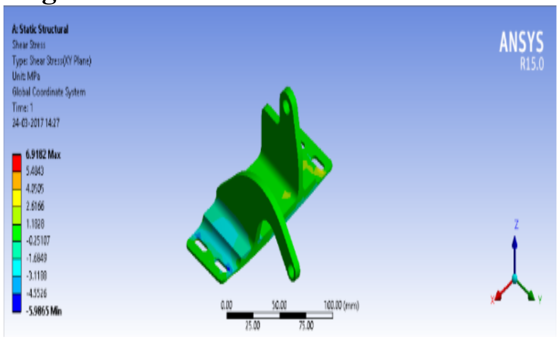


Figure shows shear stress of the hinge

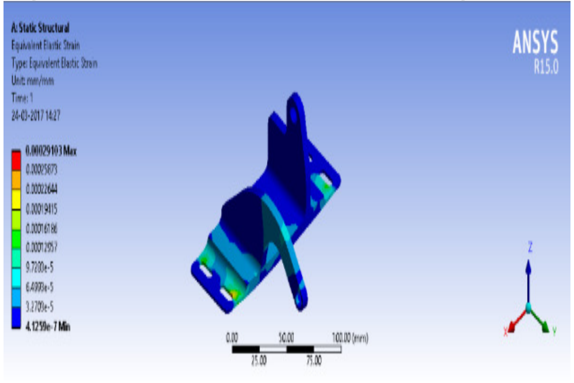


Figure shows equivalent elastic strain of the hinge

Case 3 Hinge made of material Aluminum:

