Surgical Drill End-Effector

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ME Senior Design

Executive Summary

Metro Controls is tasked with designing an end-effector with human hand like compliance for Midas Rex surgical drill, a product of Medtronic. The end-effector we designed has a similar compliance as an actual human hand, capable of holding the drill and performing fatigue tests on a bone specimen. The end effector consists of a laser sensor to direct the cutting path and a thermocouple to monitor the temperature of the drill-motor while in operation.

Fig 1. Final prototype render.

Background

Currently a person is tasked to perform fatigue test using the Midas Rex surgical drill. Medtronic wants an automated system to perform the repetitive task of fatigue testing. An end-effector is required in the system to hold the drill and perform the test.

Why not a stiff clamp hold to grip the drill?

Vibration is produced when the drill is actuated to perform the operation. This vibration of the drill would resonate with the stiff metal clamp resulting in inaccurate cutting and possible premature failure of the highly stiff end-effector. However, a human hand can resist and perform the similar operation with minimum chance of failure as fingers' viscos-elastic properties damps the vibration reducing the effect of resonance. The control of a human hand over the drill in compared to the stiff metal clamp is incomparable in terms of flexibility.

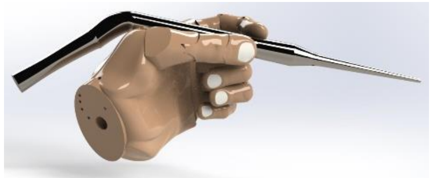


Fig 2. CAD Illustration for Human hand holding drill.

Experimentation and Analysis

Metro Controls began by studying the force-displacement relationship of human hand holding the surgical drill by performing experiment with subjects. The experiment consisted of a setup where the subject holds the drill in natural position and a loading of maximum one pounds applied from the bottom to the drill- bit. Natural displacement response of the hand was recorded using a durometer to obtain a force-displacement relationship. From the data, a linear trend was observed for the specific amount of force implied to us by the client Medtronic.

Fig 3. Experimental Setup..

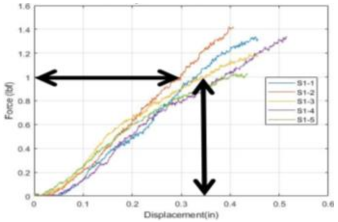


Fig 4. Linear Response [Hand experiment].

We continued the experimentation of human hand and obtained a desirable displacement range of 0.25 in to 4 in for a loading of one pounds [2.5 – 4 ppi] and moved ahead in research and selection of foam materials which yields similar response of a human hand. Closed cell- polyethylene foam materials was narrowed down as a possible replacement. To ensure the specific foam and various parameters that behaves unequivocally to our range, a similar experimental setup was designed to obtain the force-displacement response of the foam material.

Fig 5. Setup for End-Effector

The setup gives freedom to alter displacement between foams and the type of foam. The setup was placed similarly as human hand in 'Figure 3' and a loading of one pound was applied to observe the force-displacement trend. Final selection of material depends on the displacement observed for specific distance between the foams.

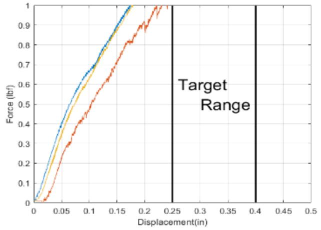
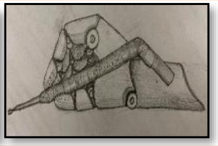


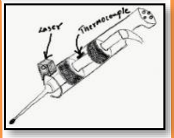
Fig 5. Plot obtained from prototype.

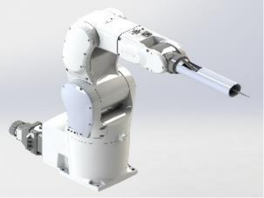
The current status of the project is on the process of finalizing the foam material to be place on the end effector. We have tested three foam specimen and the results have been closed to the desired range. However, the data obtained from the material demonstrates that for loading of one pounds, linear force-displacement response is observed. Final steps of this process includes, comparing the displacement data obtained for the human hand and the material and finalizing a perfect fit for the desired range.

Product Cycle



The design idea began with the identification of key locations on the surgical drill where the human hand comes in contact while holding and performing cutting operations. These locations were taken into consideration in every decision-making step along the design cycle. Metro Controls' first meeting with Medtronic and their problem description envisioned a hyper realistic design of an actual hand holding the surgical drill being mounted to the robot. The initial hand resembling design was reduced to a cylinder with two key contact points where the foam material was attached to replicate similar performance as a person holding the drill.





Conclusions

Detail study on viscos-elastic property of fingers, research on non-linear response of fingers and materials, dynamic testing on performance of human fingers under loading conditions are required to improve the performance and increase the functionality of our end effector. This prototype is a basic illustration with simple geometry, to demonstrate that it is possible to replace the human hand with our product. The future of the product is huge and embarks possibility to be used for automated surgery, where a surgeon can work remotely and perform his operation using the robot.

References

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