Investigation on Premature Failure of the Self-lubricated Piston Rings in Oil-free Compressor

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Contents

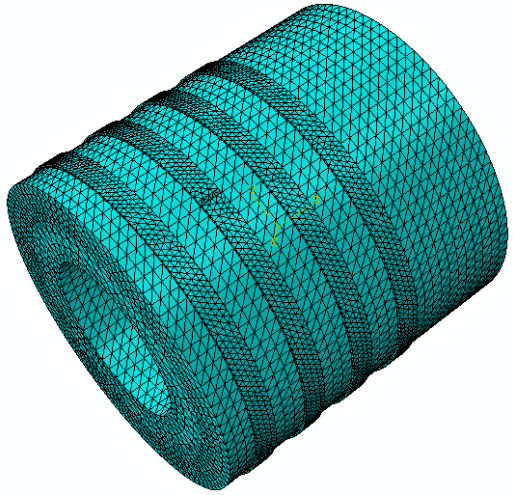
- Research background
- FEM model of piston and piston rings studied
- Mathematical model of pressure distribution
- Experimental set-up
- Comparison with numerical simulation results
- Results and discussion
- Conclusions

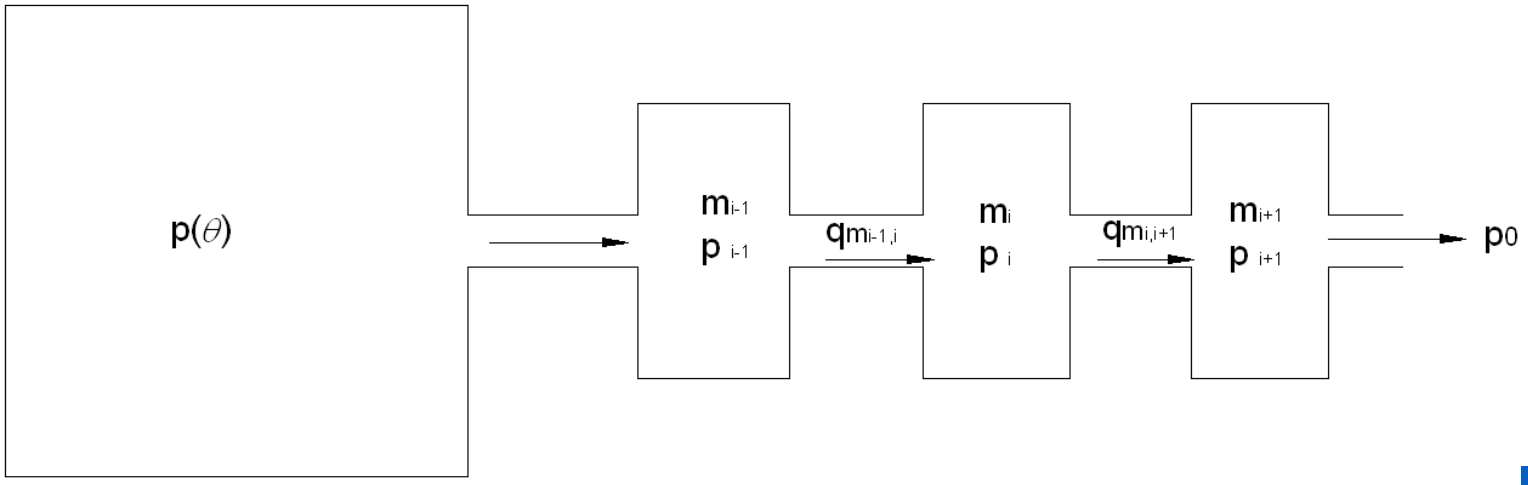
Research background

- oil-free compressors are used widely
  - self-lubricated piston rings are the key parts
  - pressure distribution and wear of piston rings
- piston rings life-span determines the compressor reliability
  - certain piston rings fail in advance
- investigation of the impact factors on premature failure of piston rings is necessary
  - pressure loads on piston rings
  - frictional heat and temperature distribution on frictional pairs
- focus on indicating the pressure load and temperature distribution on self-lubricated piston rings based on numerical simulation and verification experiment

