中国一汽

商品汽油反应机理标定及其在爆震研究中的应用

中国一汽无锡油泵油嘴研究所

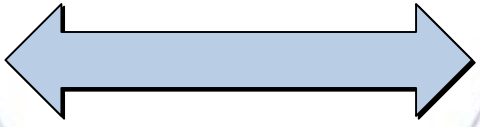
2017年10月

一　研究动机和路线

■提高汽油机热效率的要求越来越紧迫

■实现汽油机50%的ITE。

■燃烧方式的变革使得缸内燃烧计算对反应机理的依赖性增强



■开展稀燃、压燃等新燃烧方式研究

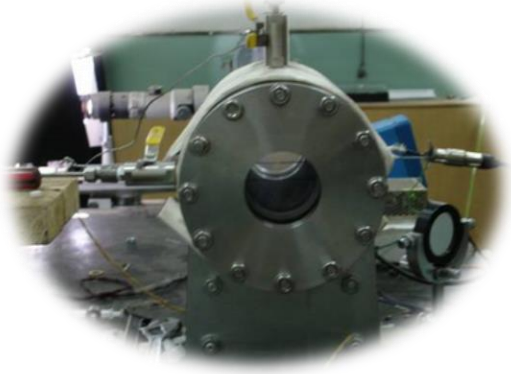
■以PRF机理对汽油进行模拟与真实汽油的自燃燃烧特性有差异

■采用现有的PRF机理进行优化标定

■采用基础燃烧试验设备和发动机获取商品汽油燃烧试验数据

试验手段

定容弹

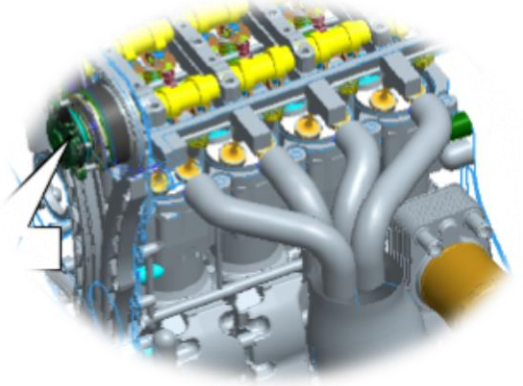


