APISAT 2019

2019 ASIA PACIFIC INTERNATIONAL SYMPOSIUM ON AEROSPACE TECHNOLOGY

SURFERS PARADISE MARRIOTT RESORT, GOLD COAST
4 – 6 DECEMBER 2019

ENGINEERS AUSTRALIA

APISAT 2019

Aerospace Systems Design I

Wei Chenhao

Optimization of an Oleo-pneumatic Shock Absorber Suitable for Subscale Aircraft

ENGINEERS AUSTRALIA

ROYAL AERONAUTICAL SOCIETY
AUSTRALIAN DIVISION

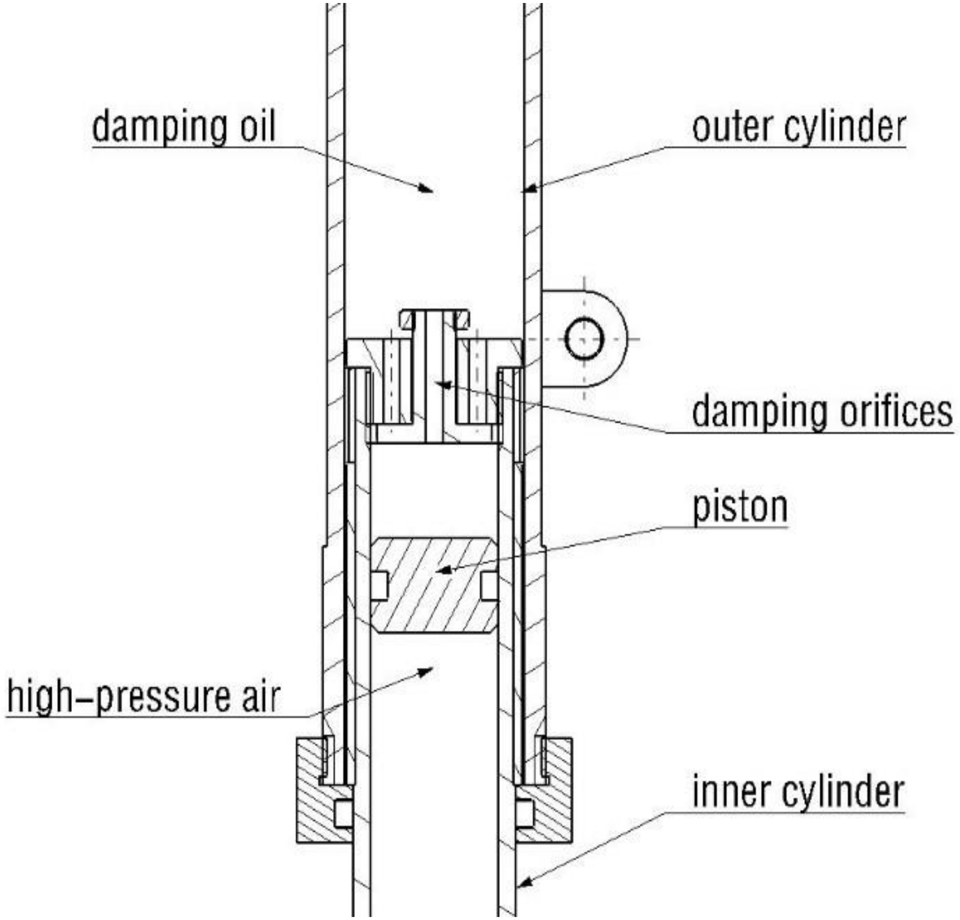
Background

- Types of shock absorbers
  - Using a solid spring
  - Using a fluid spring
  - Using a mixture of those two
- Compared with other types of shock absorbers, the oleo-pneumatic shock absorber is considered to be the most effective
- The oleo-pneumatic shock absorber is usually used on the landing gears of large aircrafts.

Background

- Difficulties for using oleo-pneumatic shock absorbers on subscale aircrafts:
  - Limit of system complexity
  - Demand of weight controlling
  - High cost
- A new form of oleo-pneumatic shock absorber is designed.
- It is miniaturized and can be used on 100Kg-class subscale aircraft.

