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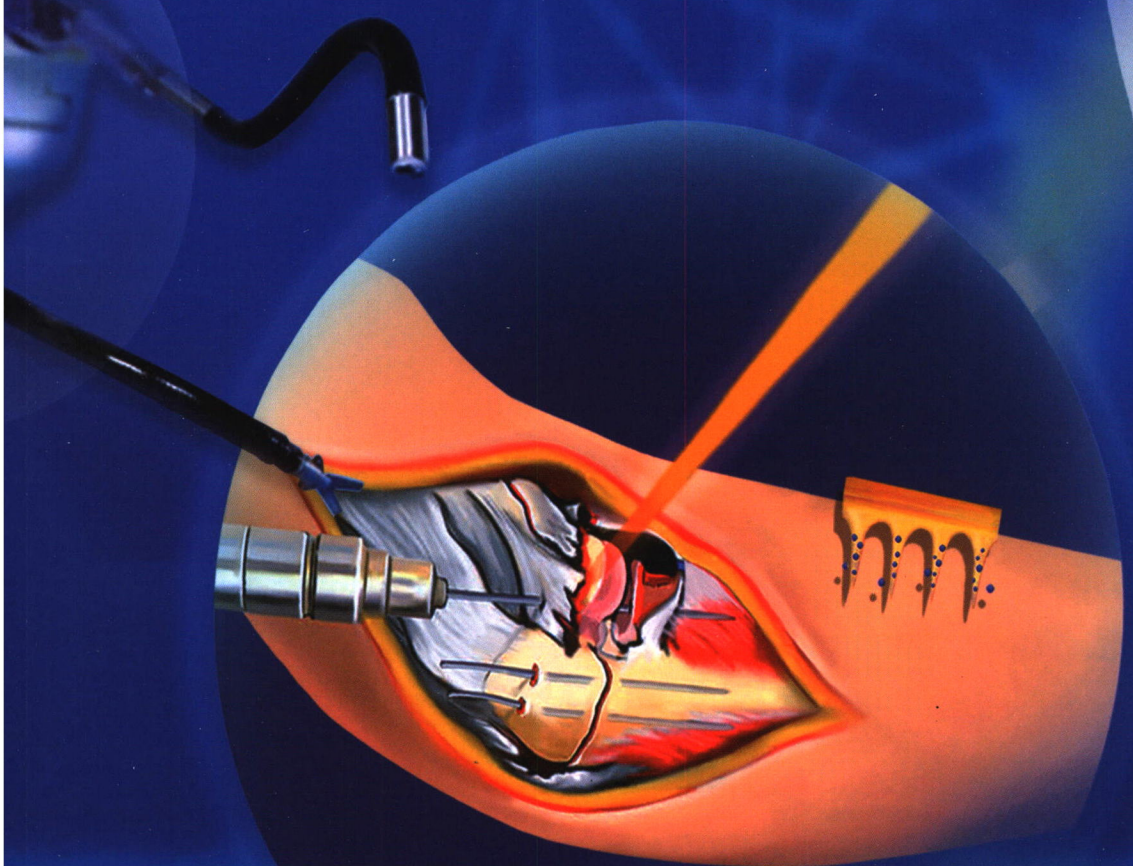

Special Issue on

Processing of Biological Tissue

Guest Editors: Chengyong Wang, Zhirong Liao, Dong Wang

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CHINESE JOURNAL OF MECHANICAL ENGINEERING

Special Issue on Processing of Biological Tissue

Guest Editors: Chengyong Wang, Zhirong Liao, Dong Wang

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Recent Advances in Processing of Biological Tissues

Chengyong Wang • Zhirong Liao • Dong Wang

(2022)35:89

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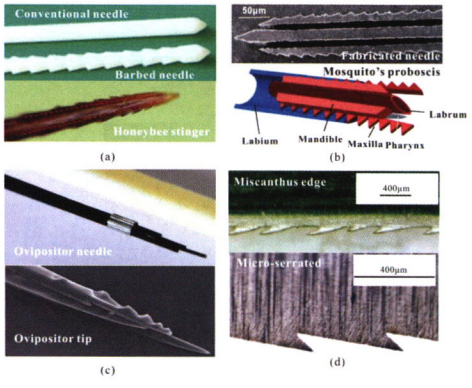
Recent Advances in Soft Biological Tissue Manipulating Technologies

Zhihua Liu • Zhirong Liao • Dong Wang • Chengyong Wang • Chengli Song
Haonan Li • Yao Liu

Abstract: Biological soft tissues manipulation, including conventional (mechanical) and nonconventional (laser, waterjet and ultrasonic) processes, is critically required in most surgical innervations. However, the soft tissues, with their nature of anisotropic and viscoelastic mechanical properties, and high biological and heat sensitivities, are difficult to manipulated. Moreover, the mechanical and thermal induced damage on the surface and surrounding tissue during the surgery can impair the proliferative phase of healing. Thus, understanding the manipulation mechanism and the resulted surface damage is of importance to the community. In recent years, more and more scholars carried out researches on soft biological tissue cutting in order to improve the cutting performance of surgical instruments and reduce the surgery induced tissue damage. However, there is a lack of compressive review that focused on the recent advances in soft biological tissue manipulating technologies. Hence, this review paper attempts to provide an informative literature survey of the state-of-the-art of soft tissue manipulation processes in surgery. This is achieved by exploring and recollecting the different soft tissue manipulation techniques currently used, including mechanical, laser, waterjet and ultrasonic cutting and advanced anastomosis and reconstruction processes, with highlighting their governing removal mechanisms as well as the surface and subsurface damages.



