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Fabrication, Analysis and Experiment of a New Design Mechanical Hand

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Abstract: One of the biggest concerns in industrial factories or science labs is the safety considerations. The mechanical hand is a safety product as an alternative hand for human to move objects around. The objective of this study is to select a proper material, design and fabricate of mechanical hand. The appropriate material is selected and the new design of mechanical hand created by using CAD software. Using ANSYS software the critical components of mechanical hand have been analyzed and to get the more accurate result the analytical calculations also done for the components. The finite element and analytical results had been compared and in conclusion the designed mechanical hand in this study meets all the objectives. After the manufacturing process and finite element analysis, the comfortability, motion, maximum load and heat experiments are done on the mechanical hand in order to investigate its performance. By selecting the proper material the strength of material is increased and also it can be used in high temperatures. The strength and safety of material is increased in new design and the possibility of failure in critical components decreased. The results give new design ideas to improve performance and design of the mechanical hands.

Key words: Mechanical hand, safety product, manufacturing process, finite element, mechanical properties

INTRODUCTION

In modern industrial society one of the most important concerns in all companies is safety. The machines and humans working together and one mistake of human can make irrecoverable injuries. Most of the injuries are in upper part of body and working with machines which require hands. The same thing can be happen in science field when most of the chemical tests are happened and the person who is doing the test should be very careful because it might makes irrecoverable injuries for many part of human body. Mechanical hand is a safety product to protect human from this kind of injuries can be happen in many fields to their hands. The workers of a factory or the people who are testing projects in science can use an external hand as mechanical hand to protect their body from injuries in dangerous areas.

The first idea of a mechanical hand has a long history around 1575; it was first worked on by Panero and Zelnik (1979). The Panero's research was published in the year 1575 contained numerous pictures and diagrams of the artificial arm and artificial leg invented. The leg had a further feature of a movable knee joint which was controlled with the aid of a flexible spring-operated foot and a piece of string. The human hand is a highly complex five-digit manipulator. It can make a large variety of grasps and grip forces for manipulating an object. This requires a large amount of processing power in the brain. To provide feedback to the brain of the grasped objects there are thousands of sensors in the skin, muscles and joints of the hand. These sensors measure temperature, pressure, slip, force and tactile sensations. The skin of the hand is also specialized for gripping. Iberall and MacKenzie (1990) found the coefficient of static friction was greater on the palm of the hand than it was on the back of the hand. The distal pulp/pads on the fingers have special epidermal ridges with self-lubricating glands whose sticky excretions help increase the friction on a gripped object. Over the last hundred years people on average have grown taller and their hand sizes have grown to match this (Panero and Zelnik, 1979). The results presented here are the average measurements for male test subjects, aged 20-29 year. These are taken and averaged from the more recent sources where possible.

The original data for these values will be given in the compendium. Kyriakopoulos *et al*. (1997) gives the maximum dimensions of the hand as being length 190 mm and width 90 mm. Wards palm depth of 28 mm does not include the thumb. When this is compared against the values given by Bain, it can be seen that the values are reasonably close to each other in size. The depth of the thumb was taken from Shimoga and Khosla (1994) and is taken from the fleshy base of the thumb metacarpal to the top of the palm.

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Table 1.Mechanical properties of selected Material

Properties	Aluminum 5052	Aluminum 6061	Stainless steel
Density	2.68 g cc^{-1}	2.7 g cc^{-1}	7.85 g cc^{-1}
Elastic Modulus	70.3 GPa	68.9 GPa	120 GPa
Poisson's Ratio	0.33	0.33	0.33
Melting Point	649°C	652°C	1455°C
Thermal Conductivity	138 W mK^{-1}	167 W/mK	16.2 W mK^{-1}
Electrical Resistivity	4.99e-006 U cm	3.99e-006 U cm	7.2e-005 U cm
Tensile Strength	262 MPa	310 MPa	505 MPa
Yield Strength	214 MPa	276 MPa	215 MPa
Hardness	91 kg m^{-2}	120 kg m^{-2}	138 kg m^{-2}

Aim: The aim of this project is to design and fabricate a mechanical hand which can connect to human body and with the same function of human hands to reduce the percentage of the injuries be can happen for people during work and analysis of the product. Firstly, the methodology and the material selection process in order to select the proper material was identified and compared to choose the best material. Then the critical components of mechanical hand identified in this chapter and had been analyzed by software and analytically and the results had been compared. Finally, the experiments done on fabricated mechanical hand to understand the comfortability, maximum and minimum size of grasping, maximum load can be carried and the maximum temperature the product can take during the work. The conclusion of the paper is covered by using the results of regarding mechanical hand and the recommendations and limitations of the project are explained.

