Static and Dynamic Deformations of a Reed Valve Immersed in Hydraulic Fluid

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Abstract

Metal reed valves provide a simple solution for flow rectification in compact electrohydraulic pumps driven by smart materials at high frequencies [1]. While the natural frequency of such a valve operating in air is easily calculated [2,3], it is difficult to predict the behavior when the surrounding fluid has considerable inertia and viscosity. Immersing a reed valve in liquid medium e.g. hydraulic fluid or motor oil, effectively leads to lowering the natural frequency of the valve, thus making it unsuitable for operation at high pumping frequencies. Simulation of this phenomenon involves modeling the fluid-structure-interaction between the bending of the reed and the flow past the valve. In this poster, we will present the static and dynamic behavior of a reed valve used to rectify the flow of hydraulic fluid.

Using the Fluid-Structure Interaction (FSI) interface in COMSOL Multiphysics® software and a 2-D model of the valve geometry, the deformations of a reed valve due to an applied pressure gradient on the fluid medium were evaluated and the corresponding loss coefficients calculated. The reed is simply a cantilever beam with a fixed condition applied at one end. The fluid was assumed to be incompressible and the reed material was set to follow Linear Elastic behavior. The Fully Coupled solver was chosen for this problem. For the static case, the inlet pressure was varied with outlet pressure at 0 and the corresponding values of fluid velocity (ufluid) were calculated (Figure 1) for different reed thicknesses. To evaluate the dynamic response, a sinusoidal inlet pressure was applied and the corresponding dependent variables were calculated.

From the results of the static deformation, shown in Figure 2, it can be seen that the mean outlet flow velocity changes in a quadratic manner; this is expected, since the minor losses are proportional to the square of flow velocity. It is also noted that the pressure gradient required to open the reed increases with increasing thickness; this too is expected since a thicker reed has higher bending stiffness. The transient behavior is more interesting; the mean fluid velocity has frequency components other than the main driving frequency, thus showing the non-linear nature of the phenomenon. Also, we see that the valve does not close completely and allows some fluid to reverse direction; this effect is lower at 100 Hz (Figure 3) than at 500 Hz (Figure 4).

The results of these simulations clearly show that a thinner reed valve will have lower pressure drop across it but might not be able to close completely in a dynamic scenario, thus allowing fluid losses due to flow reversal. Hence, optimizing the reed valve geometry for any particular application has to take into account both the minor losses as well as the bandwidth of the device,

both of which can be reliably predicted by numerical simulations.

Reference

1. A. Chaudhuri et al., “Design, test and model of a hybrid Magnetostrictive hydraulic actuator,” Smart Mat. Str., vol. 18, pp. 085019, 2009.
2. G. Cunningham et al., “Reed valve modelling in a computational fluid dynamics simulation of the two-stroke engine,” Proc. Instn. Mech. Engr, vol. 213, pp. 37 – 45, 1999.
3. A. Angeletti et al., “Optimisation of reed valves dynamics by means of fluid structure interaction modeling,” 4th European Automotive Simulation Conference, Munich, Germany, July 2009.

Figures used in the abstract

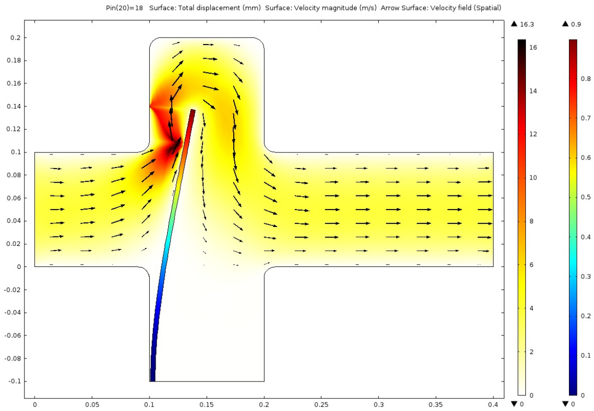

Figure 1: Static deflection of 4 mil thick reed valve and resulting fluid flow.

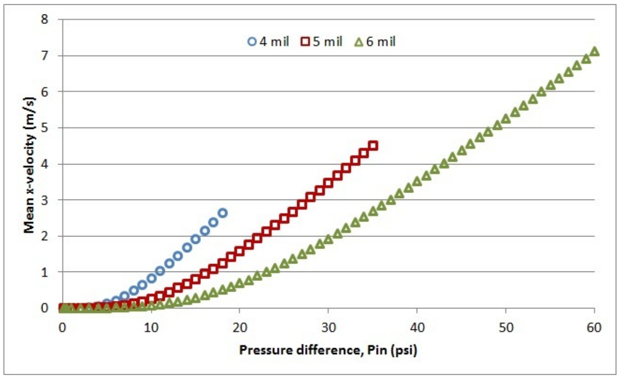

Figure 2: Mean fluid velocity at different static pressure differentials and varying reed thicknesses.

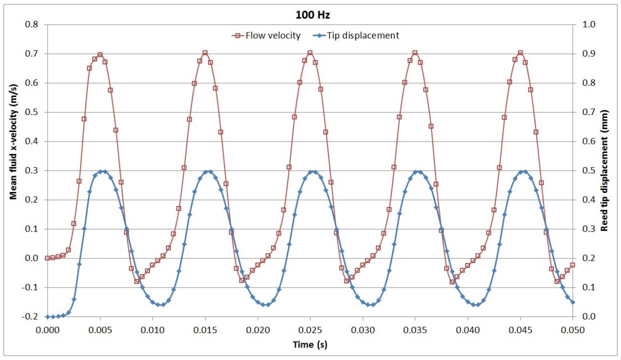

Figure 3: Mean outlet fluid velocity (normal component) and reed tip displacement at 100 Hz pumping frequency for 4 mil thick reed.

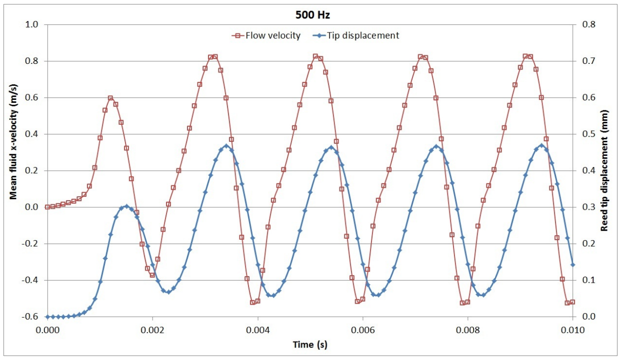

Figure 4: Mean outlet fluid velocity (normal component) and reed tip displacement at 500 Hz pumping frequency for 4 mil thick reed.