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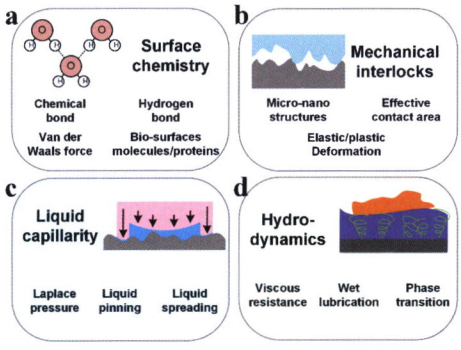
(2022)35:43
DOI: 10.1186/s10033-022-00708-1

Bioinspired Functional Surfaces for Medical Devices

Liwen Zhang • Guang Liu • Yurun Guo • Yan Wang • Deyuan Zhang • Huawei Chen

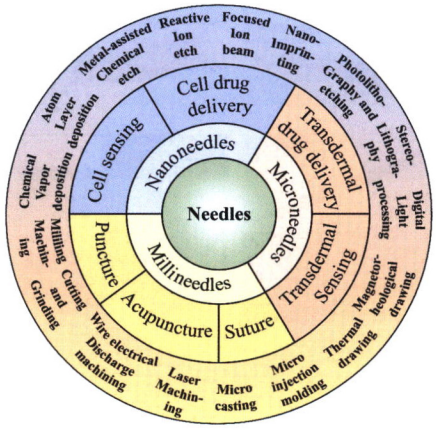


Abstract: Medical devices are a major component of precision medicine and play a key role in medical treatment, particularly with the rapid development of minimally invasive surgery and wearable devices. Their tissue contact properties strongly affect device performance and patient health (e.g., heat coagulation and slipperiness on surgical graspers). However, the design and optimization of these device surfaces are still indistinct and have no supporting principles. Under such conditions, natural surfaces with various unique functions can provide solutions. This review summarizes the current progress in natural functional surfaces for medical devices, including ultra-slipperiness and strong wet attachment. The underlying mechanisms of these surfaces are attributed to their coupling effects and featured micro-nano structures. Depending on various medical requirements, adaptable designs and fabrication methods have been developed. Additionally, various medical device surfaces have been validated to achieve enhanced contact properties. Based on these studies, a more promising future for medical devices can be achieved for enhanced precision medicine and human health.

(2022)35:106
DOI: 10.1186/s10033-022-00773-6

A Review of Nano/Micro/Milli Needles Fabrications for Biomedical Engineering

Bin Liu • Xin Yi • Ying Zheng • Zhishan Yuan • Jingbo Yang • Jian Yang • Xiao Yu
Lelun Jiang • Chengyong Wang



Abstract: Needles, as some of the most widely used medical devices, have been effectively applied in human disease prevention, diagnosis, treatment, and rehabilitation. Thin 1D needle can easily penetrate cells/organs by generating highly localized stress with their sharp tips to achieve bioliquid sampling, biosensing, drug delivery, surgery, and other such applications. In this review, we provide an overview of multiscale needle fabrication techniques and their biomedical applications. Needles are classified as nanoneedles, microneedles and millineedles based on the needle diameter, and their fabrication techniques are highlighted. Nanoneedles bridge the inside and outside of cells, achieving intracellular electrical recording, biochemical sensing, and drug delivery. Microneedles penetrate the stratum corneum layer to detect biomarkers/bioelectricity in interstitial fluid and deliver drugs through the skin into the human circulatory system. Millineedles, including puncture, syringe, acupuncture and suture needles, are presented. Finally, conclusions and future perspectives for next-generation nano/micro/milli needles are discussed.

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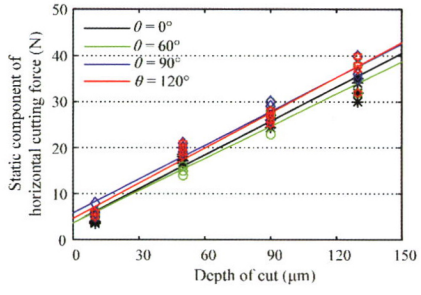