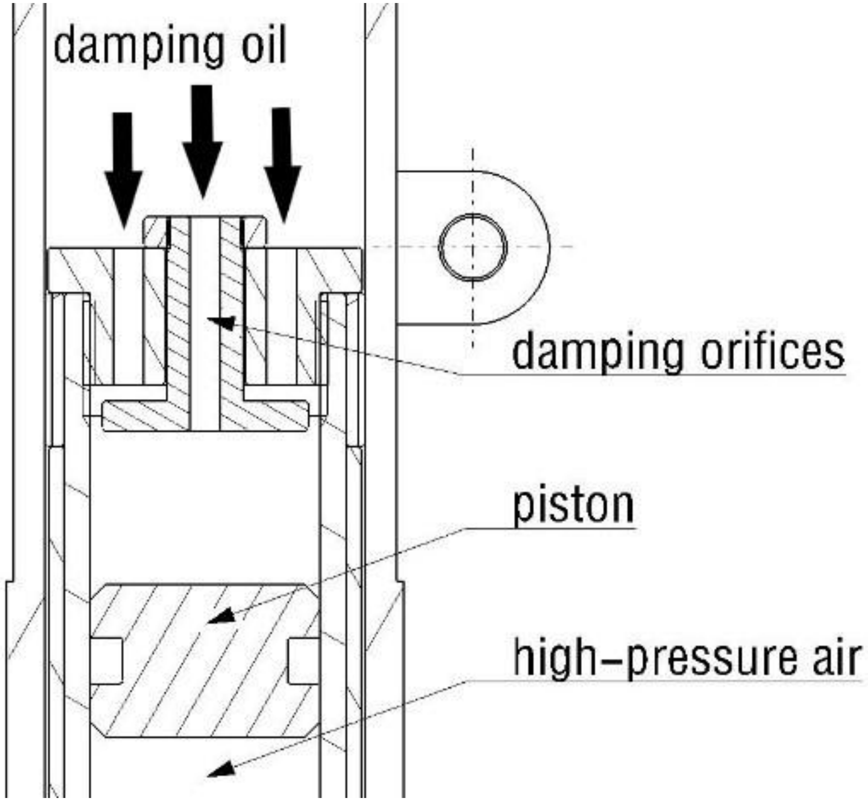
Description of the new-designed shock absorber



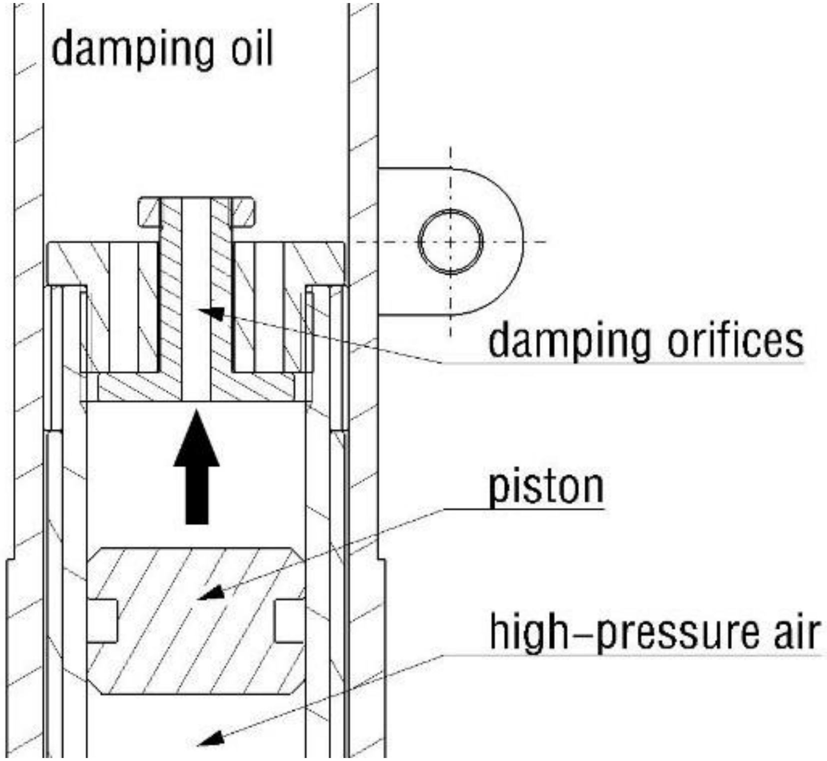
- The oil and the air is separated by the piston in the inner cylinder.
- The piston can reciprocate inside the inner cylinder.
- The number of available damping orifices is different in the dropping process.

Description of the new-designed shock absorber

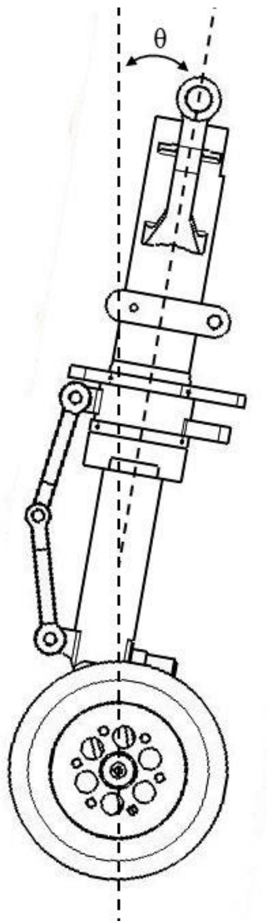
Detailed view of the damping orifice at compressed stage



