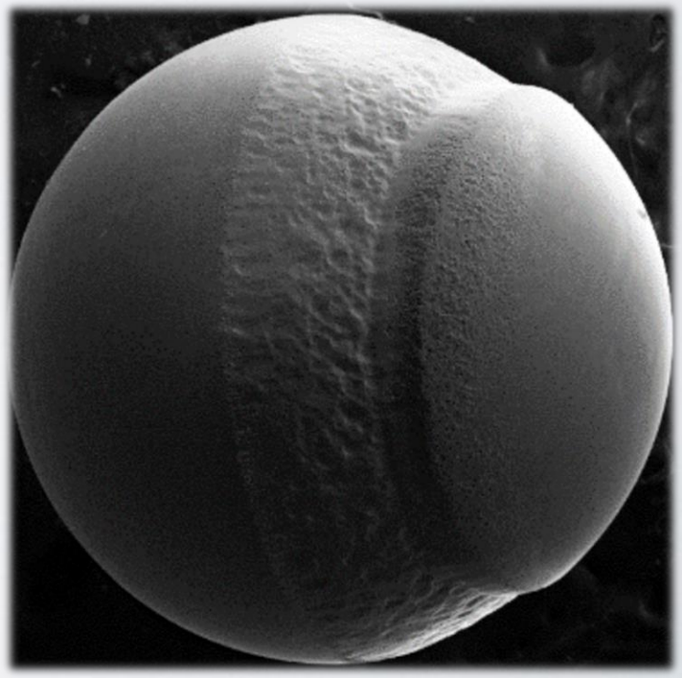
Journal of Zhejiang University-SCIENCE A

Cite this as: Liang LU, Yin-peng XU, Meng-ru LI, Qi-long XUE, Man-yi ZHANG, Liang-liang LIU, Zhong-yu WU, 2022. Analysis of fretting wear behavior of unloading valve of gasoline direct injection high-pressure pump. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 23(4):314-328. https://doi.org/10.1631/jzus.A2100685

Analysis of fretting wear behavior of unloading valve of gasoline direct injection high-pressure pump

Key words:

Fretting wear behavior; Unloading valve;
Experimental and numerical analysis; High pressure

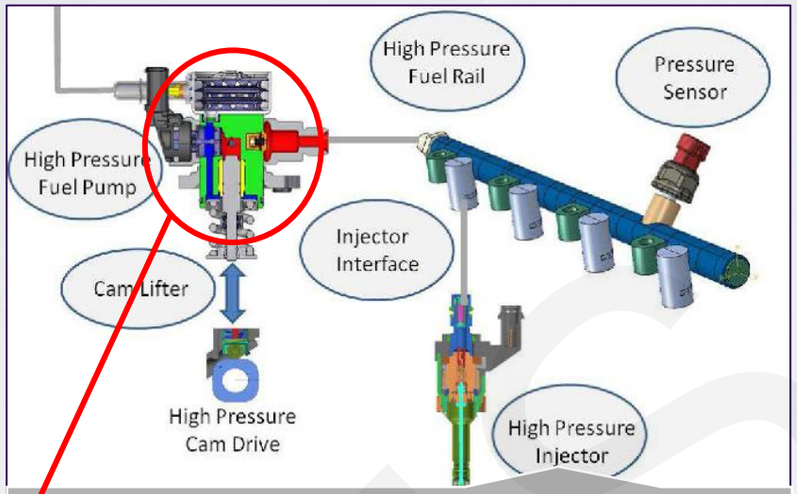


Background

GDI (Gasoline Direct Injection)

