The Design of Reusable Endosurgical Grasper using Compliant Mechanism

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ABSTRACT

Endoscopic Surgical Graspers are the basic tools in endoscopic surgery techniques. These graspers act as tissue and organ grasper during the surgery. Endoscopic graspers are designed in various forms for various types of surgery. This project is a research on the tools for endoscopic surgery techniques. This project involves designing, modification of tools, analyzing mechanism and materials used and the cost of making an endoscopic grasper using compliant mechanism concept. Five novel design concepts have been rendered as probable approaches to the tool grip. These models were then evaluated respectively to determine the best design. Commercial CAD and finite element software will be used. CATIA is used for developing the part modelling and detailing, while ANSYS software is used to analyze the feasibility of the designed models. The ANSYS software will be used to design the endoscopic grasper and carry out the analysis of maximum affirmation and displacement on the components of the endoscopic grasper through Finite Element Analysis (FEA). The design prototype will be produced. It is hoped that the design will reduce the cost of surgical operations and the disposal of surgical instrument that will help to improve the environment.

Keywords: *Compliant Mechanism, Mechanical design, Surgical Grasper, Finite Element Analysis.*

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2018-02-02
Accepted for publication: 2018-10-25
Published: 2019-08-31

Introduction

The endosurgical grasper is the state-of-the-art instrument used to manipulate through tissue in an endoscopic surgery. Typically, conventional endosurgical grasper comprised of a handle, a trigger, the neck, and its sole part; the grasper. It is a rigid medical tool made of stainless steel. However, the cost of fabricating the single tool steel that includes stamping and assembly process reaches thousandths of dollars. Hence, the concept of compliant mechanism in design of the grip for the endosurgical grasper is introduced. The modification of grip design ultimately considers the comfort of use for surgeon using the tool during a surgery. One of the innovation will be done is to decrease the component number in the grip itself by applying the concept of compliant mechanism. In general, designing a product with fewer parts, and eliminating the component assembly consequently reduce its production costs [1].

Furthermore, the research study would provide information on the feasibility design of the endosurgical grasper with compliant handle in future. The research would also be a review on the present tool design in market and improvement can be done based on the needs particularly in local medical field. This study would provide the necessary information on the different kind of tool the concept of compliant mechanism to be applied to. This would expectedly heighten the awareness of the concept which imitates the nature to how the organism consists of a stiff and a flexible structure to create motion while maintaining its rigidity [2]. To future researchers, this study can provide baseline information on the recent status of compliant medical tools for innovation. The research would be beneficial to the doctor and specialist in the gynaecology and minimally invasive surgery (MIS) sector as this study enhance the knowledge of the tool itself and users about the possible issues on its application.

Compliant Mechanism

Compliant mechanism can be defined as a single-piece flexible structure which uses elastic deformation to achieve force and motion transmission, gaining their mobility from deflection of flexible member rather than movable joints only [2,3]. The mechanism consists of flexible segments are simpler and are able to replace movable joints, rotating pins and sliding joint. Significantly, it can reduce the number of joints, and also increase mechanism precision in a tool [3].

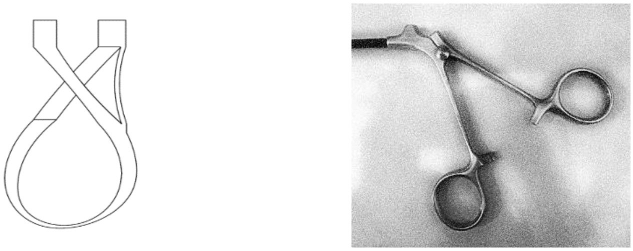
Due to the many advantages of compliant mechanisms, these devices have found numerous applications in areas such as components in transportation, actuator tailoring, smart structures, material microstructures, micro-electro-mechanical systems (MEMS), surgical tools, hand-held tools and robotics. A single piece compliant mechanism can simply be manufacture via extrusion, Computer Numerical Controlled (CNC) machine, rapid prototyping (RP), silicon surface micromachining, or injection moulding [3].

In absence of joint between links in compliant mechanism, noise problem, friction and lubrication use can be avoided. Application of compliant mechanism in tool design can shorten the process of manufacturing and assembling of the tool, also in reduction of tool weight and part count thus leading to reduction of manufacturing cost [5].

This paper covers on the design and analysis of a compliant grip using the software ANSYS Workbench. Material selections were determined by comparison using ANSYS while considering reduction of component number, weight, and size. Parts that are capable to be made compliance are: handle and spring components based on previous research [5].

