Design, Analysis of a Pneumatic Operated Mechanical Gripper for High Temperature Applications

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Abstract: Repetitive tasks and high accuracy have become the two contradictory needs of any industrial process. The need for cost effective, accurate and safe material handling equipment's is in higher demand in the present day industrial needs. Although robots are available for material handling, it remains as uneconomical for SME's but to safely handle materials especially hot materials it becomes a necessity to use some automated material handling equipment. This study deals with the Design, analysis of a pneumatic operated multipurpose mechanical gripper. The Gripper is made of heat resistant material to work on hazardous environments and provide automation in material handling applications. The main aim of the study is to analyze the pneumatic operated mechanical gripper for various load conditions, stress conditions and temperature conditions to justify its suitability for high temperature application requirements.

Keywords: Mechanical Gripper, Two fingered gripper, Pneumatic Gripper, Gripper for High Temperature applications.

Introduction

Robotic hands have been developed with the aim of copying the human hand in terms of dexterity and adaptive capabilities to function as a manipulator. Several mechanical grippers and articulated hands have been made over the past years [1, 2]. However, significant efforts have still to be made to find designs simple enough to be easily built and controlled, in order to obtain practical systems [3]. To overcome the limited success of the early hand designs, considerable emphasis has been placed on reducing the number of degrees of freedom (DOF's) without sacrificing dexterity and thereby reducing the required number of actuators. A mechanical hand has been developed based on the basic prehensile patterns of a human hand and the designed hand can grasp all basic shapes such as rectangular and triangular prisms, spheres and cylinders [2, 4]. A creative approach to designing industrial grippers by using the kinematic structure database, which contains general information about the robot gripper mechanism, kinematic structures, function, type of drive mechanism and applications is presented [3,5-7]. A classification system for grippers has been developed based on factors such as size, position and orientation of gripping force. This method is used to determine additional design constraints based on the final installation and activities that the robot would be performing [4,8-10]. In this study based on high temperature application a two fingered mechanical gripper has been designed based on several constrains [10,11]. The gripper is analyzed for various load conditions to determine stress and displacements and also the transient thermal analysis results of the gripping surface [12].

Conceptual Design of the Gripper

The gripper is designed with four kinematic links to handle the castings of different shapes. It is designed in such a way that both internal and external gripping can be done. The gripper is attached to the material handling system which is operated by pneumatic cylinder. Hence the gripper opening and closing can be

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achieved easily to hold the component of different geometries with applied pressure of 5-8 bar. The payload capacity of the gripper is about 1 kg. The gripper is designed using Pro-E Creo 2.0. The gripper should fulfil the following requirements:

- It should be able to grasp irregular objects of different shape and size.
- It should be able to take different loads (of course with upper limit)
- It should have the stability during manipulations.
- It should be independent of friction coefficient between the object and the gripping surface.
- Synchronization in finger motion to provide parallel gripping.
- It should not slip, so there should be provision of interlocking.
- It should be low cost, compact and lightweight

Major Factors in Choosing a Pneumatic Gripper and Jaw Design

(1) Part Shape, Orientation and Dimensional Variation: If the object has two opposing flat surfaces, the two jaw parallel gripper is desired since it can handle some dimensional variation. Jaws can also be designed to handle cylindrical objects with the 2 jaw concept. Keep in mind that retention or encompassing grip requires much less force.
(2) Part Weight: Grip force must be adequate to secure the object while a desired operation is performed on the object. The type of jaw is designed based on force required to clamp the component securely by considering the air pressure.
(3) Accessibility: This applies both to the work being performed on the object and the amount of room for the gripper jaws. If the work is to the exterior of the object then it may require an internal grip.
(4) Environmental: Harsh environment or clean room applications require grippers designed for those purposes.
(5) Retention of the Object: When air pressure is lost, the gripper will relax its grip on the object and the object may be dropped. To compensate for this, unidirectional check valve is provided to prevent the back flow of air.

