

The Application of Fluid Power to Meet the Needs of Surgical Robotics

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Introduction

Robotic surgery promises to produce continued development in surgical innovation. For this to occur, advanced technology for surgical devices and tools is needed. The present project aims to address the deficiencies of existing surgical tools through the development of a novel fluid powered robotic surgical platform. Unlike current robotic instruments in which a robot manipulates a set of cable driven, otherwise passive, end-effectors (tools), our vision is that the surgical tools themselves be the robotic device. This will improve accuracy and possibly introduce additional degrees of freedom. Our goals for this project include demonstrating the feasibility of a multi-articulated robotic platform in which the tools themselves comprise the robotic system rather than the more common passive end-effectors. The main challenges of the proposed device include multi-degree of freedom mechanism design, power delivery and actuation, micro-valve design and fabrication, and force-feedback control. These challenges will be met through the development of models and prototypes designed to demonstrate the necessary functionality.

Background

Due to continuing advancement in surgical technique, the current technology in surgical robotics is in a rapid state of development. Medical device designers must continue to advance the difficulty and complexity of the tasks that robotic surgical tools are capable of performing. Important considerations in tool design include, size and number of working channels, scope rigidity, suction/irrigation, and achievability of triangulation. We see fluid power as an advantageous path to achieving these goals.

Fluid power has several advantages when compared with alternatives such as electromechanical power including, a remotely located power source, ability to maintain high force/torque and greater power density (Figure 1).

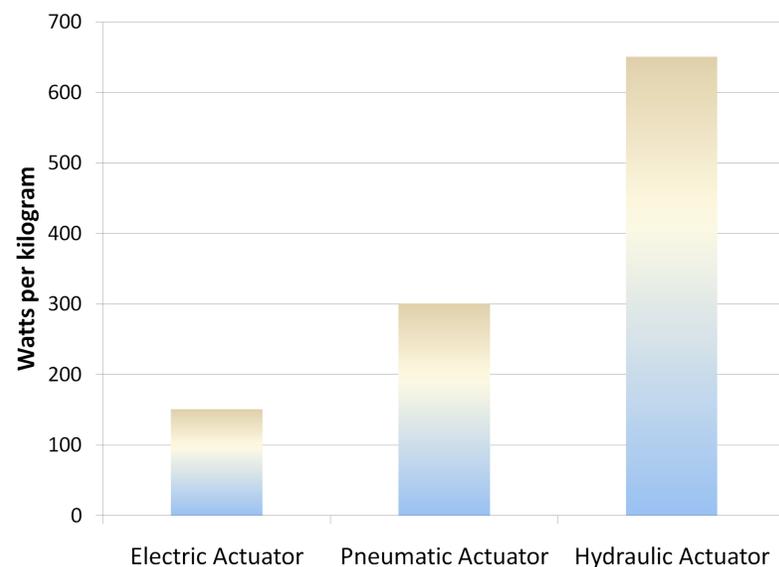


Figure 1: Comparison of the estimated power density of equivalent electric, pneumatic, and hydraulic actuators.

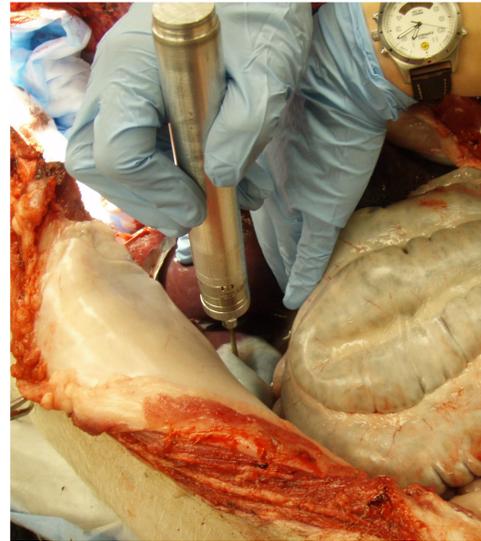


Figure 2: Abdominal force probing to identify tool requirements under various conditions using a porcine model. Forces were recorded on the order of 3.75 N.