FEM model and mathematical model

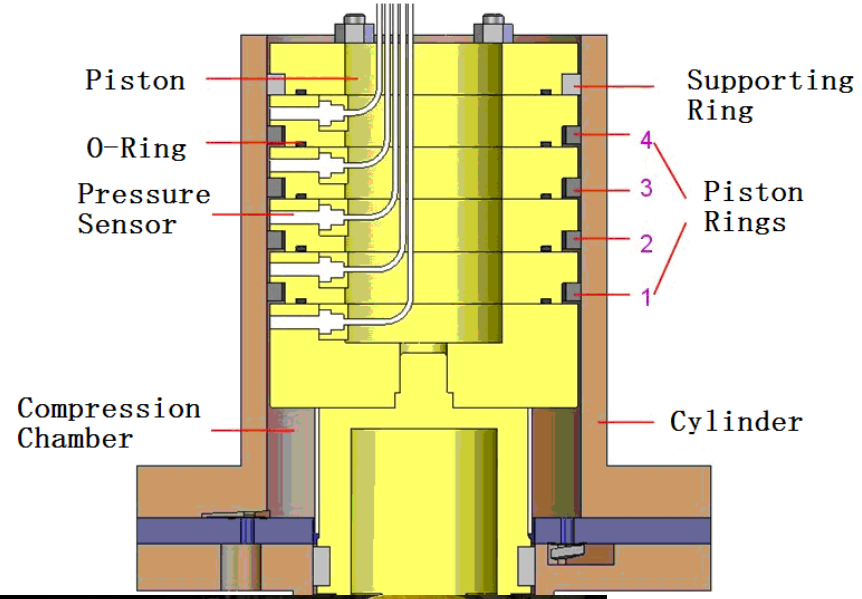
- 4 piston rings and the piston
  - speed 1500r·min-1
  - piston Aluminum Alloy
  - piston rings PTFE





