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Design and Development of Hydraulic Rescue Cylinder for Cutting and Spreading

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Abstract*: The design and development of this hydraulic rescue cylinder are one of two parts that can attach with hydraulic rescue jaw to form a rescue tool which can easily cut and spreading metals. This study will improvise most of the existing hydraulic rescue cylinder that is heavy and difficult to use by developing a new hydraulic cylinder using mild steel with design calculations. In developing this hydraulic cylinder, the area of the cylinder barrel must be first considered. The concept idea of this project was based on a hydraulic double-acting operation that can extend and retract a piston rod. Selected material of this project was mild steel, and a study about its mechanical properties have been done. The hydraulic rescue cylinder also has been testing its operation in extending and retracting piston rod. The simulation analysis of this product also has been done by using Abaqus CAE for static analysis and Solidworks 2016 software for motion study and analysis of the product. Result achieved from this analysis are that is best in term of value of deformation, maximum elasticity and factor of safety of this project. Thus, the recorded result can use for further study and future recommendation.

Keywords: Hydraulic, Rescue, Cutting, Spreading.

I. INTRODUCTION

This hydraulic rescue cylinder is a part that can be attached with hydraulic rescue jaw to form rescue tools. This project idea generated from one of rescue organization tools. This product was invented based on the number of people who died stuck in their car during accident and late arrival for the rescue organization. The common problem during the occurrence of accident in this country will cause heavy traffic on the area and make the emergency rescue team arrive late to the location. The victims from the accidents might be safe if they were being rescued earlier before the vehicle become flaming or blow, and it can cause severe injury or death. There are no rescue tools equipped in most of car nowadays, so the nearby people who are the nearest people that can help the trapped victims from the vehicle before any dangerous situation occurred

The parameters that include in this project are the force required, pressure required and the diameter or the volume of the designing cylinder that will affect the result of this project. The specific objective is as follows:

- To design a hydraulic rescue cylinder that is light and can be used for cutting and spreading metal.
- To save trapped accident victim in a jammed car's door easily by quickly cutting and spreading the car body easily.
- To developed a hydraulic cylinder with jaw of spreading and cutting that are lightweight and easy to use.

This project is about the developing and designing the hydraulic rescue cylinder to attach it rescue jaw that can be used for cutting and spreading metals. This hydraulic rescue cylinder gets the power source that is supplied from the hydraulic hand car jack which has been equipped in most of the new car nowadays. In this project, the designing of the hydraulic rescue cylinder will be lighter and more convenient to use than the existing product. In reducing the weight of the product, the measurement and material used have been analysed to get the best data for designing the product. The hydraulic rescue cylinder also only can be used for cutting and spreading jammed car doors which are most of it were not solid metals

The most common hydraulic cylinder that has been developing nowadays that were used in various type of work and condition. A hydraulic cylinder is also called a linear hydraulic motor, consisting of a mechanical actuator that is used to give a unidirectional force through a unidirectional stroke. It also has many applications that can be applied, usually in excavation and construction equipment (engineering vehicles), marine equipment and types of machinery such as cranes and the rudder of vessels, manufacturing machinery, and civil engineering.

A. Types of hydraulic cylinder

There are several types of hydraulic cylinders that the majority have been used in the various industry. Mostly in the engineering industry known as actuator and manufacturing industry known like common name, hydraulic cylinder. The following subtopic is the various type that is commonly be used in industry. The hydraulic mechanism has been used because it can reduce the workforce and cost at the same time.

B. Hydraulic cylinder components

In the hydraulic cylinder mechanism, there are many parts that involve generating the operating system. The current existing hydraulic cylinder usually has four major parts such as cylinder barrel, cylinder base, piston and piston rod. These four significant parts will run out the mechanism of the hydraulic cylinder.

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The other parts of the hydraulic will be attached in the hydraulic cylinder system to generates the others hydraulic operating mechanism. A hydraulic cylinder has the following parts:

- Cylinder barrel
- Cylinder head cap
- Cylinder base cap
- Piston
- Piston rod.

C. Mild steel material selection

Most of the hydraulic cylinder barrel that has been made in the industry was made by using mild steel. Mild steel can be widely use if it was applying to a hydraulic cylinder. Moreover, mild steel also easy to weld and fabricate, which will reduce the procedure time is taken and cost. Table below shows mechanical properties about mild steel.

