International Journal of Emerging Technologies in Engineering Research (IJETER)
Volume 6, Issue 7, July (2018) www.ijeter.everscience.org

# Bionics Technology on Resistance and Noise Reduction of Centrifugal Pump

Ayushmaan Samadhiya [1], Tanmay Pratap Singh [2], Adarsh Vaish [3], Prithvi Rao [4]
B.tech (Mechanical) SRMIST, India.

**Abstract – A centrifugal pump is a rotodynamic pump that uses a rotating impeller to increase the pressure of a fluid. Centrifugal pumps are commonly used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits into the downstream piping system. Centrifugal pumps are used for large discharge through smaller heads. In current studies, bionics technology had abilities of reducing the friction resistance between the fluid and over-current components, improving distribution of pressure and reducing radial force. It can be seen that bionics technology will be widely used in resistance and noise reduction of fluid machinery.**

**Index Terms – Bionics, Centrifugal Pump, Resistance Reduction, Noise Reduction, Impeller.**

## 1. INTRODUCTION

As one of important fluid machinery, pumps play a significant role in modern industry, so as to the high requirement of property and stability. During the actual working condition of centrifugal pumps, the flow fields in the centrifugal pump become more complicated due to the fluid separation, the cavitation and other hydraulic vibrations, which can significantly raise the resistance and reduce the working stability In addition, due to the geometric asymmetry of the impeller and the interaction between the impeller and the volute, the pressure and the velocity will be different along the radial direction, so that lead to strong pulsation and noise near the tongue of volute. The induced vibration in the centrifugal pump can bring a series of the relevant breakdown in the machines, even to result in disaster in the chemical plant so it can not only reduce the energy conservation, but also enhance the safety and stability to adapt new technology to reduce the resistance and noise of centrifugal pumps. Some traditional technology, which was firstly applied in the special field, such as the fire fighting system, the urban pollution discharge system, the ships and the underwater weapons etc, has been applied to the resistance and noise reduction for the fluid machinery, but it is nowhere near enough.

The trend of bionics technology applied in industry has arisen since the middle of twentieth Century. It has provided an effective method for the modification and innovation of industrial equipment, and become the source of more and more design and creation, such as shark, the lizard and the dung beetle, the micro structure on their surfaces has the function of the anti-adhesion, the anti-wear and could effectively reduce the resistance and noise. By modifying the interface between the fluid and the wall by processing the fringe, pits or bulges on the surface of the fluid machinery, the ordered structure of the turbulent boundary layer can be reshaped to achieve efficient, convenient and low consumption resistance reduction.

Biological principle and structure, which can realize many excellent properties. Adapted bionics technology to hydraulic design to reduce the resistance and noise. Confirmed the effect of bionic design to reduce resistance compared with traditional design. Got the idea from eagle owl feathers, applied the structure and saw tooth shape of the feathers to axial fan blades, revealed the significant effect of non-smooth surface on the reduction of resistance, noise and pressure pulsation. Their works provide a new kind of method, which is bionics technology, to reduce the resistance and noise of centrifugal pump from the design of structure .If bionics technology of resistance and noise reduction can be applied in the pump design and manufacturing, it will accelerate the development of this technology and broaden the research field of pump, which has the important engineering value and theoretical significance.

At present, there are many bionic engineering models and instances based on the efficiency.

## 2. TRADITIONAL RESISTANCE REDUCTIONAND EFFICIENCY ENHANCEMENT MEASURES TO CENTRIFUGAL PUMP

Energy from the motor to the fluid, no doubt that there are mechanical loss and hydraulic loss causing by vibration, flow separation and sharp direction change of fluid velocity, which would lead to the instability of flow and waste of energy. The viscosity of fluid is an important reason of fluid flow resistance and energy loss in centrifugal pump and how to reduce the friction resistance between over-current components and fluid is significant. In recent years, centrifugal pumps are designed and produced to meet the targets of energy saving, environment protection and high efficiency, more and more resistance reduction technology is applied to centrifugal pumps. Besides the factor of pump design, in the process of pump manufacture, the coarse unmachined surfaces, air holes and different smoothness in the casting of the inlet channel would increase the hydraulic loss. The hydraulic loss in the pump is mainly consumed in the vortex and friction. And the friction is mainly related to the friction coefficient of over-current components. So In order to reduce the surface roughness of the over-current components.