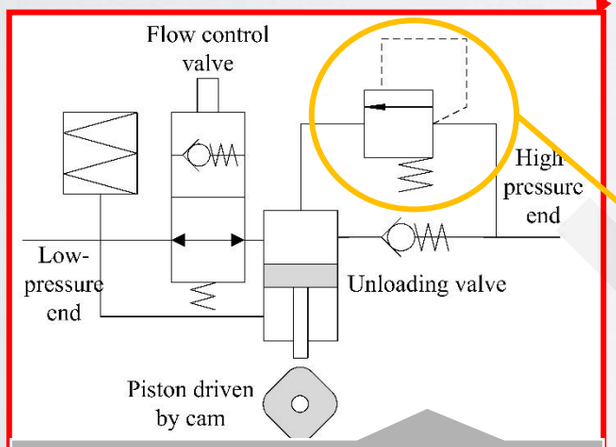
fuel cost ↓ 15%

hydrocarbon emission ↓ 30%



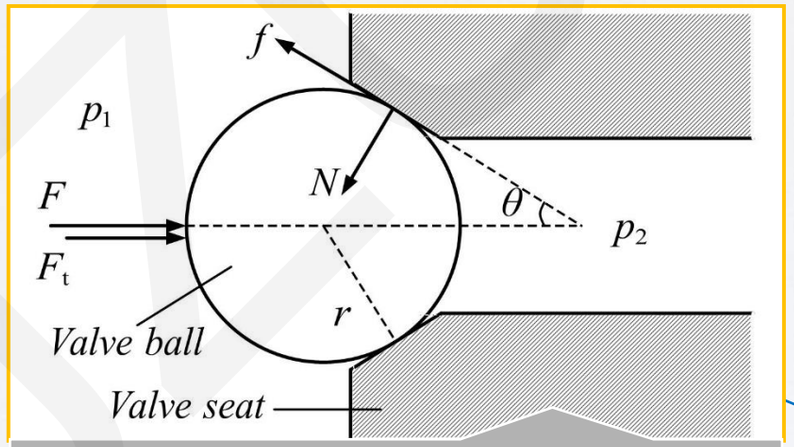
High-pressure fuel supply system

Key component: High-pressure fuel pump



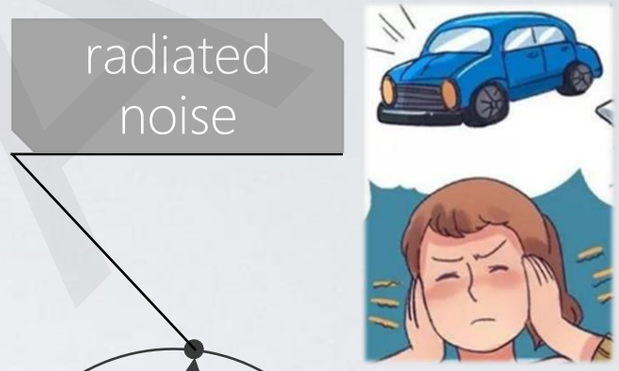
Working principle of high-pressure fuel pump

