

A Novel Steerable Single Layer Tubes of Surgcial Manipulator Based on Ni-Ti Alloy

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Abstract. Objective Minimally Invasive Surgery (MIS) requires armamentarium with high positioning accuracy and maneuverability. At the same time, the equipment need have more functions and smaller size, it can reduce patient's operative incision and pain perception when in operating can still keep steerability and stability. Method. Traditional design with multi-tubes assembled, we designed a new stucture which just have single layer tube Results Finite element method can analysis this model which designed by another 3D drawing software in different size, varied external force can conclude that the angle of end deformation. 3D model adopted the isometric atom with nickel titanium alloy we take advantage of Ni-Ti alloy's superelasticity which can recover to original shape in recoverable deformation interval, realise proximal end control distal end.

1. Introduction

In the early 19th century, philipp bozzini, a German, used candles and a series of lenses, by using the light of the candle crossed the lenses can image formation which internal features of human's bladder and urethra achieve examine make sure these organ work like as usual whether or not.

In medical domain, Endoscopes are mostly used in neurosurgery [1]. Endoscope and its appurtenances equipment can be penetrated into the cavity of human body through these natural passage or artificial opening of the human body. The internal tissue structure of human body can be imaged on the display device by imaging system, which can provide an intuitive reference object for doctors. Doctors can according these images which display internal tissue accurate cut off tumours or cysts.

In general, endoscope can be divided into hard tube endoscope and steerable endoscope by the means of control. When doctors employ endoscope into surgical operation select different types of



endoscope on the base of different part which have different structure. Ordinarily, the hard tube endoscope is used for the examination of the pharynx, nasal cavity and brain, as shown in Figure 1B checking tympanic tumor via hard tube endoscope. Usually the head of a hard tube endoscope have sloping which can expanding the surgical field of vision can get more message about tissue. The head of hard tube endoscope has high stability and is easy to operate. It can be located accurately in the internal cavity of human body so as to avoid the injury of tissues and organs, reduce the probability of secondary injury. The pathological tissue which broken to pieces by some certain ways can be removed from the human tissue and transformed by the channel of the hard tube, it's channel can be use transport cure medicines, such as disinfected or eliminate the pernicious influence medicine. It can also be provide a variety of working modes, without replacing the axis, it's head can be replaced, such as gripper or scissors can be installed[2,3,4].In this way, a variety of functions are relieved. The steerable endoscope's operational principle is that use rope traction, rope and rope between interference when in process of operation, as shown in Figure1C. Although the flexibility is larger, the angle range is wider than hard tube endoscope, but the precision of control is more difficult than hard tube endoscope. Endoscope technology has been continuously developed with the development of science and technology. Some high-tech equipment and technology are also applied with technology update. However, it's own shortcomings are becoming more and more obvious, precise positioning is not easy to achieve. The stability of terminal control still have improvment room.

Comprehensive consideration of two or more factors, the new equipment has the stability of the end of rigid endoscope and the large cavity. It is also has the large flexibility of steerable endoscope[5][6][7][8].Combine the advantages of the two design. The head of the endoscope is made into a flexible hinge, which makes the head bending, flexible and controllable in a certain range. The middle part of the endoscope is rigid enough to resist a certain amount of external load, such as the bending of the endoscope when the head is in contact with the internal tissue of the human body, which reduces the maneuverability of the endoscope and fails to remove the tumor tissue. This is not what we expect. There are many difficulties in the design of the device. The armamentarium which have multiple functions still have certain stiffness. A small size can reduce the area of the wound and make the patient recover quickly from illness. But at the same time, larger lumen still maintain with the decrease size, so that the removed lesion tissue fragments can be sucked out from the lumen of the tube, as shown Figure 1D.

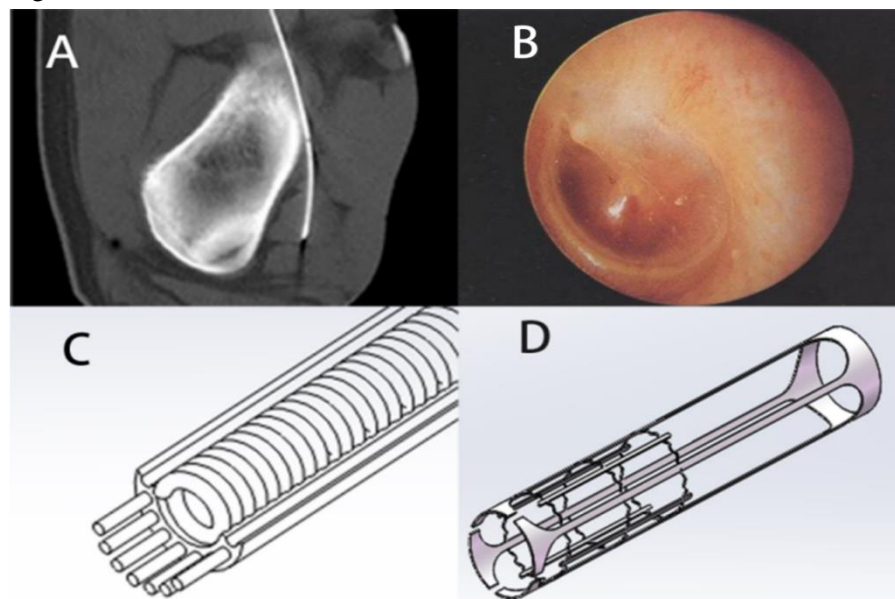


Figure.1.Application of laparoscopy in operation and real endoscope

Figure.1.(A)Products: Morrison Steerable Needle used for sampling, rounding the bone and carefully avoiding neurovascular bundle (<http://apriomed.com/products/morrison-steerable-needle/>)

