Modelling and Simulation of Pneumatic System of a Launcher for Carriage and Release of Weapon from Fighter Aircraft

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Abstract: *Fighter aircraft launcher consists of mainly two parts i.e. suspension and ejection mechanism and power drive to actuate ejection mechanism. Pneumatic system is used as power drive of the system. This project focuses on modelling and simulation of pneumatic system of a launcher. Modelling and simulation is done in AMESim software. Using available libraries in software pneumatic components are modelled. Applying all the inputs to the system simulation is carried out and results are plotted. In the results displacement, pressure and mass of gas are plotted.*

Keywords: Fighter aircraft, Launcher, pneumatic, AMESim

I.Introduction

With present day aircraft, and particularly military aircraft, the missiles may be launched at speeds varying from the subsonic through transonic and into the high supersonic. In addition, the missiles may be launched at elevations in excess of 70,000 feet. Each of these conditions imposes certain forces upon the missile which affect its performance during the launch. The missile launcher itself, in order to be practical, must in addition to directing the missile provide a minimum amount of drag before and after the release of the missile. There must be an instant and positive retraction of the launcher after a release and the missile or store must be under positive mechanical control of the launcher at all times so that a successful launch can be achieved in the presence of the many forces acting upon the missile.

Launcher consists of mainly two parts i.e. suspension and ejection mechanism and power drive to actuate ejection mechanism. Power drive of the missile launcher is one of the important parts of the system. Power drive is the actuating medium for the mechanical system of launcher. So a proper power drive needs to be selected to release the missile. Figure 1 shows the total system assembly. The front cylinder is single acting with only one connection and rear cylinder is double acting having a pressure of 15 bar in second chamber which acts as damper.

Another main part of study is modelling and simulation of pneumatic system in AMESim software. This software is best for hydraulics and pneumatics, it accepts a wide variety of inputs. Total system is modelled in the software and results are plotted. In results displacement of piston, mass flow rate through bottle, pressure variation are plotted.

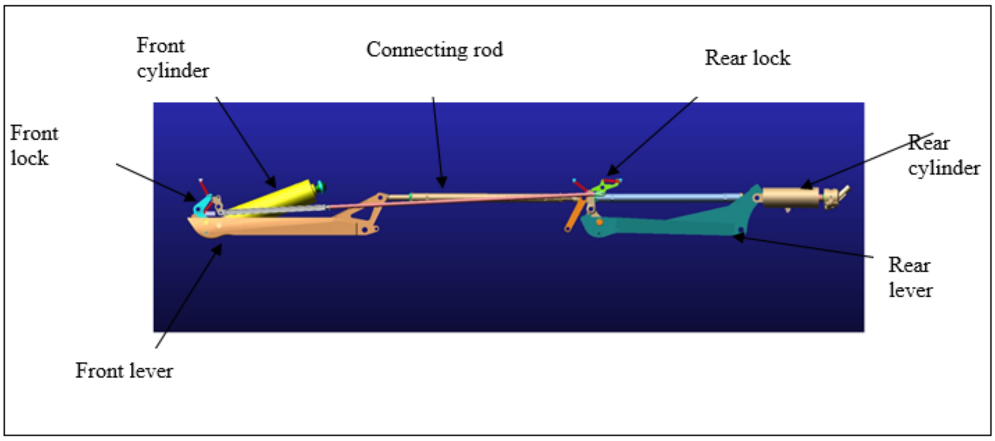


Fig. 1. Assembly of total system

I. MODELLING OF PNEUMATIC SYSTEM

Modelling of pneumatic system is done in AMESim software. It includes modelling of pressure bottle, distributor valve, front pneumatic cylinder and rear pneumatic cylinder. All these components are modelled using components in pneumatic library and pneumatic component design library. Some inputs to the components are available in given data and remaining are calculated using conventional formulas.

1.1 Modelling of Pressure bottle

- Pressure inside the bottle

Pressure bottle is the source of high pressure gas to the system and it acts as reservoir in the system. It supplies high pressure gas to front and rear cylinders during ejection of missile from aircraft and only to rear cylinder during return stroke. The volume of bottle is 2 Liter and pressure filled inside the bottle is 250 bar on the ground. As the aircraft flies at high altitude the pressure inside the bottle is decreased because of lapse rate phenomenon. The variation of pressure at different altitudes is listed below. For this altitude of 0, 5, 10, 17 Km are considered and we are simulating for 10 Km altitude.

Table 1 variation of pressure with altitude

Altitude (Km)	Pressure (bar)
0	250
5	222.6
10	190
17	183.6

- Mass of the gas inside the bottle

Filling of the gas into bottle takes place on ground so considering NTP conditions for calculating mass of gas. Known parameters are listed below.