The unloading valve is used to build and maintain pressure

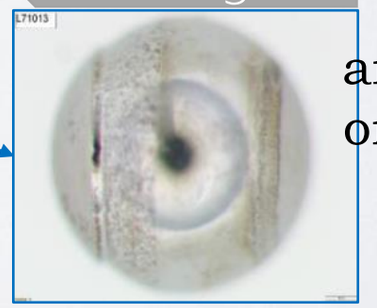


The structure of the unloading valve

The valve ball is subjected to alternating load



Structural damage

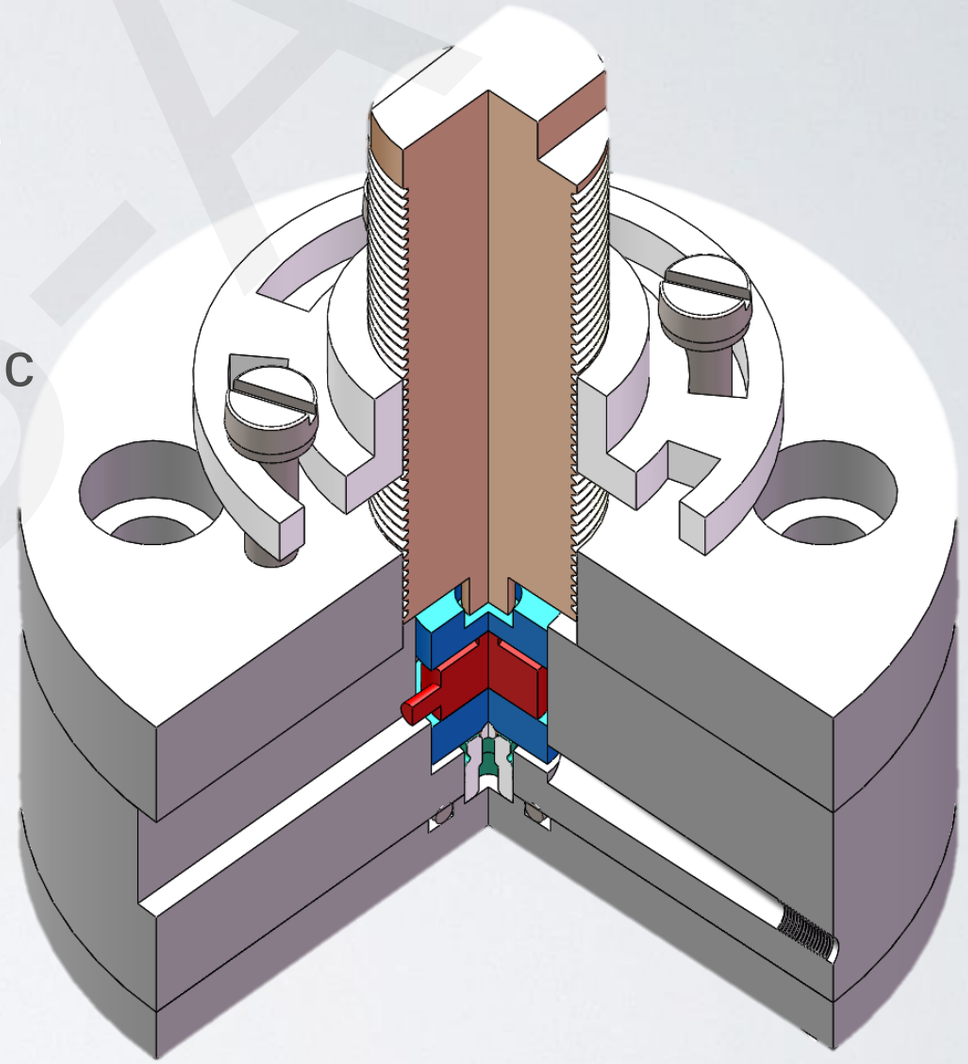


annular damage on the valve ball

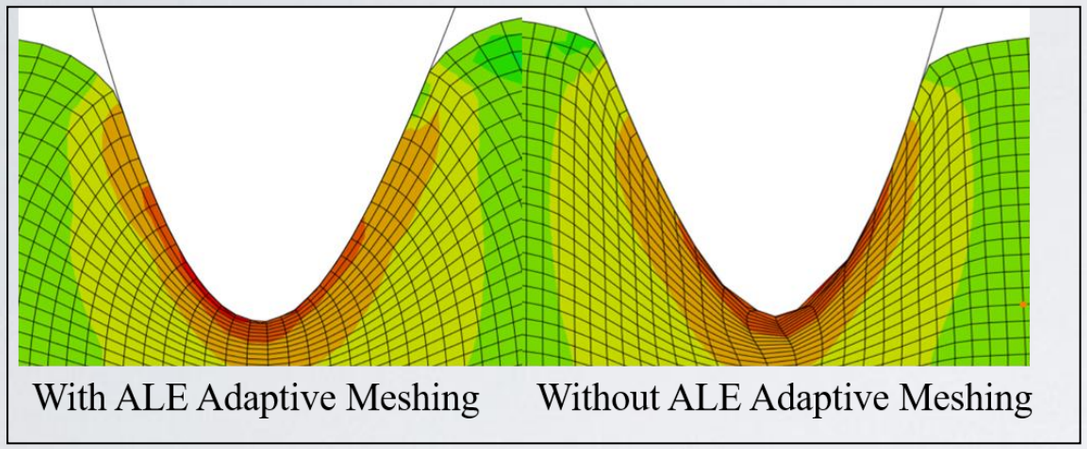
Experiment

A piezoelectric ceramic was used as the key component of the experiment device.