Experimental set-up

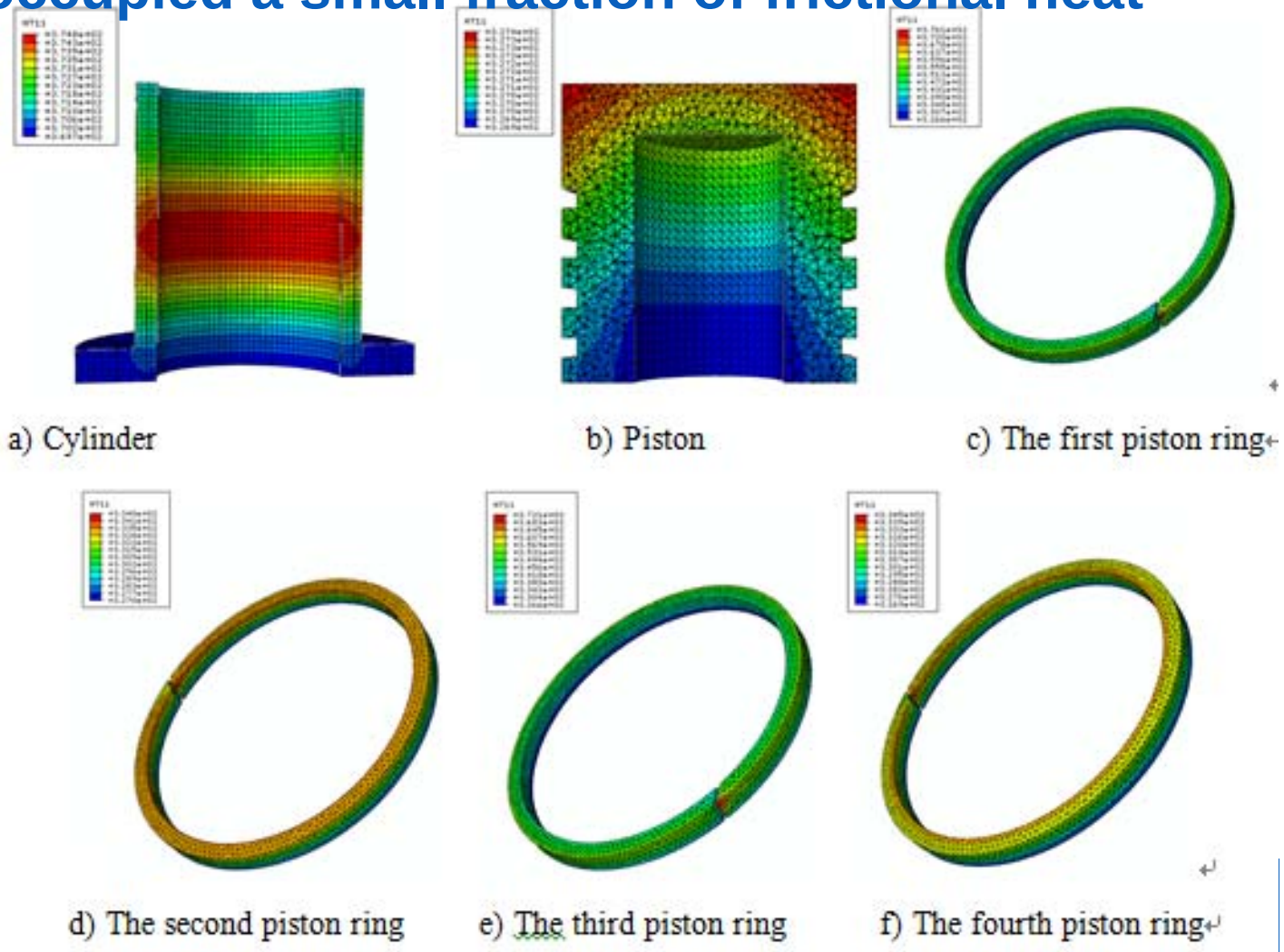
- integrated piston



conditions	PTFE	Victrex-450GL30	Victrex-450CA30
Friction coefficient	0.1	0.16	**0.26**
density/kg·m-3	2200	1510	**1410**
Specific heat/J·(kg·K)-1	1000	1700	**1800**
thermal conductivity coefficient /W·(m·K)-1	**0.25**	**0.43**	**0.92**

Temperature distribution

- highest temperature 376K
- piston rings occupied a small fraction of frictional heat



