

Analysis on Stress Distribution of the Piston Rod and the Bush while Cylinder Impact

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Abstract: The repeated movement between the piston rod and the barrel during the process of cylinder impact will lead to leak and shorten the life of the cylinder. In order to research the distribution of dynamic stress and deformation of the piston rod and the bush when the piston rod suddenly stops at the end of the cylinder with different speeds and different loads, it's necessary to analysis the system by the model simulation. This paper mainly discusses the condition that cylinder works with the load of 50~100N, the piston rod speeds of 500~1000mm/s by using the transient kinetic module of ANSYS/workbench. Simulation results show that higher speed or heavy load will cause the significantly increased stress suffered by the various parts of the system and its deformation is relatively obvious.

Introduction

Research background

Nowadays, Cylinder is widely used in various fields and plays an important role in industrial production, So it's of great practical significance to effectively improve cylinder's life and efficiency^[1]. The repeated impact between the piston rod and the barrel will lead to leak and wear, which may result in leak and shorten the life of the cylinder, so have a deep study of the stress distribution and deformation condition is very important. The static effect between the piston rod and the bush was already calculated, but the dynamic stress produced when the piston rod suddenly stops at the end of the cylinder has not been studied, Therefore, It's needed to make a further study.

This paper mainly focuses on the distribution of stress when the piston impact on the end of the cylinder. The velocity of piston, lateral load on the piston rod, the space between the piston rod and bush are major factors, so it's necessary to study the stress distribution with these different factors.

Research methods

The paper use simulation system to study the stress distribution in cylinder impact, and the model analysis is carried on ANSYS/Workbench, which is widely used. Specific research programs include:

- (1) According to the actual situation, establish the entity model of cylinder in ANSYS/workbench;
- (2) Analysis cylinder modal in the transient dynamics of ANSYS/workbench ;
- (3) Setting boundary conditions according to the objective requirements, find the optimal boundary condition that closest to the actual situation;
- (4) Analysis the cylinder under different load, different speeds;

(5) Post processing in ANSYS/workbench, observing the stress distribution, deformation, and analyzing the results ^[2].

Introduced model

Model

The cylinder model that currently used is a simplified model, all the cylinder include cylinder tube, piston rod, bush, sealing ring, piston, end cover and so on, the diameter is 32mm, stroke is 0.1m, the space between the piston rod and bush is 0.06mm, the cylinder mode is shown in the figure below.

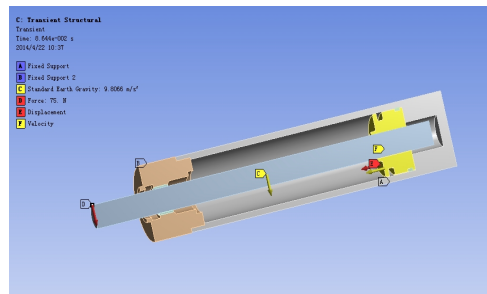


Fig.1 The 3D model of cylinder

Contact set

The model consists of seven contact surfaces, The figure below is the definition of contact type.

Table 1 Definition of contact type.

Contact element	Contact type
end cover—bush	Bonded
end cover—cylinder tube	Bonded
bush—piston rod	Frictionless
piston rod—piston	Bonded
piston—sealing ring	Bonded
piston—cylinder tube	Frictionless
sealing ring—cylinder tube	Frictionless

Mesh

The mesh quality can directly affect the calculation results, so the more detailed the better, firstly the mesh size is set to 0.005m, secondly using the partition refinement mesh, because the cylinder model is 3D model, so the mesh is divided automatically, the mesh is mostly constituted with hexahedral, In some uneven part may have some tetrahedron. After that the number of cells and the number of nodes increases obviously, which helps to improve the quality of mesh. In order to improve the impact accuracy, reduces the mesh size in the piston and the end cover^[3], mesh shown in the below figure:

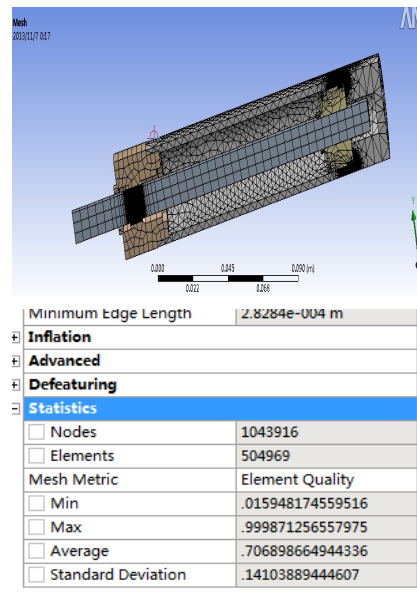


Fig.2 Mesh of the system

Earth gravity set

By adding standard earth gravity, and date of each component's size, computer can calculate the volume of the piston rod and the piston, and load the element of gravity to the system, which makes the system more close to the actual situation^{[4][5]}.

