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"IMPROVEMENT OF WEIGHT LIFTING CAPABILITY OF HYDRAULIC USING FEA"

Mr. Avinash Sharma[1]*, Mr. Sandeep Saha[2]**, Mr. Sanjay Sahu[3]***

* *Research scholar, [1](M. Tech Department of Mechanical Engg. BIT, Bhilai Institute of Technology, Raipur (C.G.), India)*

** *Assistant Professor, [1](M. Tech Department of Mechanical Engg. BIT, Bhilai Institute of Technology, Raipur (C.G.), India)*

*** *Assistant Professor, [1](M. Tech Department of Mechanical Engg. BIT, Bhilai Institute of Technology, Raipur (C.G.), India)*

Abstract: The hydraulics are used in variety of machineries. The design of piston, piston rod has significant effect on strength and safety factor. The objective of current research is to investigate the effect of hydraulic piston geometric dimensions on its strength. The strength of piston is investigated using ANSYS FEA simulation package and design is optimized using Taguchi method. The equivalent stress, deformation and safety factor are determined for each design point. The optimized design of hydraulic piston is developed which has lower mass and improved safety factor. Both the optimization variables i.e., "ifr" and "ifh" has significant effect on safety factor of piston rod. The maximum safety factor obtained from the analysis and optimization is 2.44.

Key Words: Hydraulic system, performance, pressure

1. INTRODUCTION:

The backhoes are used in various construction activities which requires elevating bucket, earth moving and other heavy duty works. The "backhoes uses hydraulic system for operation of the machine while digging or moving the material" [1]. The backhoe excavator comprises of revolute joints, swing joint, boom [2]. The working of excavator and hydraulics can be studied using kinematics which is "the science of motion which treats motion without regard to the forces that cause it and within the science of kinematics, one studies the position, velocity, acceleration, and all higher order derivatives of the position variables" [3]. The motion of excavator linkages is performed using hydraulic cylinders and actuators. The motion of hydraulics used in excavator can be studied using kinematic model describing spatial positions and orientation of bucket [4].

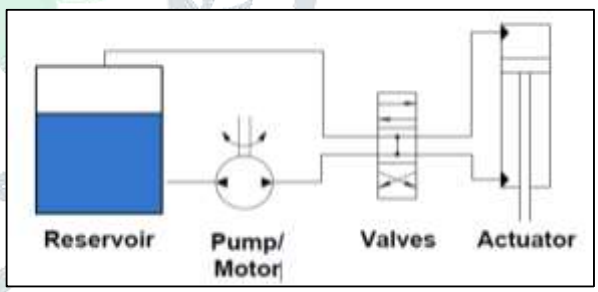

Figure 1: Components of hydraulic system [7]

2. LITERATURE REVIEW

Zhang and Chao et al. [8] has conducted experimental investigation of aircraft hydraulic system. The electro-hydrostatic actuator pump is investigated which operates at high speed. The effect of piston-slipper assembly mass difference and the geometric errors of the cylinder block are identified. The actuation system (electro hydraulic) is shown in figure 2 below.

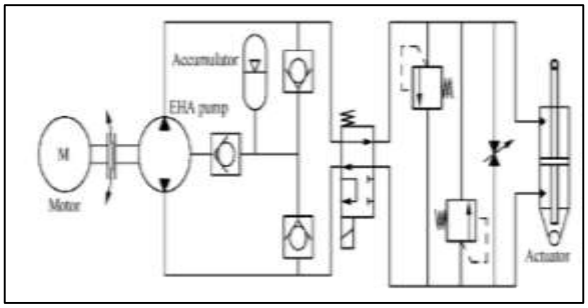

Figure 1: Schematic of an electro-hydraulic actuation system [7]

Ouyang et al. [9,10,11] has conducted fluid structure interaction (FSI's) of swash plate used in aircraft hydraulic system. The attenuating characteristics of integrated buffers are presented. The faults in aviation hydraulic systems can be identified using prognostics heat management (PHM) systems.

Wang et al. [12,13] has conducted studies on fault detection of hydraulic actuator systems. These methods are based on "layered clustering" algorithm. The algorithm is based on selection of input variables and determination of faults.

Ma et al. [14-18] studied the typical failure modes of the aircraft hydraulic pump such as wear, fatigue, and thermal aging, and proposed the accelerated lifetime test methods including strengthening the load and worsening the operation conditions.