MATERIALS AND METHODS

As depicted in Fig. 1, the hierarchy of designing, fabrication and analysis of mechanical hand is detailed. In following sections these stages are explained in more aspects.

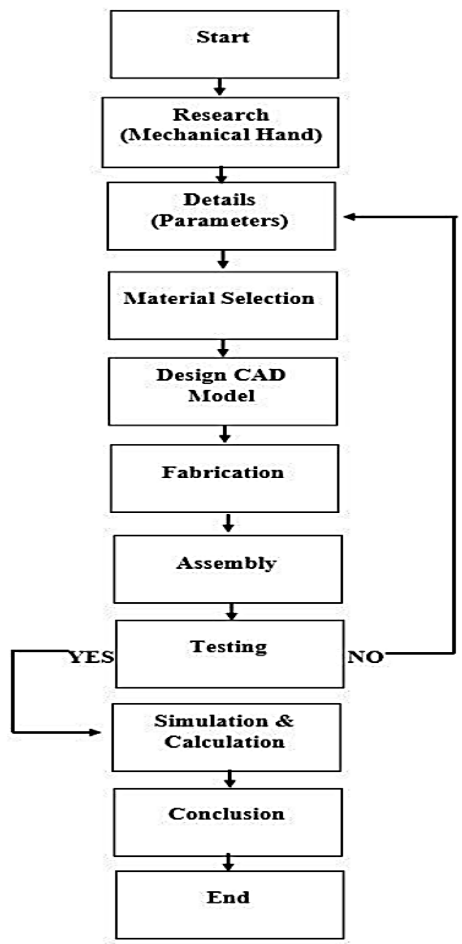

Fig. 1: Hierarchy of designing, fabrication and analysis of designed mechanical hand

Material selection: Materials play a significant role in products. In this section the possible materials had been identified and out of them the best material chosen for the mechanical hand. The material selected compared to the material of existed mechanical hand. The new material selected for this product supposed to have more strength to increase the safety and decrease the possibility of failure during the work. The possible materials are: Aluminum, Steel and Carbon Fiber.

Steel has good mechanical properties and yield strength with good price but the weight of steel is much more than aluminum and carbon fiber. To use the steel in mechanical hand makes this product heavy which can be harmful and it can decrease the safety for human hand. The aluminum is a light weight product with appropriate properties in order to be used in mechanical hand. The price is higher than steel and it cannot be welded but it can be machined easily. Carbon fiber has the best properties in these materials. It has more strength than aluminum and steel and it is also light weight compared to both of them. The only disadvantage of carbon fiber is the expensive price of it. The price of the carbon fiber compared to other materials is higher. By using the information above in conclusion, the best possible material can be select for mechanical hand is aluminum with light weight and acceptable price of it compared to

Table 2: Bill of the sub-assemble parts and related material

		Bill of Materials of Mechanical Hand		
Comonents	Part No.	Material	Number of use in assembly	Date
Hand body	10001	Aluminum 5052	One	7-sep-13
Finger link 1	10002	Aluminum 6061	Five	7-sep-13
Finger link 2	10003	Aluminum 6061	Five	7-sep-13
Finger link 3	10004	Aluminum 6061	Five	7-sep-13
Pin	10005	Alloy steel	Fifteen	7-sep-13
Bushing	10006	Alloy steel	Fifteen	7-sep-13
Roller	10007	Alloy steel	Fifteen	7-sep-13
Connection rod	10008	304 stainless steel	five	7-sep-13
finger hilder	10009	steel	five	20-sep-13
Pulley	10010	steel	One	20-sep-13
Pulley cover	10011	cast Iron	One	20-sep-13
Screw	10012	Steel	Eight	20-sep-13
Washer	10013	Steel	Eight	20-sep-13
Nut	10014	Steel	Eight	20-sep-13
Pipe	10015	Aluminum 6061	Five	7-sep-13
Ring	10016	Stainless steel	Five	7-sap-13
Connector	10017	Copper	Five	15-sep-13
Pipe Protector	10018	Aluminum 6061	One	15-sep-13
Line Rivet	10019	silver	Twenty	15-sep-13
Rivet Head	10020	Silver	Fifteen	15-sep-13
Spring 1	10021	Steel	Five	23-sep-13
Spring 2	10022	Steel	Five	23-sep-13
Belt	10023	Leather	One	23-sep-13
Buckle	10024	Stainless Steel	One	23-sep-13
Safety glove	10025	Leather	One	7-sep-13

