MINIPUMP – INVESTIGATING THE BOUNDARIES OF CONVENTIONAL ROTARY PUMP DESIGN

Lars Fischer (1), Florian Huber (1), Ulrich Steinseifer(1), Lasse Strudthoff (1), Michael Neidlin (1)

1. Department of Cardiovascular Engineering, Institute of Applied Medical Engineering, Medical Faculty, RWTH Aachen University

Introduction

Blood pumps are designed and optimized for a static target operation condition; in that an optimum in efficiency and hemocompatibility is achieved [1,2]. Off-design operation is associated with decreased performance and elevated risk of adverse events [3-4]. Depending on application, low flow rates combined with high pressure heads are required— as present in rodent sized or neonatal extracorporeal life support circuits [5,6]. According to literature, such operation conditions necessitate non-rotary pump designs that are not appropriate for blood pumps [1,2]. Therefore, this study investigates the applicability and boundaries of conventional rotary pump design methodologies for a target operation condition of Q = 70 mL/min and Δp = 115 mmHg, for flow rate and pressure difference, respectively.

Methods

A conventional design approach based on a combination of analytical turbomachinery equations and empirical correlations as described by [1,2] was used for calculation of initial pump dimensions. Additional design requirements encompass in-house manufacturability, low priming volume, bearing's long-term stability, magnetic propulsion, connectivity to 3/16" tubing, and the presence of washout holes to mitigate blood stagnation. Computational fluid dynamics was utilized for design optimization. An in-house manufactured pump head was analyzed for its hydraulic performance and compared to a commercial blood pump. The testing circuit is displayed in Figure 1.

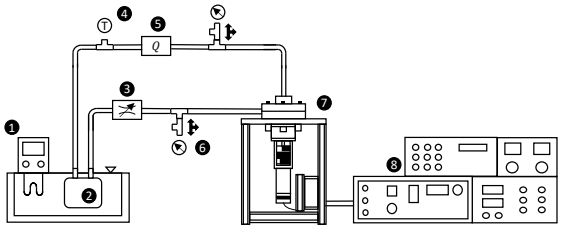

Figure 1: 1) tempered water bath, 2) flexible reservoir, 3) clamp, 4) temperature sensor, 5) flow sensor, 6) pressure sensor, 7) pump head, and 8) data acquisition.

Results

The MiniPump's priming volume is 5.4 mL, 56.1% smaller than the Deltastream DP3 rotary blood pump. Figure 2 shows the HQ-curves of the initial, and optimized MiniPump design, compared to a DP3 as reference. Conventionally calculated initial dimensions failed to meet the performance requirements.

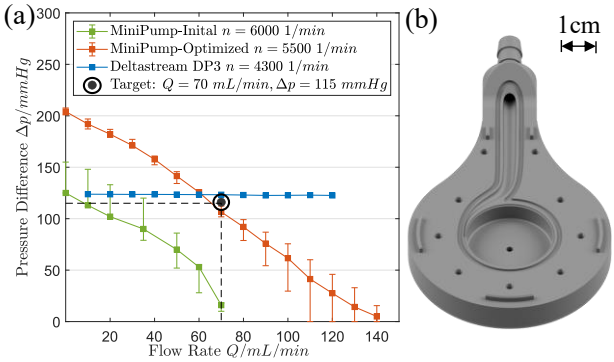

Figure 2: HQ-curves (a), MiniPump lower housing (b).

Computational optimization and adjustment lead to a suitable design, satisfying targeted requirements. The key design parameters are presented in Table 1.

Parameter	Unit	Initial	Optimized
Blade number	N/A	10	6
Inner diameter	mm	2	2.4
Outer diameter	mm	17,5	25
Blade inlet angle	deg	40	36
Blade outlet angle	deg	21,3	24.5
Blade width	mm	0,45	0.6

Table 1: MiniPump's key design parameters.

Discussion

Conventional rotary pump design methodologies fail to provide appropriate design parameters for the targeted operation range. The presented results show that the optimized MiniPump achieves the desired hydraulic performance. In comparison, the throttled Deltastream DP3 shows lower sensitivity to flow rate variations. Future work will assess and evaluate the MiniPump's hemolysis potential in comparison to a DP3 pump.

References

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