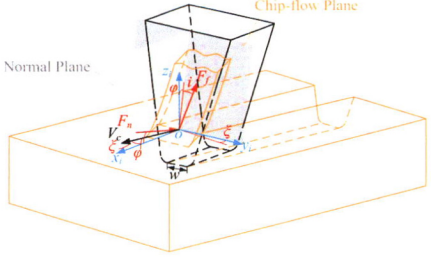

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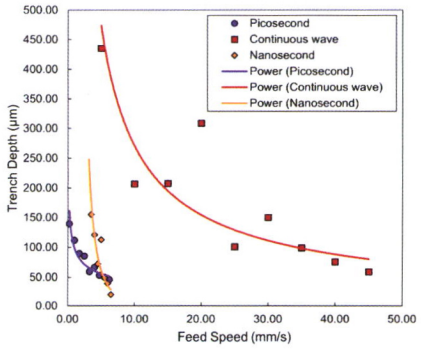

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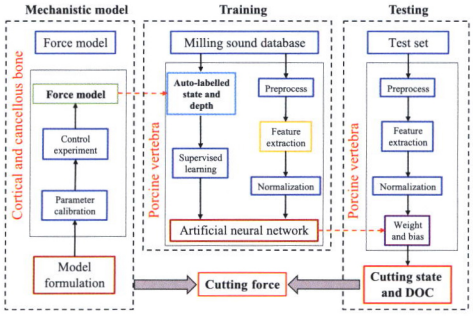
DOI: 10.1186/s10033-022-00740-1

Effect of Laser Ablation Pulse Width and Feed Speed on Necrosis and Surface Damage of Cortical Bone

Jose A. Robles-Linares • Kieran Winter • Zhirong Liao

Abstract: Bone cutting is of importance in orthopaedic surgery but is also challenging due to its nature of brittleness - where severe mechanical and thermal damages can be introduced easily in conventional machining. Laser machining is a new technology that can allow for complex cut geometries whilst minimising surface defects i.e. smearing, which occur in mechanical methods. However, comparative studies on the influence of lasers with different pulse characteristics on necrotic damage and surface integrity have not been reported yet. This paper for the first time investigates the effects of laser type on the necrotic damage and surface integrity in fresh bovine cortical bone after ex-situ laser machining. Three lasers of different pulse widths, i.e. picosecond, nanosecond and continuous wave lasers have been investigated with different feed speeds tested to study the machining efficiency. The cutting temperature, and geometrical outputs have been measured to investigate the thermal influence on the cooling behaviour of the bone samples while high-speed imaging was used to compare the material removal mechanisms between a pulsed and continuous wave laser. Furthermore, an in-depth histological analysis of the subsurface has revealed that the nanosecond laser caused the largest necrotic depth, owing to the high pulse frequency limiting the dissipation of heat. It has also been observed that surface cracks positioned perpendicular to the trench direction were produced after machining by the picosecond laser, indicative of the photomechanical effect induced by plasma explosions. Therefore, the choice of laser type (i.e. in terms of its pulse width and frequency) needs to be critically considered for appropriate application during laser osteotomy with minimum damage and improved healing.



(2022)35:61
DOI: 10.1186/s10033-022-00744-x

Bone Milling: On Monitoring Cutting State and Force Using Sound Signals

Zhenzhi Ying • Liming Shu • Naohiko Sugita

Abstract: Efficient monitoring of bone milling conditions in orthopedic and neurosurgical surgery can prevent tissue, bone, and tool damage, and reduce surgery time. Current researches are mainly focused on recognizing the cutting state using force signal. However, the force signal during the milling process is difficult and expensive to acquire. In this study, a neural network-based method is proposed to recognize the cutting state and force during the bone milling process using sound signals. Numerical modeling of the cutting force is performed to capture the relationship between the cutting force and the depth of cut in the bone milling process. The force model is used to calibrate the training data to improve the recognition accuracy. Wavelet package transform is used for signal processing to understand bone-cutting phenomena using sound signals. The proposed system succeeds to monitor the bone milling process to reduce the surgical risk. Experiments on standard bone specimens and vertebrae also indicate that the proposed approach has considerable potential for use in computer-assisted and robot-assisted bone-cutting systems used in various types of surgery.

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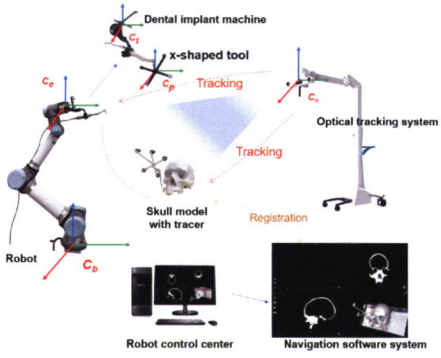
Optics-guided Robotic System for Dental Implant Surgery

Biao Yan • Wenlong Zhang • Lijing Cai • Lingxiang Zheng • Kaiyang Bao • Yuming Rao
Lin Yang • Weitao Ye • Peifeng Guan • Wei Yang • Jiang Li • Rongqian Yang

Abstract: At present, dental implant surgery mainly relies on the clinical experience of the doctor and the assistance of preoperative medical imaging. However, there are some problems in dental implant surgery, such as narrow space, sight obstruction, inaccurate positioning, and high requirements of doctors' proficiency. Therefore, a dental implant robot system (DIRS) guided by optical navigation is developed in this study, with an x-shaped tool and an irregular pentagonal tracer are designed for spatial registration and needle tip positioning strategy respectively. The coordinate system of each unit in DIRS is unified through system calibration, spatial registration, and needle tip positioning strategy. Then the surgical path is planned on the computed tomography (CT) images in the navigation software before operation. The automatic positioning method and the auxiliary positioning method can be used in the operation to achieve accurate positioning and assist doctors to complete the operation. The errors of spatial registration, needle tip positioning strategy, and the overall accuracy of the system were evaluated respectively, and the results showed that they all met the needs of clinical surgery. This study preliminarily verified the feasibility of the precise positioning method for dental surgery robots and provided certain ideas for subsequent related research.