测量火焰传播速率

激波管

测量高温滞燃期

发动机



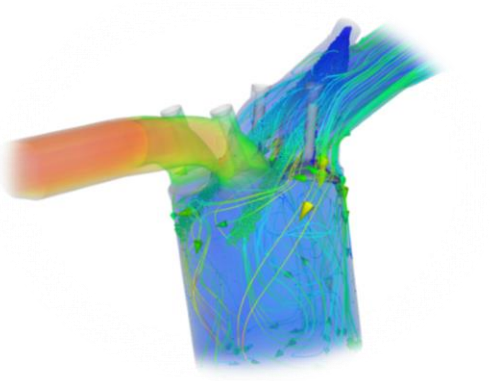
测量缸内燃烧爆震

计算手段

CHEMKIN

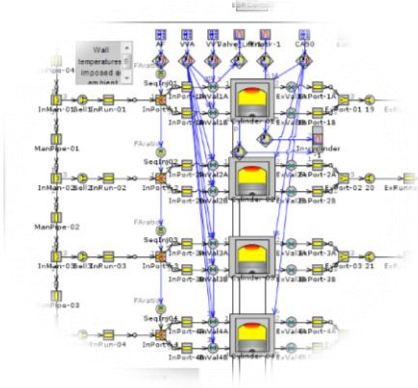
标定优化反应机理

Converge



缸内燃烧计算

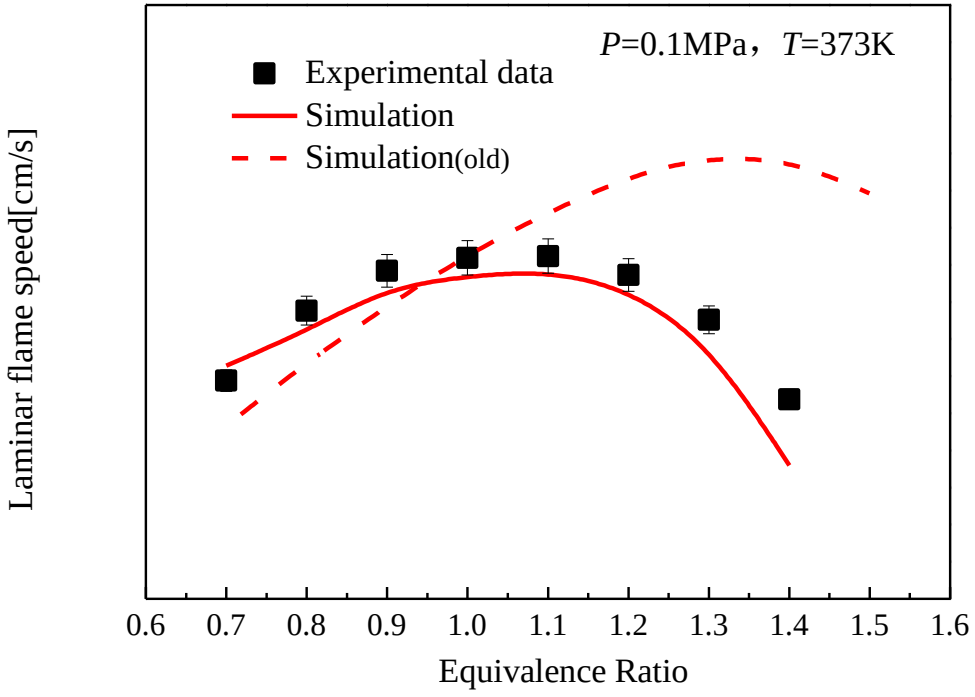
GT-Power



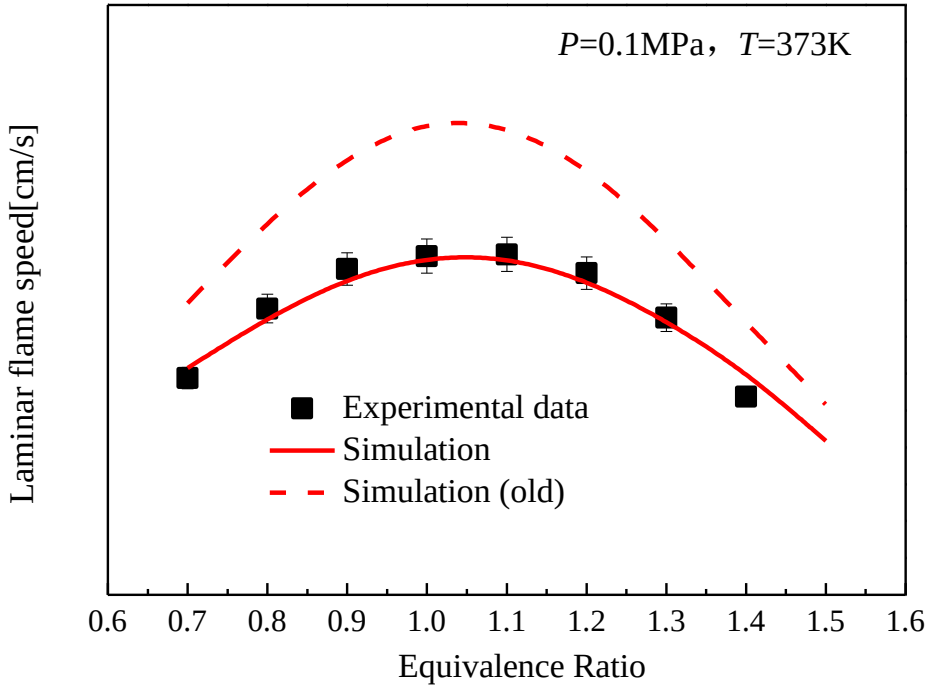
理论计算，提供边界条件

火焰传播速率

- 汽油样品为92#市售汽油，同时还开展了其他标号及掺醇汽油试验。
- 初始反应机理来自UW-ERC*，包含了49种物质，138个反应，在计算精度和速度上折中性较好。