Table- I: Mechanical properties

	Density	Tensile strength	Modulus Elasticity	Poisson Ratio
Mild Steel	7.87 g/cm^3	Min: 370 MPa Max: 440MPa	205GPa	0.290

D. Theory calculations

The equations followed by pressure is for per unit area that applied to the surface of an object and for completing the equation the amount of area need to be confirmed at first it can help calculate the actual force that can get using it. Here, A is the active area of cylinder which is the difference between the area of the piston and the piston rod. The total difference between the two areas will be the force to be produced that is proportional to the area of the cylinder at constant pressure. Hypothesis for that, the larger the active area the large the force will be (Sainath et al., 2014). This such project used for spreading and cutting something. It is a short-stroke hydraulic cylinder which is fed from hand pump.

Pressure = Force / Effective Area of Cylinder (1)

II. METHODOLOGY

The main function of the project methodology is to understand this project main suitable concept. The step by steps of this study conduct was explained in this chapter. The hydraulic rescue cylinder is a design and development process study. The hydraulic rescue cylinder was designed by calculation and then have been tested using Abaqus CAE and Solidworks 2016.

A. Calculations of Hydraulic cylinders

The theory calculation applying on this project, a theory of calculation needs to be done as it is including the operation of pressure.

Area Involved = Area Cylinder − Piston Rod Area (2)

Area of Cylinder = 12959.61 mm − 11703 mm

Area of Cylinder = 1256 mm = 0.001256 m2

Area of Cylinder = 0.001256 m2

Based on previous research on chapter 2, the pressure which produced from most of hydraulic hand pump jack to run this hydraulic rescue cylinder was 10000 psi which equals to 689.48 bar and the force produced by the effective area in the cylinder was 0.001256 m2. By using all this information, the amount of force created on the hydraulic.

Force (N) = Pressure (bar) / Area (m^2)

Force (N) = 689.48 (bar) / 0.001256 (m^2)

Force (N) = 86598.7 N = 87 kN

A. Material selection

The main material has been chosen for this project was Mild Steel. The choice of materials in engineering design is a key factor for engineers (Romeo Mogbeyi, 2015). Therefore, to make the best product from available materials, proper consideration of what is expected of the design while its function, cost, environment implication and more crucial is mechanical properties. This mild steel has excellent weldability, and it is considered as the best steel for carburised parts. It is also a good balance of toughness, strength and ductility.

III. RESULTS AND DISCUSSION

The testing of the hydraulic cylinder has discussed in the previous chapter. The hydraulic will be testing their double-acting function as well the expanding and retracting the piston rod. The actual hydraulic cylinder needs to be testing with extending and retract operation. The working simulation of this project then analysed at Abaqus CAE and Solidworks 2016. The Abaqus software will provide the data of static analysis and deformation result while Solidworks 2016 will provide the data about motion study.

A. Result observation on testing hydraulic cylinder

The hydraulic cylinder in the figure below shows, the hydraulics have been extending entirely and will make the spreading mechanism if it is combining with hydraulic rescue jaw. The extension length also has been recorded. The figure below is shown; the hydraulic cylinder was in a retracted position. The maximum retracting length was recorded. The retract operation will make cutting mechanism until it is combined with hydraulic rescue jaw.

B. Result for Static analysis on ABAQUS / CAE

This project has been testing using Abaqus CAE as an analysis simulation to analyse their maximum stress, displacement, reaction force and maximum elasticity. The analysis only is done to the piston rod and piston. The amount of maximum stress which is 1.307e+04 will be divide with the material yield stress. The displacement happens at the piston rod was only 1.07 mm. The value was small if there is any deformation happen, the difference between length before deformation with after deformation was too little. The displacement will not make any changes to the hydraulic piston rod. The amount of the reaction force is 1.911 Mpa. It happens when the force applies is at the piston and the load force was coming from outer parts of piston rod and transferred to the other end of hydraulic piston rod. The maximum elasticity was their maximum amount of elasticity. Mild steel material usually does not have a much higher amount of elasticity, and unlike plastic the deformation shape will remain unchanged but mild steel deformation shape will back it to normal measurement. Figure (d) shows that the maximum amount of elasticity was 2.367 m^2.