Compliant Endosurgical Grasper Grip versus Conventional Endosurgical Grasper Grip

Figure 1 shows the visual comparison of a compliant versus the conventional endosurgical grasper in terms of geometry and working mechanism. The design objective is to eliminate extra assembly costs and able to withstand fatigue through compactness and minimal components. Cost reduction can be done by using cheaper material and minimizing the assembly cost.



(a) (b)

Figure 1: (a) Compliant Grasper Grip and (b)Conventional Grasper Grip

Finite element analysis (FEA) is the better solution in determining deflection and stresses in compliant mechanism compared to pseudo-rigid-body model. The task of analyzing the geometry with various cross sections provided the proper boundary condition made FEA much quicker and more accurate. For design in (a) however, using the pseudo-rigid-body model (PRBM) to obtain approximate solution face difficult challenge in getting the accurate dimension along its link because of the irregular geometry. There will be a big disparity in the calculation of stress and stiffness, when compared to the Finite Element Analysis using ANSYS. Further refining of the final prototype design can be done in future, to solve the PRBM calculation.

Methodology

This section explains about methodology that will be used to collect and formulate data in order to complete the project. It illustrates the process flow in obtaining the data and method of data to be analyzed. It will acts as a guideline in doing this project. Overall, design approach will be carried out as being shown in Figure 2.

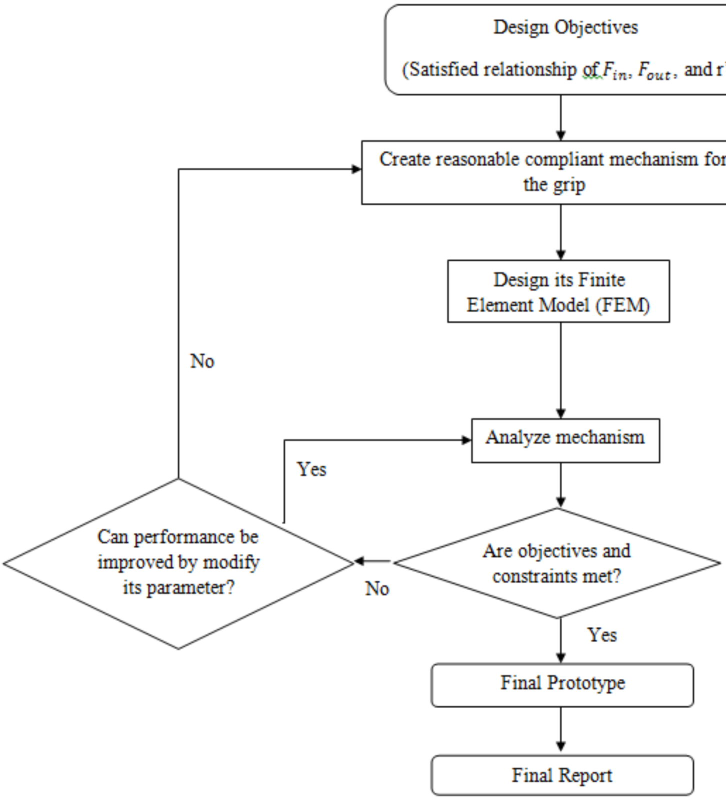


Figure 2: Design flowchart of compliant handle for endosurgical grasper

Analysis Of Mechanism

Mechanism Description

Figure 3 shows the free-body diagram proposed design of a compliant handle for endosurgical grasper. The design proposed is based on the feasibility study done among 4 other design and proven to be the best in terms of stress handling and linear force transfer at the spring force, Fs. The nature of the proposed mechanism imitates the mechanism found in various scissor design [7, 8, 9, 10].

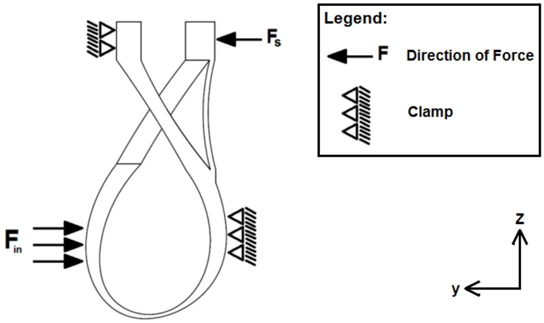


Figure 3: Design of compliant handle for endosurgical grasper

The input force, Fin applied on the handle by surgeon will produce reaction force, Fs, at the tip (Figure 3). The thumb grip actuating on the opposite handle act as clamp on mechanism were fixed as boundary condition. A linear reaction force acting on y-axis is produced.