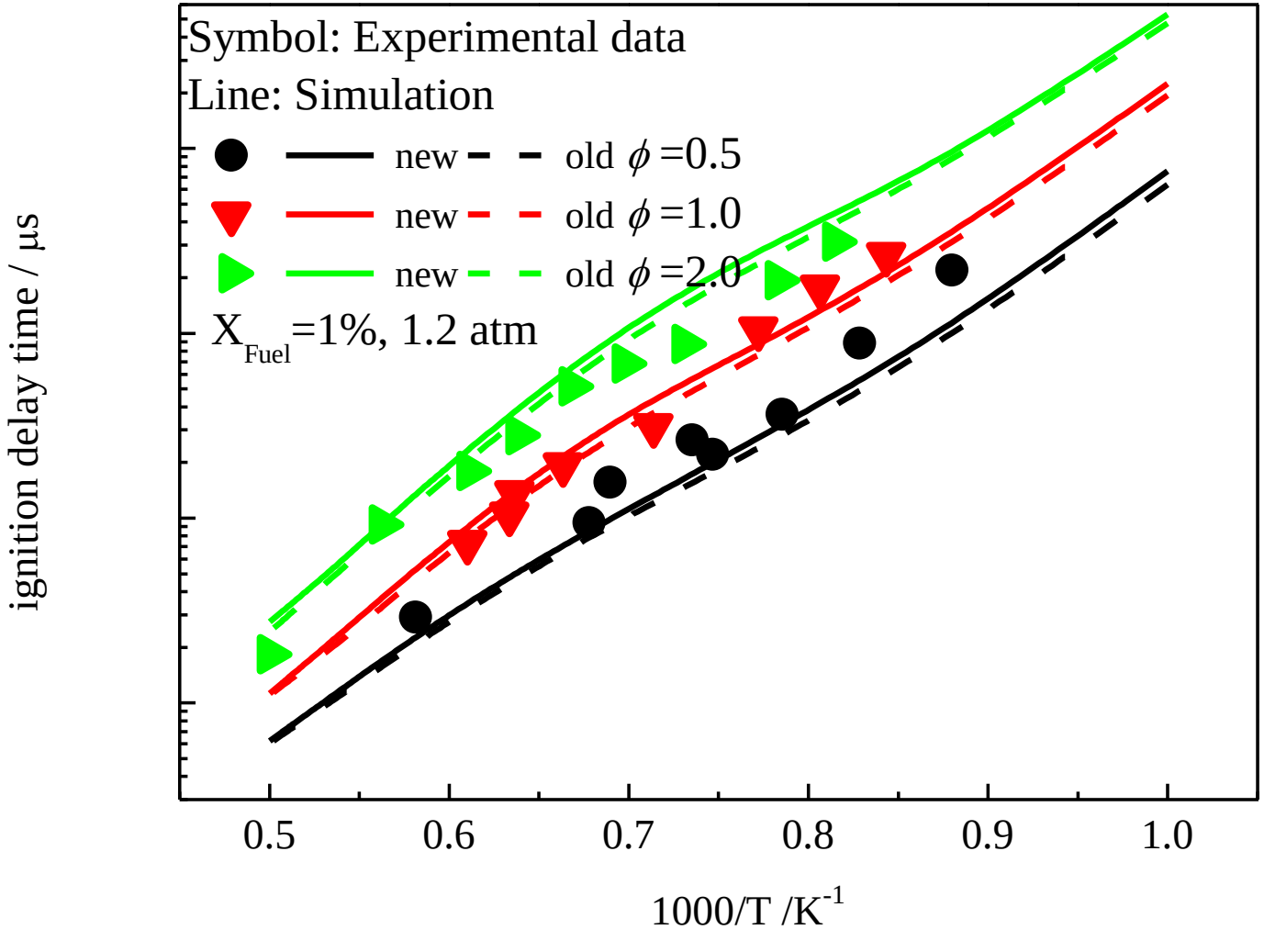
标定前后火焰传播速率对比（反应动力学模型）



标定前后火焰传播速率对比（Gulder公式）

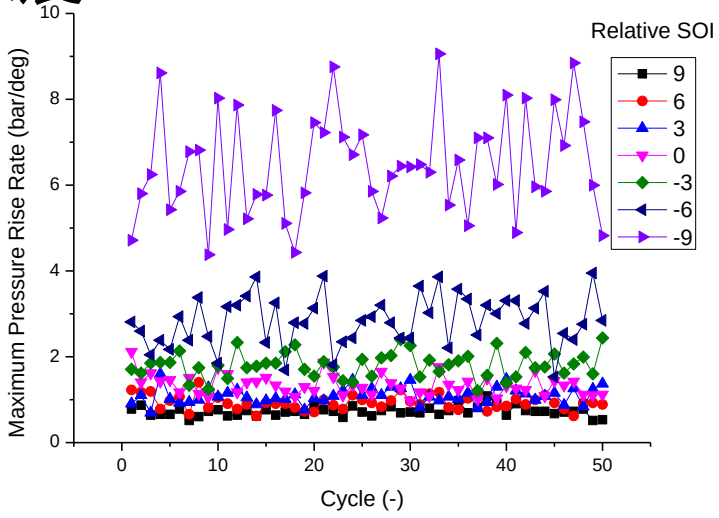
*Adam Brian Dempsqy, Dual-Fuel Reactivity Controlled Compression Ignition(RCCI) with Alternative Fuels, PhD thesis, University of Wisconsin-Madison