a) Cylinder b) Piston c) The first piston ring

d) The second piston ring e) The third piston ring f) The fourth piston ring

Figure 5: Simulated temperature of the cylinder, piston and piston rings

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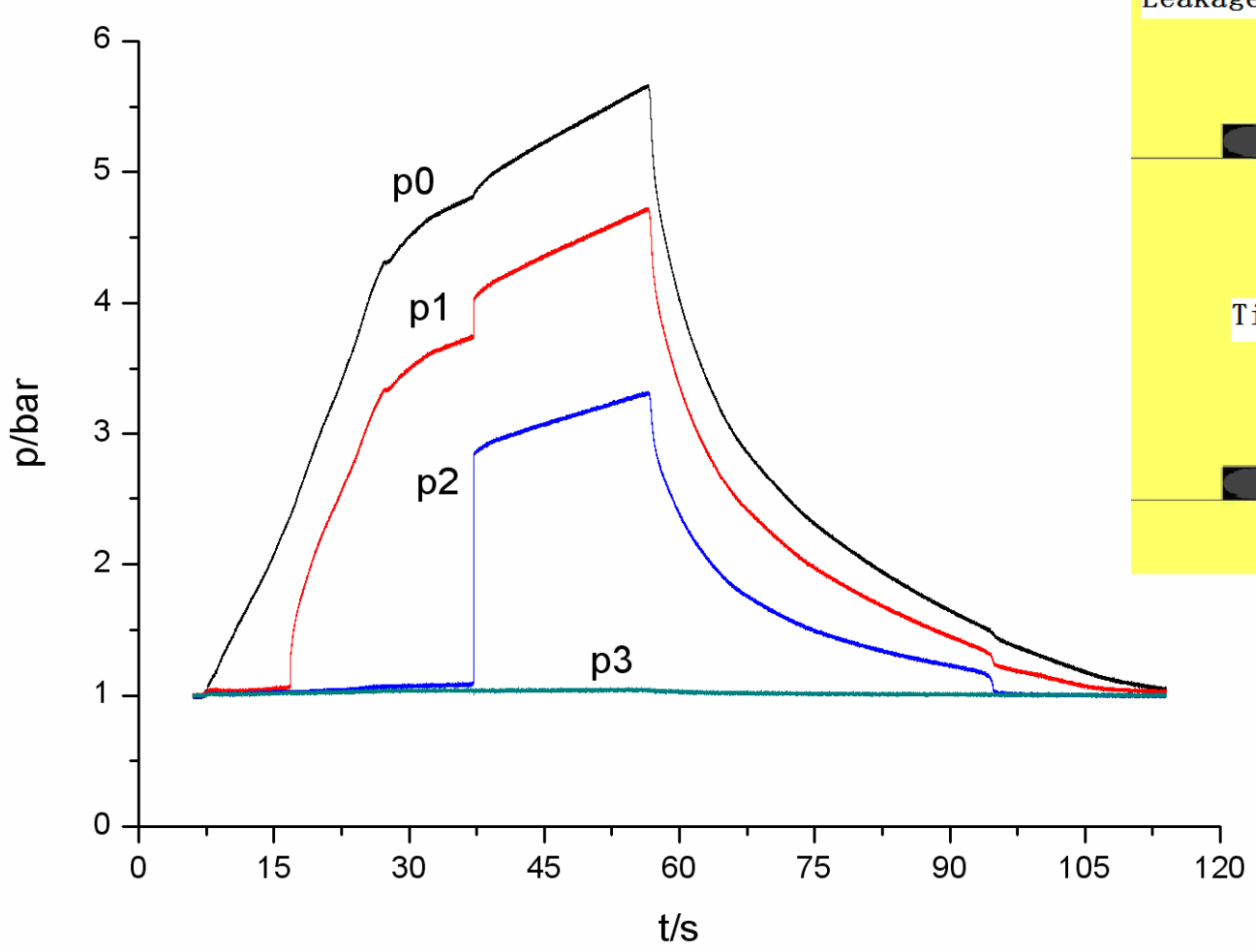
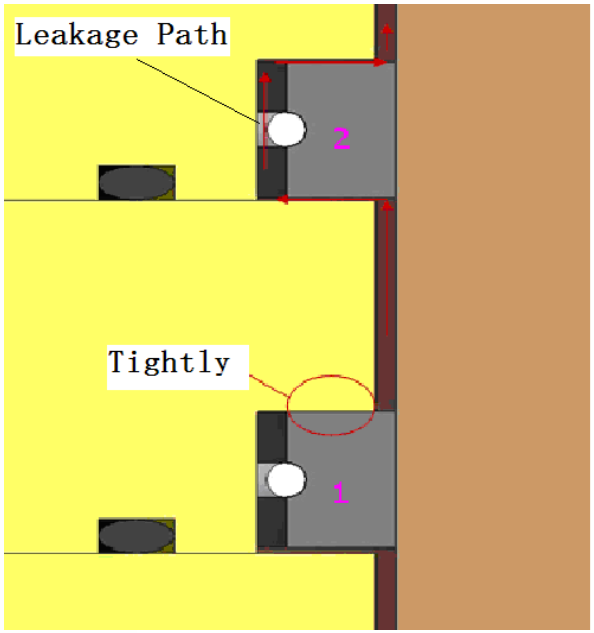
Pressure distribution

