Abstracts Submitted

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Title High-Frequency Vibration Driven Cutting
with Biological Inspiration for Minimally Invasive Surgery

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Content

Abstract

Minimally Invasive Surgery has become more and more important in the medical application. It reduces the operation danger and also the ache of patient. In this process the small surgical utensils will be inserted through natural pathways to the operation site, or one mobile micro robot moves firstly through to make one hole to the operation site for the following action.

For the minimally invasive surgery different working methods have been reported. Many use electrically driven cutter to execute operation. Electrical energy brings ease, but although well protected, it is still one great danger for the safety, especially for the operations at where nerves are densely located, for example in spinal disc surgery. For this type of surgery, surgical utensils driven with high-frequency vibration are much more safer. There are no sudden changes of effect at organism for vibrations with frequency below 40kHz.

The cutting behavior of leaf-cutting ants makes use of high-frequency vibration produced with an special organ. When harvesting fresh vegetation, leaf-cutting ants anchor with their hind legs on the leaf edge and rotate using the legs as a pivot. During cutting, ants produce high-frequency vibrations that led their mandibles to vibrate at about 1 kHz, with an amplitude of about 1 µm, a process that mechanically facilitates the cutting of the leaf tissue. This method is especially suited for cutting tender leaves, and ants have been observed to reach a cutting speed of 0.22mm/s [1].

The work in this paper deals with transferring high-frequency vibration energy, or ultrasonic energy with conductor to the operation site. Ultrasonic lithotriptor made of steel has been previously used for the removal of ureteric stones [2]. But it will be difficult for solid conductor to transfer energy through bends with high curvature. Fluid metal as the conductor for vibration was investigated.

Galinstan is one product of Geratherm [3]. It is one mixture of Gallium, Indium and Titan, and has a melting point of -20°C. At normal body and room temperature it is in fluid state. It has the Density of 6,44g/cm⁄. And with Echo-Pulse-Method the propagation velocity of longitudinal sound wave has been measured to amount about 2950 m/s. Thus it has an acoustic impedance of about 18.9´10 kg/(m◊s), which fits well with the acoustic impedance of vibrator made of Titan (acoustic impedance 18,7´10 kg/(m◊s)). And it has also low absorption factor of 20cm/20dB. Furthermore this material is harmless to the health.

For energy transferring, fluid metal, Galinstan, was filled in Teflon-tube with inner diameter of 0.7mm. At proximal end the tube was connected with vibrator. At distal end one small piston was stuck in the tube. The Teflon-tube bounds the sound wave, and the vibration is transferred through Galinstan to drive the piston reciprocating. The tube could be bent with high curvature. Still there was no great energy output loss at piston. Two methods of energy coupling between Galinstan and vibrator and test results will also be presented.

[1] J. Tautz, F. Roces and B. Hölldobler: Use of a Sound-Based Vibratome by Leaf-Cutting Ants; Science, Vol 267, 6.January 1995, pp84-87.
[2] U. Stumpff: Die Erzeugung und Übertragung von Ultraschalldehnwellen hoher Energiedichte in flexiblen Wellenleitern im 20 kHz-Bereich für therapeutische Anwendungen. Dissertation, 1978, RWTH Aachen.
[3] Geratherm GmbH Sicherheitsdatenblatt nach 93/112/EG, 1998, D-98716 Geschwenda