Proposed Gripper

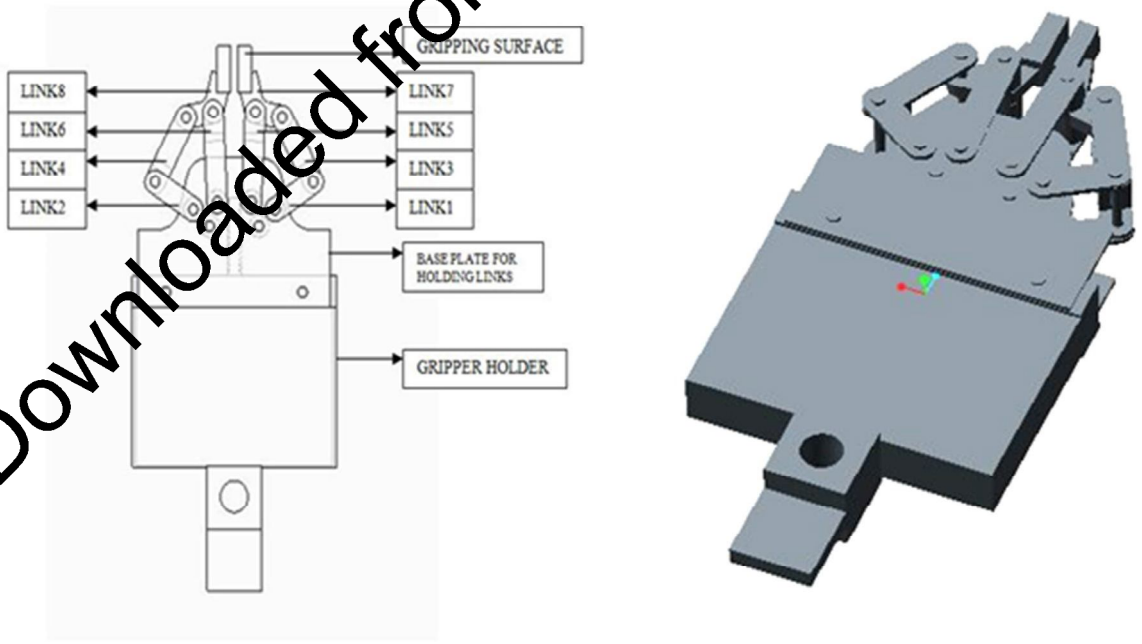


Fig 1 (a) Line diagram of the Gripper (b) Isometric View of the Gripper

The gripper is designed with a concept of four bar mechanism which consist of about eight links which are attached to a base plate and all these links possess a relative motion with each other. The relative motion is achieved by the movement of gear and rack. As shown in the fig 1, bottom end of the links 1,2,5 & 6 are attached to the base plate of the gripper which are in turn attached with the gears to have relative motion with each other. A rack is fitted in between the gears to have relative motion. The top ends of link 1 & 2 are attached to the bottom ends of link 3 & 4 respectively. The top ends of link 3, 4, 5&6 are attached to the bottom and top ends of the link 7 & 8 respectively. The entire gripper is attached to the gripper holder which in turn is attached to the horizontal arm of the material handling equipment as shown in the fig 2.

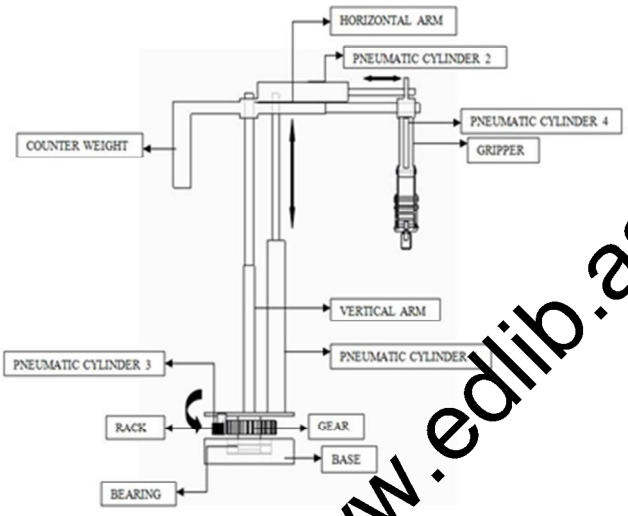


Fig 2 Operating System for the Gripper

Results and Discussion

Stress and Displacement

The stress and displacement analysis are carried out for the gripper using Autodesk Simulation Multi physics and the following results are obtained.

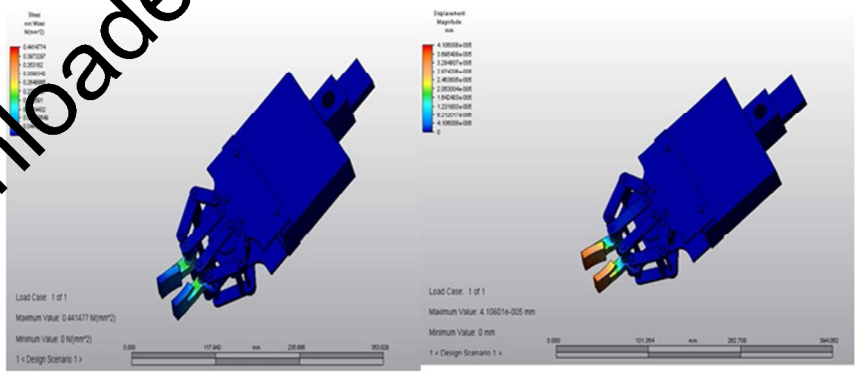
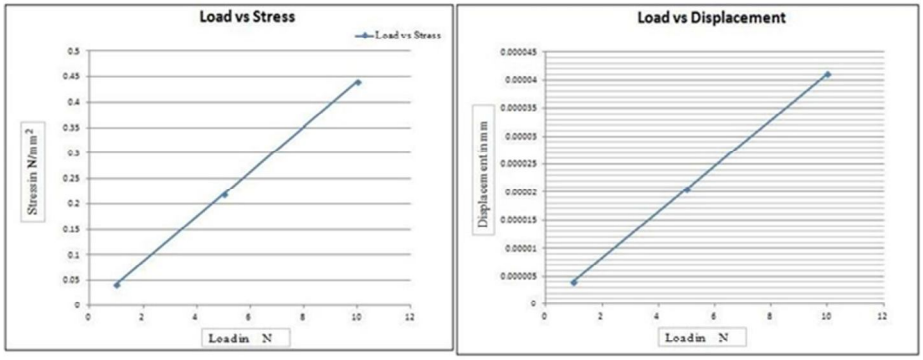