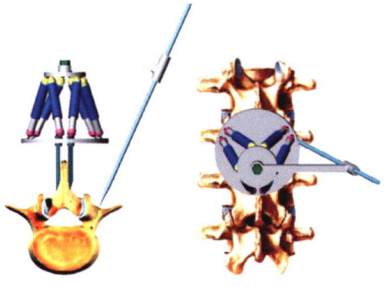


(2022)35:35
DOI: 10.1186/s10033-022-00689-1

Workspace and Accuracy Analysis on a Novel 6-UCU Bone-attached Parallel Manipulator

Kaijie Dong • Duanling Li • Xingyu Xue • Chang Xu • Haowei Wang • Xianming Gao

Abstract: With the increasingly more extensive application of the medical surgical robot in the clinic, higher requirements have been put forward for medical robots. The bone-attached robot, a popular orthopedic robot in recent years, has a tendency of miniaturization and refinement. Thus, a bone-attached parallel manipulator (PM) based on 6-UCU (universal-cylindrical-universal) configuration is proposed, which is characterized by small volume, compact structure, high precision and six-dimensional force feedback. To optimize the structure and make it more compact, the workspace of the 6-UCU PM is analyzed based on the analysis of three kinds of constraint, and workspace model is established through spherical coordinate search method. This study also analyzes the influence of structural parameters on workspace, which may contribute to improving the efficiency of design and ensuring small-sized robots possess relatively large workspace. Moreover, to improve the motion accuracy, an error modeling method is developed based on the structure of 6-UCU PMs. According to this established error model, the output pose error curves are drawn using MATLAB software when the structure parameters change, and the influence of the structure and pose parameters change on the output pose error of PMs is analyzed. The proposed research provides the instruction to design and analysis of small PMs such as bone-attached robots.



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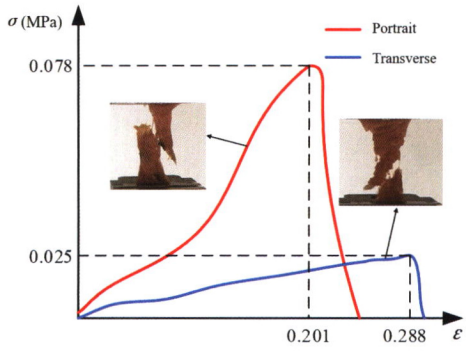
3D Cohesive Finite Element Minimum Invasive Surgery Simulation Based on Kelvin-Voigt Model

Yonghang Jiang • Qinghua Song • Xichun Luo



Abstract: Minimally invasive surgery is an important technique used for cytopathological examination. Recently, multiple studies have been conducted on a three-dimensional (3D) puncture simulation model as it can reveal the internal deformation state of the tissue at the micro level. In this study, a viscoelastic constitutive equation suitable for muscle tissue was derived. Additionally, a method was developed to define the fracture characteristics of muscle tissue material during the simulation process. The fracture of the muscle tissue in contact with the puncture needle was simulated using the cohesive zone model and a 3D puncture finite element model was established to analyze the deformation of the muscle tissue. The stress nephogram and reaction force under different parameters were compared and analyzed to study the deformation of the biological soft tissue and guide the actual operation process and reduce pain.

(2022)35:40
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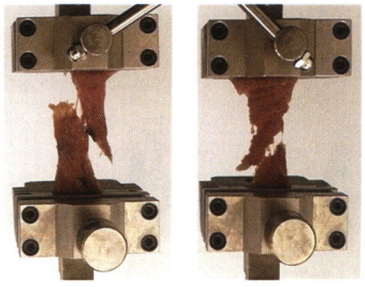
Three-dimensional Modeling and Simulation of Muscle Tissue Puncture Process

Zongkai Lv • Qinghua Song • Fan Gao • Zhanqiang Liu • Yi Wan • Yonghang Jiang


Fiber direction Vertical fiber direction

Abstract: Needle biopsy is an essential part of modern clinical medicine. The puncture accuracy and sampling success rate of puncture surgery can be effectively improved through virtual surgery. There are few three-dimensional puncture (3D) models, which have little significance for surgical guidance under complicated conditions and restrict the development of virtual surgery. In this paper, a 3D simulation of the muscle tissue puncture process is studied. Firstly, the mechanical properties of muscle tissue are measured. The Mooney-Rivlin (M-R) model is selected by considering the fitting accuracy and calculation speed. Subsequently, an accurate 3D dynamic puncture model is established. The failure criterion is used to define the breaking characteristics of the muscle, and the bilinear cohesion model defines the breaking process. Experiments with different puncture speeds are carried out through the built in vitro puncture platform. The experimental results are compared with the simulation results. The experimental and simulated reaction force curves are highly consistent, which verifies the accuracy of the model. Finally, the model under different parameters is studied. The simulation results of varying puncture depths and puncture speeds are analyzed. The 3D puncture model can provide more accurate model support for virtual surgery and help improve the success rate of puncture surgery.