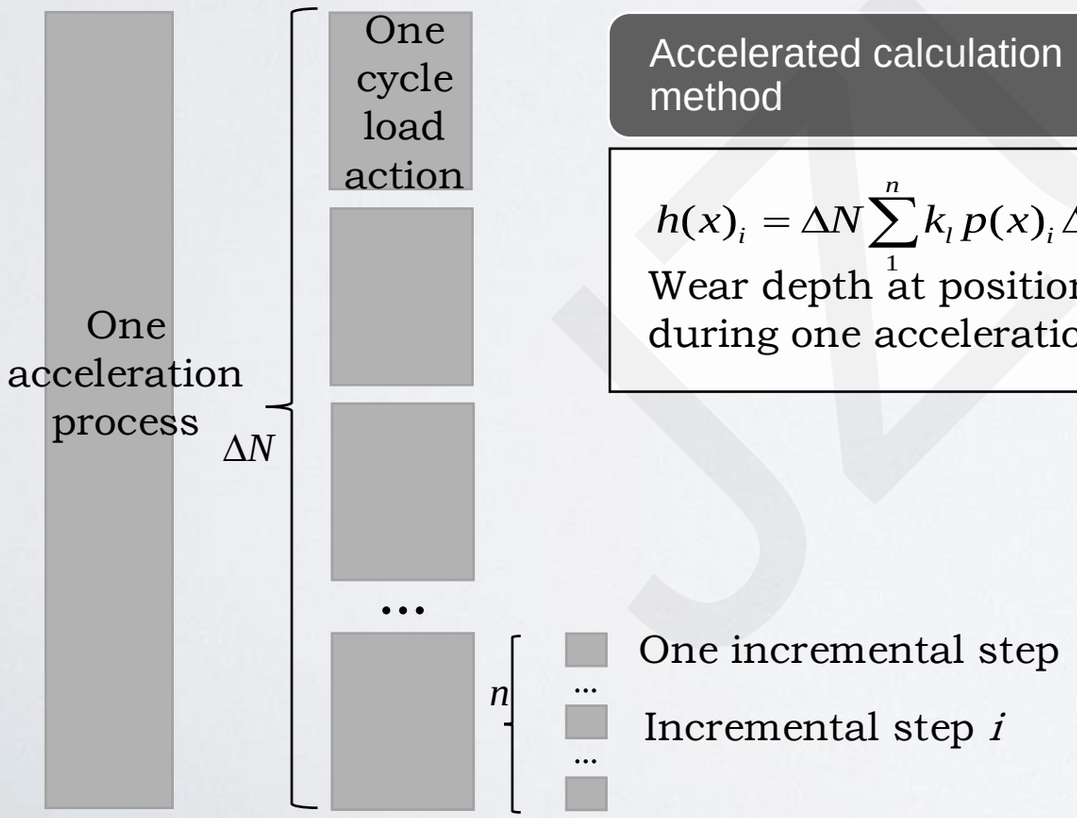
- The unloading valve needs to be fixed during the experiment
- Locate and fix the relative position of piezoelectric ceramics and the unloading valve
- A micro pressure sensor needs to be added between the piezoelectric ceramic and the unloading valve
- The frequency demand of amplifier and data collector needs to reach more than 20 times the loading frequency



Method



ALE adaptive mesh



Accelerated calculation method

$$h(x)_i = \Delta N \sum_{1}^{n} k_l \, p(x)_i \, \Delta s(x)_i$$

Wear depth at position x during one acceleration

Umeshmotion subroutine

Initial Parameters

- Geometry
- Load
- Wear Coefficient (K_H)
- Sliding Distance (S)
- Incremental Sliding Distance (Δs)
- Material Properties
- Boundary Conditions
- Coefficient of Friction (μ)
- Total Sliding Distance (S_{max})

Solve the contact problem using FEM to obtain the contact pressure for the incremental sliding distance

Obtain the nodal wear depth increments using the Archard's wear law
$\Delta h_i = k_H p_i \Delta s$

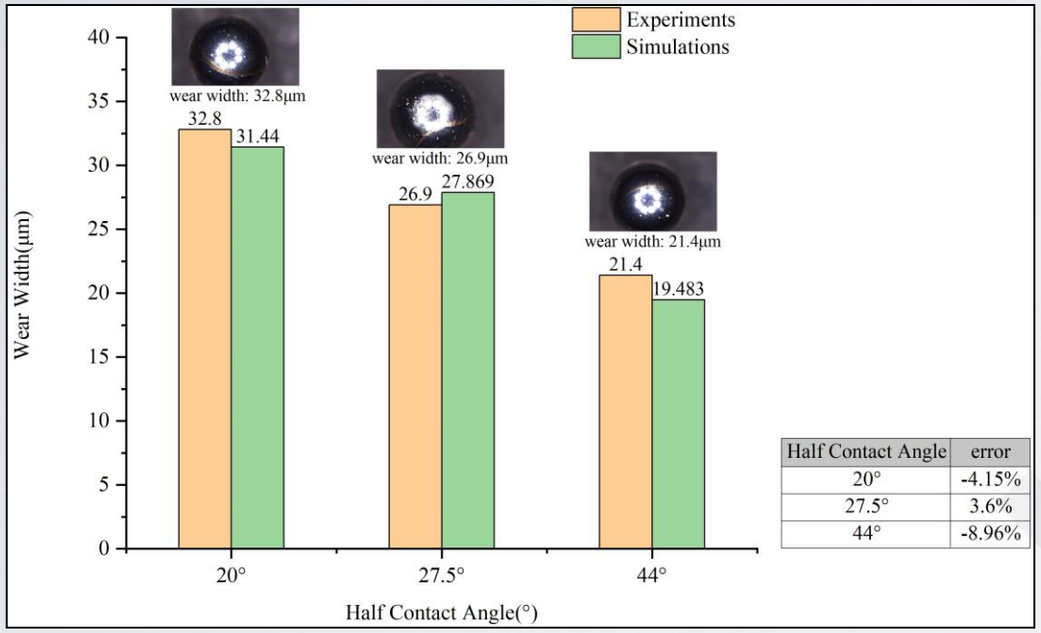
Use extrapolation technique to extrapolate the wear after one cycle to 'N' cycles
$\Delta h_{ex} = N \Delta hi$