Table 2 Known parameters of bottle

Charging pressure	250 bar
Temperature	293^0c
Volume	2 L
Gas constant	287 J/KgK

From these parameters and applying ideal gas equation PV = m × R × T we get mass of gas inside bottle = 0.561Kg

- Software model

The following figure shows the symbol of bottle used in modelling.

1	To the pipe

Fig. 2. Symbol of pressure bottle

The inputs to this software model are shown in following figure.

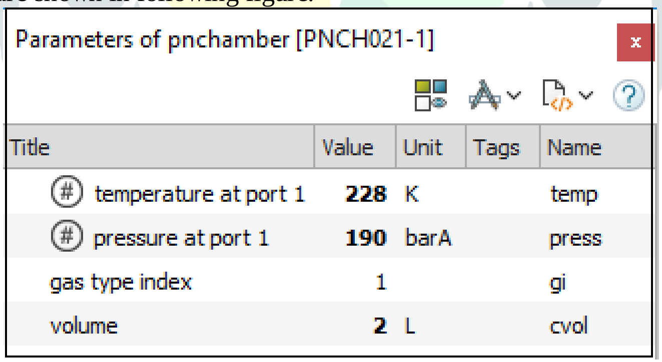


Fig. 3. Parameters of bottle

1.2 Modelling of distributor

Distributor is similar to two directional control valve, but it is not conventional. This distributor connects bottle and two cylinders. Its main function is to connect bottle and both cylinders only during ejection stroke and for return stroke to connect bottle with rear cylinder. During return stroke the front cylinders expanded gas is released to atmosphere through same input port. This unit is modeled in special library known as pneumatic component library where we can customize the component as we needed. The following figure shows the model of distributor unit.

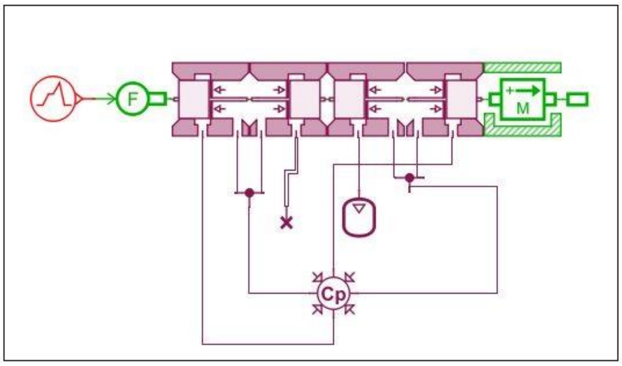


Fig. 4. AMESim Model of distributor unit

In figure F shows the force icon which applies force for movement of red spools. The mass like icon is used to consider mass of spools. The middle red part shows spools arrangement in valve.

1.3 Modelling of front cylinder

The front cylinder used in the system is single acting having only one input for supply and release of gas from cylinder. Generally single acting cylinder has spring for its return stroke but in this there is no spring (giving input of spring constant as 0). The return motion of piston is achieved with rear cylinder as these two are synchronous with each other. This synchronous motion is achieved with the help of mechanical linkages which connect front and rear levers. The following figure shows AMESim model front piston.

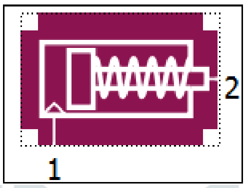
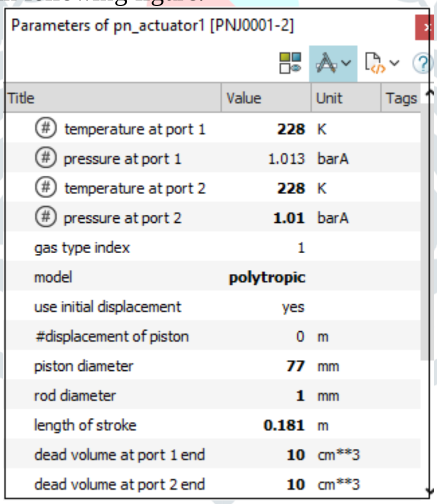


Fig. 5. AMESim model of front cylinder

The inputs to the software model are shown in following figure.



