Multi-body Dynamic Simulation of Acti-Valve

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ABSTRACT

A computer simulation of a valve (Acti-Valve) is generated using LS-DYNA. Fluid-structure interaction is considered in the finite element analysis (FEA). The stress, displacement and pressure distributions are analyzed during the opening movement of the valve under 1000 psi line pressure.

INTRODUCTION

Acti-Valve is a U.S. patented valve. It requires only a small portion of the energy to operate compared to traditional automated ball or globe valves. Figure 1 shows the Acti-Valve in the closed position. Actuation can be accomplished by a pneumatic cylinder. Piston seat VP-1(a) can be moved horizontally toward the face of piston VP-2 by means of an actuator. The media can flow through the center port of piston VP-2 to its rear surface. The soft seat SS-1 on piston VP-2 sits firmly on the hard seat (HS-1). The VP-1 tapered hard seat (HS-3) sits firmly on hard seat HS-2.

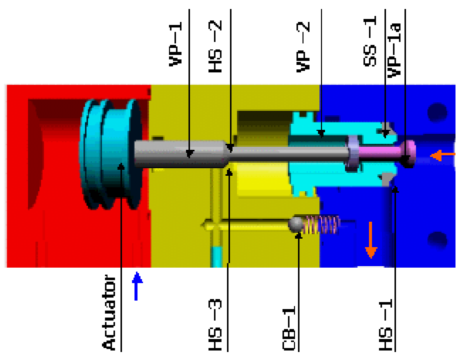

Figure 1. Closed position of Acti-Valve

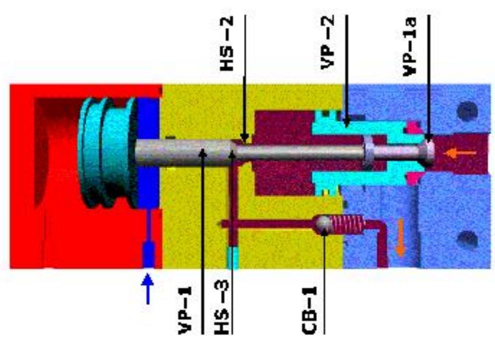

Figure 2. Valve in the process of opening

Figure 2 shows what happens as line pressure instantly powers Acti-Valve pistons (VP-1 and VP-2) into the open position. The line pressure provides the power. The actuator is engaged to retract piston VP-1 until VP-1(a) seats itself onto the face of VP-2. Simultaneously, the seal created by tapered seats HS-2 and HS-3 is broken and the media in the chamber behind piston VP-2 flows downstream through the check ball CB-1 outlet. The line pressure instantly powers pistons VP-1 and VP-2 to the open position.

APPROACH

In this research, a finite element model of the actuation process of the valve is generated by using LS-DYNA. The stress distribution of the elastic structural model and the pressure distribution of the fluid are then analyzed to find the detailed movement of each component versus time and determine how they affect each other. Fluid-structure interaction is considered by using Eulerian and Lagrangian coupling technology.

Material and FEM Models
In the FEM analysis, only one half of the entire valve is modeled because of symmetry. There are 13 solid parts, 2 fluid parts and 1 spring.

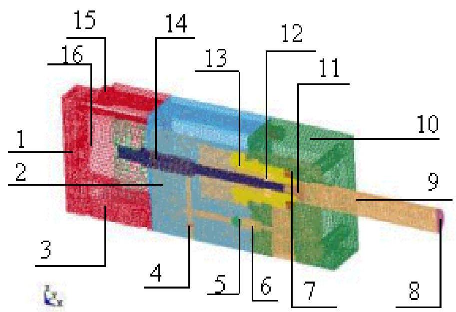

Figure 3. FEA model of the valve body and fluid

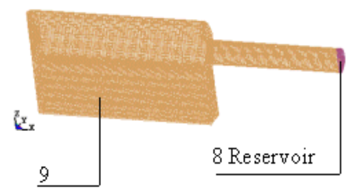

Figure 4. FEA model of the fluid parts

The following table lists all the parts indicated above:

Part ID	Name	Material	FEM Model	Remark
1	Valve Body A	Steel	Shell Element	Rigid
2	Valve Body B	Steel	Shell Element	Rigid
3	Lower Screw	Steel	Brick Element	Elastic
4	Block	Steel	Shell Element	Rigid
5	Check Ball	Steel	Shell Element	Rigid
6	Spring	Steel	Discrete Element	Fixed on Parts 10 &5
7	O-Ring	Rubber	Mooney-Rivlin_Rubber	
8	Reservoir	Water	Null Material Gruneisen	$6.895\times10^{-5}\,Mbar$
9	Media (water)	Water	Null Material Gruneisen	No Pre-pressure
10	Valve Body C	Steel	Shell Element	Rigid
11	Cap	Steel	Brick Element	Elastic
12	Diffuser	Steel	Brick Element	Elastic
13	Piston	Steel	Brick Element	Elastic
14	Stem	Steel	Brick Element	Elastic
15	Upper Screw	Steel	Brick Element	Elastic
16	Actuator	Steel	Brick Element	Elastic