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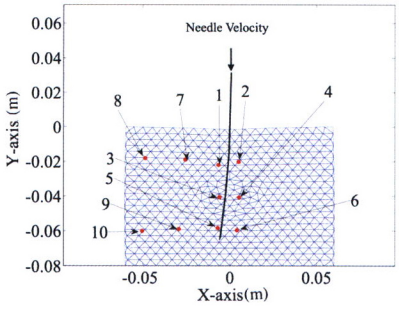

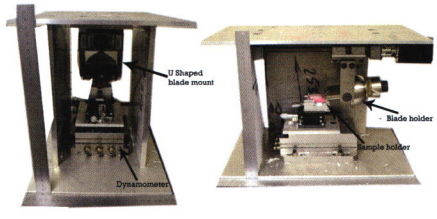

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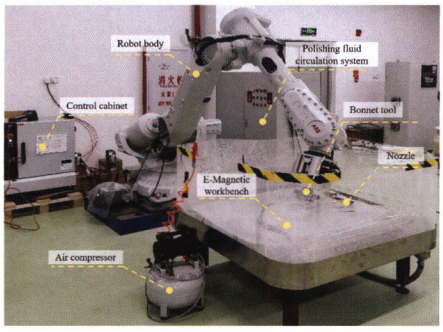
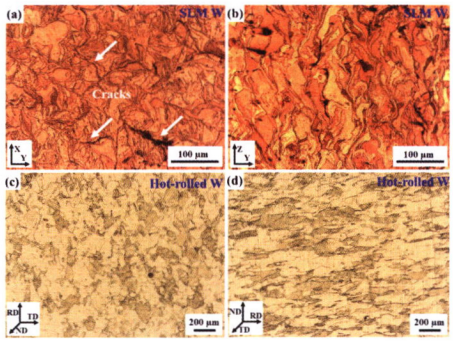
Research Highlight

Intelligent Manufacturing Technology



Abstract: With the increasing demand for high-precision optical components, bonnet polishing technology is increasingly being used in the polishing process of optical components owing to its high removal efficiency and high surface accuracy. However, it is expensive and difficult to implement dedicated bonnet polishing machine tools, and their processing range is limited. This research combines bonnet polishing technology with industrial robot-assisted processing technology to propose a robotic bonnet polishing control model for large-diameter axisymmetric aspherical optical components. Using the transformation relations of the spatial coordinate system, the transformation relations of the workpiece coordinate system, local coordinate system of the polishing point, and tool coordinate system of the bonnet sphere center are established to obtain the bonnet precession polishing motion model. The polishing trajectory of large-diameter axisymmetric aspherical components and the variation in the linkage angle difference were simulated by adding an efficiency-optimal control strategy to the motion model. The robot motion was simulated in Robostudio to verify the correctness of the precession motion model and control algorithm. Lastly, the robotic bonnet polishing system was successfully applied to the polishing process of the optical components.



Abstract: A comparative study on the influence of different manufacturing methods (selective laser melting and hot rolling) on the microstructure, mechanical and thermal behaviours of tungsten (W) was presented for the first time. The results indicated that the selective laser melting (SLM) W exhibited a finer grain sizes, a lower strength ductility, hardness and thermal conductivity compared to hot-rolled W. The main reason for this result was that the laser underwent rapid heating and cooling when it was used to melt W powder with high energy density, resulting in large internal stress in the sample after manufacturing. Subsequently, the internal stress was released, leading to the generation of micro-cracks at the grain boundaries, thereby affecting the performance of SLM W samples. In addition, the higher fraction of high-angle grain boundaries (HAGBs) of SLM W was found to be the key factor for intrinsic brittleness. Because the HAGBs are the preferred crack paths, which could promote crack propagation and decrease fracture energy.