S<Smax

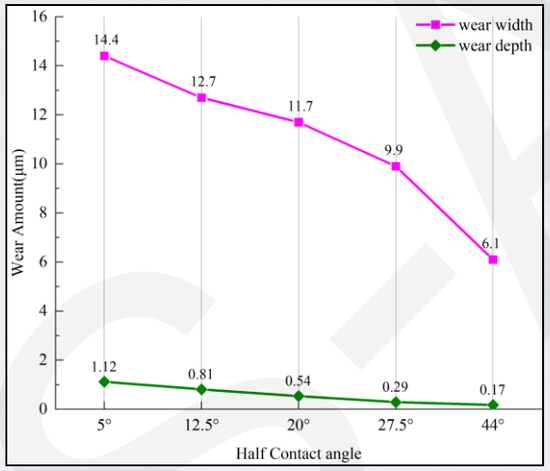
Update the geometry using the UMESHMOTION+ALE technique

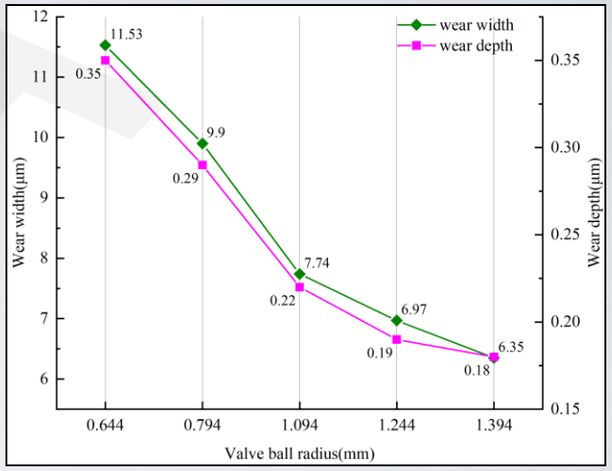
End simulation if maximum sliding distance (S_{max}) is reached

Results and conclusions

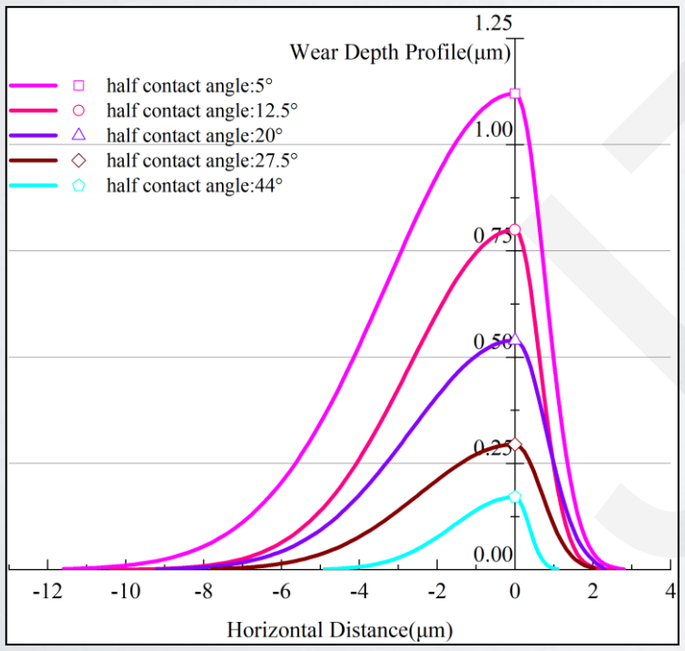


Half Contact Angle	error
20°	-4.15%
27.5°	3.6%
44°	-8.96%





The experimental results of 4.5×10^5 cycles show that the wear width and depth of the valve ball decrease with the increase of the half contact angle and the radius of the valve ball



The experimental results of 4.5×10^7 cycles are in good agreement with the simulation results

The wear profile of the valve ball is roughly U-shaped, which is consistent with the experimental result