Detailed view of the damping orifice at spring back stage

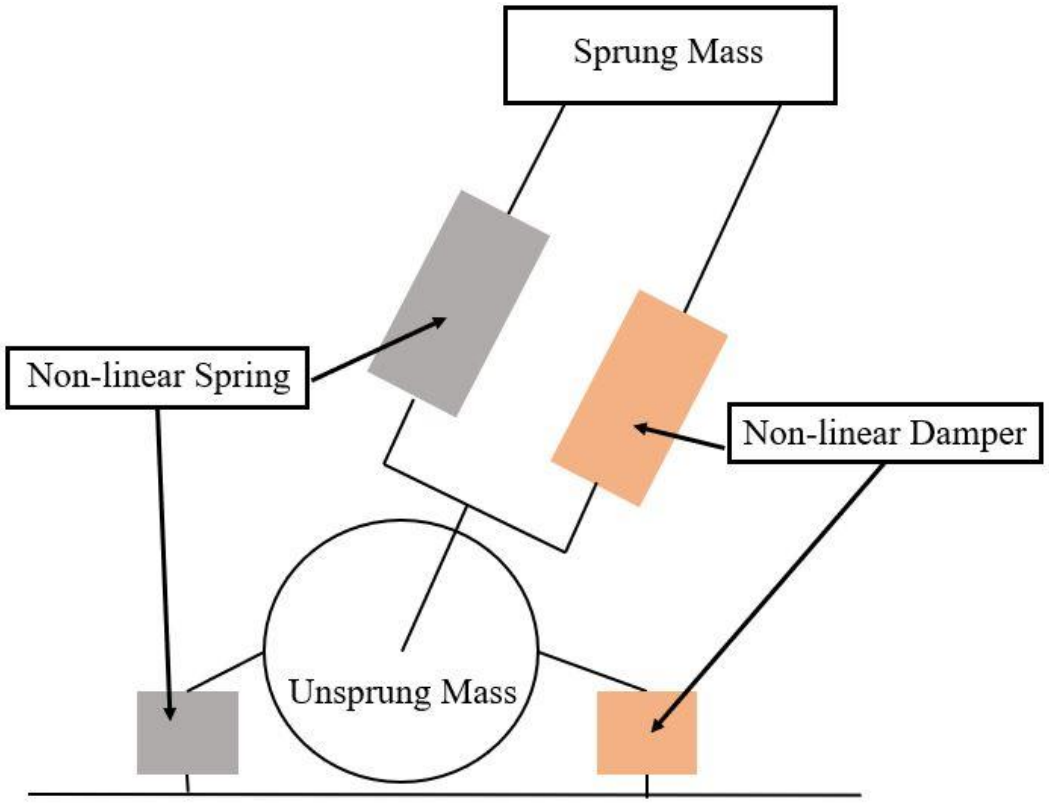


Modeling of the study object



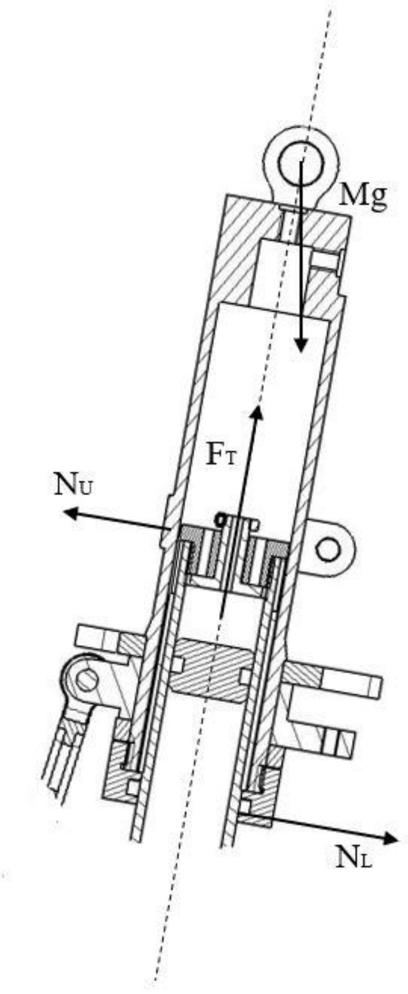
- The new-designed shock absorber is used in the nose landing gear of a 100KG-class aircraft.
- The nose landing gear system can be converted into a spring-mass-damper system.