[9]. (B)Using Hard endoscope check Tympanic tumor[10].(C)Traditional steerable endoscope: outer catheter has hole around from circumference, in that metal wire in it which can be controlled by these guide wires[11].(D)New technology designed in minimally invasive surgery which can imply large inner diameter and just have single layer thin wall.

In the field of laparoscopic technology, Leonardo da Vinci robot has occupied an unshakable position[12]. It consists of three parts: the surgeon control's workbench, the bedside manipulator system, and the imaging system. Its patented wrist rotator can achieve 7 degrees of freedom, and the range of movement is even wider than the palm of the human hand. Greatly improve the flexibility of the instrument, can help doctors to complete the excision and suture more efficient. Traditional endoscopy has less flexibility, because the head of the endoscope does not have the same flexible mechanism as human wrist joint. Endoscopic surgery is more in the natural cavity or artificial opening of the single-hole surgery. Single-hole surgery requires more flexibility than the natural canal.

2. Present method

Many endoscope products use the structure of manipulable wire to realize the precise control of the end structure. The product structure of this design mostly adopts the structure with holes in the pipe wall, which metal wire inside the hole can realize movement along these holes. As shown as Figure 1C. Of course there are other structural options. For example, the company's products use its own structure to achieve bidirectional bending. The product has a structural wall size of 0.82mm, an inner wall size of 0.68mm and a length of 170mm as shown Figure 1A[13]. The structure of this design is compact, and it does not adopt the structure design of metal wire with holes in the pipe wall. It can control the far end bend through the control handle, so that it can accurately locate and remove the focus. The outer diameter and the inner diameter of the endoscope with wire are large and small, so that there can be room for the wire. The wire can pass through the holes in the tube wall to control the endoscope head. This greatly increases the cross section size of endoscope, reduce the rigidity of endoscope, reduce the stability of the end structure, reduce the ability to resist external interference, and is not conducive to the operation. Small internal diameter do not allow for other medical procedure, such as channeling broken tissue through channels to reduce the risk of direct exposure to air. A wire-controlled endoscope structure that connects the wire to the wall in the head by welding or otherwise. This operation reduce the service life of the endoscope and is difficult to maintain[14-17].

In view of the above problems, this paper adopts a new structure. By using the super-elasticity of Ni-Ti alloy material, the large deformation of the structure is realized, and the deformation of the terminal structure can be achieved by remote control. Nickel-titanium alloy materials were discovered in 1960 by U. S. Naval Ordnance Laboratory at the National Navy Laboratory[18]. Nickel-titanium alloy materials are widely used in many fields, such as aerospace, medical domain and so on. For example, orthodontic nickel-titanium alloy arch wire, cardiac vascular stent and so on. Nickel-titanium alloy materials have two great properties: shape memory effect (SME) and superelasticity (SE)[19]. When the external load is removed, the sample can be restored to its original state without plastic deformation. We can see the property of Ni-Ti and Stainless Steel in Table 1.

Table 1. The property of Ni-Ti and Stainless Steel

property	Ni-Ti	Stainless Steel
Recoverable strain	8%	0.8%~1%
Biocompatibility	Excellent	Fair
Ultimate Tensile Strength(UTS)	~1240Mpa	~760Mpa
Density	6.45g/cm ³	8.03g/cm ³
Magnetic	No	Yes

3. Numerical analysis

We use another 3D designed model software design structure and we use the finite element software to analyze the model [20]. The deformation of the structure can be accurately calculated by applying external load to the structure as shown Figure 2A, we can change the load size, analysis different load caused deformation and the stress and strain of the structure can be seen from the deformation diagram. Before the stress-strain analysis, the structural model of the material is set up, and then the structure is meshed, and the whole structure is divided into discrete and finite meshes, it's vital to next step, the quality of meshes can influence the accuracy of results. The stress and strain at any point can be analyzed by the finite element software when the structural load is applied. We can analyze it in finite element software by changing the size of the structure, such as thin-wall thickness, section shape or size of the connecting side rib, and the length of the deformed end, and by comparing the differences between them. Determine which parameters have the greatest effect on the end bending angle. Of course, through the finite element software analysis, we can analyze the maximum angle of the end structure deformation as shown Figure 2B.