others. The main components of the mechanical hand like hand body, pipe and fingers are made by aluminum. The components which connect the finger parts together are made by stainless steel which will affect the performance of the mechanical hand. They are bushing, roller and pin which are made by alloy steel. Properties of Aluminum 5052, 6061 and stainless steel are tabulated in Table 1 (Rosheim, 1994; Wright and Stanisic, 1990)

The Mechanical hand is going to be making entirely within the CAD software (Fig. 2). In particular solid works creates feature-based parametric solid models which are fully associative, able to be constructed with or without constraints and can utilize relations to implement the users design intent. There are four basic structures of organization in the creation of the models for the Hand and in the models associated within it. The first structure type was the one used for the finger and thumb assembly models. The second and third types are the palm assembly and hand assembly models. The fourth structural type was the one used for the linked models of the finger and thumb assembly.

Manufacturing process: Fabrication of the components of mechanical hand has many processes, called as manufacturing process. The process done by tools and machines described to produce the components designed. All of the components of mechanical hand have their own materials which had been prepared during the manufacturing project and other components bought from available markets to be used in mechanical hand assembly. Cutting process is to cutting the aluminum sheet in order to create the hand body. The aluminum (5052) had been cut into the specific dimensions found before. The cutting process had been done by cutting machine. Other manufacturing processes which have been used to fabricate the mechanical hands are: grinding, drilling, riveting, milling, filing, cleaning and punching. As shown in Fig. 3 after finishing all the processes, the component and sub-assemble of the finger should be assembled in order to make the mechanical hand. After that the pipe protector assembled in their specific location. The pulley is also assembled next to the thumb to connect the connection rod to it. The big springs installed at the back surface of the fingers to the surface of the hand body to control the motion. Then the springs and line rivet heads goes through the connection rods and the connection rods goes through the pipes. In the other side the connection rod goes through the connector and ring and it becomes tight by connector screws. In this step the belt and gloves are installed in their location. The comfortability and grasping test is also applied on this step. There should be no touching surface between hand of human and the mechanical hand. Table 2, detailed the sub-assemble parts and related material.

Finite element analysis: The analysis is done by finite element software ANSYS and analytical model and both analyses results have been discussed and compared. After defining the materials for components and loading, the meshing process is one of the important steps of the

