National Conference with International Participation
ENGINEERING MECHANICS 2001
Svratka, Czech Republic, May 14 - 17, 2001

CIRCUIT RESISTANCE MODELING IN FAILING HEART ROTARY PUMP SUPPORT

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Summary: *The stepwise resistance increase caused by the throttle valve usage in the mock-line circuit comprising the pulsating ventricle in failing heart modus and supported by rotary pump set up in parallel was studied. Though this kind of throttling does not simulate the mechanism of the resistance increase in the cardiovascular system rather a significant portion of flow kinetics due to the rotary pump performance was demonstrated. It appears thus important to regulate the support system producing a continuous type of flow to such a regime not allowing the pulsating flow of the failing heart to disappear and preventing the mean systemic pressure value before substantial increase.*

1. INTRODUCTION

The previously described phenomena influencing the performance of the supporting system, i.e. rotary pump (RP), connected in parallel to the failing ventricle, concerned the limiting states of RP performance and the systemic compliance effect of the aortic segment [1, 2]. The problem of the resistance index increase has been discussed in connection with the usage of the RP in [3] as partially clarified phenomenon. In order to enlarge our knowledge about the behaviour of the supported failing heart, as to the flow changes caused by the sudden resistance increase, we evaluated these phenomena, using the throttle valve technology in the mock-line circuit.

2. MATERIAL AND METHODS

The magnetically driven rotary pump (RP type Sarns, USA) was set in parallel with the pulsating ventricle in a simplified mock-line circuit [see Fig. 1]. The manually changeable resistance controlled the common flow of both the RP and the pulsating failing heart with circuit. The indicator of the flow direction via the RP was followed up on the thread movements placed halfway in the inside of the outlet RP tubing. The pulsating ventricular frequency (beats per minute) and the rotational speed (rot per minute) were manually changed from 60 to 100, 120, 150 and 200 b/min and 1000, 2000 and 3000 rot/min using the driving pressure of the ventricle at constant value 20 kPa, i.e. well as rotations of RP from 0 to 10, 30, 50 and 70 degrees of the crow-sectional area of the circuit tubing. All measured data were registered, analysed and correlated with the calibrating curve.

3. RESULTS

Provided one compares the pressure and flow runs, i.e. continuous flow, while the resistance in the circuit be gradually elevated, one notices the enormous mean pressure elevation at the maximum

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rotation, i.e. 3000 rot/min at 70 throttling of the valve in comparison with the pressure values at 200 beats/min. under the same resistance conditions. The flow values under the latter conditions demonstrate a rather slight decrease (5 l/min) in comparison with the flow run of the pulsatile flow (about 1 l/min). These findings indicate an enormous kinetic contribution due to the enhancement of the flow velocity under all regime conditions with the RP [see Fig. 2, 3 and 4].

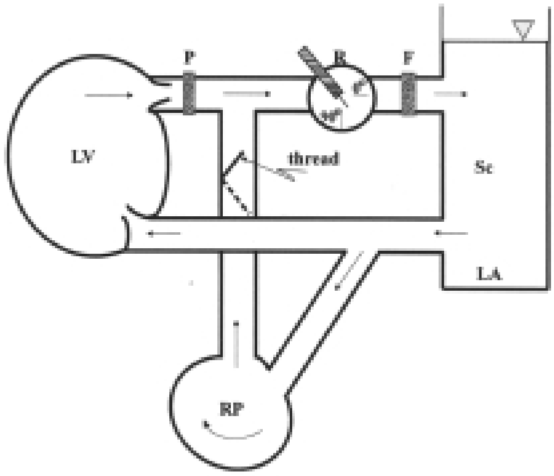

Figure 1: Mock-line circuit
Symbols used:
LV – left ventricle
RP – rotary pump
Sc – systemic compartment
LA – left atrium compartment
P – pressure transducer
R – throttling valve (resistance)
F – flow transducer

