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Design and Analysis of Mechanical Gripper for High Temperature Applications

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Abstract: *The main objective of this paper is to design and perform a detailed finite element analysis of a Mechanical gripper for holding the high temperature substance in the forging unit of the manufacturing industry We have taken Mild steel ,Cast iron and Inconel 600 for the analysis. Efforts are made to reduce these stresses and deflections by altering the materials of gripper assembly to increase factor of safety. The outcomes of the present analysis is stress developed for a pay load of 5000N is calculated for the created model and also the stress and deflections that are developing due to the thermal loads and structural boundary conditions are plotted. The combination of better suitable material has to be sought out based on the results. 3D modeling is performed in the CATIA V5 software and analysis is done in the finite element analysis software Ansys.*

Keywords— *Mechanical gripper, Structural analysis, Different materials,* Catia V5,Ansys

I. Introduction

A robot is an important handling machine, which roughly reproduces the human arm. In order to be effective, it also requires mechanical hands, which are generally referred to as grippers. These are also required on pick-and place devices and a wide range of other automatic systems. In principle, there are two basic designs of grippers, those designed in the form of fingers and those, which do not resemble fingers. The role of mechanical hands is to replace the human one. Studies to date have proved that if the gripping capacity of a 5-finger mechanical hand is considered 100%, then the gripping capacity of a 4-finger mechanical hand is of 99%, that of a 3-finger hand of 90% and that of a 2-finger hand, namely of a 2-jaw gripper is only of 40%. The maximum number of motions to be conducted by a gripping system is six, as illustrated in Fig. 1, namely three translations and three rotations (pitch, twist and yaw). The gripper achieves its role by clamping, namely it grasps the object by means of mechanical contact forces, unlike other types of gripping systems that can be magnetic, vacuum-based, electro-static, etc.. In industrial robotics the actuation of gripping mechanisms is achieved mechanically, electrically, hydraulically or pneumatically, by deploying linear or rotating motors. Stress analysis is carried out for MSM gripper using FEM for finding the stresses in various components of mechanism when the gripper is holding the known weight.[1] The design and fabrication of a multi-fingered gripper is done by [2]. The research is motivated by the requirement for grasping of objects of arbitrary shape and size. The key issues consider here are: the gripper should be able to grasp the object of any shape, size and weight (with a maximum limit), stability of the object held during manipulations, should not dependent of frictional forces between gripper and object, synchronization in fingers motion and employment of minimum number of actuators to manipulate the gripper. Kinematic and dynamic analysis of gripper is made to support this novel design. The gripper is successfully designed, fabricated and tested and hence can find many applications, e.g., as a robot end-effector, prosthetic hands etc. Theoretical and experimental study of the operational behavior of a fluid driving system based on pneumatic muscles, and concrete application of pneumatic muscles is presented by[3] By adequate selection of working parameter values the optimum variant of the gripper is obtained

