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# Cavitation erosion in bloods *

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**Abstract:** The cavitation in a mechanical heart valve (MHV) is a serious concern. In most of the investigations of the MHV cavitation in vitro, the tap water, the distilled water, or the glycerin are used as the test liquids, instead of the real blood. Therefore, the effects of the liquid properties on the cavitation can not be well revealed. In this paper, the cavitation erosion in the porcine bloods is experimentally investigated as well as in the tap water and the distilled water by means of a vibratory apparatus. The results show that the blood produces a weaker intensity of the cavitation erosion than the tap water or the distilled water. The cavitation erosion decreases with the decrease of the liquid temperature or with the increase of the concentration of the blood, especially with the increase of the liquid viscosity. It is the viscosity that could be a major dominant factor affecting this erosion. The temperature or the concentration of the blood changes the viscosity, and in turns changes the intensity of the cavitation erosion.

**Key words:** Cavitation erosion, blood, concentration, temperature, in vitro

Early in 1952 the prosthetic valve started to be implanted clinically in patients with aortic insufficiency. Since then, various mechanical heart valves (MHVs) were designed for use in both aortic and mitral positions[1]. Today, approximately $1.2\times10^6$ MHVs[2] are implanted each year worldwide on the basis of estimations of 10% patients. There have been the cases of leaflet escape[3,4], and it was observed that were the confined areas of pitting and erosion on the leaflet and the housing surfaces[5]. Now, it is convinced that the pitting and the erosion are the results of the cavitation of the blood, and the failure of the MHV is closely related to the cavitation erosion.

The previous investigations of the MHV cavitation in vitro mainly include following four aspects:

(1) Structure and function of MHVs: tilting disk valve and Bileaflet valve, or Björk Shiley Convexo Concave, Carbomedics, Medtronic Hall, St. Jude Medical, Sorin and Duromedics Edwards[6-9].

(2) Materials of MHVs: various prosthetic materials and pyrolitic carbon[6,10].

(3) Flow and characteristics of cavitation: squeeze flow, water hammer, and vortex[6,8,11-13].

(4) Effect of test liquids and their properties on the cavitation and its erosion: the tap water, the distilled water, and the glycerin solution, or the nuclei, and the viscosity[12-15].

With respect to the effect of test liquids and their properties on the cavitation and its erosion of the MHV in vitro, the tap water is a main liquid before 2004. After that, the distilled water, and the glycerin solution are used in the investigations of the field[14,15].

It is well-known that, it is the cavitation nuclei in the liquid that are the internal cause of the cavitation occurrence, and the cavitation will not occur without such nuclei in the liquid. The ambient pressure fields round the nuclei are the external conditions that make the nuclei grow into cavitation bubbles. So, it is crucial to understand the effects of the liquid property on the cavitation and its erosion.

Lee et al. conducted experiments of the MHV cavitation by using three liquids: the tap water, the

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distilled water and the 40% glycerin solution. Their results suggest that, the cavitation intensity in the glycerin solution is greater, but the cavitation occurrence probability is less than in the tap water (see Figs.1, 2). These results are related to the cavitation nuclei and the viscosity of the liquids[14,15]. It is difficult to understand and accept these results. Since the tap water has much more cavitation nuclei than the distilled water or the glycerin solution, it should bring about an intenser cavitation. Secondly, generally, the viscosity of the glycerin solution is larger than the tap water or the distilled water. The results show that a large viscosity of liquid results in a large cavitation intensity.

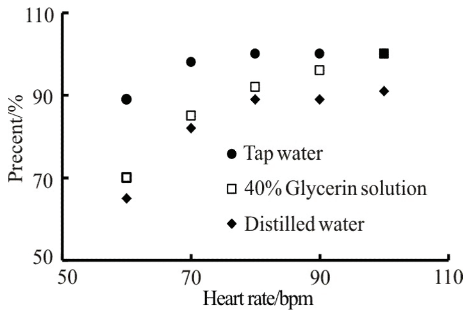


Fig.1 Cavitation occurrence probability for various testing liquids[14]