Fig 3 Typical results obtained for stress acting on the gripping surface for load 10N

Fig 4 Typical results obtained for the total displacement on the gripping surface for 10N

From the above results it is clear that the stress and displacement are proportionate to the load acting on the gripper and are shown in the graph below.



(a) Load vs Stress (b) Load vs displacement

Fig 5 Graphs showing the proportionate stress and displacement values

Temperature Analysis

Transient thermal analysis is carried out using ANSYS 14.0 and the following results were obtained.

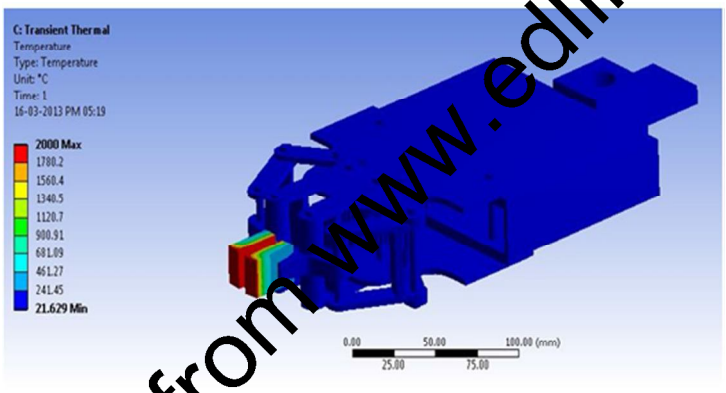


Fig 6 Gripper showing the temperature values acting on the gripping surface

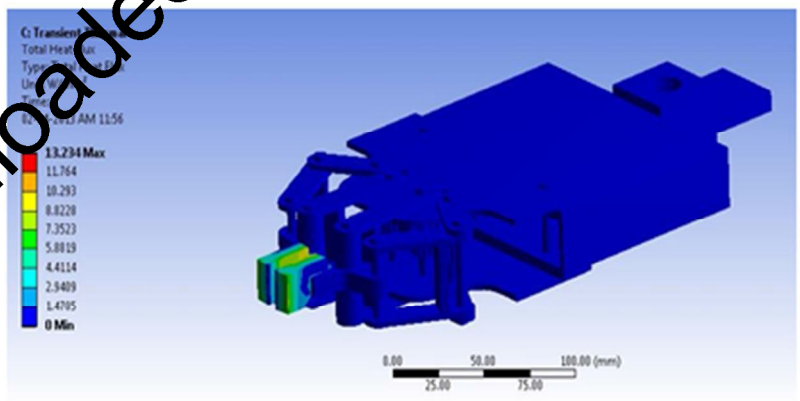


Fig 7 Gripper showing the transient heat flux values

Maximum Heat Flux $\frac{Q}{A}$

From Fourier law of heat conduction,

$$\frac{Q}{A} = K\left(\frac{T2-T1}{L}\right) \quad \text{..... (1)}$$

Where, K - Thermal conductivity of material

L - Length of gripping surface

T1 - Outer surface temperature

T2 - Inner surface temperature

Thermal conductivity of SG Iron at 2000 °C = 58 W/mK = 0.058 W/mmK

$$\frac{Q}{A} = 0.058\left(\frac{2273-294}{10}\right),$$

$$\frac{Q}{A} = 11.5 \text{ W/mm}^2$$

The result obtained from analysis is found to be 13.234 W/mm^2 which is near to the theoretical value 11.5 W/mm^2.

Conclusion

In this study, a pneumatic operated multipurpose mechanical gripper is analysed for various load conditions, stress conditions and temperature conditions to justify its suitability for high temperature applications.

From this analysis, the proposed pneumatic operated multipurpose mechanical gripper has the capability of handling the hot components in foundry with a payload capacity of 1kg. The maximum von mises stress is found to be 0.4414774 N/mm^2. The maximum displacement is found to be 4.106008 x 10^{-5}mm. The gripper can withstand maximum temperature of about 2000°C. This pneumatic operated multipurpose mechanical gripper will go handy to handle hot components especially in small and medium scale foundries.

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