Parameters of pn_actuator1 [PNJ0001-2]

Title	Value	Unit	Tags
temperature at port 1	228	K	
pressure at port 1	1.013	barA	
temperature at port 2	228	K	
pressure at port 2	1.01	barA	
gas type index	1		
model	polytropic		
use initial displacement	yes		
#displacement of piston	0	m	
piston diameter	77	mm	
rod diameter	1	mm	
length of stroke	0.181	m	
dead volume at port 1 end	10	cm**3	
dead volume at port 2 end	10	cm**3	

Figure 6. Inputs of front cylinder

1.4 Modelling of rear piston

The rear piston is double acting type and the port two end is having pressure of 15 bar. This 15 bar pressure acts as damper which absorbs sudden shocks. The rear piston plays an important role during return stroke. During the return stroke compressed gas is supplied to return stroke which brings rear piston to original position. Due to synchronization between front and rear levers front piston also comes to original position and thus cycle completes. The following figure shows the model of rear piston.

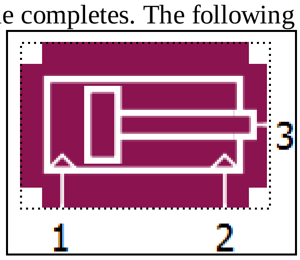
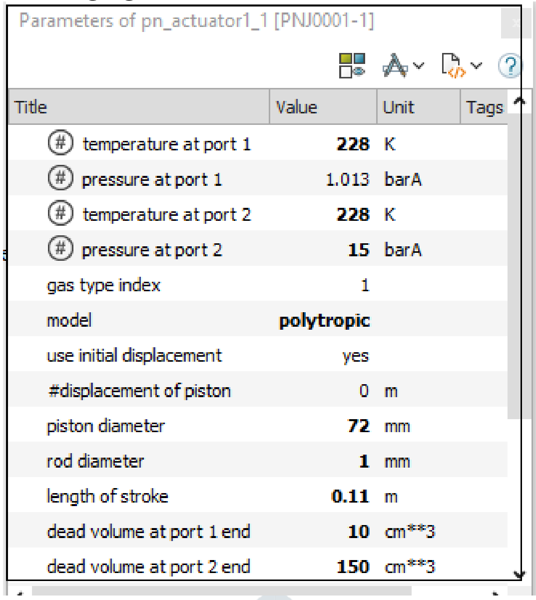


Fig. 7. AMESim model of rear piston

The inputs for rear piston are shown in following figure.



Parameters of pn_actuator1_1 [PNJ0001-1]

Title	Value	Unit	Tags
temperature at port 1	228	K	
pressure at port 1	1.013	barA	
temperature at port 2	228	K	
pressure at port 2	15	barA	
gas type index	1		
model	polytropic		
use initial displacement	yes		
#displacement of piston	0	m	
piston diameter	72	mm	
rod diameter	1	mm	
length of stroke	0.11	m	
dead volume at port 1 end	10	cm**3	
dead volume at port 2 end	150	cm**3	

Fig. 8. Parameters of rear piston

2 Modelling of total pneumatic system.

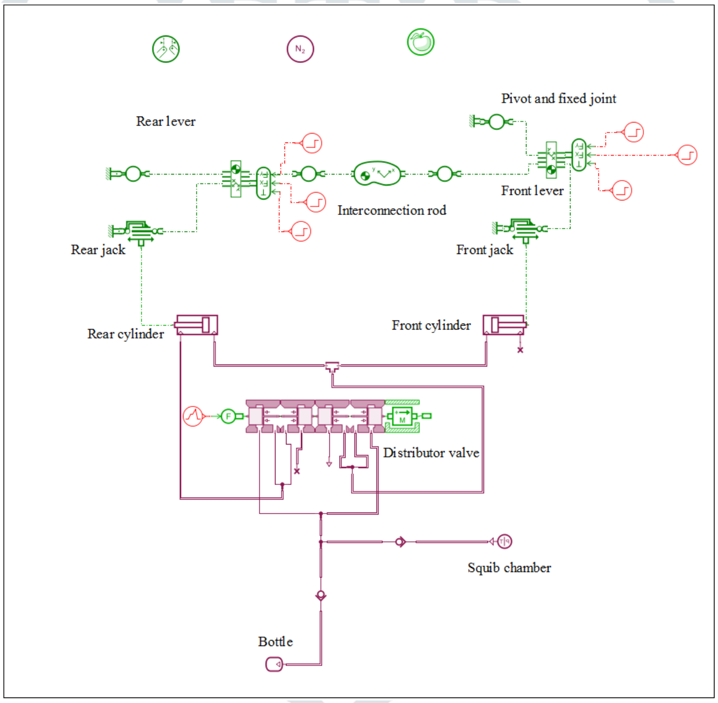


Fig. 9. AMESim model of pneumatic system

The above figure shows the complete modelling of system in AMESim software. The red part shows the pneumatic components of system and green part shows mechanical components of the system. In this front and rear cylinders are connected with each other by using planar mechanical elements.