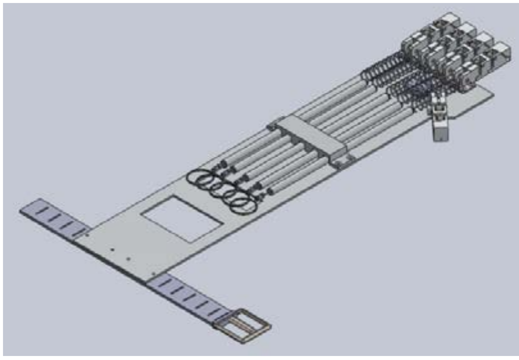

Fig. 2: Isentropic view of assembled mechanical hand

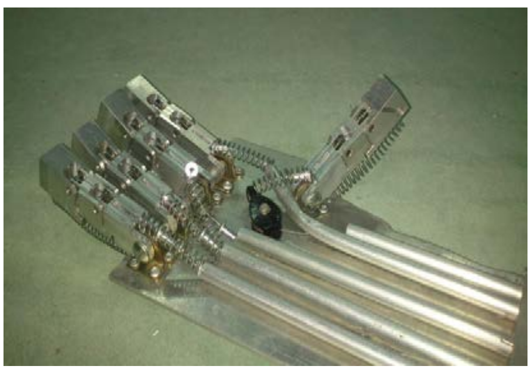

Fig. 3: Final assembly of mechanical hand

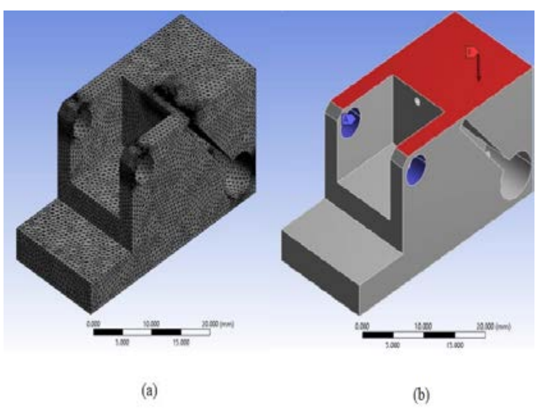

Fig. 4: a) Finite element model; b) Boundary condition

analysis which can affect the results. The mechanical hand components to be analyzed are all done in fine mesh Fig. 4a In each analysis the mesh size is defined to discretizing the domain of the component plays an important rule. The next step to run an analysis in pre-processing step is to define the boundary condition and applying the force on the component. For each individual component the boundary condition, the force applied and the direction of the force are different. With introducing the boundary condition of the component and the force applied we can run the analysis. The magnitude of force applied on all the components is 100 N which is an approximation load can be applied on mechanical hand components. This value is selected by considering the function, components shape and the material selected for the mechanical hand. Figure 4b is an example of the boundary condition and the force applied with the direction of force on finger link 3.

RESULTS AND DISCUSSION

Results of finite element analysis:

Hand body: Hand Body is one of the main components of mechanical hand which carries most of the loads and the human hand is also fixed on it. Almost all the components in mechanical hand are connected to hand body and it has been chosen for one of the critical components of mechanical hand to be analyzed. The critical location of the hand body is cut in order to be more focused on maximum Von Mises stress and deformation of it the hand body model on this location because most of the forced applied on this component is on the front surface of it which includes the fingers (palm). The model had been cut from the corner side curved shape of mechanical hand and had been analyzed as shown in figure. The back surface of the hand body assumed to be fixed and the load applied on the holes which finger holders are connected to them and the direction of it is downward. The magnitude of the force applied is also 100 N. Material selected for this model is Aluminum 5052 with yield strength of 214 MPa. As shown in Figure 5, the results shows the maximum Von Mises stress due to the 100 N force applied downward to the holes of hand body is 51.784 MPa and the minimum Von Mises stress is 0.0049715 MPa. The location of the maximum stress is last hole near to the boundary condition of the hand body as shown with red color and the location of the minimum stress is at the front surface of the hand body. The maximum deformation is 0.67145 mm and the location of it is at the front surface of the hand body. Factor of safety of safety of this due to the maximum Von Mises stress which is 51.784 is 4.13. So the component is safe after applying 100N force.

Finger links analysis: The fingers are actually sub assembly of 3 links, bushing, roller and pin which are connected to finger holders. To analyze the fingers the most important components in this sub -assembly are the finger links which are connected together and their function is to grasp the objects. To get the accurate results and specifying the links, all the links had been analyzed individually. The material selected for all figure

Table 3: Finite element results of the finger links due to the 100 N force applied

Component	Von mises stress (MPa)	Deformation (mm)	Maximum Principal stress (MPa)	Normal stress (MPa)	Factor of safety
Finger link 1					
Max.	5.976	0.0031869	5.5473	-0.71007	46.18
Min.	0.0013986	0	-0.71007	-1.1835	
Finger link 2					
Max.	18.046	0.0063486	0.41076	2.0097	15.29
Min.	4.6683e-5	0	-13.631	-3.0627	
Finger link 3					
Max.	41.132	0.018339	36.672	9.9555	6.71
Min.	0.00022969	0	-8.2982	-12.493	

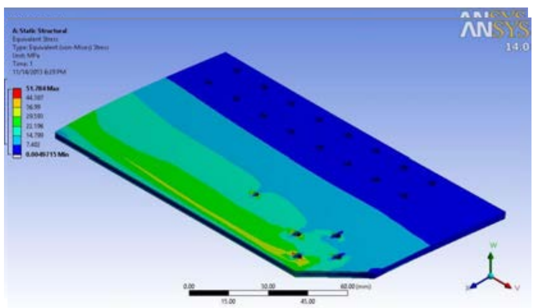

Fig. 5: Finite element result of Von Mises stress due to the 100 N force applied downward to the holes of hand body (palm)