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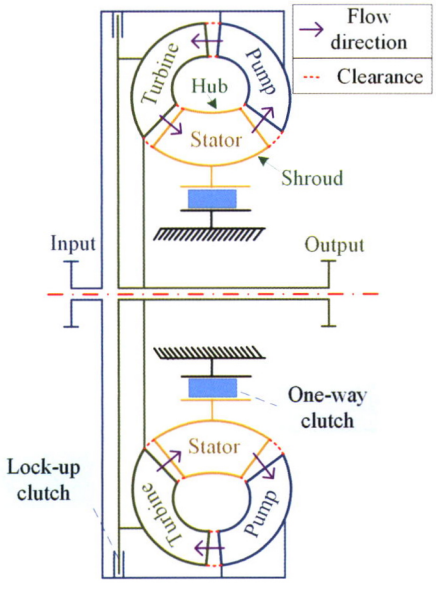
Abstract: Rheological properties are the theoretical basis and the key to common problems in ferrofluid applications, therefore they are expected to be adjustable to satisfy different technical requirements through altering the microstructure of ferrofluid during the process of preparation. In this paper, Four ferrofluid samples with different magnetic particle size were prepared by controlling the concentration of precursor solution during co-precipitation process and the rheological properties of these samples were investigated. These samples exhibited field-controlled rheological properties. Eternal magnetic field would enhance the formation of microstructures, resulting in an increase of viscosity. While with the increase of shear rate, microstructures tended to be destroyed, causing viscosity to decrease. There were two opposing mechanisms of the influence of precursor solution concentration. On one hand, the reduction of the precursor solution concentration would produce primary magnetic particles of smaller size. But on the other hand, the surfactant became insufficient to completely coat the magnetic particles because of an increased specific surface area, causing the magnetic particles to aggregate and form secondary clustering structures which strongly enhanced the magnetoviscous effect and weakened the viscoelastic effect.



Abstract: Cavitation inside a torque converter induces noise, vibration and even failure, and these effects have been disregarded in previous torque converter design processes. However, modern torque converter applications require attention to this issue because of its high-speed and high-capacity requirements. Therefore, this study investigated the cavitation effect on a torque converter using both numerical and experimental methods with an emphasis on the influence of the charging oil feed location and charge pressure. Computational fluid dynamics (CFD) models were established to simulate the transient cavitation behaviour in the torque converter using different charging oil pressures and inlet arrangements and testing against a base case to validate the results. The CFD results suggested that cavitating bubbles mainly takes place in the stator of the torque converter. The transient cavitation CFD model yielded good agreement with the experimental data, with an error of 7.6% in the capacity constant and 7.4% in the torque ratio. Both the experimental and numerical studies showed that cavitation induced severe capacity degradation, and that the charge pressure and charging oil configuration significantly affects both the overall hydrodynamic performance and the fluid behaviour inside the torque converter because of cavitation. Increasing the charge pressure and charging the oil from the turbine-stator clearance were found to suppress cavitation development and reduce performance degradation, especially in terms of the capacity constant. This study revealed the fluid field mechanism behind the influence of charging oil conditions on torque converter cavitation behaviour, providing practical guidelines for suppressing cavitation in torque converter.

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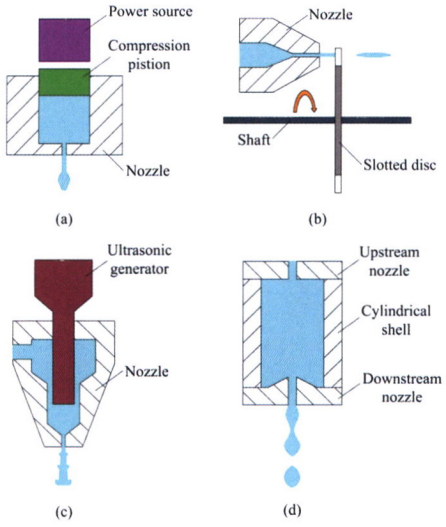

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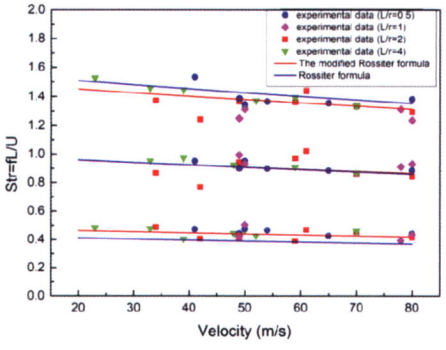
DOI: 10.1186/s10033-022-00713-4

Formation Principle and Characteristics of Self-Supercharging Pulsed Water Jet

Zhaolong Ge • Yuanfei Ling • Jiren Tang • Yiyu Lu • Yangkai Zhang • Lei Wang • Qi Yao

Abstract: High-pressure pulsed water jet technology has considerable development potential in the field of rock fragmentation. To overcome the shortcomings of existing pulsed jets, a self-supercharging pulsed water jet (SSPWJ) generation method is proposed, which is based on the theory of the pulsed water jet and the principle of hydraulic boosting. The proposed method changes the flow direction of the fluid medium through the valve core to make the piston reciprocate in the cylinder and relies on the effective area difference between the front and rear chambers in the stroke stage of the piston to realize the organic combination of "pulse" and "supercharging" of the jet, thus forming an SSPWJ. On the basis of the formation principle of the SSPWJ, a SSPWJ testing platform was constructed, and tests were performed on the jet pressure acquisition, morphology capture, and granite erosion. Both the jet pressure and the jet morphology exhibited periodic changes, and a higher pulse pressure was obtained at lower inlet pressure. The error of the pressure ratio calculated according to the experimental results was <3% relative to the theoretical design value, confirming the feasibility of the method. The pulse pressure and pulse frequency are controllable; that is, as the inlet flow rate increases in the stroke stage of the piston, the pulse pressure and pulse frequency increase, and the pulse duration decreases. As the inlet flow rate increases in the backward-stroke stage of the piston, the pulse frequency increases, and the pulse pressure and pulse duration remain unchanged. Under the combined action of the water-hammer pressure, high-speed lateral flow, and high-frequency dynamic load of the SSPWJ, local flaky exfoliation was observed when the granite surface was eroded. The results of this study lay the foundation for enriching the theory of pulsed jet generation and expanding its application range.