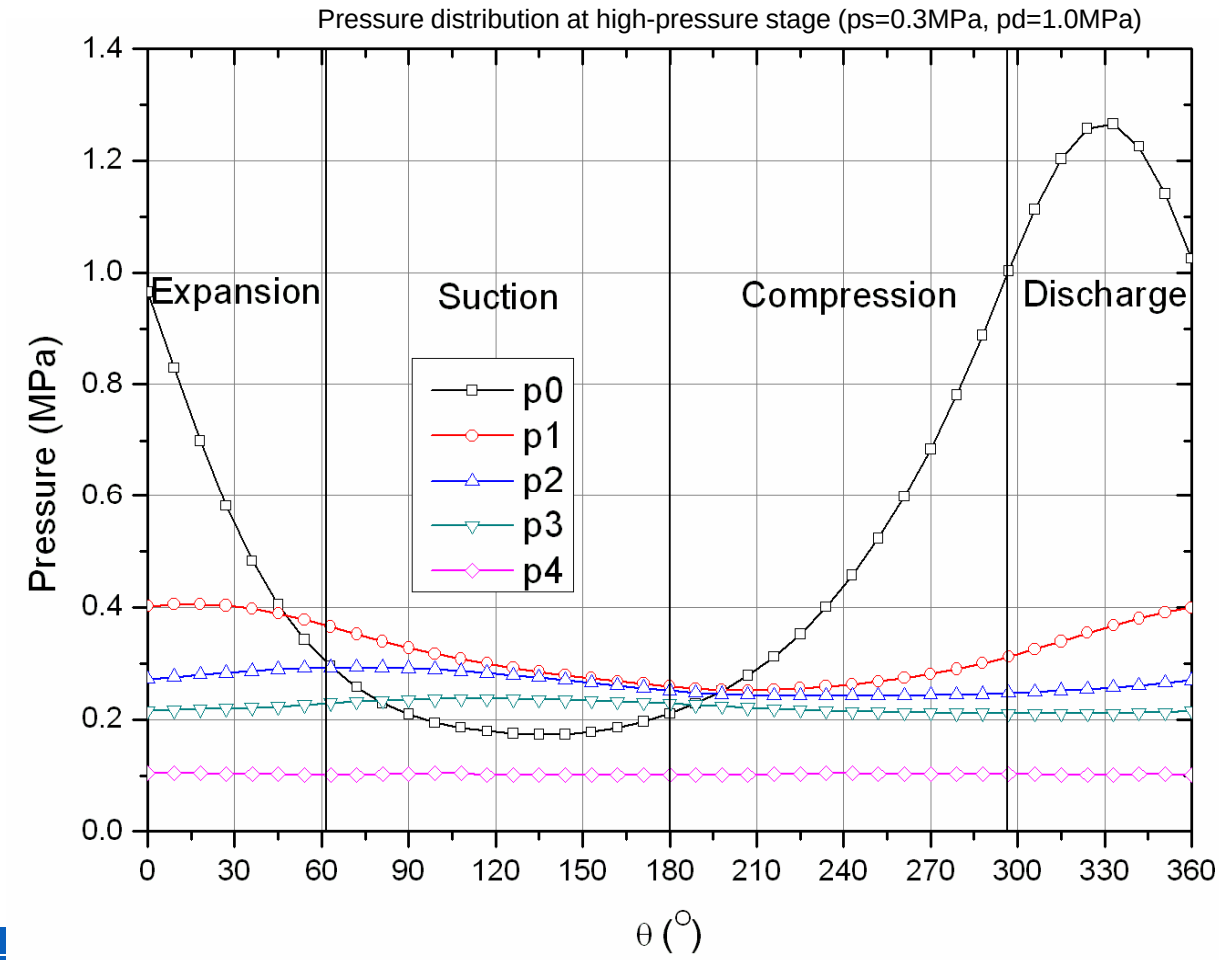
- static pressure difference formed





Pressure distribution

- dynamic pressure distribution