高温滞燃期

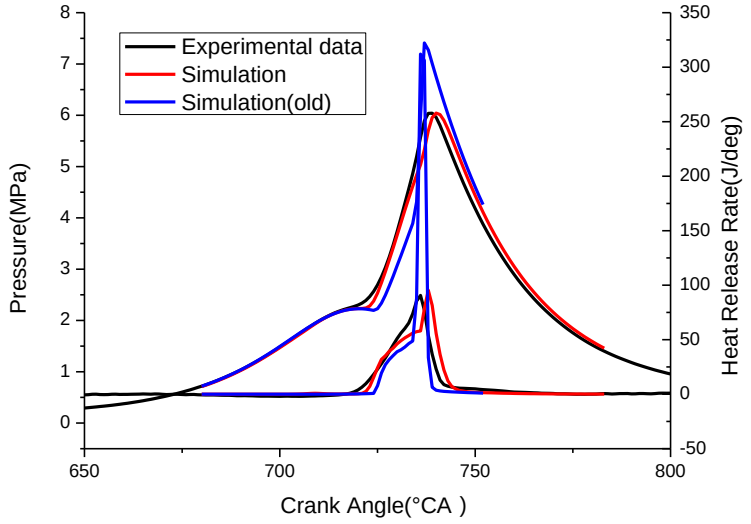


标定前后高温滞燃期对比

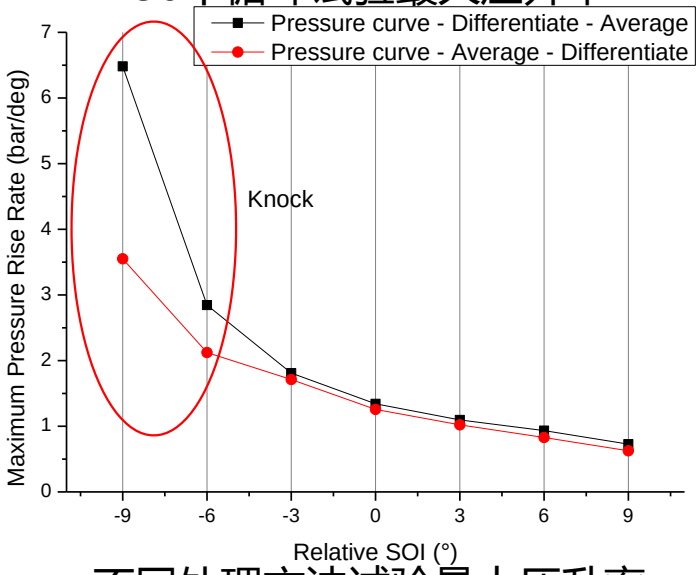
缸内燃烧爆震



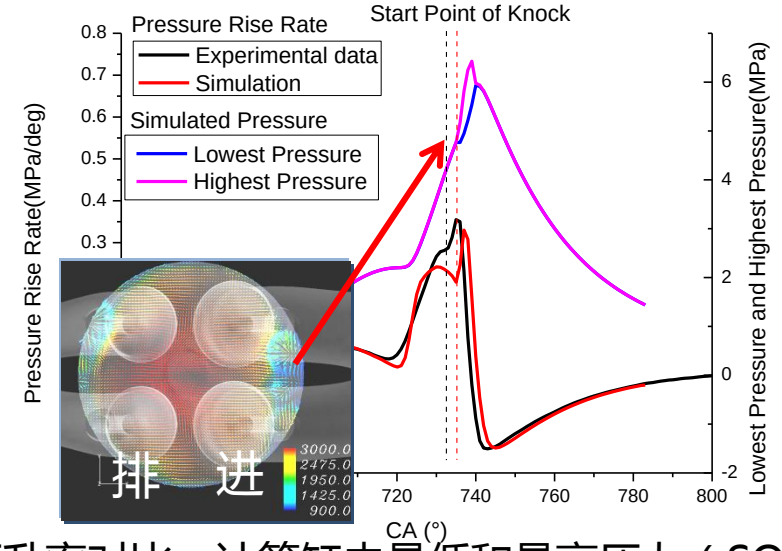
50个循环试验最大压升率