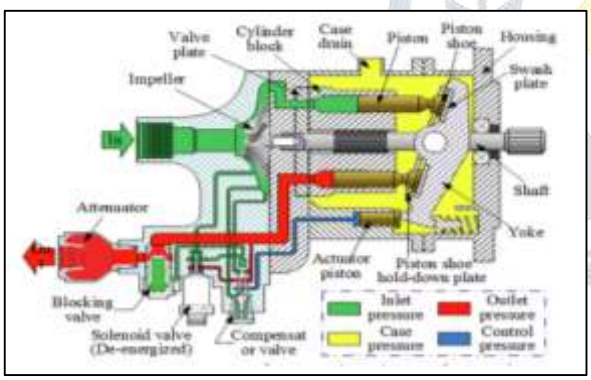

Fig. 2 Cross-section view of a typical civil aircraft hydraulic pump [14]

3. OBJECTIVES

The objective of current research is to investigate the effect of hydraulic piston geometric dimensions on its strength. The strength of piston is investigated using ANSYS FEA simulation package and design is optimized using Taguchi method. The equivalent stress, deformation and safety factor are determined for each design point.

4. METHODOLOGY

The CAD model of piston and rod is developed in design modeler. The variables for optimization is assigned in design modeler itself. The design of piston rod is shown in figure 3 below.

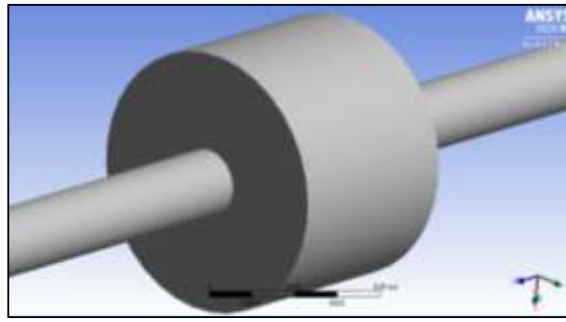

Fig. 3

CAD design of piston rod

The piston rod design is meshed using tetrahedral elements with growth rate set to 1.2 and sizing set to medium. The meshed model of piston is shown in figure 4 below.

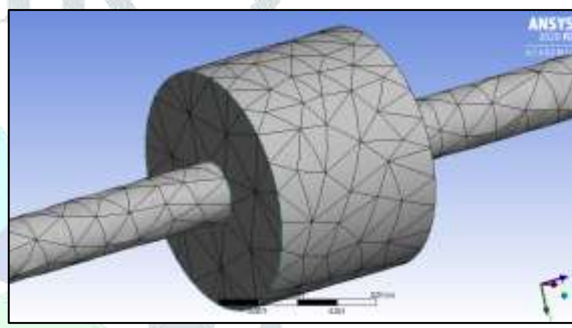

Fig. 4

Meshed model of piston rod

The material of piston rod is applied with steel material. The properties of steel material are shown in figure 5 below.

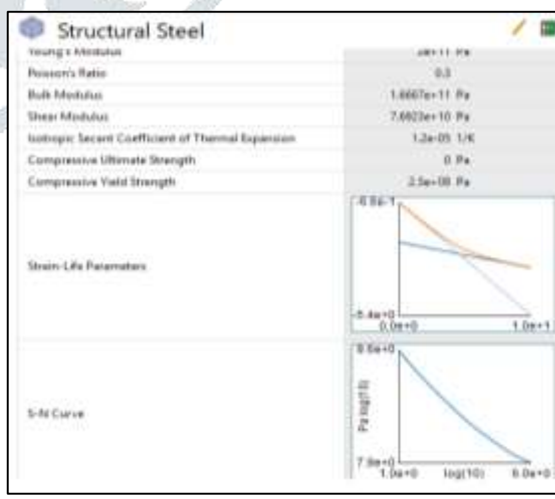

Fig. 5

Steel material properties

The specific loads and boundary conditions are applied on piston and piston rod. The displacement support is applied at the cylinder side faces and axial force is applied on exposed faces of rod.