Table 1. FEA model of the valve body and fluid

Boundary Conditions

Valve body C (Part10) is fixed. Valve bodies A and B are connected to C by the lower and upper screws. The screws are fixed on the valve body C and contact with valve body A and B. The cap (part 11) and diffuser (part 12) are fixed to the stem (part 14). The stem is fixed on the actuator (part 16). The O-Ring is fixed to the piston (part13). The pressure in the reservoir is 1000 psi ($6.895\times10^{-5}\,Mbar$). There is no pressure acting on the actuator in the first 500 microseconds. After that, 100 psi ($6.895\times10^{-6}\,Mbar$) pressure acts on the right side of the actuator.

DISCUSSION OF RESULTS

Through use of LS-POST, the desired results can be generated. The units are Mbar, cm and microsecond. One can use SCALE to change the history data so that one can obtain the data in psi and inches.

Pressure Distribution of Fluid Parts

Figure 5 shows the results at the time of 6740.7 microseconds.

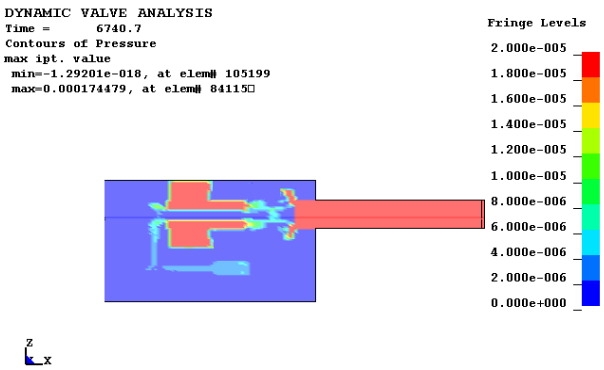

Figure 5. Pressure (Mbar) distribution at 6740.7 microseconds

To see things more clearly, one can choose 5 elements and find their pressure data history. Elements A and B are on the outside of the cap and piston, C and D are inside the chamber and E is the in the outlet of the chamber.

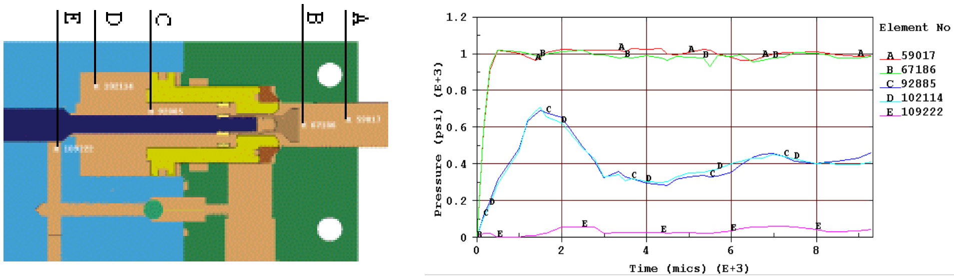

Figure 6. Fluid pressure (psi) versus time

From Figure 6, one can see that the pressure decreases after goes through the gap between the piston and the cap. The pressure inside the chamber is increasing before the VP-1(a) seats itself onto the face of VP-2 (Figure 1 and Figure 2). After seating, the pressure keeps decreasing until a balance, which is caused by the down flow and the pushing pressure of the moving piston, is reached.

Stress Distribution of Solid Parts

Figure 7 shows the results at the time of 6740.7 microseconds. The maximum stress is located at the left end of the upper screw. The stress is caused by an axial force as well as bending moment.

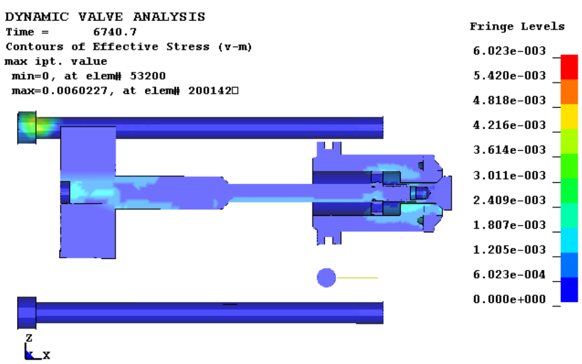

Fig 7. VM-stress (Mbar) distributions of the elastic elements

To analyze things more clearly, one can choose 4 elements and find their Von-Mises stress data history.