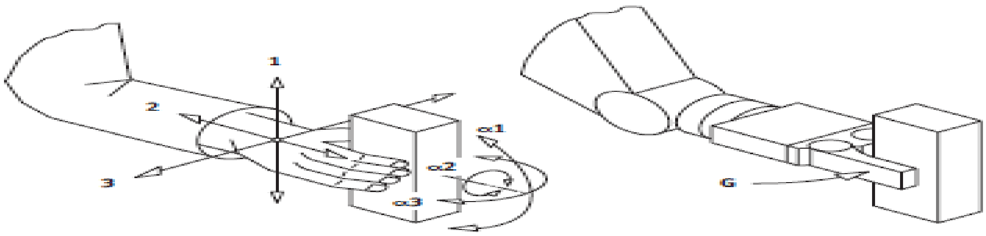

Fig 1.Shows the Motions to be conducted by a gripping system

II. Methodology

- Evaluate the input for existing design of the gripper mechanism or perform design calculations if required.
- Design all components of the gripper mechanism (Links, Pivots, gripper jaw and gripper body) using CATIAV5 software.
- Perform assembly of the gripping mechanism using CATIAV5 software.
- Evaluate the boundary conditions and force distribution on the gripper assembly for the static analysis.
- Perform thermal analysis on the gripper assembly by applying the temperature conditions using Ansys software for different materials.
- Calculate temperature distribution from the thermal analysis on the components of gripper.
- Perform structural static analysis on the gripper assembly by applying the evaluated boundary conditions and loading using Ansys software for different materials.
- Calculate the stresses and deflections from the analysis.
- Perform the coupled thermal structural analysis of the gripper for Steel, Cast iron and Inconel 600 materials.
- Plot the temperature distribution, deflection and stress developed due to the thermal and structural loads.
- Sort out the best possible material for the gripper with better sustainability

III. Design Modeling Of Gripper

The 3D model which is required for the finite element analysis is created by using the CATIA V5 software

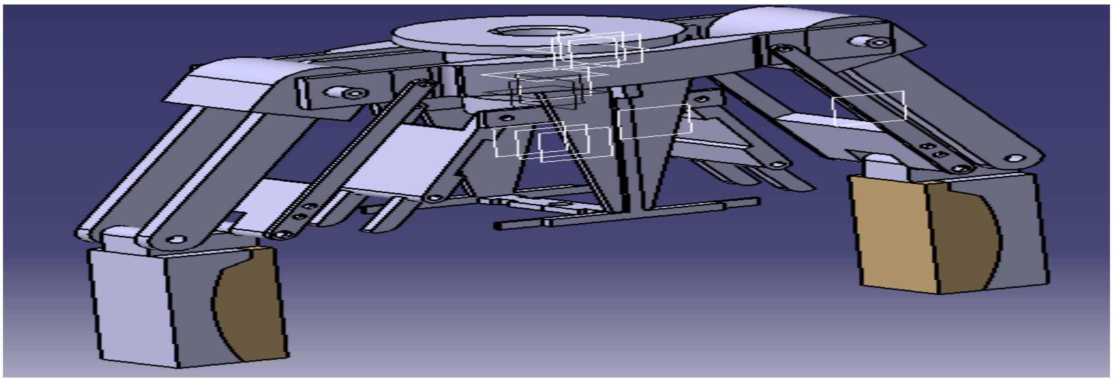

Fig. 2: Shows The isometric view of the gripper

IV Finite Element Analysis Of The Gripper With Mild Steel, Cast Iron And Inconel 600 Materials

3D assembly of the Gripper is done in CATIAV5. The model was then converted into a parasolid file to import into ANSYS workbench. Initial load conditions of the gripper are considered and calculated. i.e., a gripping force of 5000N is applied on each gripper which is considered for a load of 500Kgs. The materials chosen for the finite element analysis of the grippers are Steel, Cast iron and Inconel 600

S.NO	Parameter	Mild Steel	Cast Iron	Inconel600
1	Young's Modulus(MPa)	2e5	1.1e5	2.14e5
2	Poisson's ratio	0.3	0.27	0.32
3	Density(kg/m^3)	7850	6600	8470
4	Yield Strength(Mpa)	250	270	310
5	Thermal onductivity(w/mK)	60.5	50	14.9
6	Thermal Coefficient(10^{-6} /K)	0.15	0.12	0.133
7	Melting point ^{0}C	1370	1510	1413