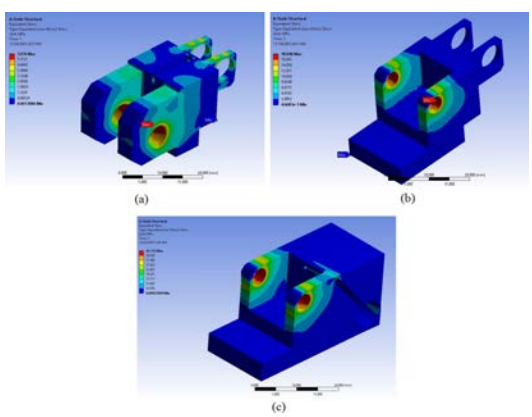

Fig. 6: Finite element result of Von Mises stress due to the 100 N force applied downward to the finger links: a) finger link 1; b) finger link 2; c) finger link 3

link 1-3 is aluminum 6061 with yield strength of 276 Mpa. As depicted in Fig. 6, the results of maximum and minimum Von Mises stresses in finger links are shown and tabulated in Table 3. Factor of safety of all components related to finger links are more than 1, so the components are safe after applying 100N.

Connection rod analysis: The connection rod is the components which assembled through the fingers and helps human fingers to apply the force on the fingers of mechanical hand to move them. According to assembly of

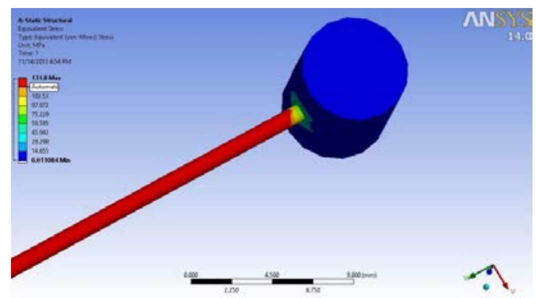

Fig. 7: Finite element result of the location of the maximum and minimum Von Mises stress

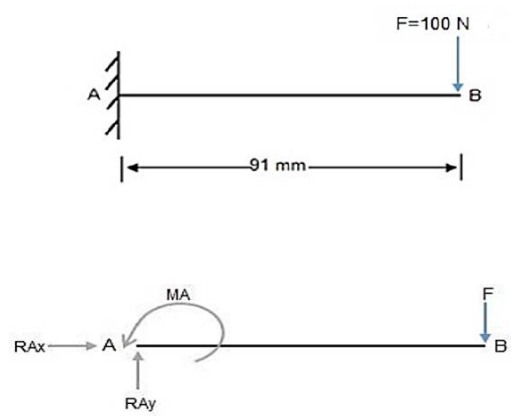

Fig. 8: The hand body is assumed as a cantilever beam

mechanical hand and the function of the connection rod, this component identified as one of the critical components to be analyzed. The assembly of connection rod shows the head of this component had been installed in finger link 3 and the wire of it goes through the fingers and from other side it is connected to the ring by a connector. The force applied on this components is tensile force and we can assume the head of connection rod can be define as boundary condition of this component. The material selected for this model is stainless steel with yield strength of 215 Mpa. The results shows the maximum Von Mises stress due to the 100 N forces applied upward to the down surface of connection rod is 131.8 Mpa and the minimum Von Mises stress is

Table 4: Critical components of mechanical hand.

Component	Von mises stress Theo. (MPa)	Von mises stress FE. (MPa)	Diff.(%)
Hand body	127.38	131.80	3.30
Finger links	44.625	41.132	7.80
Connection rod	40.440	51.784	21.9

0.011084 MPa. The location of the maximum stress is near to the boundary condition as shown with red color and the location of the minimum stress is at the front surface of link away from the boundary condition as it is shown with blue color (Fig. 7). The maximum deformation is 0.27672 mm and the location of it is at the bottom of the wire. Factor of safety of safety of this component due to the maximum Von Mises stress which is 131.8 Mpa = 2.09. So, the component is safe after applying 100 N.

Analytical analysis: The objective of analytical solution is to get the maximum von Mises stress and the location of it on critical components of mechanical hand. The critical components described before in section 4 are analyzed with assumptions. By considering a boundary condition in all of the critical components, we can assume they are cantilever beam and by using the cantilever beam solutions the maximum von Mises stress can be found. After finding the analytical solution for the components the results of the simulation and analytical results can be compared in order to get the accurate results. All of the calculations are static structural solutions.