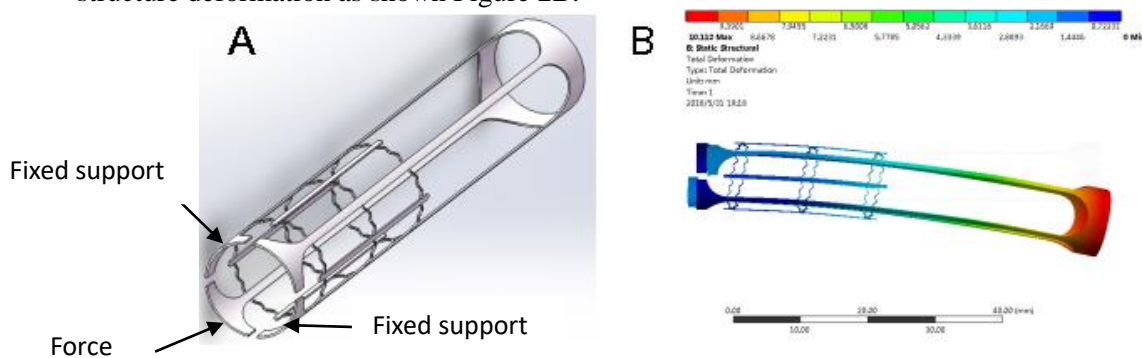


Figure.2. Apply external force and displacement diagram

Figure.2.(A) The direction of the arrow in the figure is the direction of the applied load. (B) The picture shows the deformation of applied 5N, we can see total deformation by analysis software.

4. Results and Discussions

Use new model which have different size, such as length or diameter. Results shown as follow as Figure.3. we use different model in order to make sure that indifferent environment which external force and self-size can have effect on deformation.

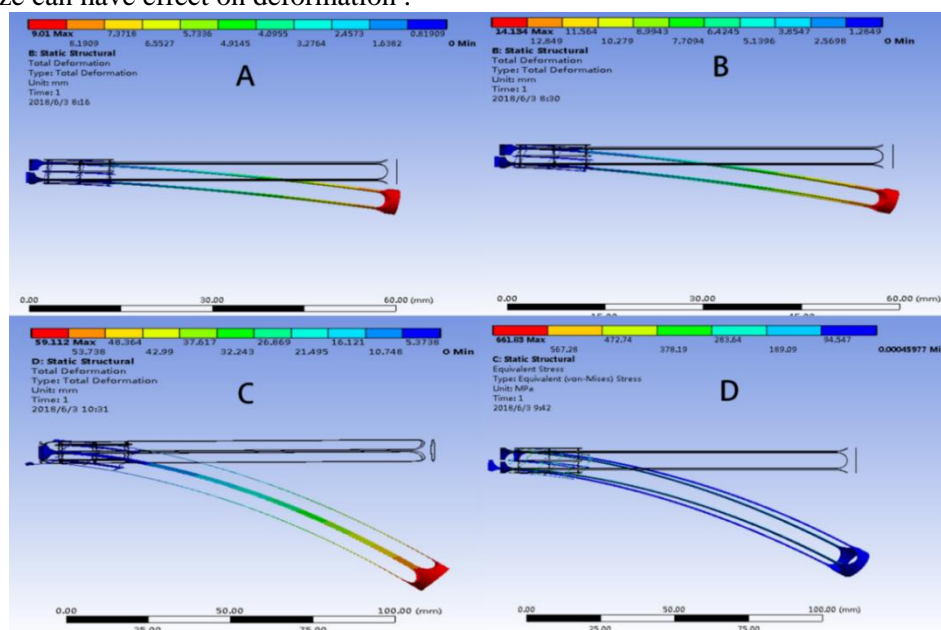


Figure.3. Different external force displacement

Figure.3.(A)The displacement cloud diagram of flexible mechanism with load of 1 N, inner diameter of 9.8 mm, wall thickness of 0.2 mm, length of 60 mm is represented.(B)The displacement cloud diagram of flexible mechanism with load of 3 N, inner diameter of 9.8 mm, wall thickness of 0.2 mm, length of 60 mm is represented.(C)The displacement cloud diagram of flexible mechanism with load of 5N,inner diameter of 9.8 mm, wall thickness of 0.2 mm, length of 120 mm is represented.(D)The displacement cloud diagram of flexible mechanism with load of 5N,inner diameter of 9.8 mm, wall thickness of 0.2 mm, length of 120mm is represented.

From the above displacement and strain cloud diagram, we can see that under the same external diameter the deformation of the distal mechanism can be increased by increasing the load. Under the condition that the external diameter remains constant, the end deformation of the flexible mechanism can be increased significantly by increasing the length of the flexible mechanism and increasing the external load. Compared with the traditional flexible mechanism controlled by flexible cable, the flexible mechanism of this kind of single-layer thin-walled pipe fittings will not occur crosstalk phenomenon. And there is a lot of space inside the monolayer to accommodate other devices, such as the optical fiber of a minimally invasive imaging system, or the splinter of a cyst or tumor, which can be sucked out by a suction device through the cavities. The near end structure is controlled and the end structure is deformed by long and thin strip transfer of tension and compression load. From the cloud figure.3.D,we can see that the end deformation angle of the monolayer thin-walled tubular structure can reach nearly 30 °when the external load was applied by 5N.

Acknowledgements

The study is financially supported by Science and Technology Commission of Shanghai Municipality under grant No.17441901200.

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