II. SIMULATION OF PNEUMATIC SYSTEM

Simulation of the pneumatic is done using AMESim software. The major aim of the simulation is to determine the displacement of front and rear cylinders, pressure mass variation of gas inside the bottle, and extension and retraction time of the cylinders. The inputs for simulation are pressure and volume for the bottle and input current signal to actuate the direction control valve, both cylinders diameter, length of stroke and other parameters.

III. RESULTS AND DISCUSSION

- Bottle

First we will discuss the results of bottle. In this mass of gas, pressure inside the bottle are shown below

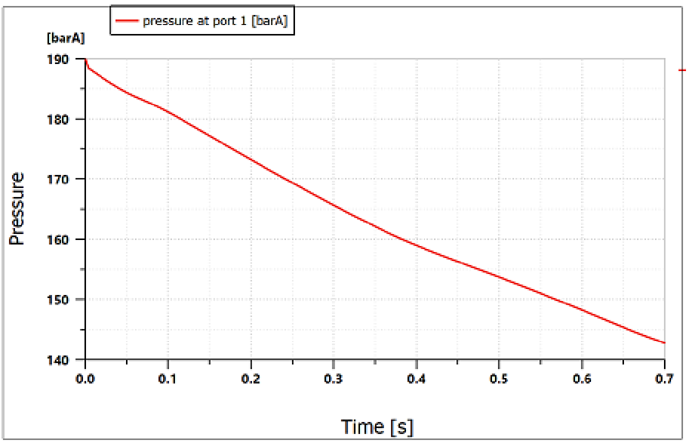


Fig. 10. Pressure variation in bottle

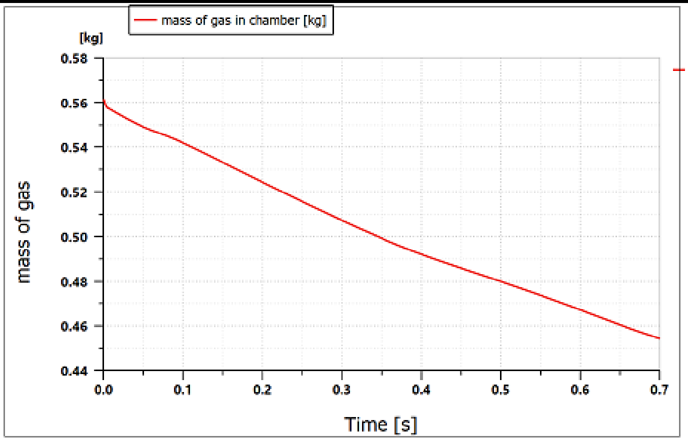


Fig. 11. Mass variation of gas in bottle

In the above graphs we can see pressure and mass of gas variation in bottle is almost linear. As the cycle starts the stored pressure and mass of the gas starts to flow into system and thus its starts decraesing. It follows linear curve because of ideal gas equation is linear one. The pressure at the start it is 190 bar and at the end it is about 144 bar. the massof gas at the stsrt is 0.561 kg and at the end it is 0.45 Kg.