标定前后缸压和放热率曲线对比（SOI=-9）



不同处理方法试验最大压升率



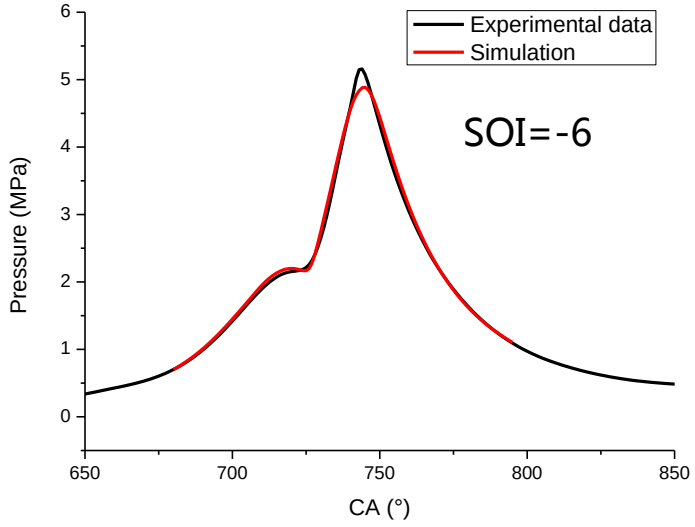
压升率对比、计算缸内最低和最高压力（SOI=-9）

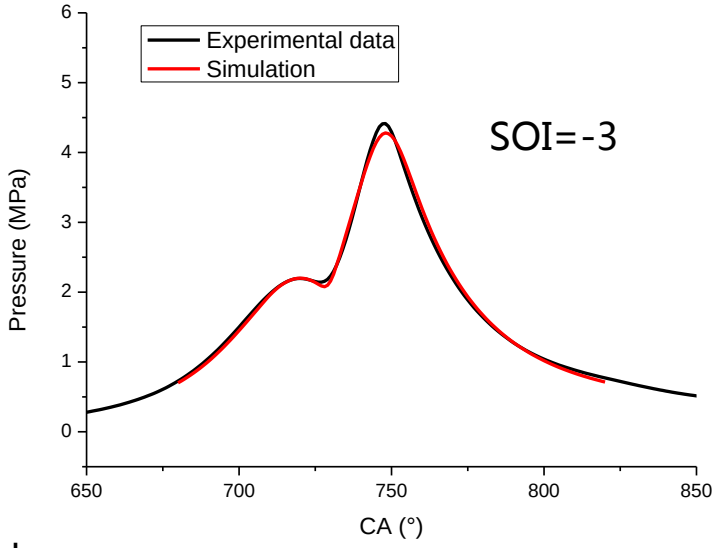
转速：1000rpm