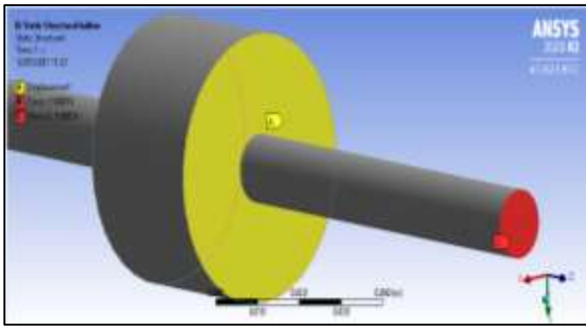

Fig. 6

Loads and Boundary conditions

After defining loads and boundary conditions for hydraulic piston rod, the simulation is run. The process involves use of sparse matrix solver in formulation of stiffness matrices of elements and calculation of results at nodes. The results are calculated at each node i.e. deformation and stresses.

5. RESULTS AND DISCUSSION

The FE simulation is conducted on hydraulic piston rod to determine deformation and equivalent stresses. The deformation plot is generated as shown in figure 7 below. The maximum deformation is at the free end of rod. The deformation obtained is more than .0494mm which reduces on moving towards the fixed end rod.

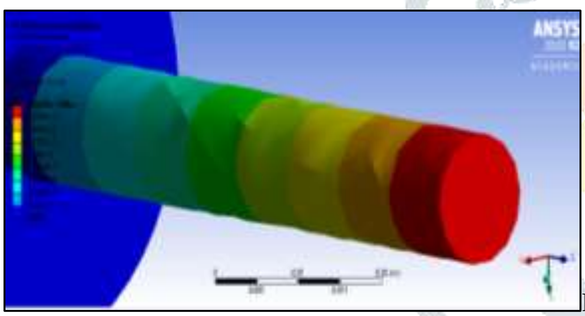

Fig. 7

Deformation plot

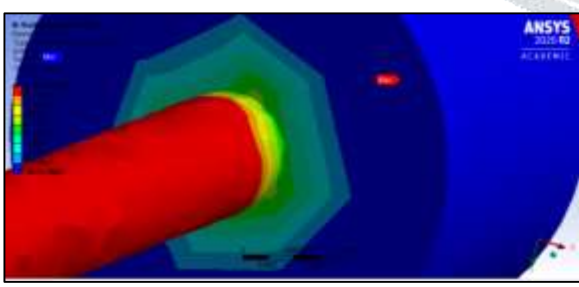

Fig. 7

Equivalent stress plot

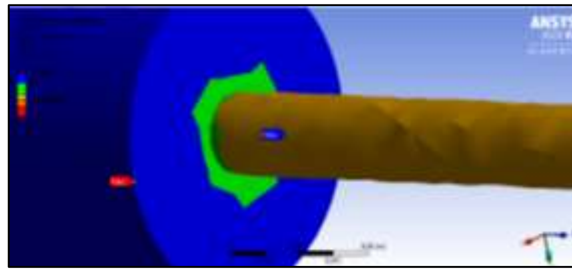

Fig. 8

Safety factor plot

The equivalent stress plot is obtained for hydraulic cylinder rod as shown in figure 7 above. The plot shows maximum equivalent stress at the intersection region of piston and piston rod. The equivalent stress obtained from the analysis is more than 98MPa. The equivalent stress is minimum at the outer regions of piston. The design of piston rod is then optimized to get different design points. The design points are generated for different combinations of both the optimization variables. The output parameters i.e., safety factor, equivalent stress and mass is determined. The variation of safety factor with respect to different design points is shown in figure 8 below. The plot shows maximum safety factor is observed for design point number 8. The “ifr” at design point 8 is 18mm and “ifh” is 27.5mm.