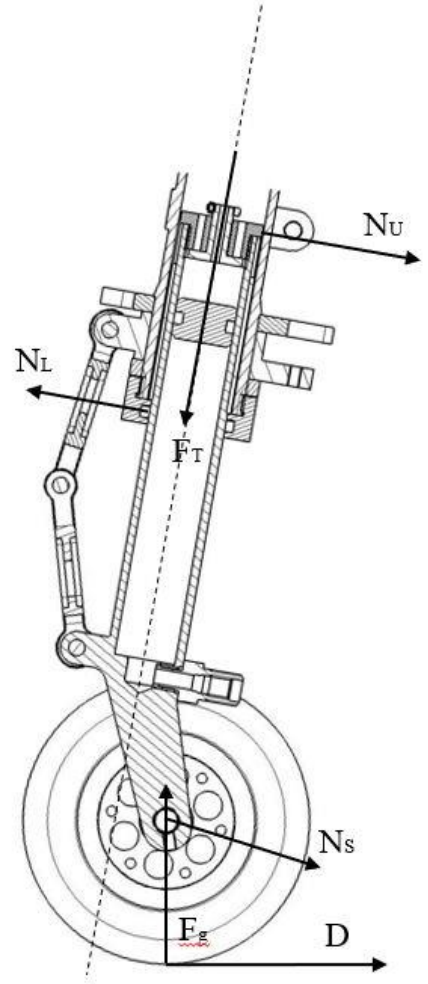
Modeling of the study object



- The system consists of non-linear spring and nonlinear damper.
- Sprung mass:
  - The mass of the aircraft and the upper part of the nose landing gear
- Unsprung mass:
  - The mass of the lower part of the nose landing gear and the wheels

Modeling of the study object





- The displacement of sprung mass:

$$Mg - F_T \cdot \cos\theta + N_s \cos\theta = M\ddot{Z}_1$$

- The shifting of unsprung mass:

$$mg + F_T \cdot \cos\theta - N_s \cos\theta - F_g = m\ddot{Z}_2$$

- The stroke of the absorber:

$$S = \frac{Z_1 - Z_2}{\cos\theta}$$

Modeling of the study object

- The total axis force on the landing gear: $$F_T = F_h + F_a$$

- Air pressure force: $$F_a = A_a [p_0 (\frac{V_0}{V_0 - A_a s})^{\gamma} - p_{atm}]$$

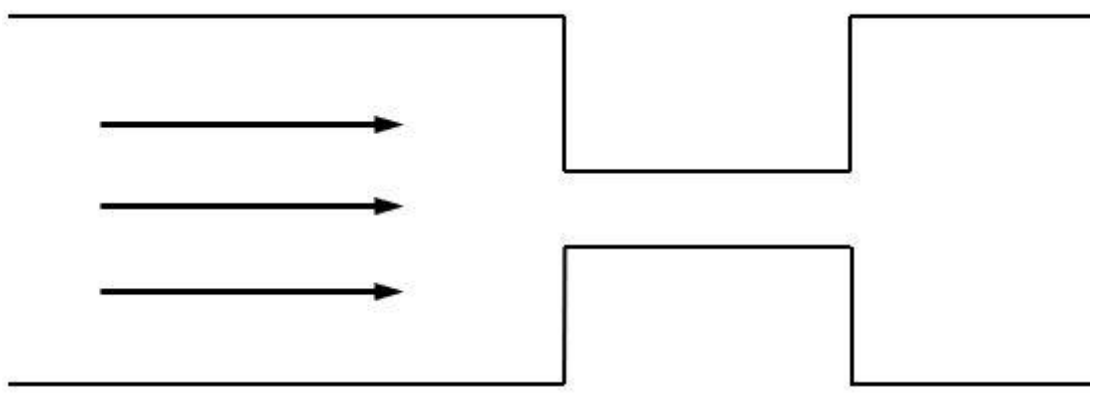
- Fluid damping force: $$F_h = \frac{\rho A_o^3}{2(C_d A_h)^2} \dot{u}^2$$

- C_d is the discharge coefficient and its value comes from previous experiments.

Modeling of the study object

- The above equations may be unsuitable for the new-designed shock absorber:
  - The special design of the damping orifices and the dimension of the absorber makes the method estimating C_d different
  - The area of orifices in both compressed stage and spring back stage are different
- In formula of fluid damping force, C_d is the factor that needs to be modified

Modeling of the study object



$$\xi = \xi_c + \xi_p + \xi_0$$

- The discharge coefficient can be estimated:

$$C_d = \frac{1}{1+\xi}$$

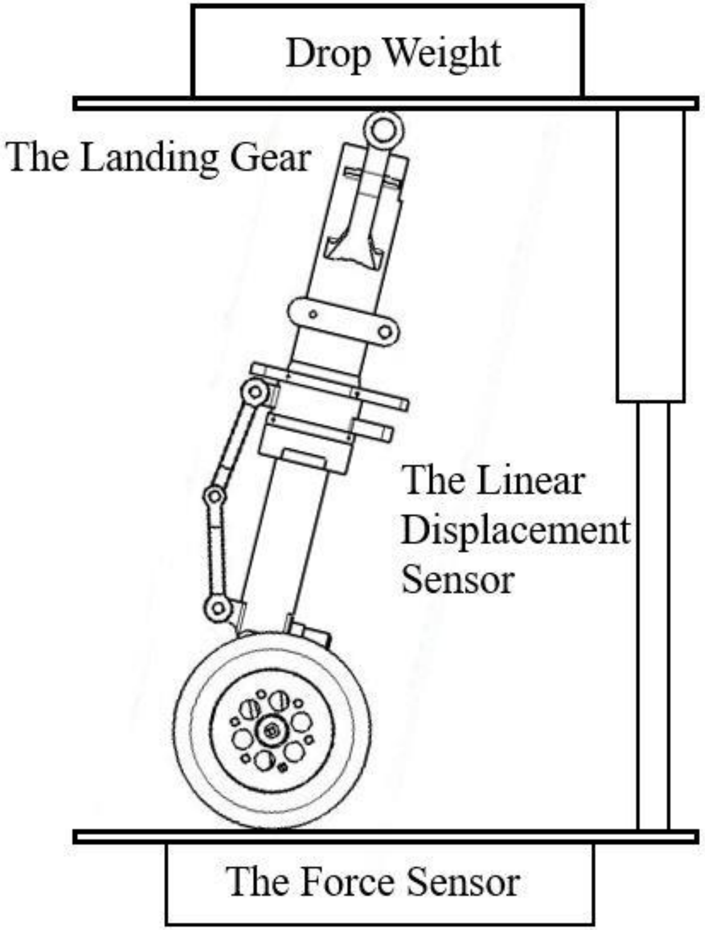
- ξ can be obtained through experiments for different structures
- The damping orifices can be simplified to a pipeline, which has sharp changes in its cross section.