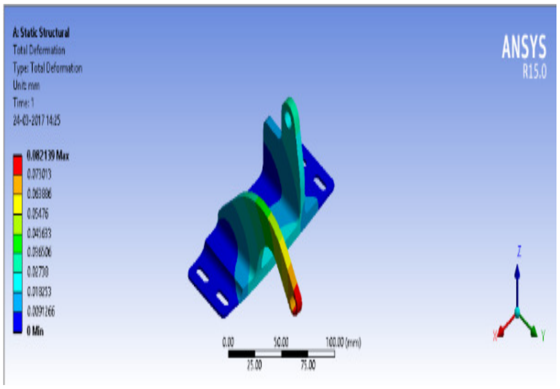


Figure shows total deformation of the hinge

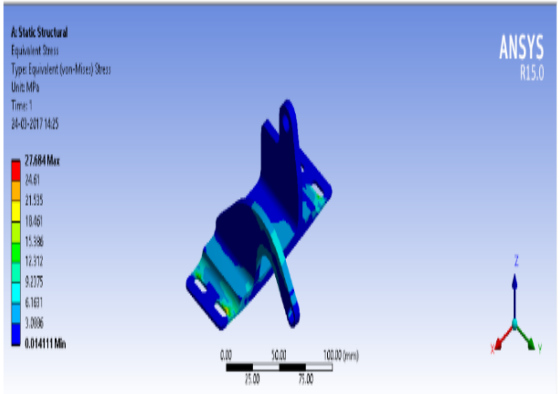


Figure shows equivalent stress of the material

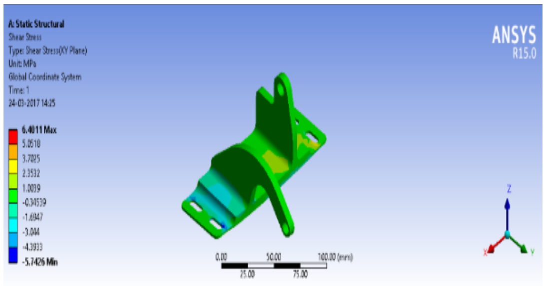


Figure shows shear stress of the material

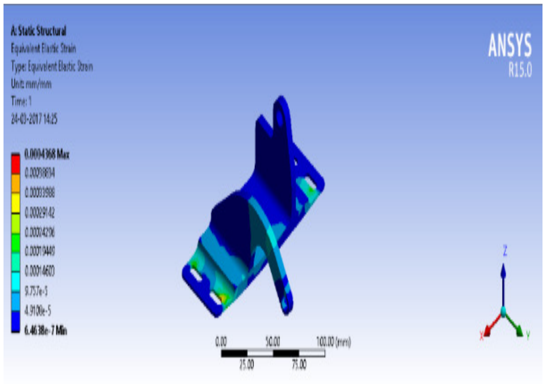
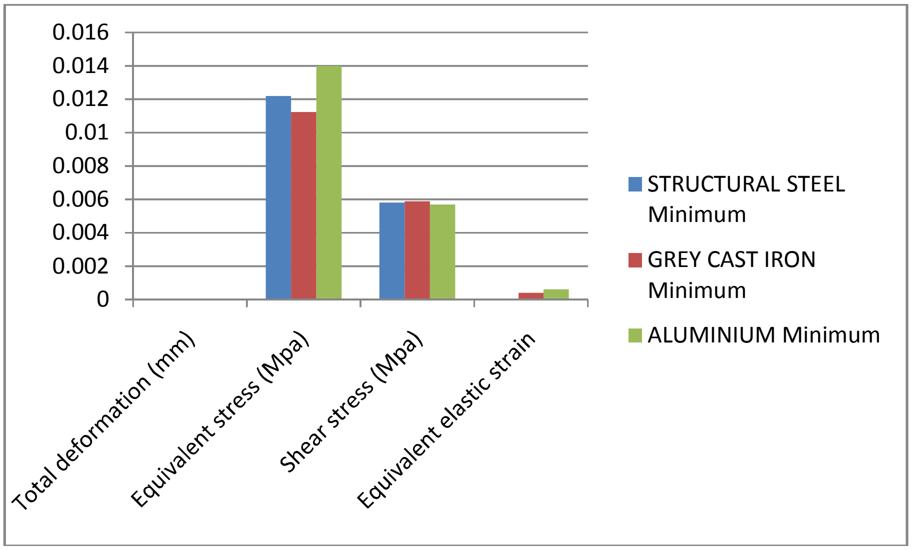


Figure shows equivalent elastic strain of the material

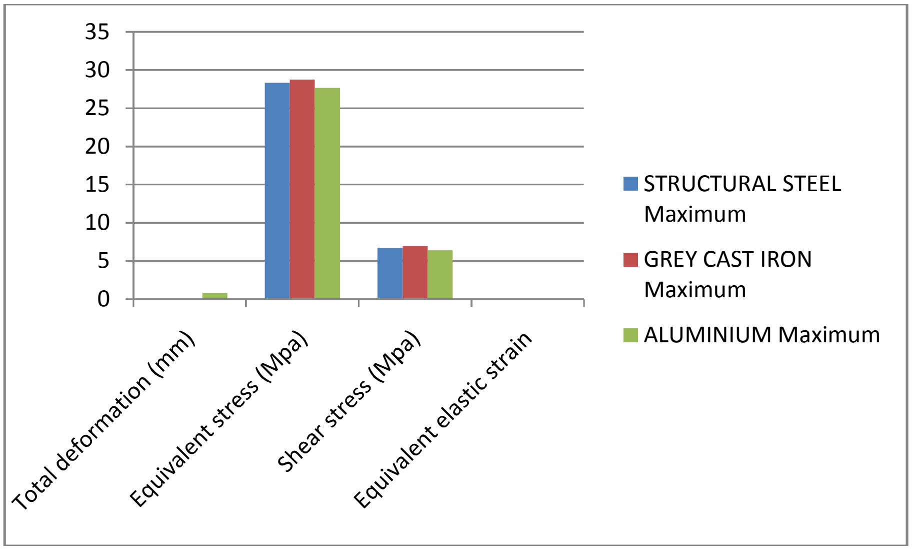
Table below shows variations in the hinge due to various materials

PARAMETERS	STRUCTURAL STEEL	GREY CAST IRON	ALUMINIUM
	Minimum	Minimum	Minimum
Total deformation (mm)	0	0	0
Equivalent stress (Mpa)	0.0122	0.01123	0.014
Shear stress (Mpa)	0.0058	0.0059	0.0057
Equivalent elastic strain	0	0.0004	0.00062



Graph shows variations in minimum value parameters with different materials

PARAMETERS	STRUCTURAL STEEL	GREY CAST IRON	ALUMINIUM
	Maximum	Maximum	Maximum
Total deformation (mm)	0.029221	0.0531	0.821
Equivalent stress (Mpa)	28.343	28.728	27.684
Shear stress (Mpa)	6.723	6.918	6.40
Equivalent elastic strain	0.000158	0.00029	0.00043



Graph shows variations in minimum values of parameters with different materials

CONCLUSION:

The paper researches that the design of the hinge with given design parameters using CATIA. The structural analysis is done with use of ANSYS and the ANSYS is done for three materials Structural steel, Grey cast iron, Aluminum. The conditions such as deformation, equivalent stress, shear stress and equivalent elastic strain is taken for all three materials. It is found that the Aluminum shows the better results either in shear and deformation than other two. So that it is concluded that the hinge made of aluminum gives the better results when compared to steel and grey cast iron.

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