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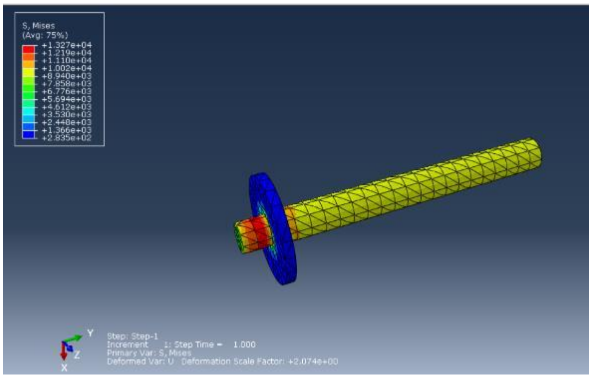
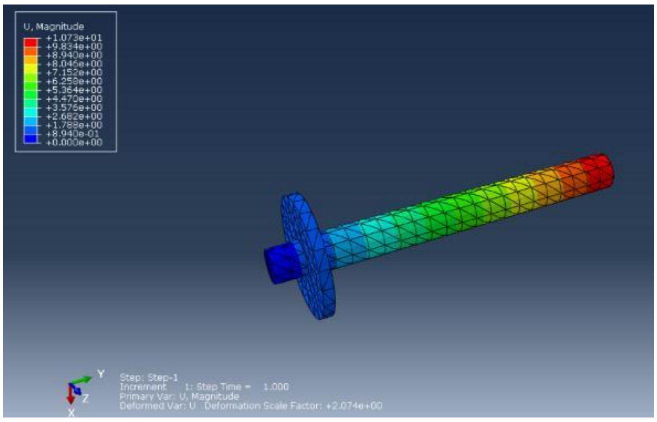
(a)

(b)

Fig. 1.(a) Hydraulic cylinder in the external position (b) Cylinder in retract position



(a)



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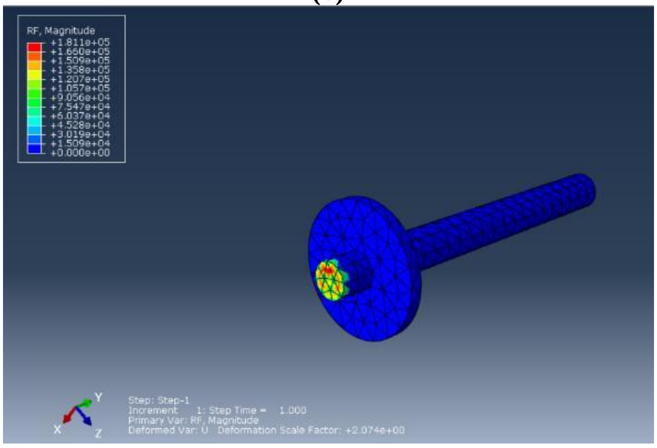

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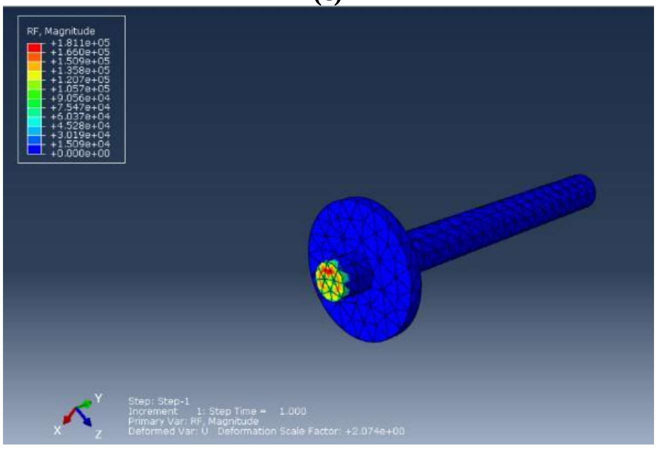

(d)

Fig. 2. (a) maximum amount and location stress; (b) Total displacement and location; (c) Reaction force location; (d) The maximum amount of elasticity and location

C. Result of motion analysis on Solidworks 2016

The motion analysis that has been analysing from SolidWorks Motion will provide the linear displacement, linear velocity, linear acceleration and motor force of the product.

1) Linear Displacement graph

The first result that can get from the motion analysis is the displacement graph. The graph showed that the piston had been move to 195.74 mm from the selected surface which refers to hydraulic cylinder barrel base.

At the beginning of the piston displacement, it shows that the piston has difficulty in early extend process cause of the force applied.