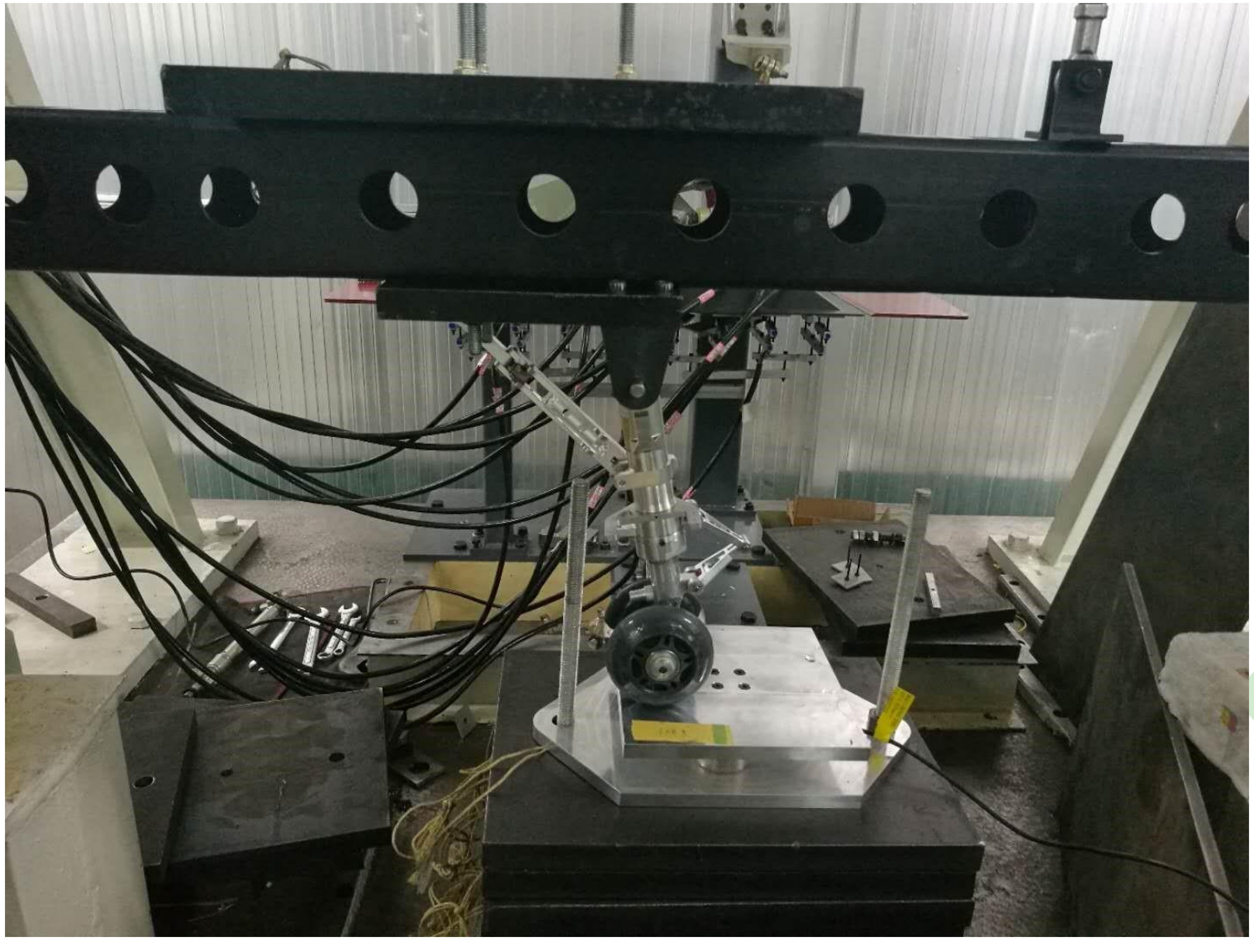
Modeling of the study object

- On the above basis, Matlab / Simulink is used to simulate the landing process.
- The Simulink model is divided into two parts that are used to calculate the velocities and the displacements of sprung mass and unsprung mass.