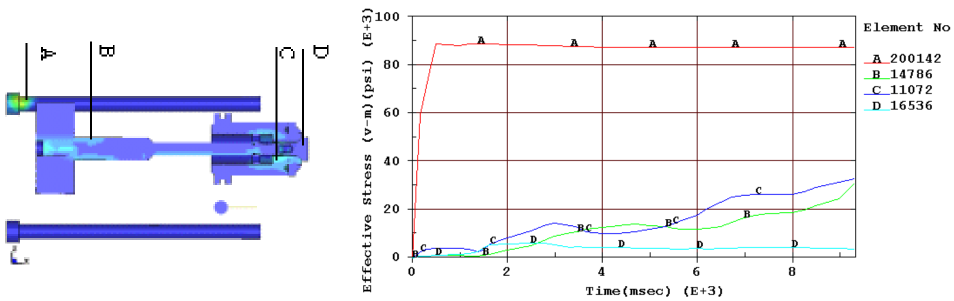

Figure 8. Stress (psi) distribution versus time

From an inspection of the above, one can see the maximum stress is always located on the upper screw. The stress on the other parts increase as time goes on.

Displacement and Velocity

Because the deformation of the elastic parts is small compared to the displacement of the actuator and the piston, one can choose 2 nodes on the piston and the cap to represent the displacements of the actuator and the piston.

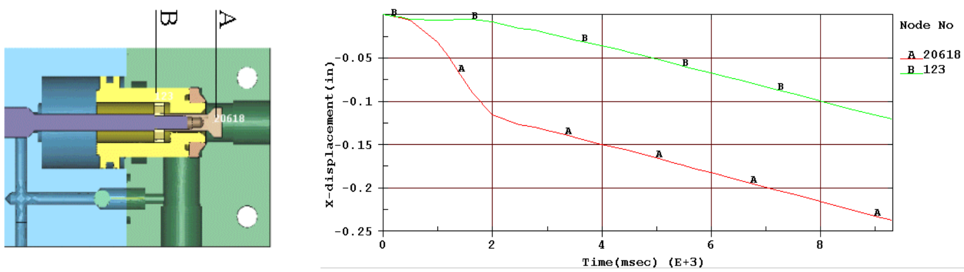

Figure 9. Displacement of the cap and piston

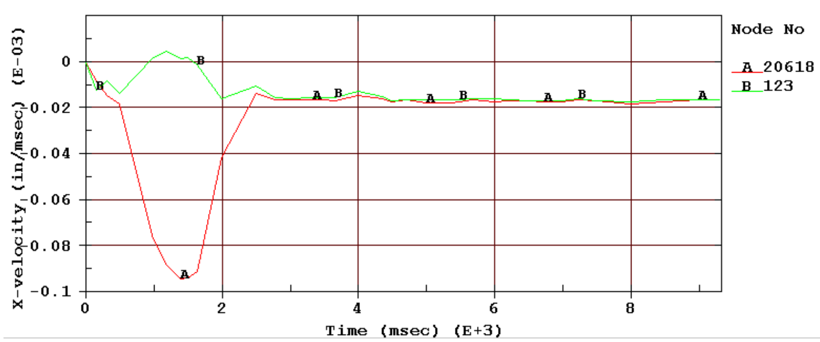

Figure 10. Velocity of the cap and piston

From these figures, it is seen that before the VP-1(a) seats itself onto the face of VP-2 (Figures 1 and 2), the piston experiences a small amount of vibration because the impact of the fluid and the force generated at the different front and rear areas of the piston. After seating, the velocity of the piston and the cap start to converge to the same value. The actuator, stem, diffuser, O-Ring and piston then move at the same velocity at 0.000018in/micosecond (18in/s). The valve starts to open.

SUMMARY AND CONCLUSIONS

1. Under 1000psi line pressure, the maximum stress always occurs in the upper screw. The stress of the screw can reach to 90,000psi because it is subjected to both the bending as well as the axial force action. It is suggested that the customer choose the upper screw material carefully to make sure it can satisfy the strength requirement.
2. The fluid pressure in the chamber of the valve is lower than the line pressure. This makes it for the valve to open and reduces the actuating energy.
3. After the cap seats on the piston, the valve will open with a velocity of approximately 18 in/s. The valve opens in 0.05 second.

ACKNOWLEDGMENTS

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