Design of New Scissor Type Micro-stirrer for Efficient Thrombus Dissolution

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Abstract: Cerebral thrombus or blood clot should be dissolved timely to prevent some serious illnesses such as cerebral ischemic injury or even death. In this paper, a new design of micro-stirrer which has high performance for thrombus dissolution is presented. The new type structure of micro-stirrer transmits the longitudinal vibration excited by piezoelectric actuator through a bar and converts to two opposite transverse vibrations at the end effector, which makes it work like scissor and reduces the dissolution time effectively. A theoretical model of the micro-stirrer is developed to analyze the mechanism of the micro-stirrer. The high efficiency of stirring effect of the micro-stirrer is examined experimentally.

Key-Words: *Micro Stirrer, Piezoelectric Actuator, Thrombus Dissolution, Transverse Vibration*

1. Introduction

Cerebral thrombus is one of common diseases, which blocks blood vessel and obstructs bloodstream. In many situations, thrombus should be dissolved or removed timely in order to avoid causing serious illnesses or even death. In the current clinical treatments, some thrombolytic agents for example t-PA (tissue plasminogen activator), is used to help dissolve blood clot. However, the thrombolytic agents work slowly and bring high risk of hemorrhage complications. Another advanced therapy dissolving the clot quickly and safely by using a micro-stirrer based on mechanical vibration with injecting tiny amount of thrombolytic agent into the clot was proposed [1]. In this paper, a new design of micro-stirrer which works like a scissor and dissolves the blood clot faster is presented. Furthermore, the vibration mode and high efficiency of stirrer are examined by experiments.

2. Structure Design

Figure 1 shows the theoretical model of stirrer made for test in laboratory. The stirrer is composed of a bar, two slight beams and a spring tension structure. A piezoelectric actuator is embedded at the spring tension structure to obtain pre-tightening force. One side of the spring tension is clamped, the other side of the spring tension connects with the bar and the slight beams attaching at the bar's end face. Each slight beam has a groove at the head end of the slight beam.

The longitudinal force excited by piezoelectric actuator transmits through the bar and impinges on the slant surface of groove, then the force direction changes and converts to shear force at the end effector. Because of the completely opposite directions of grooves, the directions of shear forces in two beams are opposite, which leads to opposite bending deformations at end effector and makes the stirrer work like a scissor.

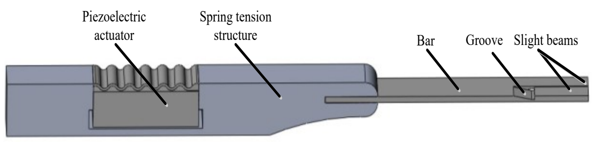

Figure 1 Scissor Type Stirrer

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3. Modes & Stirring Performance Test

Figure 2 shows the overall experiment setup for measuring vibration modes of the stirrer. The input sinusoidal wave signal formed by a function generator is magnified by a power amplifier and then added to the piezoelectric actuator. The vibration displacements are captured by a laser velocity sensor and scanned the bar to the slight beams. The distance between measurement points on the stirrer is 1mm. The maximum displacements of test points in figure 2 show three vibration modes at 1208Hz, 3734Hz and 3885Hz. It's obvious that the vibrations directions of two slight beams are opposite at 3734Hz, which means the longitudinal vibration converts into transverse vibration effectively at mode 2.

Another stirring experiment is set up to compare the stirring effects at different vibration modes. The test liquid is made up of transparent glycerol and red mixture of normal saline and rat blood which are used to imitate the thrombus and blood in blood vessel respectively. The depth of the stirrer tip under the surface of glycerol is 2mm and the stirring time is 25 minutes. In the process of the stirring test, the turbulence is strong at mode 2 but weak at mode1 and mode 3, as the figure 3 shows. The comparison results after stirring in figure 4 shows that a large amount of glycerol dissolves in mixture at mode 2. What's more, the impedance test of mixture after stirring in figure 5 shows that the impedance peak is lowest at result of mode 2, which means the concentration of mixture after stirring at mode 2 is biggest based on the previous research [2]. All above results show that the scissor type vibration of stirrer produces strong turbulence in the liquid and assists dissolution of glycerol quickly.

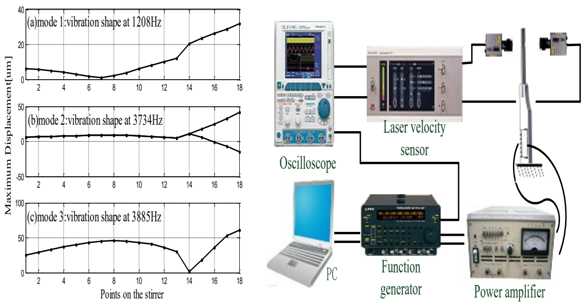

Figure 2 Experiment Setup of Vibration Mode Test

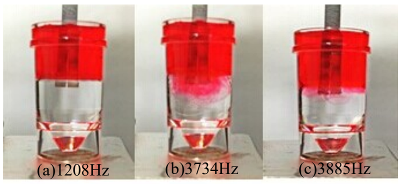

Figure 3 Phenomenon of Turbulence

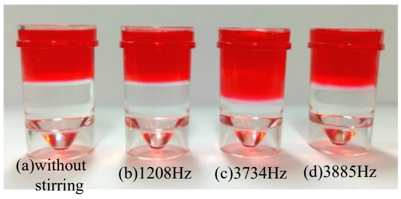

Figure 4 Comparison Results after Stirring

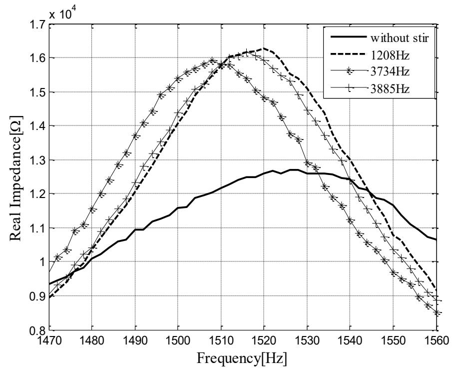

Figure 5 Impedance Variation Corresponding to Concentration of Mixture

4. Conclusion

A new type of micro-stirrer for dissolving cerebral thrombus or blood clot, which can produce a scissor type vibration at the end effort, is presented. The stirring experiment proves that the scissor type vibration of stirrer has the potential to dissolve the thrombus or blood clot more quickly to help re-open blocked blood vessel so that patients can be saved timely after the stroke symptom onset.

References:

[1] Z.W.Jiang, Z.H.Liu, et al,Fundamental Study on A Novel Method for Dissolution of Cerebral Thrombus by Micro Piezo-stirrer, Joint Conference on Micromechatronics for Information and Precision Equipment,2003,pp. 379-3980.

[2] Z.W. Jiang, M. Morita, et al, "Study on In-vivo Measurement of Solubility for Cerebral Thrombus Dissolution", International Journal of Applied Electromagnetics and Mechatronics, Vol.24, 2006, pp.225-234.