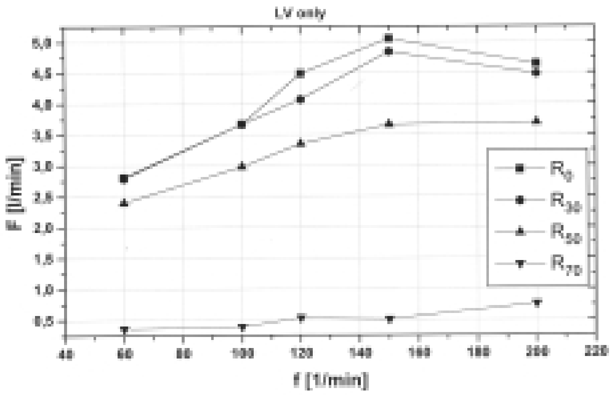

Fig. 2

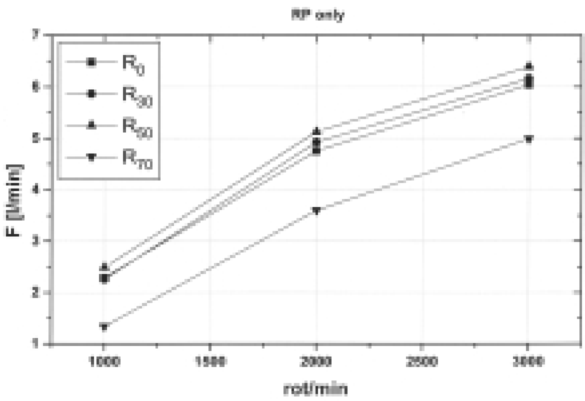

Fig. 3

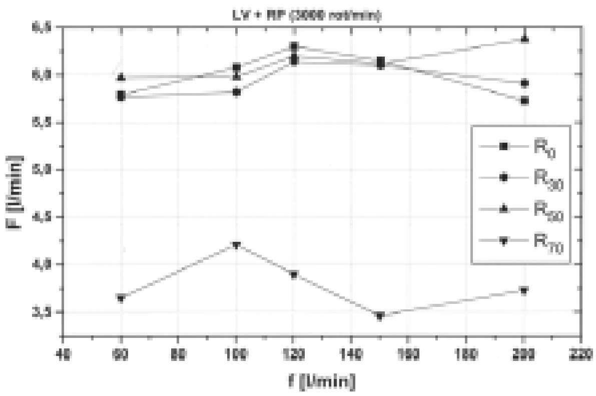

Fig. 4

Fig. 2, Fig. 3, Fig. 4: The flow runs of the pulsating failing ventricle only (LV), RP only and both the failing ventricle and RP together at 3000 rot/min.
Symbols used:
F – flow (l/min)
f – beats/min
rotations (rot/min)
R_0, R_{30}, R_{50}, R%70 – indicate the resistance values at 0, 30, 50, 70 degrees of the throttling

4. DISCUSSION AND CONCLUSIONS

The update trials of RP assist devices as well as other types of support devices generating continuous flow motivated our mechanical study on a simplified mock-line with gradually increased resistance by throttle valve usage. The resistance increase might be realised by other measures, e.g. by hydrostatic pressure elevation at the outlet tubing of the pulsating ventricle, by further multiple branching of the main outlet tubing, or finally by throttling valve manipulation.

The flow run of the RP, while the resistance increased stepwise from 0, to 30 and 50 degrees of throttling the tube's diameter, revealed a distinct increase together with the mean pressure elevation. A slight flow increase is distinguishable in all flow runs which the resistance be elevated with the exception of the throttling 70 degrees. Closely before the resistance elevation reached 70 degrees the flow fell down and the mean pressure values increased by the magnitude of order at the 3000 rot/min. The flow values decreased by the resistance elevation and dropped under less than 1 l/min in 70 degrees of throttling in case of the pulsating pumping under the same conditions of resistance. Thus we may presume that there exists some critical value of the continuous flow generated by the RP, while the resistance conditions in the circuit reach more than 50 degrees of the throttling.

Provided the failing pulsating ventricle be supported by the RP, one may notice that the flow run zones referring to the pulse frequencies (60 – 200 per minute) do not fall under 3 l/min while the resistance does not reach 70 degrees of throttling. Other flow values of the increased resistance, i.e. 30 and 50 degrees) do not influence distinctly the flow values in the combined pumping regime, i.e. pulsating and continuous) reaching the zone of nearly 6 l/min continuously [see Fig. 5 – the calibrating curve].

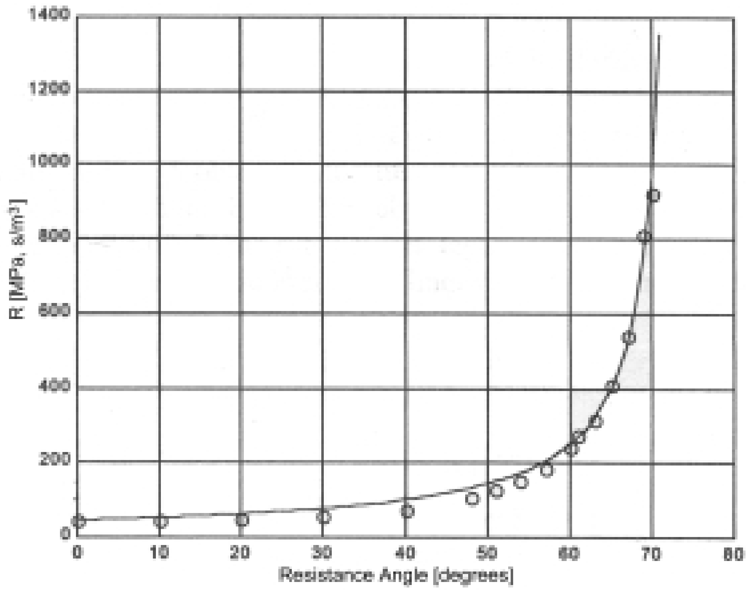

Fig. 5 Calibrating Curve

5. REFERENCES

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