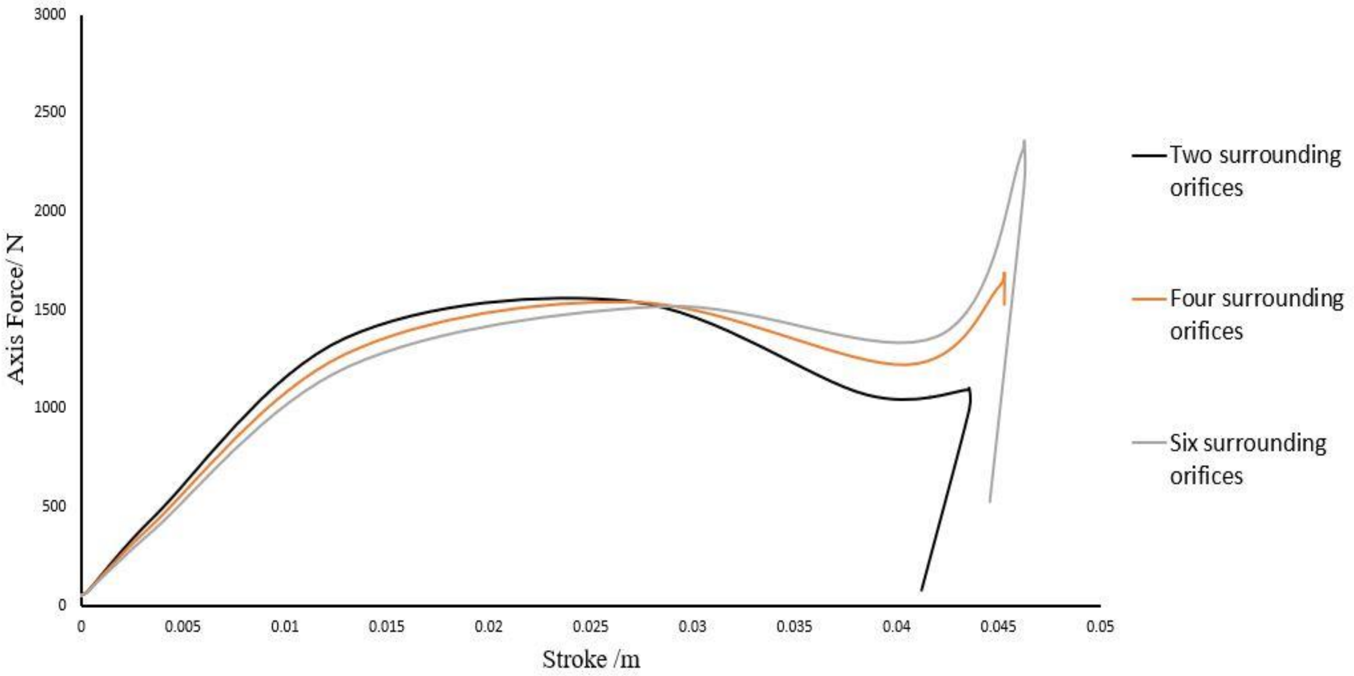
Parameters	Values
Section area of outer cylinder	$3.4 \times 10^{-4}\ m^2$
Section area of inner cylinder	$1.7 \times 10^{-4}\ m^2$
Diameter of the damping orifice	$2.0 \times 10^{-3}\ m$
Initial volume of inner cylinder	$1.7 \times 10^{-5}\ m^3$
Polytropic exponent	1.3
Initial air pressure in inner cylinder	$4.0 \times 10^{5}\ Pa$
Density of damping oil	$900\ kg/m^3$