Table 1: It shows material propertied for Mild steel,CastIron,Inconel600

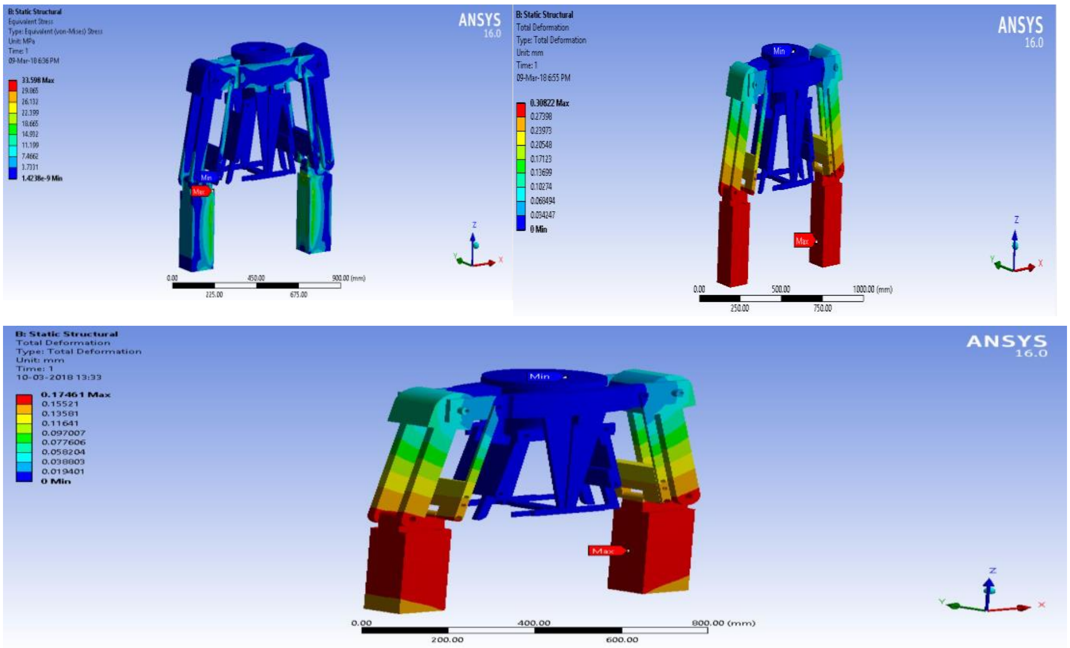

Fig:3 : Shows the total deformation of Mild steel ,Cast Iron and Inconel600

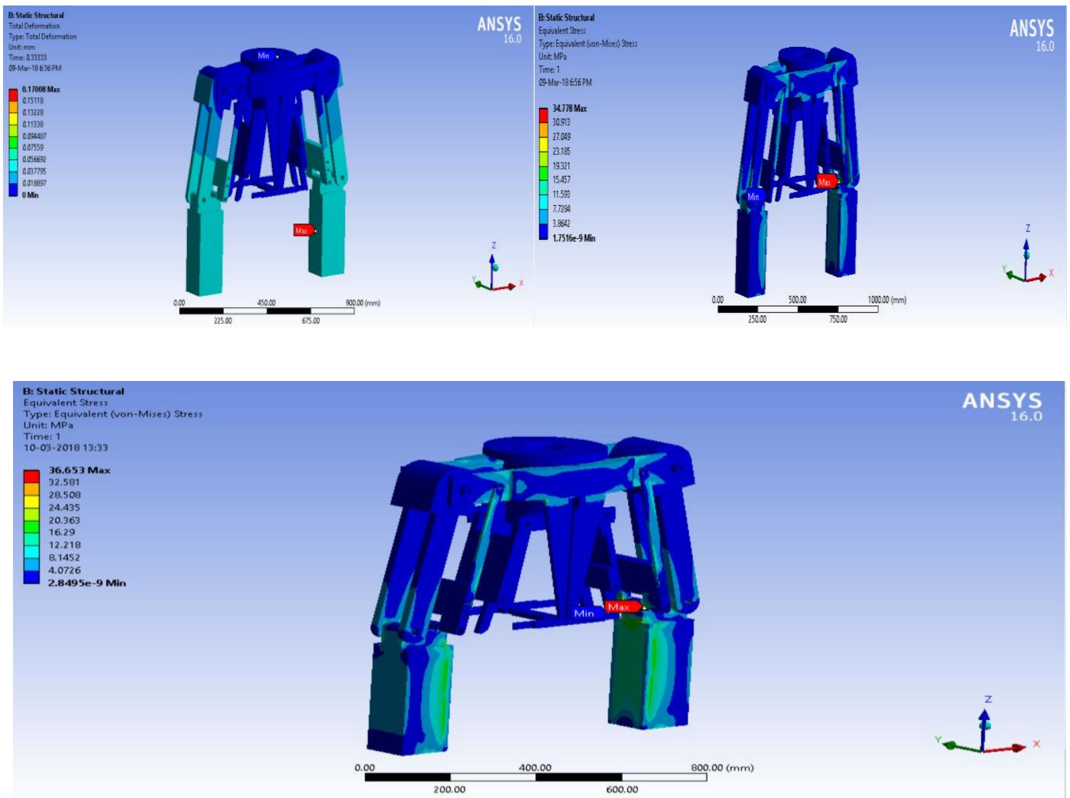

Fig:4 Shows the Vonmises stress of Mild steel ,Cast Iron and Inconel600

V Experimentation of Coupled Thermal - Structural Analysis of Mechanical Gripper for Different Materials

In couple field analysis, thermal analysis is performed and it is followed by the structural analysis. The temperature of the object to be hold reaches up to 1200^0 C. Thus the same temperature is chosen to perform the thermal analysis of the gripper.