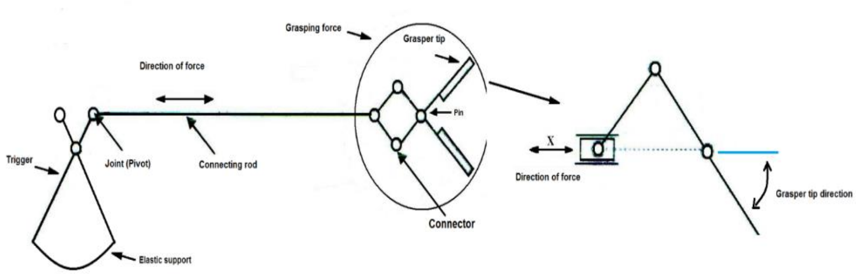


Figure 4: Mechanism of the proposed design

Finite Element Analysis

In the analysis, the boundary conditions were analyzed in 3-dimensional using ANSYS Workbench Software. The conditions set were in static structural analysis as listed in following Figure 4. The material chosen was Polypropylene, among Polyethylene and Polycarbonate, due to its tough and flexible properties. Polypropylene is known for its good resistance to fatigue and best price per weight ratio compared to the other materials. The chosen material properties were shown in Table 1.

Table 1: Material Properties used in FE model

	Polypropylene
Modulus of Elasticity, E	1.2GPa
Yield Stress,	35.2MPa
Specific Gravity, SG	1.384
Poisson's Ratio	0.42
Melting Point	150-164 'c
Price/kg (USD)	Bulk polypropylene US $1.75-1.86 / Kg

Due to the curved geometry of the handle, area of 20 mm^2 were slotted on point A and B of the grip that exhibits the operational condition of the surgeon's hand during an operation (Figure 5).The area considered was from the maximum stress concentration that the surgeon's grip would be focusing on the handle. The maximum force of 25 N was set exerting on point A. Determination of the maximum force acting upon handle was based on previous study done [4]. The material stiffness property was added to simulate the resilience towards the reaction force [9].

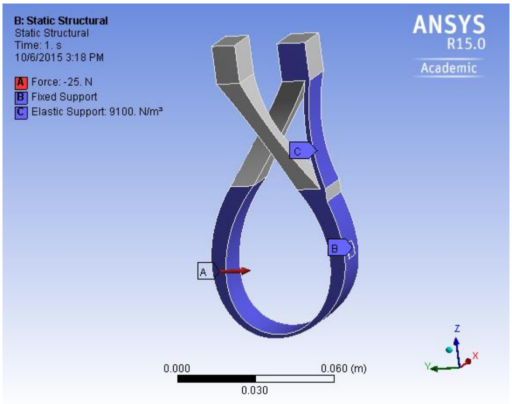
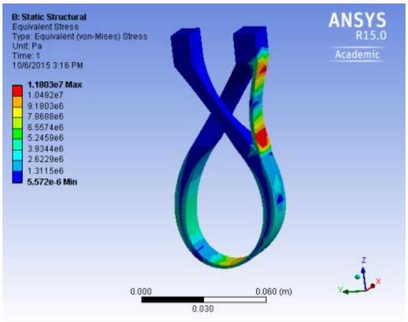


Figure 5: Static Structural analysis of the compliant handle

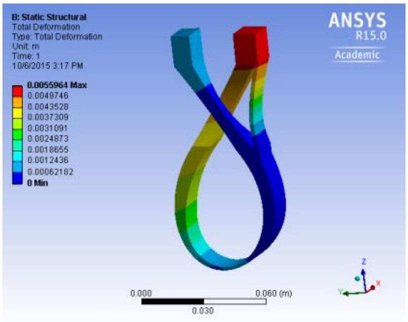
The input force was increased at an interval of 5N to 25 N imitating the gradual change of force by the surgeon's hand. The displacement of the tips from end-to-end in the y-direction were allowed at maximum of 5mm, therefore any displacement exceeding the limit would indicate the tips reaching maximum extent of the connecting rod to the grasper itself (refer Figure 4).

Results and Discussion of Results

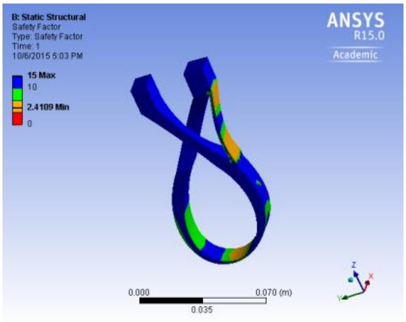
Figures 5(a), (b), and (c) shows the results obtained from finite element analysis using material Polypropylene. Equivalent von Mises stress, Total Deformation, and Safety Factor of each of the material selection were analyzed and compared to be chosen as the suitable material. The maximum Force of 25 N were applied on the handle to get the maximum affirmation of the analysis (Figure 6, 7, 8).