As shown in Fig. 8, the hand body assumed to be a cantilever beam. The boundary condition applied on the hand body is at the end of it and the force applied on the holes is considered as a point load. The 4 holes of the thumb and the force applied on it is neglected because the 4 holes compared to other 16 holes are smaller and the effect of them will be neglected by accepting the error in the results. The shape of the hand body assumed to be a rectangular shape by neglecting the curve shape next to the thumb position because the length of the curved shape is smaller compared to other lengths of the hand body. Principle stress and von Mises stress is calculated trough Eq. 1 and 2 two as followed:

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy^2}} \quad (1)$$

$$\sigma_{\text{van Mises}} = \sqrt{\sigma_{x^2} + \sigma_{y^2} - \sigma_x \sigma_y} \quad (2)$$

By calculating the principle stress and von Mises stress these value can be obtained: $\sigma_1 = 0$, $\sigma_2 = 40.44$ Mpa and $\sigma_{\text{von Mises}} = 40.44$MPa which has a good agreement with finite element results.

Comparative study between finite element and theoretical results: By similar assumption to hand body, the theoretical analysis can be carried. The results obtained from simulations on ANSYS is compared to the results of analytical calculation in this section in order to get the more accurate results and the difference between them and the reason of the difference is discussed in order to understand the behavior of the critical components designed under pressure. As shown in Table 4, difference between the simulation and theoretical results is due to the assumptions made during the analytical calculation. The components are assumed to be a cantilever beam which a point load applied on the end of it. The shape assumed to be completely rectangular and the holes for thumb finger neglected because of it was small compared to the holes for other fingers. In addition, the mesh size on simulation can change the results as well which can make different results at the end for maximum von Mises stress.

Table 4 comparative study between finite element and theoretical results of von Mises stress (Theo: Theoretical result, FE: Finite Element result, Diff: Difference) The finger links designed for mechanical hand analyzed based on static structural analysis and by applying 100 N/mm force the components are safe which shows that the strength of the component increased in this new design and by selecting this proper material. The new design of the finger links and the compliable shape of them is to increase the performance of the mechanical hand and to increase the strength as well. By using this cubic shape finger links and connecting them together the strength of the five fingers of mechanical hand increased. Both results obtained from simulation and analytical calculation shows that the connection rod is safe under 100 N force applied as a tensile force. The factor of safety for both of them are above 1 because the maximum von Mises stress is less than the yield strength of the 304 stainless steel. The factor of safety for connection rod is less than other critical components of mechanical hand. The analysis based on factor of safety on this component shows that because of the thin body of the connection rod and the long length of it the possibility of failure is more than other critical components of mechanical hand (Table 4).

Experiments of mechanical hand: After final assembly of the mechanical hand and fabricating the product the experiments which can be done on the mechanical hand

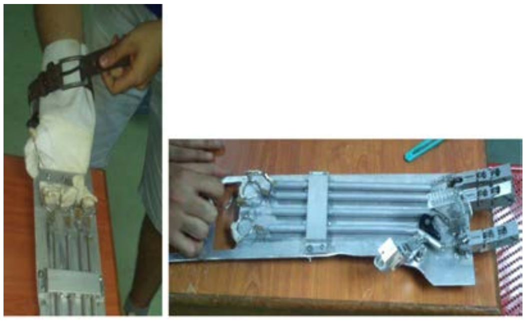

Fig. 9: Comfort and motion experiment

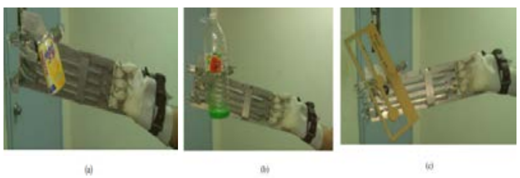

Fig. 11: Grasping experiment: a) Minimum size experiment; b) Average size experiment; c) Maximum size experiment

fabricated. The experiments selected for mechanical hand are in order to identify the function of the product and to analyze the performance of it.