- Front cylinder

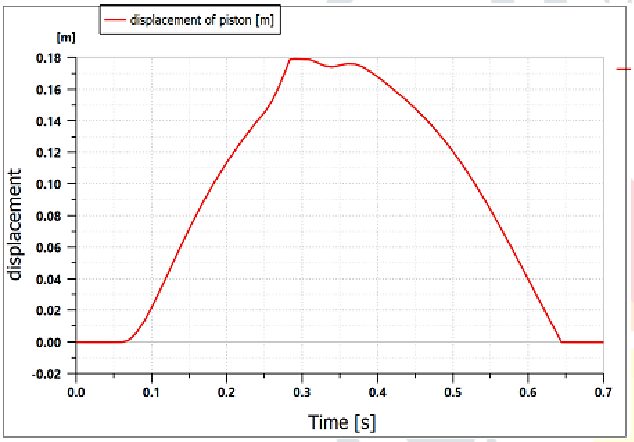


Fig. 12. displacement of front piston

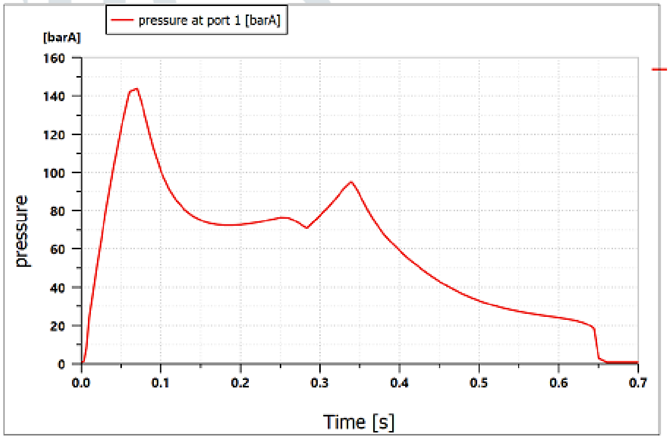


Fig. 13. Pressure variation inside the front cylinder

The above graph shows the displacement and pressure variation of gas inside the cylinder of the front piston. The total displacement of front piston is 181 mm. In the displacement graph the displacement is almost zero until 0.09 sec because of that much time is required to gas to fill the dead volume inside the cylinder. After that gas starts to exert pressure on piston and piston displacement starts about 0.28 sec piston reaches at its final position. After 0.3 sec signal to directional control valve is reversed but still after that retraction of piston is not started. This is because a time of 0.03 sec is required to change the position of spools of control valve and after 0.32-0.34 sec piston reached to its original position.

The same nature is for pressure variation. Maximum pressure reached inside the cylinder is about 141 bar and this drop is because of pressure drop in control valve and piping. At the start of cycle piston is stationary so pressure is high and after the displacement starts pressurized gas starts to expand in cavity of cylinder thus pressure drops. After 0.3 sec when signal is reversed again pressure starts to develop because of decrease in cavity volume.

- Rear piston

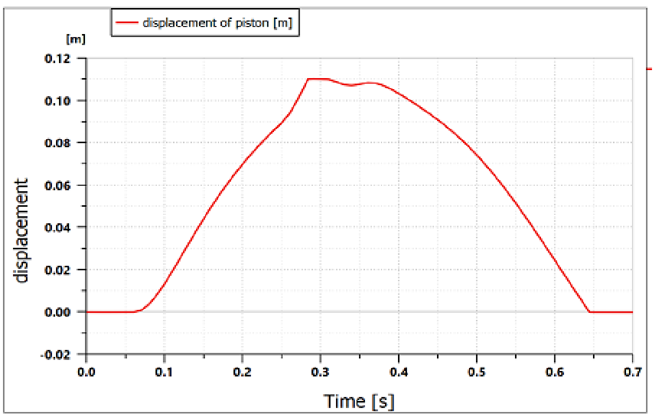


Fig. 14. Displaaceament of rear piston

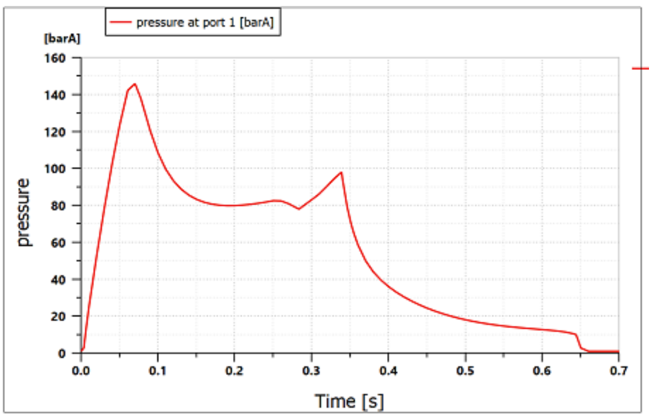


Fig. 15. Pressure variation in rear cylinder-forward stroke

As the front and rear pistons are in synchronisation the nature of graph of rear psiton is as same as front piston. The main difference is displacement of piston which is 110 mm in rear one. The pressure variation shown in figure is for forward stroke of rear piston. The pressure variaton is exactly same as front piston because we have divided flow of gas between two cylinders, so both pistons are in parallel connection and thus having same pressure variation.

VI. CONCLUSION

In this paper each element of pneumatic system of launcher is modeled and simulated individually and are successfully integrated to model complete pneumatic system using AMESim software. The integrated system is successfully simulated under normal conditions to analyze and determine pressure, displacement of cylinders and mass of gas inside the bottle. Also mechanical and pneumatic system is successfully integrated so as to achieve synchronization between tow cylinders. The mathematical calculations are done for bottle parameters. The AMESim model of pneumatic system can be further used for troubleshooting and fault diagnosis purpose.

VII. Acknowledgment

This work was carried out as part of an M. Tech. Dissertation, at the Department of Mechanical Engineering, Walchand College Engineering Sangli, under the sponsorship from Hindustan Aeronautics Limited (HAL), Nasik. Authors wish to thank HAL (AURDC), Nasik for the support to this work.

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