Drop test


Drop Weight
The Landing Gear
The Linear
Displacement
Sensor
The Force Sensor

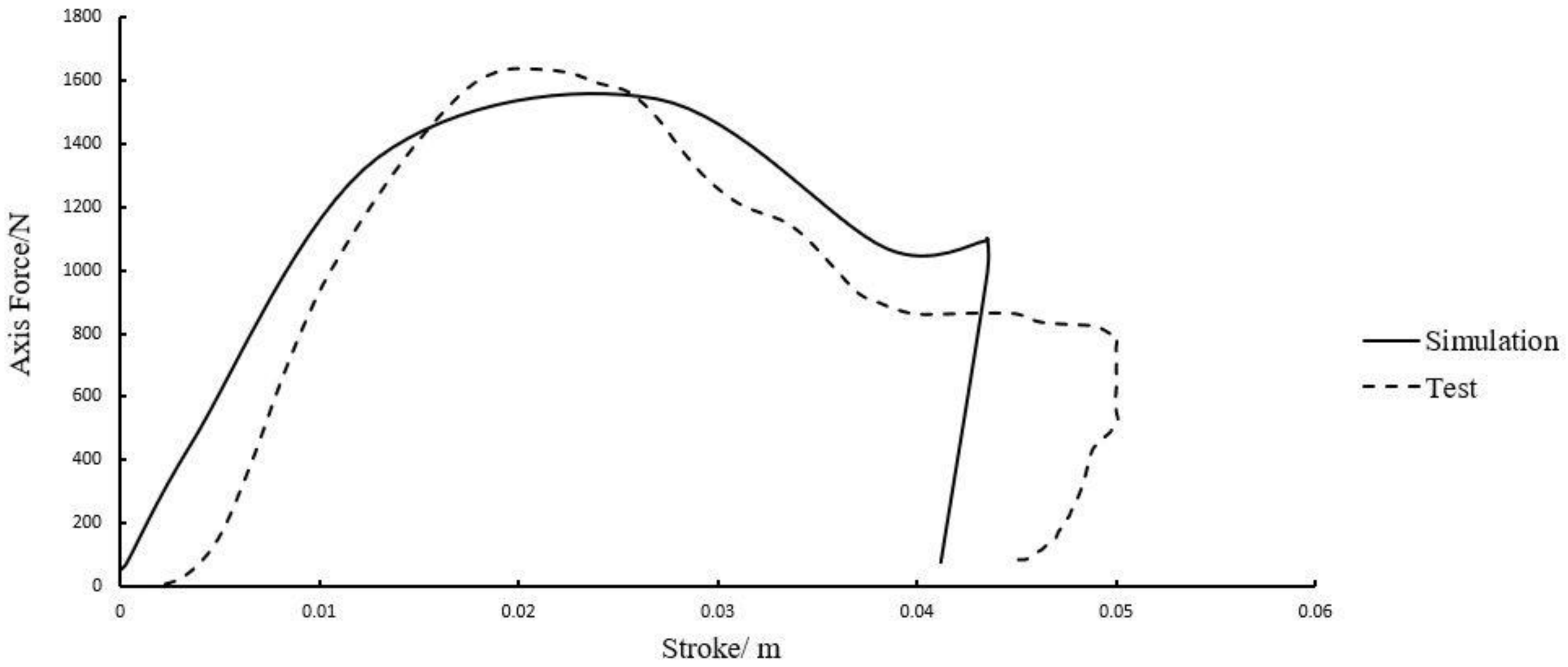


Results analysis

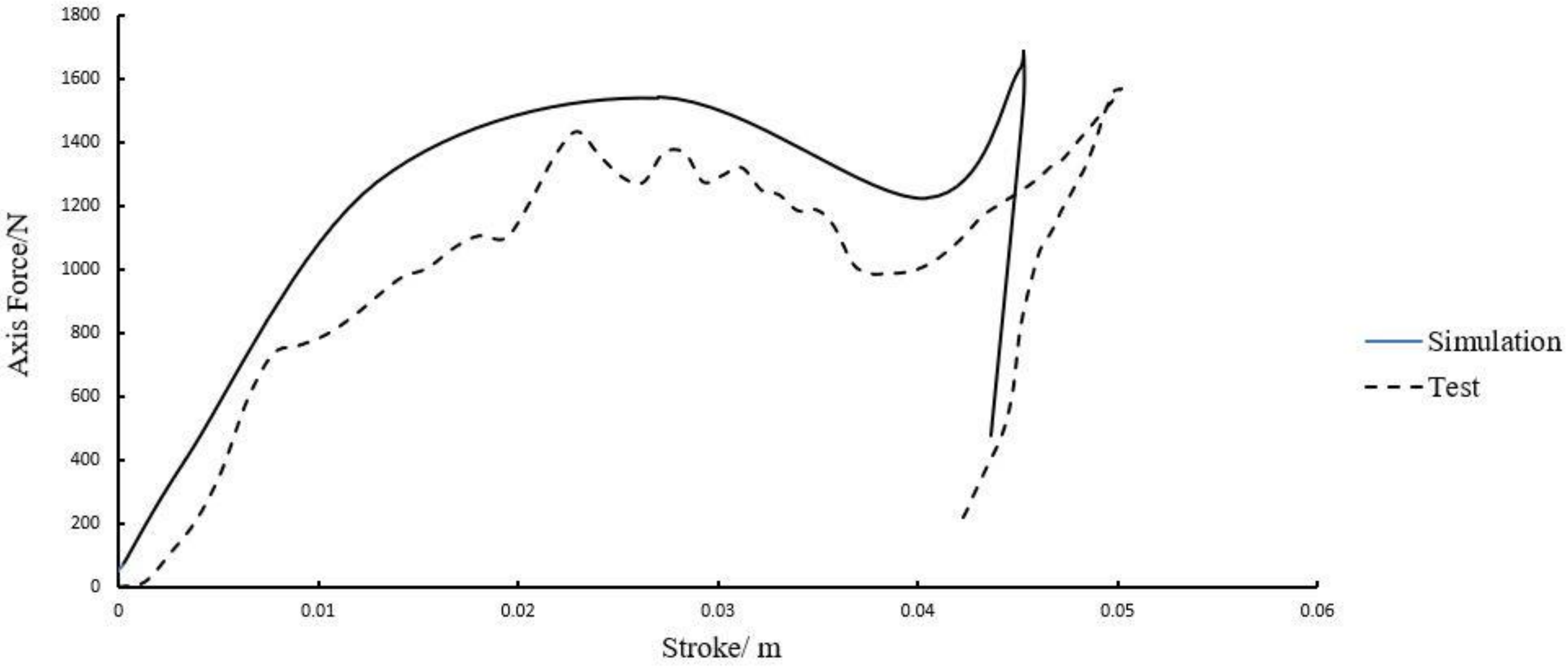


- The absorber with six surrounding orifices has the longest stroke through all three tested absorbers
- The absorber with two surrounding orifices has the highest efficiency through the three forms of absorbers in the drop tests

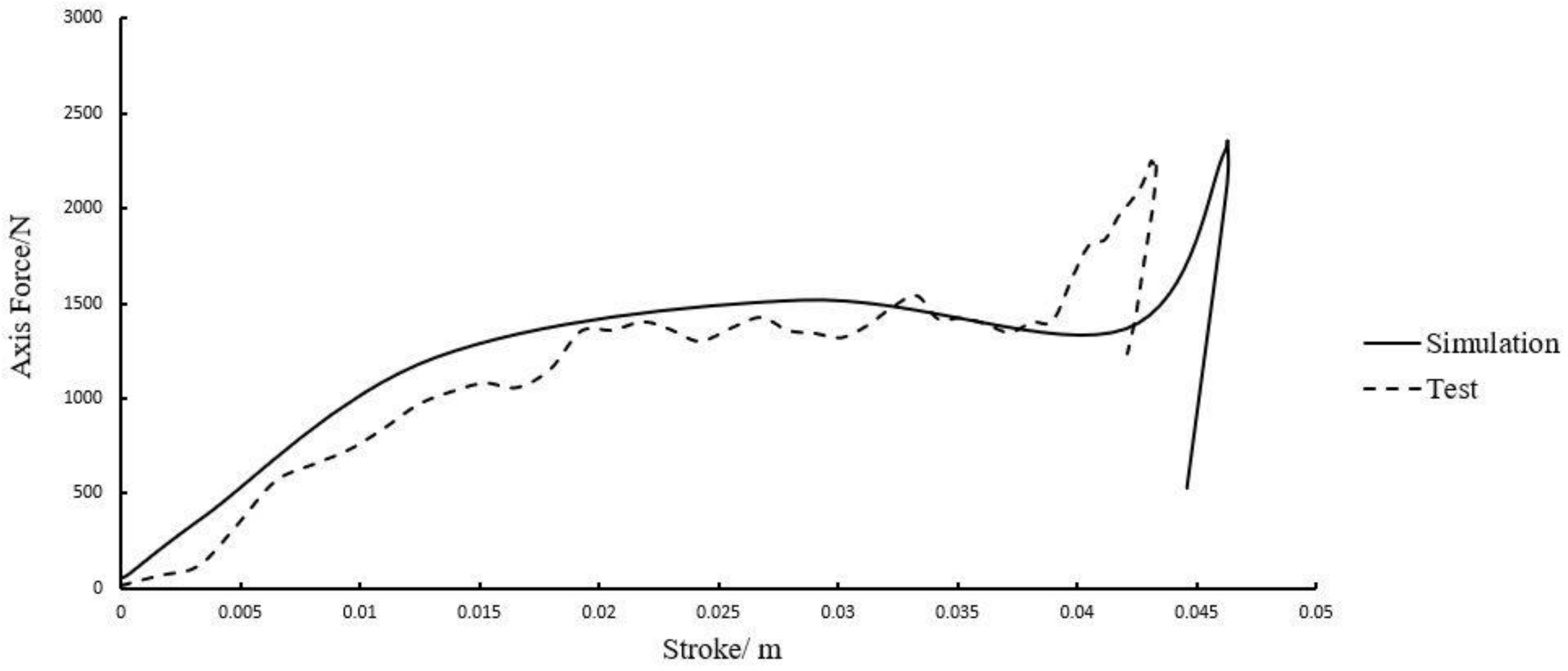
Results analysis



Results analysis



Results analysis



Conclusion

- A new form of oleo-pneumatic shock absorber is designed and its dynamic model is established.
- Dropping process of the shock absorber is simulated and performed.
- The results show that under the designed working condition the absorber with two surrounding orifices has the highest efficiency.

Next plans

- Improve the drop test devices.
  - Improve the measurement accuracy of the linear displacement sensor
  - Improve the sampling frequency of the force sensor
- Change the diameter of surrounding orifices, optimize the drop performance of shock absorber within a wider ratio of surrounding orifice area to central orifice area.

END

Thanks for listening

Questions?

APISAT 2019

ENGINEERS AUSTRALIA

ROYAL AERONAUTICAL SOCIETY AUSTRALIAN DIVISION