The resistance reduction of coating is applied to the centrifugal pump. The experiments prove that the over-current components coating of water pumps can improve the hydraulic efficiency about the 2%~7% by smooth coating. In addition, by adding the polymer into the fluid, the flow resistance of the centrifugal pump can be effectively reduced. On the one hand, the polymer can hinder the vortex formation on the other hand the polymer can reduce the rotation rate of whirlpool. Together these two effects lead to turbulent resistance reduction effect.

## 3. BIONICS TECHNOLOGY USED IN CENTRIFUGAL PUMP FOR RESISTANCE REDUCTION

Besides the traditional methods of resistance reduction, with the development of science and technology, bionic resistance reduction technology is becoming more and more mature and bionic non-smooth surface resistance reduction is also used in the centrifugal pump. The idea of bionics is to imitate biological systems, or based on biological system characteristics, to bring about design optimization and transform products into a new bionic ones through the modification of the function, shape, structure and materials etc. At present, more and more scholars apply bionics principle to fluid machinery.

Based on the earthworm rough surface optimized the sealing performance of wear of slurry pump piston to reduce resistance. Invented a new type of peristaltic pump, the worm pump by imitating the movements of caterpillar crawling. Invented a film type micro fluidic liquid drive pump, the minipump is based on the bionics principle of plant gas transpiration. According to the surface structure of carabid beetles and other organisms whose non-smooth surface showed excellent properties of resistance reduction, antifriction, ant adhesion and antiwear , adapted the bionic non-smooth surface technology into the impeller blade to reduce resistance and noise. The key Laboratory of bionic engineering in Jilin University researched the centrifugal water pump with imitation shark skin using single factor bionic technology and found that the resistance reduction effect was significant in some flow segments.

Researchers use scanning electron microscope to observe the lotus leaf surface and found the submicron papillae structure. Because of the existence of such microstructures, the lotus leaf has the effect of super hydrophobic and a good self-cleaning property called this behavior “lotus effect”. Cottin-Bizonne found that this super hydrophobic surface of the lotus leaf surface could significantly reduce the flow resistance. For the resistance reduction mechanism of super hydrophobic surface is generally considered that the contact mode between fluid and solid is changed to rolling from sliding due to the microstructures. So that the velocity gradient of boundary layer is decreased, the shear force is reduced. Because of the hydrophobic properties, the application of super-hydrophobic materials on the over-current components of pump is in promotion. With super hydrophobic coating, the probability of forming sharp peaks and valleys was greatly reduced, effectively control the roughness of the pump inner surface, the original and with coating samples of impeller and Thus it reduced the fluid friction on the outer edge of the impeller. Also it reduced energy loss caused by the vortex flow between the pump shells.

Super hydrophobic coating showed effective properties in preventing the formation of crystals on the surface of cast iron, preventing small solid particle deposited on the internal surface and reducing the viscosity of the fluid, The application of non-smooth resistance reduction technology based on biological surface is more and more widely in engineering. Typical representatives of non-smooth surface resistance reduction are golf. In order to make golf fly farther, people have made its surface into non-smooth surface with pit type, compared to smooth surface golf it’s only about half the resistance.Ren use the bionic non-smooth surface resistance reduction technology in agricultural machinery-bionic plough.

Research results show that compared with the ordinary plough, the plough with bionic non-smooth surface can reduce the oil consumption 5.6%~12.6%. And the plowing resistance can be reduced 15% to 18%, also has good wear resistance and soil removal. As the fastest aquatic animal in the sea, shark not only benefit from its streamline body to reduce the resistance, but also due to non-smooth surface structure on the body which can reduce the friction resistance. Observation of sharks showed that shark’s surface is not smooth. It composed with a lot of groove shaped scales.

It orderly arrangement and compact with the type of dentate. The key Laboratory of bionic engineering in Jilin University, based on bionic non-smooth technology, change the structure of liquid flow in centrifugal pump through the imitation of the non-smooth structure of shark skin. Previously non-smooth surface manufacture with method of metal corrosion. Experimental results show that in some flooding Regions, pump efficiency up to 3.45% and increase efficiency up to 6.81%. However, this method has significant limitations, now the casting method is used for processing. After optimization, the pump efficiency can be increased to more than 5%. In the study of blade with non-smooth surface, the non-smooth surface can be designed into different shapes like oval groove; serrated groove; rectangular groove; Semi-circular pits and

V-shaped groove. The structures were, and efficiency of different samples .When the fluid flow in impeller, Tangential resistance generated when the fluid is sliding relative to the impeller, internal friction formed due to the viscous of fluid, fluid adhesion on the wall generated shear stress and friction. Researchers found that shear stress of blade arrangement with non-smooth surface was lower than the corresponding smooth surface. Further studies conclusively showed, the fluid velocity gradient was significantly reduced in non-smooth surface of blade compared to smooth surface; the distribution of velocity in normal direction is relatively uniform. That was because that the non-smooth surface of the blade changed the structure of turbulent boundary layer near the wall. Due to the effect of non-smooth surface structure on the blade, low velocity fluid was kept in non-smooth unit groove, high velocity flow of fluid near the wall was blocked, reducing the velocity gradient on boundary layer, which resulted in reducing the shear force on the solid wall, so that reduced the wall surface viscous resistance.