Comfortability and motion experiment: In this experiment the mechanical hand is going to be tested to find the level of comfort for the customer. The mechanical hand is going to be connect to human's fingers by rings made by stainless steel and it should be comfortable and easy to install or remove (Fig. 9). The hand will be on the safety gloves designed to be on the hand body to make no attachment to the surface of the mechanical hand because of thermal and electrical conductivity of aluminum. This experiment will show the comfort of a human hand inside the glove while using the mechanical hand in different locations. The belt installed also is going to be tested to find the adjustability function of the product.

Result of this experiment as it is shown in Fig. 9, shows that the designed mechanical hand is comfortable for human hand. The glove installed is smooth and appropriate for this kind of functions and the human hand is comfortable inside. The rings prepared and the location of them are easy to installed and the two holes inside the hand body created for handling the mechanical hand during the work will not make any problem for the human hand. The belt installed at the end of mechanical hand is completely adjustable for different human hand size and the handling of the mechanical hand is easy by using the belt and the hole inside the hand body which makes a proper balance for the mechanical hand. The motion of the fingers is also tested during this experiment which as it is shown in the finger each individual finger includes thumb has been tested. All the fingers motions are correct and they move in their own expected direction in order to grasp.

Grasping experiment: The new fingers and designed mechanical hand need to be tested in order to test the performance of the product based on grasping. The grasping experiment is done by different size and shape object to grasp and the objective of this experiment is to identify the specific size of the objects mechanical hand designed can grasp. The objects used to be grasp are explained in this section and the minimum average and maximum size which mechanical hand can grasp are identified. In order to identify the minimum size which can be grasping by mechanical hand the can by dimension 65 mm is used as shown in Fig. 10. The can used is approximately the minimum size by dimension 86 mm which can be grasping by mechanical hand. The grasp type used in this experiment is power grasp. To find the average size of the object which can be grasping by mechanical hand the bottle by dimension 125 mm is used as shown in Fig. 11a. The bottle used is almost empty and the weight of the bottle is not considered in this experiment. The size of the bottle is approximately the average possible size can be grasping by mechanical hand (Fig. 11b). The grasp type used in this experiment is power grasp. The maximum size which can be grasp by mechanical hand is an object made by plastic which has the appropriate dimensions to be tested. The dimensions of the plastic shape object as shown in Fig. 11c is approximately maximum size which can be grasp by mechanical hand. The grasp type used in this experiment is power grasp also.

Maximum load experiment: To identify the maximum load can by carried by mechanical hand the super glue box which is full of liquid glue is used for this experiment. It should be noticed that as long as the force applied to the mechanical hand is due to the force applied by human hand on mechanical fingers, so the maximum load can be carried depends on the muscles of the human hand which is using it. If the power of the human hand using the mechanical hand is more so the load which is going to be carried is more. In addition, the experiment done on super glue box is used by hooking grasp type. The weight of the super glue box is 5 kg and it has been grasping by mechanical hand as shown in Fig. 12.

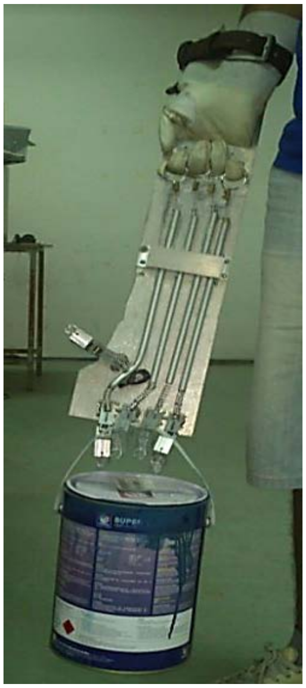

Fig. 12: Maximum load experiment

Fig. 13: About 100 °C temperature used for the first experiment

Heat experiment: The safety experiment is to test the mechanical hand designed in different situations. According to the function of the mechanical hand this product designed to be used in dangerous areas, so by using this experiment the capability of the product in dangerous areas can be identified. The material used to manufacturing the finger links are going to be tested in high temperature in order to get the highest temperature it can handle. By testing the material selected under pressure also the maximum load can be applied on the product can be identified as well. The heat experiment is done in three different areas with three different temperatures. The first temperature used for this experiment is 100°C. By burning a piece of wood with specific dimensions and measuring the surface temperature of the burned wood the temperature reached 128°C. The mechanical hand fabricated tested by grasping the burned wood and holding it for a while. As shown in Fig. 13 during the experiment the temperature of the burned wood did not make any problem for mechanism and also no injuries for human hand. So the mechanical hand designed is safe at 128°C.