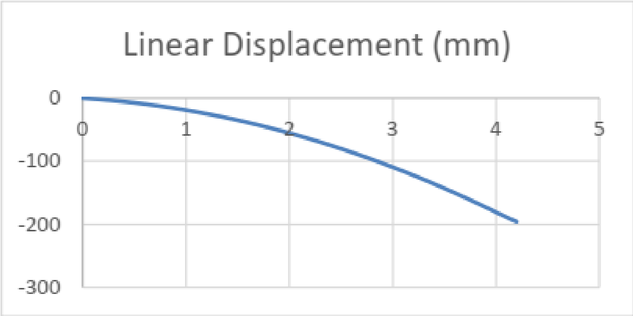

Fig. 2.Linear displacement graph

2) Linear velocity graph

Due to analysis did for this product, the linear velocity graph will provide the amount of velocity involve for the product to complete the motion analysis. The linear velocity shows the product speed in given direction to time. The figure below shows the linear velocity of the product. Based on the graph shown, it can be defined the velocity of the piston were quickly increase in value, but at the time 4 seconds it can notice started to decrease in value. It may cause the speed needed to push the piston have reached its end.

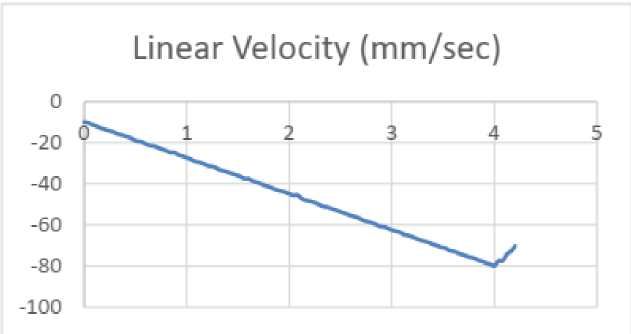

Fig. 3.Linear velocity graph

3) Linear displacement graph

The graph below is shown, it can be defined the velocity of the piston were quickly increase in value, but at the time 4 seconds, it can notice started to decrease in value. It may cause the speed needed to push the piston have reached its end.

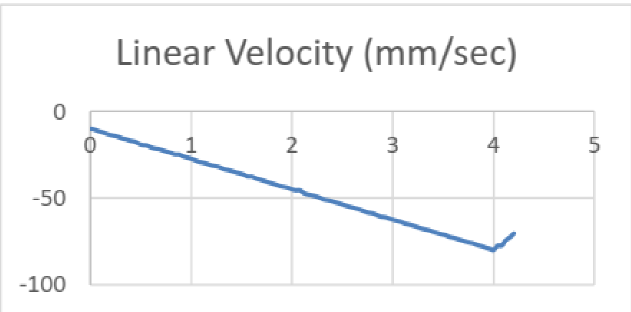

Fig. 4.Linear displacement graph

4) Graph comparison between stress, displacement and reaction time

The graph above shows a comparison graph between stress, displacement and reaction force. The reaction force was the straight line which the value of y-axis was always zero while the displacement ascending straightly. The stress graph was descending from 1.273 mm to zero. All the selected graph was compared against time.

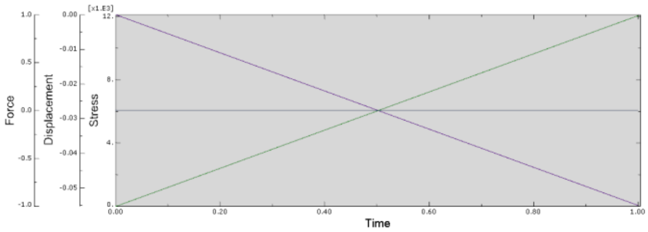

Fig. 5.Graph Comparison of Stress, Displacement and Reaction Force against Time

IV. CONCLUSION

To conclude, this hydraulic rescue cylinder was designed and selection of product concept idea. The designing process was conducted using usual sketch and CAD software like Solidworks 2016. This project design generated based on the previous product. This Hydraulic Rescue cylinder then will combine with Hydraulic Rescue Jaw to form hydraulic rescue tools. This product has been tested and analysed using Abaqus CAE for static analysis and Solidworks 2016 for motion analysis. The result has been recorded for future recommendation. To complete this project, the suitable material choice for both developments of hydraulic rescue cylinder and jaw was mild steel. In development phase the moderate and robust price material was used to testing the project output and objective. The maximum length of this project can be extended for the jaw was 283.51mm. The difference of this project maximum extend length with any previous similar project; this project has achieved a higher maximum length than the others. The result will justify this project success. The maximum stress for this project was 13270 Pa with force apply over 10000 Pa while the maximum elongation for this project was 2.367 m^2 because of the hydraulic operation in the product. Somehow this project still can be applied modification and future recommendations.

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