Figure 3: Testing the force requirements of suturing for a variety of needle sizes and tissue properties. Forces recorded at 3.25 N for tissue puncture and 5.5 N for suture tying.

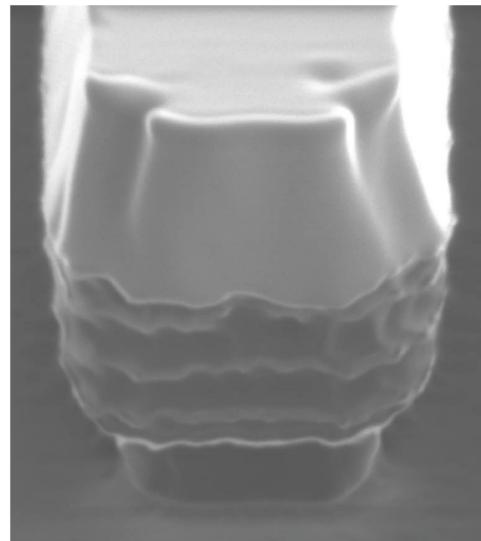


Figure 4: Scanning electron microscope image of MEMS structure at 60000x magnification showing surface deformities resulting from the anisotropic Bosch process.



Figure 5: Articulation joint structure using the common beam and disk arrangement to achieve tool positioning.

Considerations

In pursuit of developing the concepts and principles governing a fluid power based surgical platform, several key areas must be considered.

- Characterization of tool requirements through review of the relevant literature and measurement of tool forces (Figures 2 and 3).
- Design and development of a MEMS based flow control valve capable of high pressures at low flow rates (Figure 4).
- Exploration and characterization of methods for accurate tool positioning provided a known input (Figure 5).
- Evaluation of methods for achieving the necessary force and position output from the tool/end effector (Figure 6).

Each of these areas is being considered in detail and assembled to provide the framework for a fluid powered surgical platform that can be adapted for a range of surgical methodologies.

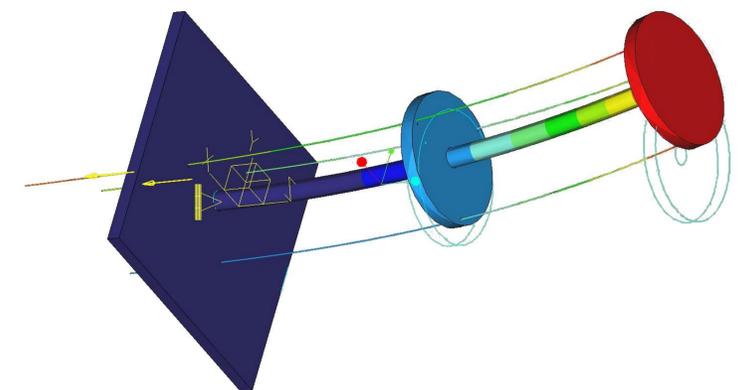


Figure 6: Structural simulation of static system behavior.

Summary

The use of robotics for surgical applications will likely continue to move towards the forefront of advanced surgical procedures. This is particularly true for minimally invasive surgical techniques. As this occurs, it will become increasingly necessary to develop advanced surgical instruments capable of performing difficult procedures within limited available space. While medical device designers are working quickly to develop these tools, a new direction may be necessary to facilitate the scale of miniaturization that is necessary for these devices to be successful. Fluid power carries with it the characteristics necessary to achieve greater miniaturization while maintaining the level of sophistication required by surgeons.

This alternative approach to the design of a robotic multi-articulated endoscopic surgical tool will allow us to achieve greater maneuverability and higher force output at a scale which is appropriate for novel surgical procedures.

Future work on this project will focus on the validation of concepts and principles currently being developed in the areas of manufacturing, device articulation, and control.

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