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DOI: 10.1186/s10033-022-00714-3

Characteristics of Oscillation in Cavity of Helmholtz Nozzle Generating Self-excited Pulsed Waterjet

Miao Yuan • Deng Li • Yong Kang • Hanqing Shi • Haizeng Pan

Abstract: Cavity flow oscillations in the axisymmetric cavity are critical to the operating efficiency of self-excited pulsed waterjets, which are widely employed in many practical applications. In this study, the behaviors of a turbulent flow in axisymmetric cavities causing cavity flow oscillations are investigated based on wall pressure characteristics. Experiments are performed using four Helmholtz nozzles with varying length-to-radius ratios at flow velocities of 20–80 m/s. Three orders of hydrodynamic modes in axisymmetric cavity are obtained through the spectral analysis of wall pressure. Based on the experimental results, the empirical coefficient of Rossiter's formula is modified, and the values of the parameter phase lag and the ratio of convection velocity to free stream velocity are obtained as 0.061 and 0.511, respectively. In addition, the spectral peak with a relatively constant frequency shows that the flow-acoustic resonance is excited significantly. A modified model is introduced based on the fluidic networks to predict the lock-on frequency. The results obtained can provide a basis for the structural optimization of the nozzle to improve the performance of self-excited pulsed waterjets.

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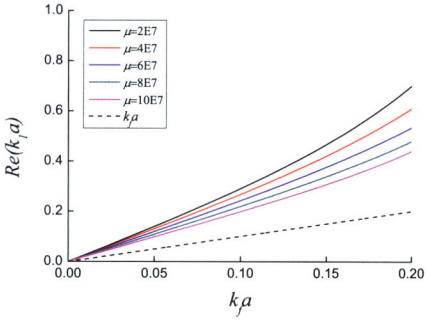
Influence of Shear Effects on the Characteristics of Axisymmetric Wave Propagation in a Buried Fluid-Filled Pipe

Ping Lu • Xiaozhen Sheng • Yan Gao • Ruichen Wang

Abstract: The acoustic propagation characteristics of axisymmetric waves have been widely used in leak detection of fluid-filled pipes. The related acoustic methods and equipment are gradually coming to the market, but their theoretical research obviously lags behind the field practice, which seriously restricts the breakthrough and innovation of this technology. Based on the fully three-dimensional effect of the surrounding medium, a coupled motion equation of axisymmetric wave of buried liquid-filled pipes is derived in detail, a contact coefficient is used to express the coupling strength between surrounding medium and pipe, then, a general equation of motion was derived which contain the pipe soil lubrication contact, pipe soil compact contact and pipe in water and air. Finally, the corresponding numerical calculation model is established and solved used numerical method. The shear effects of the surrounding medium and the shear effects at the interface between surrounding medium and pipe are discussed in detail. The output indicates that the surrounding medium is to add mass to the pipe wall, but the shear effect is to add stiffness. With the consideration of the contact strength between the pipe and the medium, the additional mass and the pipe wall will resonate at a specific frequency, resulting in a significant increase in the radiation wave to the surrounding medium. The research contents have great guiding effect on the theory of acoustic wave propagation and the engineering application of leak detection technology in the buried pipe.



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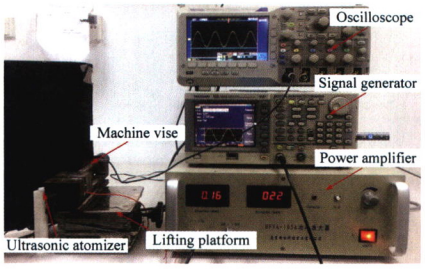
DOI: 10.1186/s10033-022-00754-9

Study on the Formation and Separation Process of Droplets in the Medical Piezoelectric Atomization Device Induced by Intra-hole Fluctuation