Simulation analysis

The simulation results under different impact velocities

The study use 1000mm/s, 500mm/s two different speed load to simulate the impact situation with different velocity that between cylinder piston and piston rod, the load is set at 0N, the space of bush and piston rod is 0.06mm, study on the stress distribution that influenced by different impact speed, and carries on the contrast.

The stress distribution under 1000mm/s

Setting the velocity at 1000mm/s. Cylinder stroke in the model is 100mm, the solution time is set to 0.1s. The relationship curve of speed and time is shown blow. The impact solution on the bush shown in figure 3.

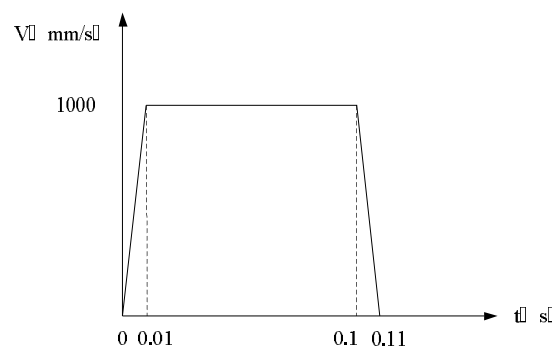


Fig.3 The relationship curve of speed and time under 1000mm/s

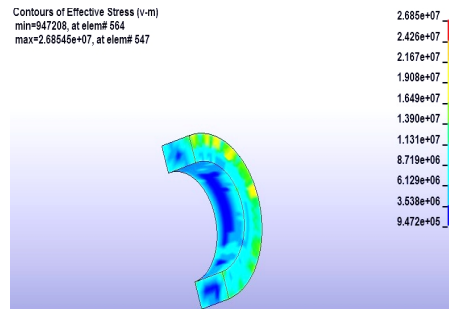


Fig.4 Stress distribution on bush when impact occur under 1000mm/s

In the first moment of collision, the stress mostly concentrate the on inner surface of bush, the maximum stress is 10MPa. It can be seen from Figure 4 that , when a collision occurs, the stress on the piston rod and bush occur surge, and the bushing stress distribution changes, It mostly occur on the posterior surface of bush. and the maximum stress is 27MPa.

The stress distribution under 500mm/s

In order to compare the simulation result with the condition of 1000mm/s, there also showed the stress distribution of 500mm/s.

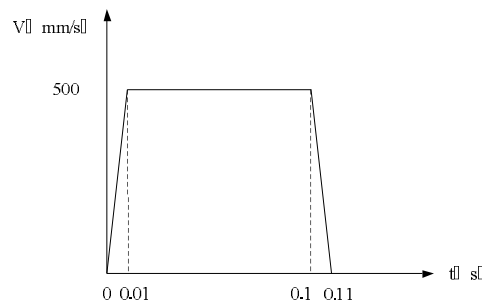


Fig.5 The relationship curve of speed and time under 500mm/s

The stress distribution is shown as blow.

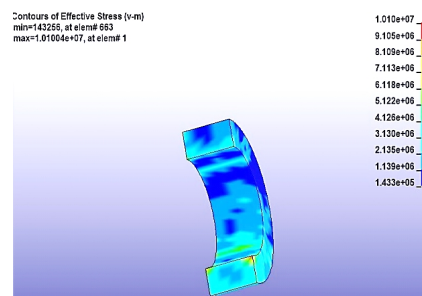


Fig.6 Stress distribution on bush when impact occur under 500mm/s

In the first moment of collision, the stress is also mostly concentrate the on inner surface of bush, the maximum stress is 8.7MPa . It can be seen from Figure 6 that, maximum stress is 10MPa.

The study above shows that under different speed the stress distribution on the bush is similar, but under 1000mm/s the stress is larger than the 500mm/s situation. So a higher speed will produce a larger stress.

The simulation results with different load

After setting up the simulation conditions, the load is set at 75N and 100N on the top of the bush, the space of bush and piston rod is 0.06mm, the velocity set at 1000mm/s, study on the stress distribution that influenced by different load, and carries on the contrast.

The stress distribution with 75N

The paper mainly study on the stress distribution of bush and piston rod, so there we respectively intercept three moment on the impact process to observe the stress distribution of them. As it can be see from the blow figures, with the continuous movement of the piston rod, the stress of bush increases, at the same time, stress of the piston rod is becoming larger and larger.