(a)



(b)



(c)

Figure 5: Results of FEA on proposed model using material Polypropylene

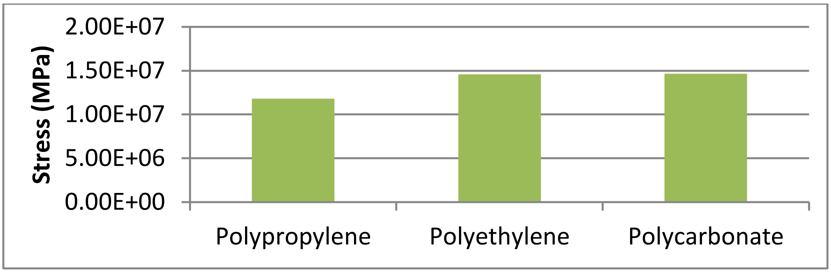


Figure 6: Comparison of the maximum stress between materials

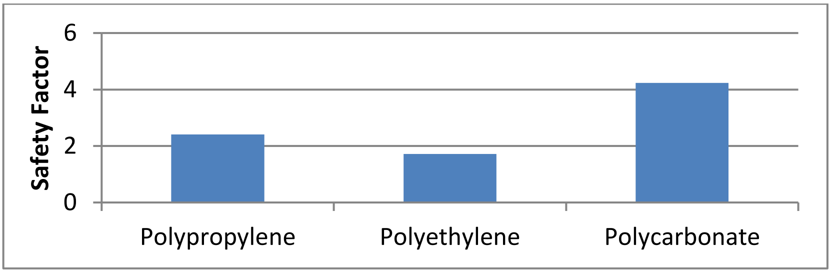


Figure 6: Comparison of the maximum stress between materials

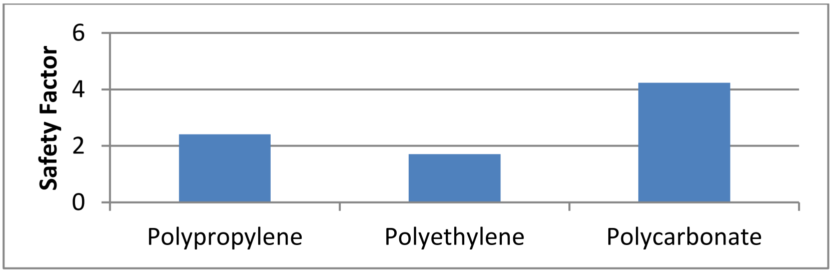


Figure 7: Comparison of Safety Factor between materials

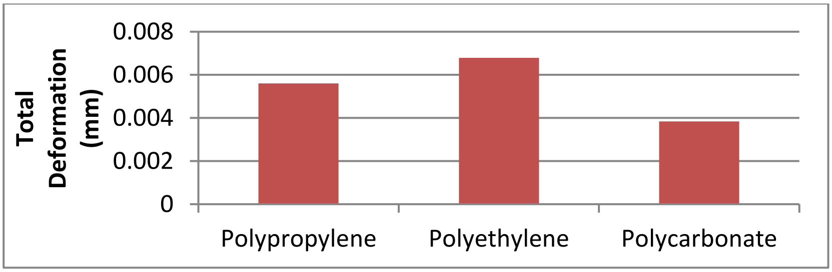


Figure 8: Comparison of the maximum displacement from tip-to-tip in y-direction between materials

From the graphs in Figure 7, 8, 9, generally can be see that the polypropylene is the best material choice for compliant mechanism. It is due to the low manufacturing cost in high volume. The safety factor of the materials compared shown polypropylene to be at the minimum, meaning acceptable yield stress over maximum stress. The maximum displacement from tip-to-tip in y-direction proved the polypropylene to be at maximum compared to other material and also close to the limit 5mm. The objective of designing and analyzing these handle is to reduce the components to only one component. This way will minimize the probability of the input force loss as friction energy. From manufacturing aspect, decrease in part count will make assembly much easier. The price of the chosen material insignificantly affects production cost especially when manufactured in high volume.

Conclusions

This paper presented a design and analysis of a compliant handle in endosurgical grasper using comparison of analysis. From the above study, we can conclude, the compliant handle design has a potential to replace a conventional handle due to its reduction in weight and component number. These advantages will bring less fatigue to surgeon's hand. However, there is still lot of works to be done such as pseudo-rigid-body method calculation where the proposed design dimension is improved and its performance is tested.

Acknowledgement

The authors would like to thank the Research Management Institute (RMI) of Universiti Teknologi MARA (UiTM) and Ministry of Education, Malaysia for financial support and facilitating this project support to this study through Research LESTARI GRANT awards 600-RMI/DANA 5/3 (43/2015).

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