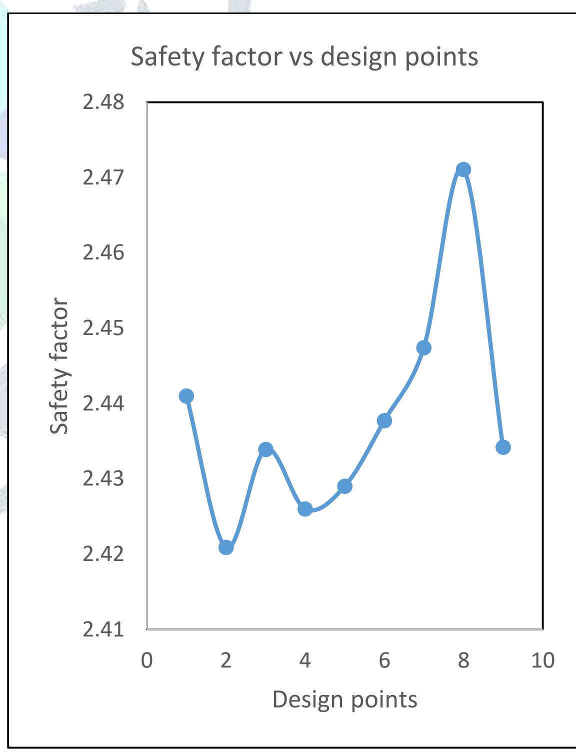

Fig. 8

Safety factor vs design points

The lowest safety factor is observed for design point number 2. The “ifr” at design point 2 is 18mm and “ifh” is 25mm. Subsequent studies are conducted to determine the individual effect of “ifr” and “ifh” on safety factor. The variation of safety factor with respect to “ifh” is shown in figure 9 below. The safety factor is minimum at 22.5mm “ifh” which increases linearly and is observed to be maximum at “ifh” of

25.2. The maximum safety factor obtained from design optimization is 2.44.

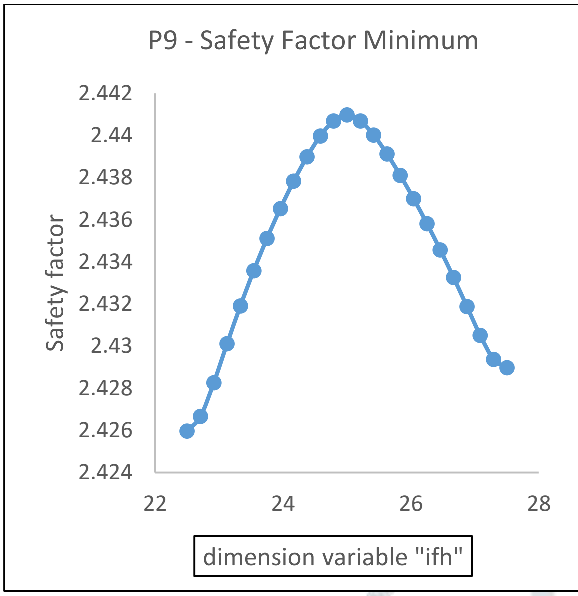

Fig. 9

Safety factor vs "ifh"

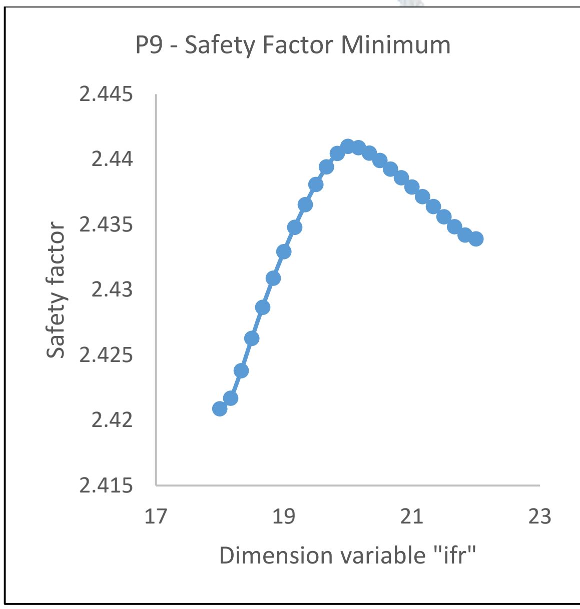

Fig. 10

Safety factor vs "ifr"

The variation of safety factor with respect to "ifr" is shown in figure 10 above. The plot shows increase in safety factor with respect to "ifr" and it reaches maximum value at 20mm "ifr". The safety factor then decreases gradually.

6. CONCLUSION

The FE analysis is conducted on hydraulic piton to determine its structural stability under maximum loading conditions. The optimized design of hydraulic piston is developed which has lower mass and improved safety factor. Both the optimization variables i.e., "ifr" and "ifh" has significant effect on safety factor of piston rod. The maximum safety factor obtained from the analysis and optimization is 2.44.

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