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論文要約

Plasma skimming in the spiral groove bearing refers to excluding red blood cells from the ridge gap into the groove gap of the bearing inside a hydrodynamically levitated rotary blood pump. High-efficiency plasma skimming is hopeful of preventing hemolysis inside the narrow bearing gap. However, no study reports the method to improve plasma skimming through the spiral groove bearings' design. Therefore, this study aims to reveal the method to improve plasma skimming inside the bearing gap and optimize the design of spiral groove bearing to obtain both high-efficiency plasma skimming and sufficient load-carrying capacity in a hydrodynamically levitated rotary blood pump.

Firstly, plasma skimming was verified in an experimental shearing test rig under physiological level hematocrit conditions. The hematocrit decline of sampled blood from the shearing gap when the gap decreased under 100 μm indicates the potential of inducing plasma skimming to the clinical rotary blood pump.

Secondly, three different spiral groove bearings were designed and manufactured to investigate the impact of different spiral groove bearings on plasma skimming. It was hypothesized that the spiral groove bearing most similar to the actual blood flow in the bearing gap has the best plasma skimming efficiency. An experimental device that mimics the flow conditions of the ridge gap in the rotary blood pump was designed and manufactured. This experimental device enabled the quantitative evaluation of plasma skimming with a high-speed camera. The statistical analysis result of plasma skimming with three bearings has verified the hypothesis. In addition, the complete exclusion of red blood cells was realized when the blood flow was the same as the spiral groove shape.

Next, optimization of spiral groove bearing was conducted. A hydrodynamically levitated rotary blood pump was designed and manufactured to simulate the actual flow environment of the clinical centrifugal rotary blood pump. The blood flow inside the designed blood pump was analyzed and recorded with a high-speed camera. Based on the testified design principle that the spiral groove shape should be designed to match the blood flow, a spiral groove bearing aiming to provide excellent plasma skimming effect and adequate load-carrying capacity was optimized. Then the optimized spiral groove bearing was manufactured and installed in the design hydrodynamically levitated rotary blood pump. The results of blood tests show that the optimized spiral groove bearing reaches excellent plasma skimming effect with high hematocrit conditions. The optimized spiral groove bearing induces an expected high-efficiency plasma skimming and provides adequate load-carrying capacity.

This thesis reveals the method to improve plasma skimming inside the bearing gap by designs of spiral groove bearings. The basic parametric studies and application of the optimized spiral groove bearing provide insights into utilizing plasma skimming to prevent hemolysis in the future development of hydrodynamically levitated rotary blood pumps.