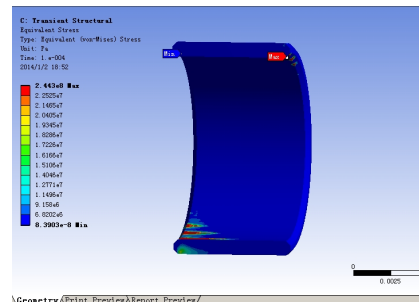


Fig.7 The initial time of bush with 75N load

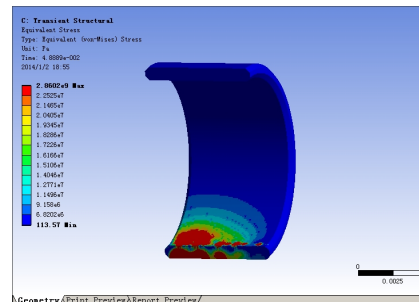


Fig.8 The middle time of bush with 75N load

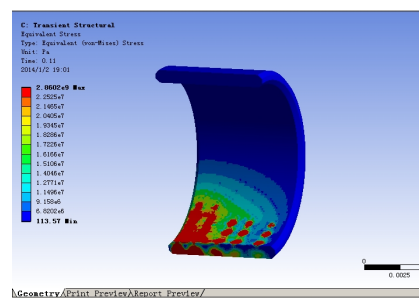


Fig.9 The impact time of bush with 75N load

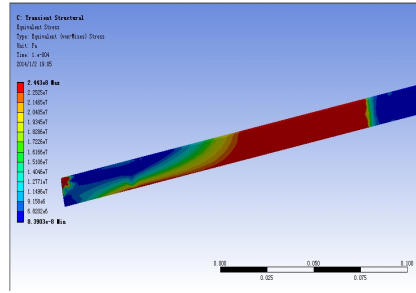


Fig.10 The initial time of piston rod with 75N load

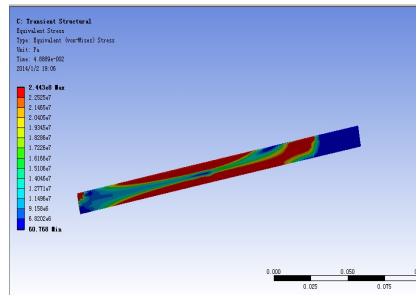


Fig.11 The initial time of piston rod with 75N load

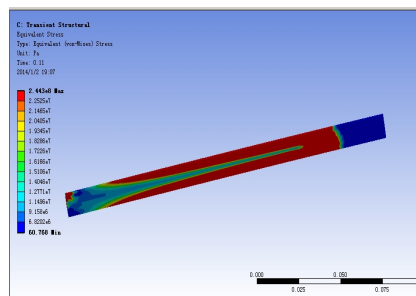


Fig.12 The initial time of piston rod with 75N load

Below is the description of the bush and piston rod, The figure 11 show that, when load is 75N, the maximum description of bush along the vertical direction is 1.04×10^{-5} m, the maximum description of piston rod is 9.60×10^{-4} m.

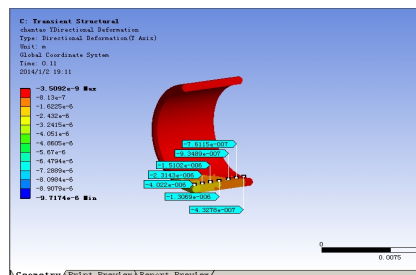


Fig.13 The description of bush with 75N load

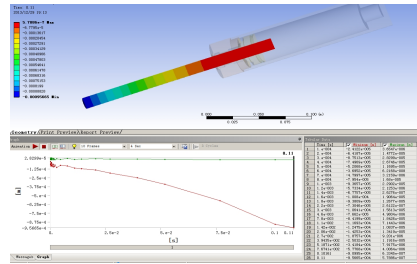


Fig.14 The description of piston rod with 75N load

The stress distribution with 100N

Under the load of 100N, the stress distribution is similar to 75N, but it is larger. As below also respectively intercept three moment on the impact process to observe the stress distribution of the bush and piston rod.