The second type of the testing done in this experiment for temperature is the welded metal. The metal used to be welded prepared and the surface temperature of it measured. As it is shown in Fig. 14 the surface temperature of the metal welded is 278°C. The mechanical hand fabricated tested on grasping and holding this piece of metal. By grasping and holding the welded metal piece of holding it for a while there is no effect of the temperature on components of mechanical hand. The mechanism and performance of the mechanical hand is not affected by the temperature and the human hand inside the glove is also completely safe.

The third type of the heat experiment done on mechanical hand is by using the material selected for fingers of mechanical hand on 300°C. The material selected for mechanical hand's fingers which is aluminum 6061 is cut in rectangular shape piece in order to be tested for heat experiment. The FURANCE machine used in this experiment in order to reach the temperature to 300°C and the aluminum piece is used to be tested by the FURANCE testing machine. The mechanism of this type of machine shows that the temperature inside the testing machine cannot increase suddenly because it can spoil the material used inside the machine so there is time setting for the maximum temperature selected. By setting the machine on maximum temperature and putting the aluminum piece inside the machine the process started. In conclusion, by doing the heat experiment the mechanical hand and the

Table 5: Specification of mechanical hand

Specifications	Description
Performance	Mechanical
Features	Safety
Length	600 mm
Width	150 mm
Color	Light gary
Shape	Rectangular
Weight	1.7 kg
Model	5 Finger hand
Maximum load	5 Kg
Maximum temperature	300°C
Maximum size of grasping	125 mm
Life time	10-13 years

Fig. 14: Total 278°C temperature used for the second experiment

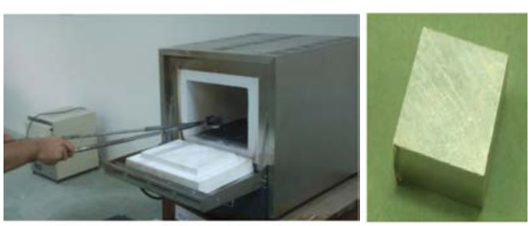

Fig. 15: The furance machine used for the third experiment on 300°C

material used for the fingers, it had been tested and the product is completely safe under 100, 200 and 300°C temperature. There is also no threat for human hand while using the mechanical hand and grasping hot objects. After the experiments down in previous sections, the final specification of mechanical hand can be summarized in Table 5.

CONCLUSION

In this article, based on selecting the proper material for mechanical hand (the aluminum types selected (6061 and 5052) the strength of the product is increased. According to the results obtained on finite element simulation and theoretical analysis, the of safety factor of the new designed mechanical hand components has sufficient strength to meets the objectives. Due to the fact that the force 100 N applied on each individual designed components of mechanical hand, the results show that all of them were safe and it is a proof that the designed mechanical hand is stronger and because of the material selected, it is also light weight.

With experiments done on mechanical hand the product is comfortable, safe on heat and it can grasp several of objects with different dimensions. The strength of fingers and critical components also tested on maximum load experiment which shows the improvement of the mechanical hand based on the new material selected. In order to decrease any possible injuries to human hand during the work with mechanical hand because of the high thermal and electrical conductivity of aluminum, the safety glove added makes a big difference in the range of safety for the mechanical hand. Analysis of the mechanism of the mechanical hand was based on the critical components which show the features and principles of the mechanical hand system identified and the motion of fingers controlled. The pulley added to the mechanical hand also helps the mechanism of the thumb which has an important role in grasping process. The analysis and simulation runs based on the critical components of the mechanical hand shows the maximum von Mises stress on each individual component with the location of the maximum stresses. The factor of safety of all the critical components proves that the components are safe under specific pressure applied on them.

The fabricated mechanical hand used for experiments in order to get the expected results of the product produced. The comfortability, grasping, maximum load and the heat experiments done on mechanical hand and the results of these experiments shows that the mechanical hand fabricated based on the new design and the material selected is comfortable and adjustable, it can be used by different types of grasping to move object and it can carry 5 kg load. The heat experiment also shows that the mechanical hand is safe at 300° of Celsius. By using the data and information collected in experiments the function of the mechanical hand the area of usage identified. By considering, the weight of the mechanical hand the hand body designed can be extended and some components such as connector and ring can be changed to stronger components in order to increase the resistance of them under high pressure and applied force.

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