At the same time, non-smooth surface transformed from laminar boundry layer to turbulent boundary layer, reduced the turbulent energy dissipation rate, so flow layer near the wall was more stable. Resistance reduction mechanism can be concluded as the reverse vortex with low velocity flow inside the groove of non-smooth surface, the sliding friction between the fluid and the wall is changed into the rolling friction, forming “micro-rolling bearing”.Multiferroic TbMn2O5 nanorods and TbMn2O5 micrometer crystals were ratio nally gained by Hans The field-dependent magnetizations of TbMn2O5 and TbMnO3 observed at 5 K are almost saturated at high field as 8000 Oe, due to a weak ferromagnetism of Mn array. In our previous work, the hydrothermally synthesized YMn2O5 and DyMn2O5 nanorods represented a weak ferromagnetic ordering.

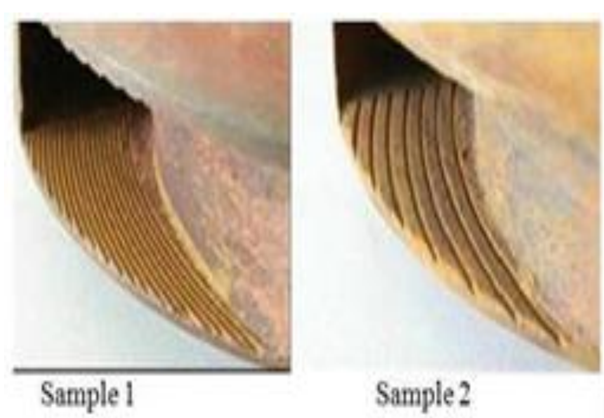
The coercivity increases while the exchange bias decreases owing to the finite size effect. Perovskite LnMnO3 (Ln ¼ Er, Tm, Yb and Lu) particles, consisting of needles and plates, were hydrothermally synthesized by Stampler The excellent magnetic responses of $ErMnO_3$, $TmMnO_3$, $YbMnO_3$ and $LuMnO_3$ (observed at 5 K, 100 Oe). As a well-studied multiferroic material, microcrystals $BiFeO_3$ microspheres, microcubes and one-dimensional (1-D) single-crystalline nanowires were also hydrothermally synthesized. Herein, we report a facial, controllable hydrothermal synthesis of 1-D $HoMn_2O_5$ nanorods, where environmentally friendly nature surfactant, i.e. arabic gum, are employed as a template to alter the morphology and size of resultant $HoMn_2O_5$.

To highlight the magnetic properties, $HoMn_2O_5$ nanorods were investigated using a SQUID magnetometer. The magnetic response observed as a function of size of the $HoMn_2O_5$ nanorods increases to a critical value owing to the finite size effect. More importantly, we observe that $HoMn_2O_5$ shows complicated series of magnetic transitions involving the Mn and Ho ions on cooling below Neel temperature. (e.g. paramagnetic-antiferromagnetic transition and antiferromagnetic-canted antiferromagnetic transition.