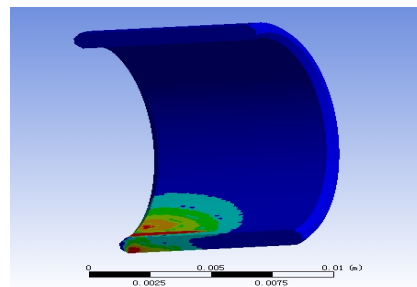


Fig.15 The initial time of bush with 100N load

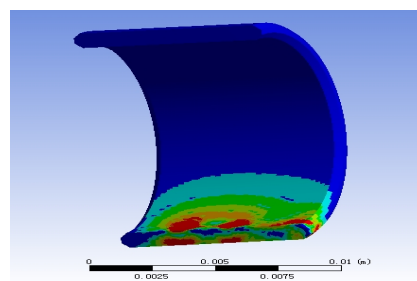


Fig.16 The middle time of bush with 100N load

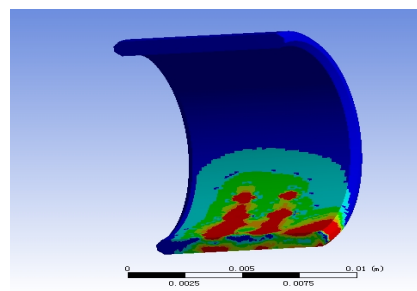


Fig.17 The impact time of bush with 100N load

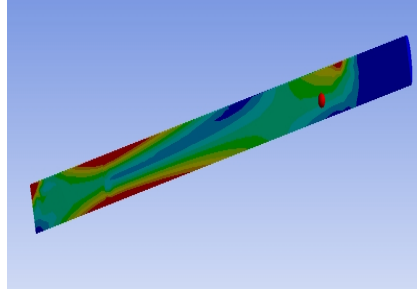


Fig.18 The initial time of piston rod with 100N load

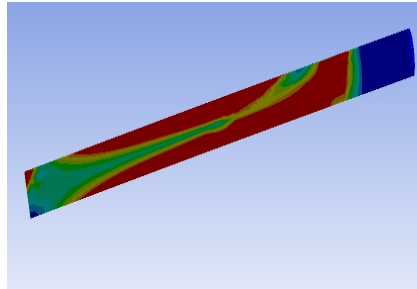


Fig.19 The initial time of piston rod with 100N load

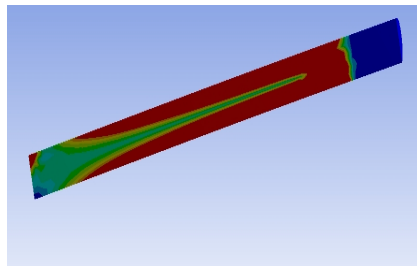


Fig.20 The initial time of piston rod with 100N load

Below is the description of the bush and piston rod, figure 18 show that, when load is 100N, the maximum description of bush along the vertical direction is 2.40×10^{-5} m, the maximum description of piston rod is 1.30×10^{-3} m.

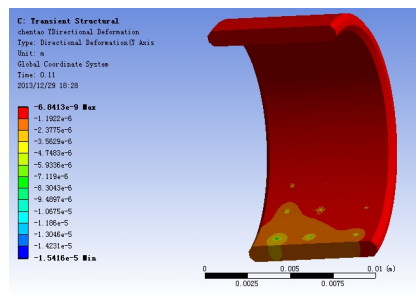


Fig.21 The description of bush with 100N load

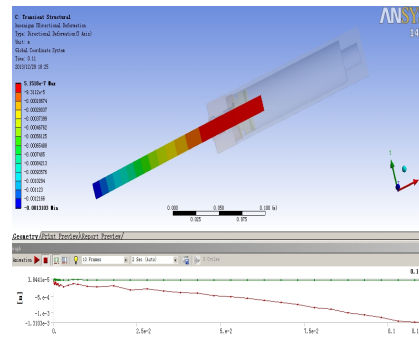


Fig.22 The description of bush piston rod with 100N load

The study above show that with different load the stress distribution on the bush is similar, but with 100N load the stress is larger than the 75N situation. The description is also more obvious, so a larger load will produce a larger stress and larger description.

Conclusion

The paper mainly analysis the distribution of dynamic stress and deformation of the piston rod and the bush when the piston rod suddenly stops at the end of the cylinder with different speeds and different loads, based on the above analysis, the stress distribution under different speed or different load is similar, the maximum stress increases with the speed increases and so to the load. And the values of maximum stress surged when the piston impact end cover, surged amplitude is also increases with the speed or load increases. so if people can be careful with the speed and load, it would effectively reduce wear and lengthen the life of cylinder.

References

- [1] Birong Liu, Stress analysis of small diesel engine crankshaft based on ANSYS, Tractor & Farm Transporter, 2004, 3, pp.30-33.
- [2] Zhixing Huang, Chengzhu Liu, ANSYS Workbench14.0 super learning manual, People's Posts and Telecommunications Press, 2013.
- [3] Silva FS, Fatigue on engine pistons: a compendium of case studies [J]. Engineering Failure Analysis , 2006, 13, pp.480-492 .
- [4] Xiaoli Yu, Yajiao Wu , Rui Huang, et al. CFD calculation and analysis of cooling jacket flow and heat transfer for car engine [J] . Vehicle Engine, 2010, 3, pp.50 -55 .
- [5] Wu Yi , Tang Lan, Temperature field analysis of engine heated parts based on finite element method, journal of jiangsu university, 2012, 33-6, pp.638-642.