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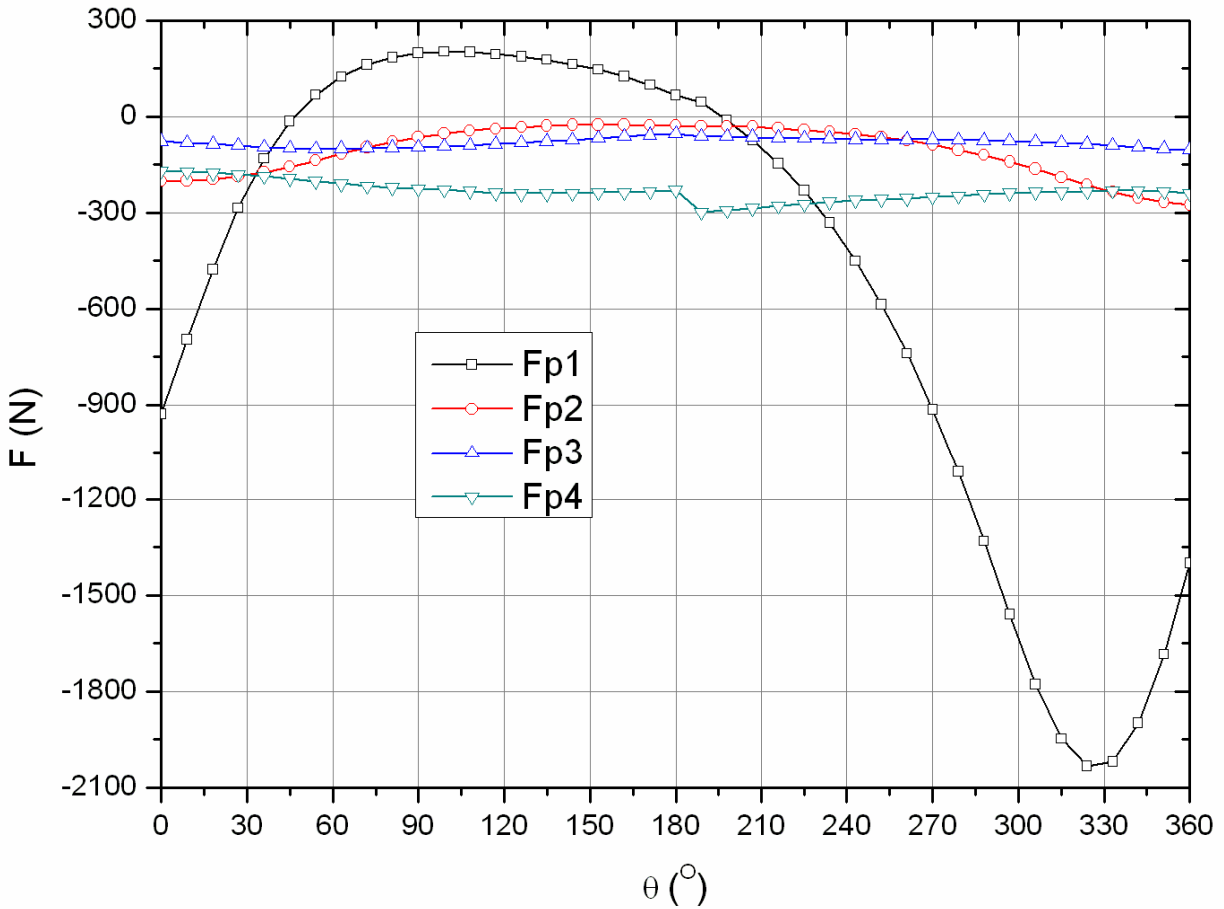
Pressure distribution