[1] Original sample

[2] Sample with hydrophobic coating

[3] original impeller [4] superhydrophobic impeller



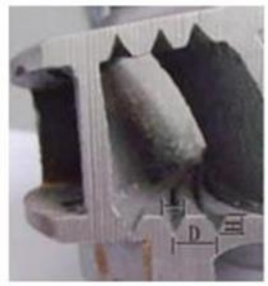
Sample 3 Sample 4

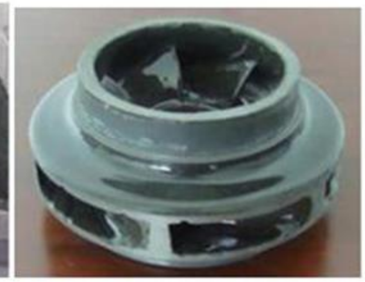
Sample 5 Sample 6

Sample 7 Sample 8

## 4. BIONIC USED IN CENTRIFUGAL PUMP FOR NOISE REDUCTION

With the gradual development of bionics technology, bionics technology of noise reduction has been widely promoted in fluid machinery. Based on the noise reduction properties of owl, goshawk and birds, morphological characteristics bionics has been used in fan machinery products. Combination of bionics, the fan noise reduction research mainly concentrated in the radius, angle, shape and gap of the tongue. Based on the eared owl skin, designed the axial flow fan blade into non-smooth surface to introduce coupled acoustic noise reduction technology, found that compared with the original of the centrifugal fan, the bionic centrifugal fan showed a significant noise reduction function, . According to the long-eared owl wings organizations, designed coupled acoustic structure across the tongue, the study found that the structure not only had the noise reduction effect, but also enhanced the performance of the centrifugal fan. Similar with the working principle of fan, due to the vibration mechanism of flow field in the centrifugal pump and the unsteady flow dynamic phenomenon, the gap between centrifugal pump impeller and tongue plays a vital role on the distribution of internal flow Bionics has been mainly used in the design of tongue to carry out the research of internal flow state, pressure pulsation and radial force ripple characteristics. The noise interference of pressure and flow filed is only predict and obtained to achieve the bionic volute vibration noise reduction function. In the hydraulic design of volute centrifugal pump, to Analysis showed that the bionic volute could long-eared owl non-smooth morphology has been adapted reduce the pressure pulsation amplitude significantly.





[4] Bionic groove [5] Bionics coupling

## 5. COCLUSION

With the principle of bionics, through the research on the mechanism of resistance and noise of centrifugal pump, coupled with the traditional technique, super hydrophobic pump, bionic non-smooth blade, ladder tongue and bionic volute tongue have been designed. Compared with the smooth blade, the velocity gradient of bionic non-smooth surface and super hydrophobic pump decreased greatly, the distribution of velocity became more uniform, the structure of the near wall turbulent boundary layer was improved, thus reduced the surface viscosity resistance; and non-smooth surface postponed the laminar boundary layer transition to turbulence, reduced the turbulent kinetic energy dissipation rate, the flow became more stable. Follow the bionics technology applied in fan machinery, ladder tongue and bionic volute in centrifugal pump has been designed. Due to the special structure of the ladder tongue, it could effectively restrain the cyclotron, and weakened pressure pulsation. With bionic volute, the max pressure pulsation amplitude was significantly reduced, and the pulse maintained stability in each frequency. Convex structure bionic volute formed fluid elastic region to reduce the vortex area of impeller, improved the distribution of the pressure in the volute, significantly improved the flow state in the volute. With the application of bionics technology in the centrifugal pump, the resistance and noise has been effectively reduced, and the high efficiency and energy-saving centrifugal pump based on bionics technology will play a significance role in the long-term development.

## REFERENCES

[1] Wang K, Song BW, Pan G. Drag reduction of riblets-surface of underwater vehicle. Mechanics in Engineering.

[2] Tian J, Xu JF, Xue QJ, et al. The technique of viscosity drag reduction and its application. Journal of Experimental Mechanics. 1997

[3] Tian LM, Ren LQ, Han ZW, et al. Applications of anti-adhesion and anti-resistance of biomimetic non-smoothsurface in engineering. Transactions of The Chinese Society of Agricultural Machinery. 2005

[4] Song XW, Lin PZ, Liu R, et al. Skin friction reduction characteristics of variable ovoid non-smooth surfaces. Journal of Zhejiang University-SCIENCE A. 2017

[5] Han X, Zhang DY, Li X, et al. Bio-replicated forming of the biomimetic resistance-reducing surfaces in large area based on shark skin. Chinese Science Bulletin. 2008

[6] Liu CB, Li L, Lei YL, et al. Resistance Reduction and Performance Improvement of Hydraulic Torque Converters with Multiple Biological Characteristics. Applied Bionics and Biomechanics. 2016.

[7] Chen K, Liu QP, Liao GH, et al. Aerodynamic noise reduction of small axial fan using hush characteristics of eagle owl feather. Journal of Jilin University. 2012

[8] Ru SF. Optimization design of mud pump piston biomimetic surface and research on wear-resistance and sealing. Changchun: Jilin University; 2015

[9] Tian LM, Gao ZH, Wang YC, et al. Design and experiment of bionic coupling functional surface caused by dual factors of form and flexible material. Journal of Jilin University: Engineering and Technology Edition.

[10] Tian LM, Ren LQ, Liu QP, et al. The mechanism of drag reductionaround bodies of revolution using bionic non-smooth surfaces. Journal of Bionic Engineering. 2007