Qiufeng Yan • Wanting Sun • Jianhui Zhang

Abstract: Traditional atomization devices always exhibit many drawbacks, such as non-uniform atomization particle sizes, instability of transient atomization quantity and uncontrollability of precise energy, which seriously restrict further practical application of atomization inhalation therapy. The formation and separation process of droplets belongs to a microphenomenon of atomization. The investigation of the droplet formation and separation process will be favorable for understanding the atomization mechanism. In present work, the Conservative Level Set Method (CLSM) is successfully applied on the simulation of the formation and separation of droplets in a medical piezoelectric atomization device induced by intra-hole fluctuation. The intra-hole fluctuation mechanism is systematically explored and analyzed, and also the expression of the volume change in the micro cone hole is built and evaluated. Both the control equation and simulation model of droplet formation and separation process have been well established by meshing the simulation model, and thereby the process of droplet formation and separation is simulated. The corresponding results demonstrate that the breaking time of droplets is decreased with the inlet velocity and liquid temperature rising, while enhanced with the liquid concentration increasing. Meanwhile, the volume of droplet is decreased with the inlet velocity and liquid concentration increasing, but increased with the liquid temperature rising. The velocity of droplet is enhanced with the inlet velocity and liquid temperature rising, and reduced with the increase of liquid concentration. When the large side diameter of micro-cone hole is set as 79 μm, the breaking time of the droplet reaches a minimum value of 38.7 μs, whereas the volume and the velocity of droplet reach a maximum value of 79.8 pL and 4.46 m/s, respectively. This study provides theoretical guidance for the design of medical piezoelectric atomization devices and contributes to the promotion of inhalation therapy in practical use.



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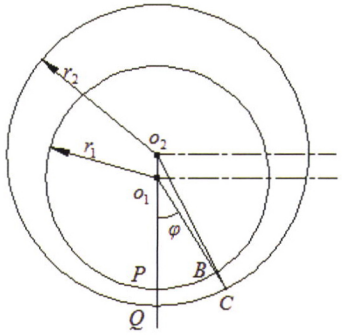

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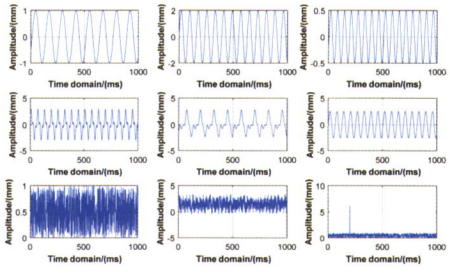
Vibration Characteristics of Rotor System with Loose Disc Caused by the Insufficient Interference Force

Zhinong Li • Fang Qiao • Wenxiu Lu • Jie Liu • Dong Wang • Fulei Chu

Abstract: The rotating parts looseness is one of the common failures in rotating machinery. The current researches of looseness fault mainly focus on non-rotating components. However, the looseness fault of disc-shaft system, which is the main work part in the rotor system, is almost ignored. Here, a dynamic model of the rotor system with loose disc caused by the insufficient interference force is proposed based on the contact model of disc-shaft system with the microscopic surface topography, the vibration characteristics of the system are analyzed and discussed by the number simulation, and verified by the experiment. The results show that the speed of the shaft, the contact stiffness, the clearance between the disc and shaft, the damping of the disc and the rotational damping have an influence on the rotation state of the disc. When the rotation speed of the disc and the shaft are same, the collision frequency is mainly composed of one frequency multiplication component and very weak high frequency multiplication components. When the rotation speed of the disc and the shaft is close, the vibration of the disc occurs a beat vibration phenomenon in the horizontal direction. Simultaneously, a periodical similar beat vibration phenomenon also occurs in the waveform of the disc-shaft displacement difference. The collision frequency is mainly composed of a low frequency and a weak high frequency component. When the rotation speed of the disc and the shaft has great difference, the collision frequency is mainly composed of one frequency multiplication, a few weak high frequency multiplication components and a few low frequency multiplication component. With the reduction of the relative speed of the disc, the trajectory of the disc changes from circle-shape to inner eight-shape, and then to circle-shape. In the inner eight-shape, the inner ring first gradually becomes smaller and then gradually becomes larger, and the outer ring is still getting smaller. The obtained research results in this paper has important theoretical value for the diagnosis of the rotor system with the loose disc.



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Method for Fault Feature Selection for a Baler Gearbox Based on an Improved Adaptive Genetic Algorithm

Bin Ren • Dong Bai • Zhanpu Xue • Hu Xie • Hao Zhang

Abstract: The performance and efficiency of a baler deteriorate as a result of gearbox failure. One way to overcome this challenge is to select appropriate fault feature parameters for fault diagnosis and monitoring gearboxes. This paper proposes a fault feature selection method using an improved adaptive genetic algorithm for a baler gearbox. This method directly obtains the minimum fault feature parameter set that is most sensitive to fault features through attribute reduction. The main benefit of the improved adaptive genetic algorithm is its excellent performance in terms of the efficiency of attribute reduction without requiring prior information. Therefore, this method should be capable of timely diagnosis and monitoring. Experimental validation was performed and promising findings highlighting the relationship between diagnosis results and faults were obtained. The results indicate that when using the improved genetic algorithm to reduce 12 fault characteristic parameters to three without a priori information, 100% fault diagnosis accuracy can be achieved based on these fault characteristics and the time required for fault feature parameter selection using the improved genetic algorithm is reduced by half compared to traditional methods. The proposed method provides important insights into the instant fault diagnosis and fault monitoring of mechanical devices.

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