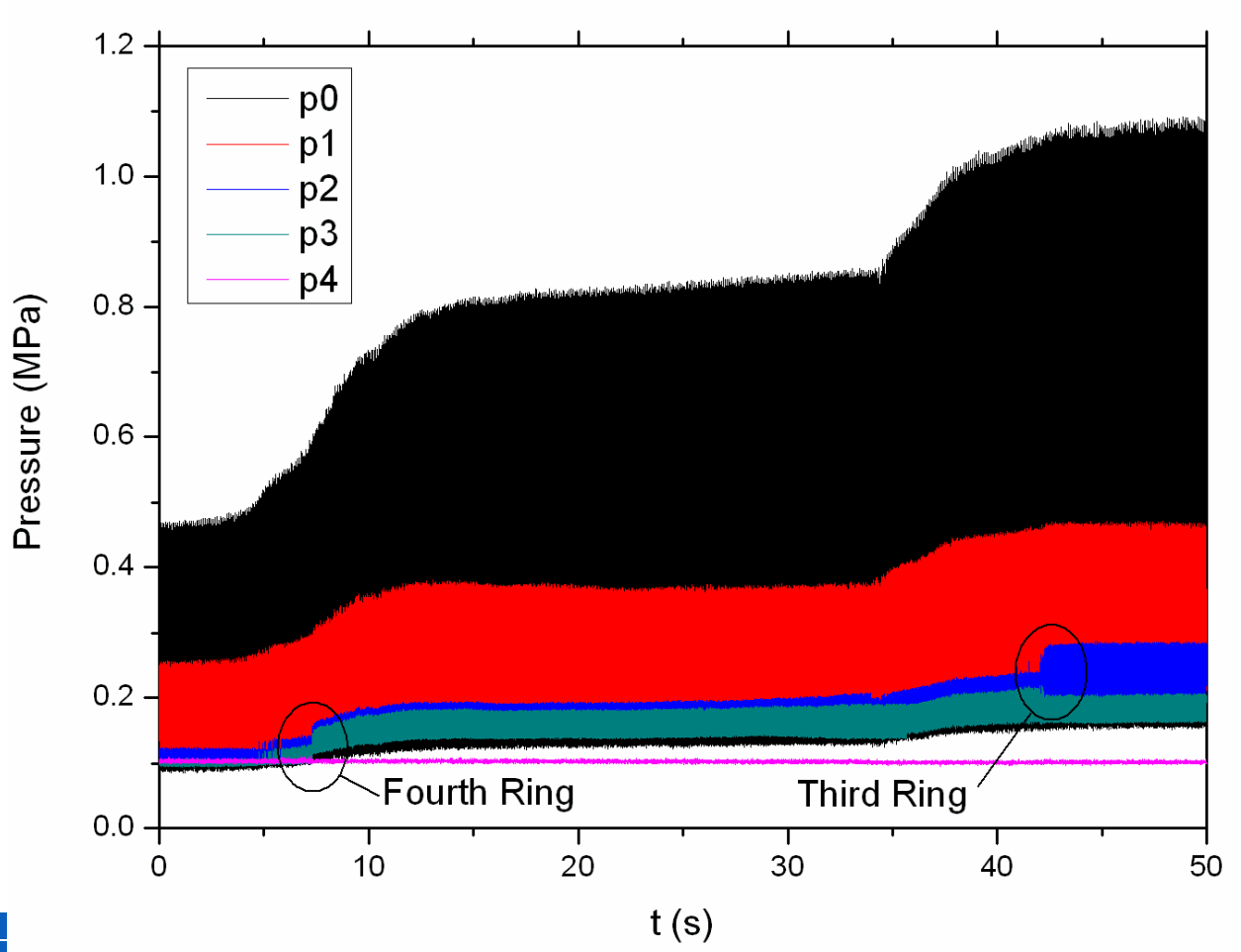
- dynamic pressure distribution



Axial reaction forces on piston rings at high-pressure stage

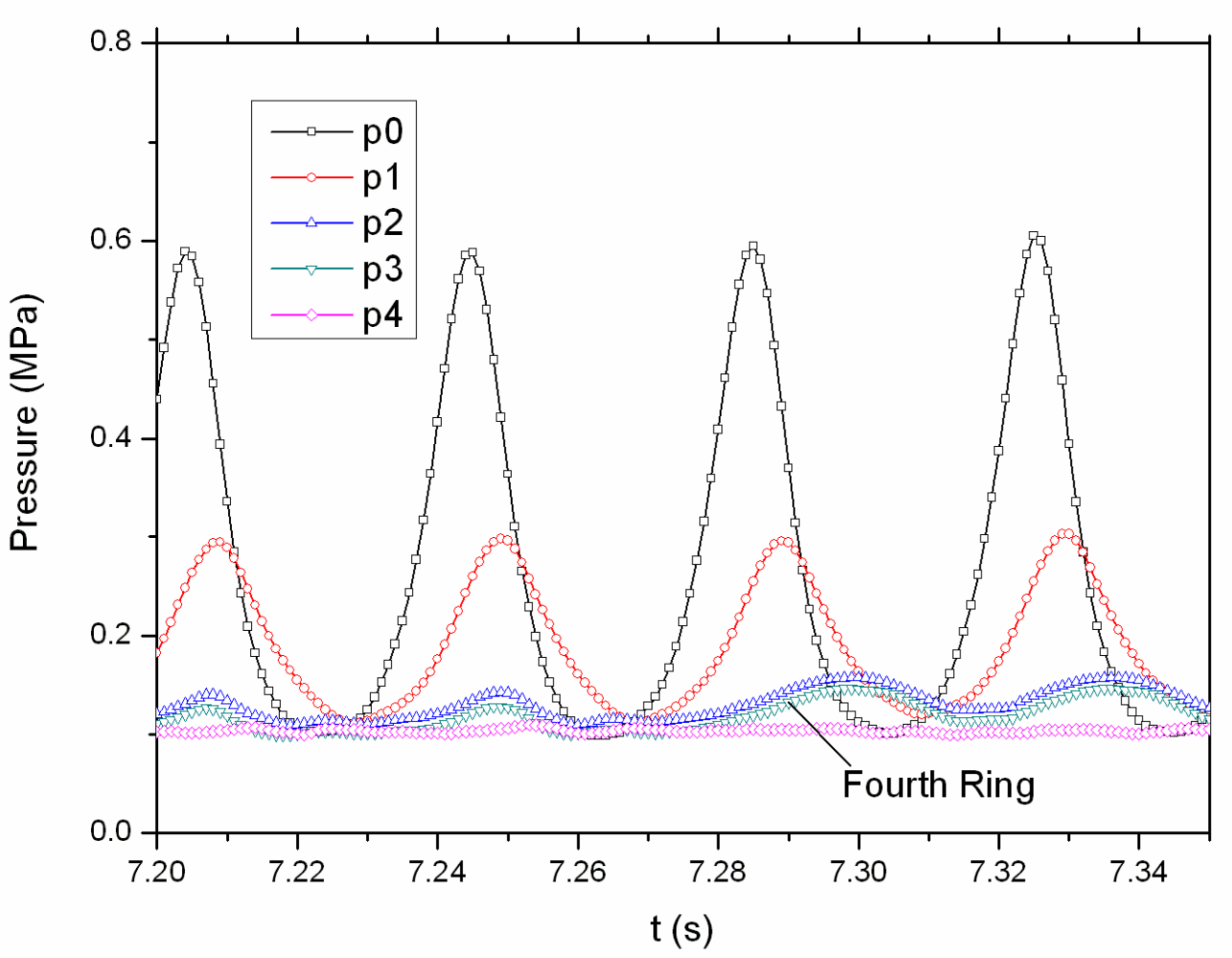
Pressure distribution

- pressure distribution as dynamic pressure difference formed



Pressure distribution

- pressure distribution as dynamic pressure difference formed



conclusions

- The frictional heat distributed to the piston rings increased with the increasing of the thermal conductivity coefficient of the self-lubricating materials.
- The thermal conductivity coefficient of the filling component was observed to be proportional to the quantity and thermal conductivity of the filling particles, but had no direct relationship with the filler's size.
- In the high-pressure stage of the compressor, where the suction pressure exceeded the pressure in the crank case, most of the pressure difference (about 75%) was on the first piston ring; the second and last rings also took about 10%, and the third ring about 5%

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conclusions

- The seal mechanism of the piston ring prevented the pressure differences between the rings from forming at the same time. This implied that each piston ring began to work only when the pressure difference on it reached a required value, which contributed to the non-uniform pressure distributions and short life-time of the whole piston ring set.

Thank you !