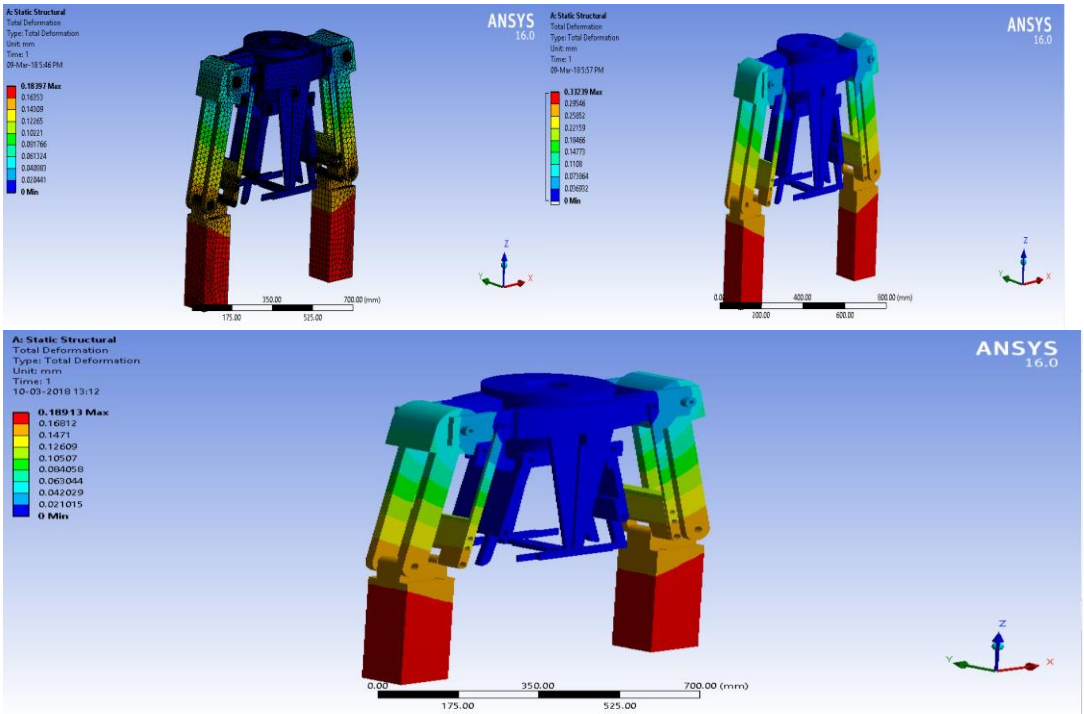

Fig:5 : Shows the total deformation of Mild steel ,Cast Iron and Inconel600

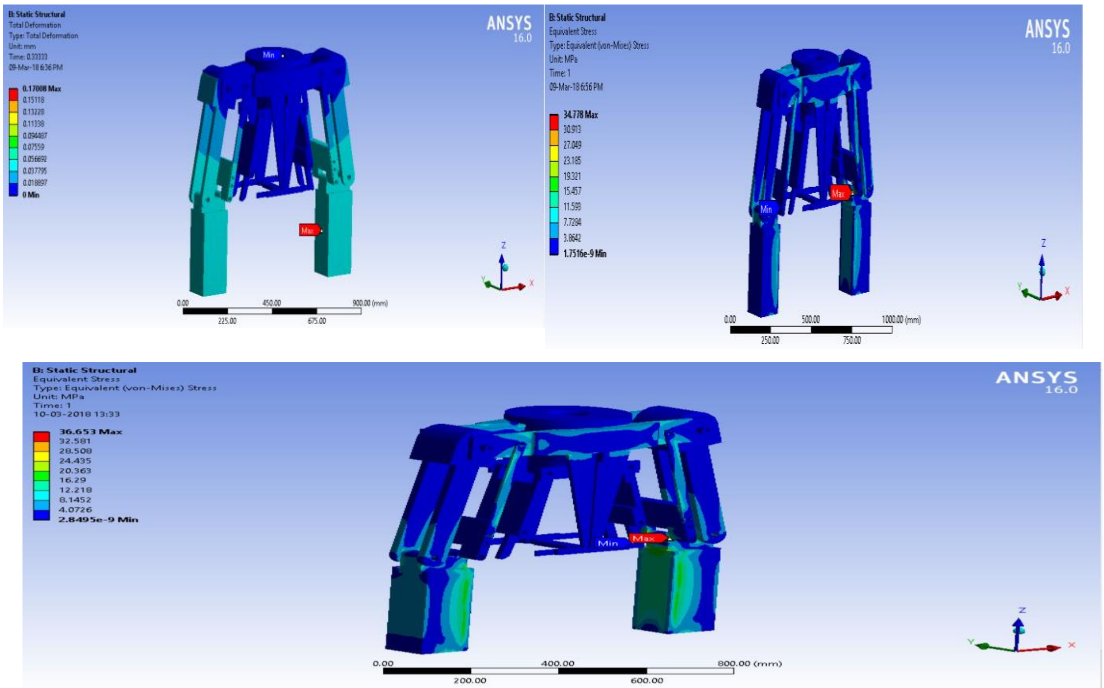

Fig:6: Shows the Vonmises stress of Mild steel ,Cast Iron and Inconel600

VI. Results

Material/Parameter	Mild Steel	Cast Iron	Inconel 600
Deflection (mm)	0.1708	0.30822	0.17461
Vonmises Stress(Mpa)	33.598	34.778	36.653
FOS	7.44	7.763	8.457

Table.2: Shows Structural Analysis for Mild steel, Cast Iron&Inconel600

Material/Parameter	Mild Steel	Cast Iron	Inconel 600
Temperature	1252.36^{0}C	1252.45^{0}C	1252.9^{0}C

Table.3: Shows Thermal Analysis for Mild steel, Cast Iron&Inconel600

Material/Parameter	Mild Steel	Cast Iron	Inconel 600
Deflection (mm)	0.18397	0.33239	0.18193
Vonmises Stress(Mpa)	36.119	36.206	39.731
FOS	6.92	7.45	7.80

Table.4: Shows couple field Analysis for Mild steel, Cast Iron&Inconel600

VII. Conclusion &Future Scope Of Work

The results shows that the deflection developed in the Cast Iron (0.33239mm) material is marginally greater than the Mild Steel (0.18397mm) and Inconel 600(0.18913mm) and von misses stress developed in Inconel 600(39.731MPa) is more than the Mild steel (36.119MPa) and Cast Iron (36.206MPa). Further the factor of safety developed in the Inconel 600 (7.80) is greater than the Mild Steel (6.92) and Cast Iron (7.45).Thus by selecting the below consideration Good factor of safety It can be under stood that from the above results that though Inconel 600 is having higher deflection and more von misses stress. The factor of safety is high in this material. Hence it is proposed Inconel 600 for this high temperature applications.

Future Scope:

In this paper, the static analysis is done to determine the deflection and stress. Further the analysis is carried out for both thermal and structural (coupled) analysis. The project can be extended further to conduct transient dynamic analysis and weight optimization.

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