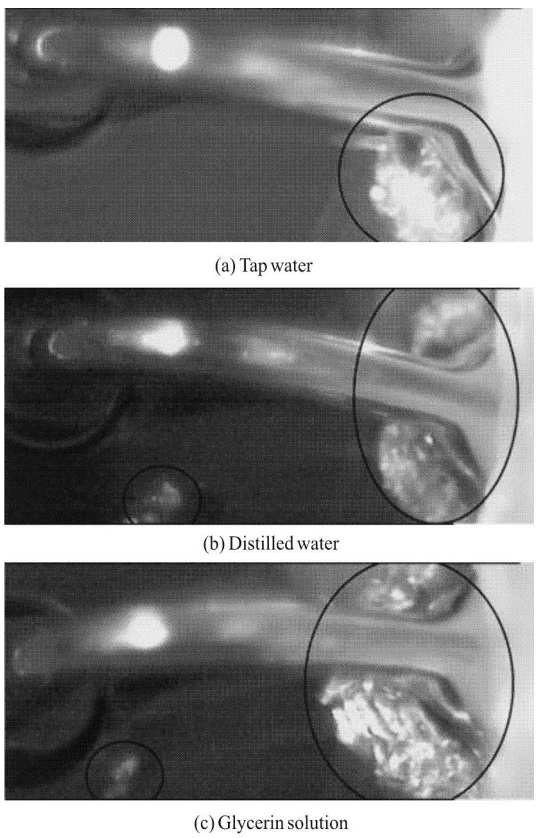


Fig.2 Cavitation bubbles at a heart rate of 100 bpm in MHV[14]

In order to clarify the effects of the liquid properties on the cavitation and its erosion, experiments of the cavitation erosion are conducted in the High-Speed Flow Lab at Hohai University (Nanjing, China). The experimental setup is shown in Fig.3. The cavitation erosion tests are performed by means of a vibratory apparatus[16,17], which produces longitudinal oscillations of a test specimen at a frequency of $f = 20 \pm 2$ kHz with an amplitude of $A = 50 \pm 5$ μm, in accordance with the GB/T6383-2009 test method[18] at the different liquid temperatures. The test liquids include the tap water, the distilled water, and the porcine blood of different concentrations, and the material of the test specimen for the cavitation erosion is No. 45 steel.

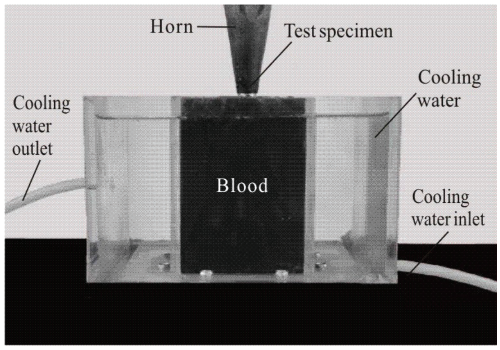


Fig.3 Experimental setup

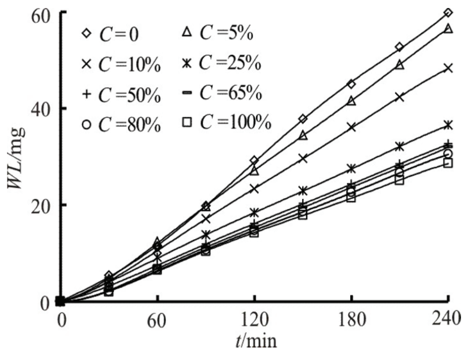


Fig.4 Variation of $WL$ with $t$ for different blood concentrations (38°C)

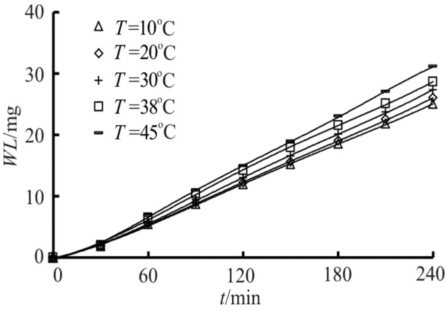


Fig.5 Variation of $WL$ with $t$ at different blood temperatures (100% blood)