负荷：外特性

湍流模型：RNG-k-ε
燃烧模型：G方程+SAGE

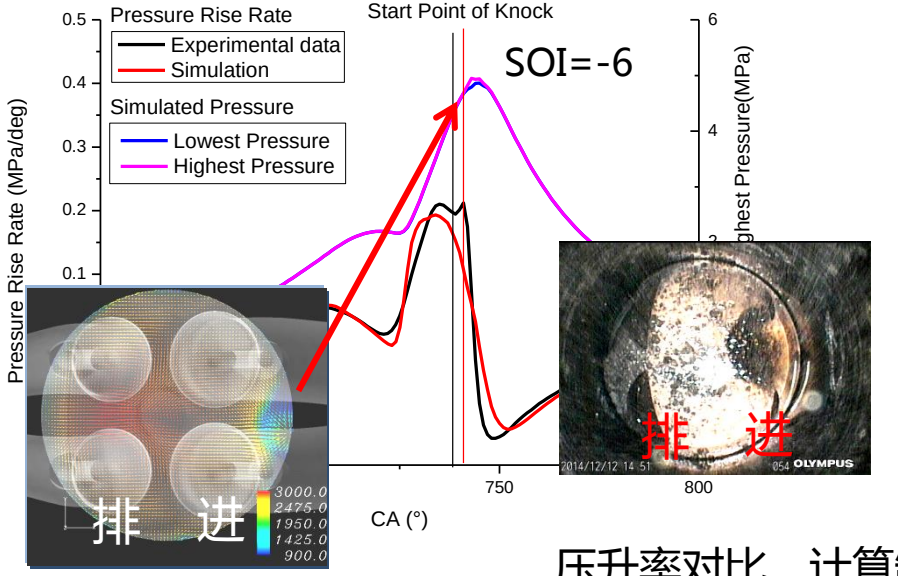
所有工况机理、模型、网格参数设置均相同

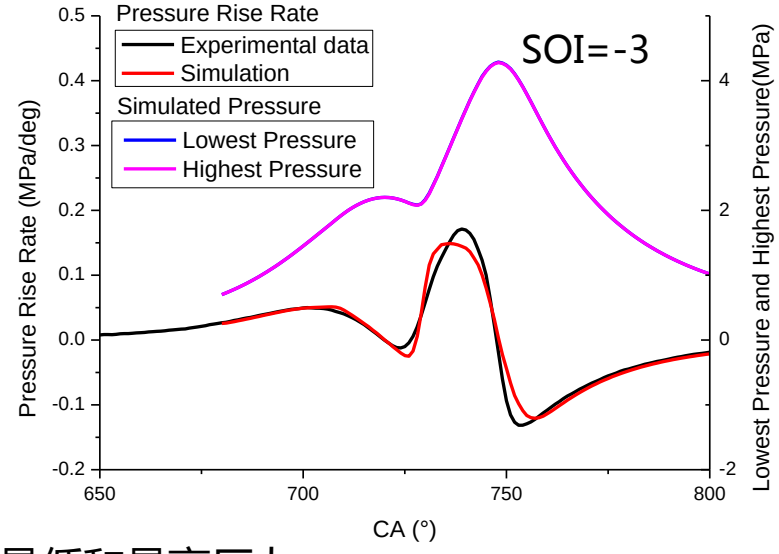
缸内燃烧爆震





缸压曲线对比

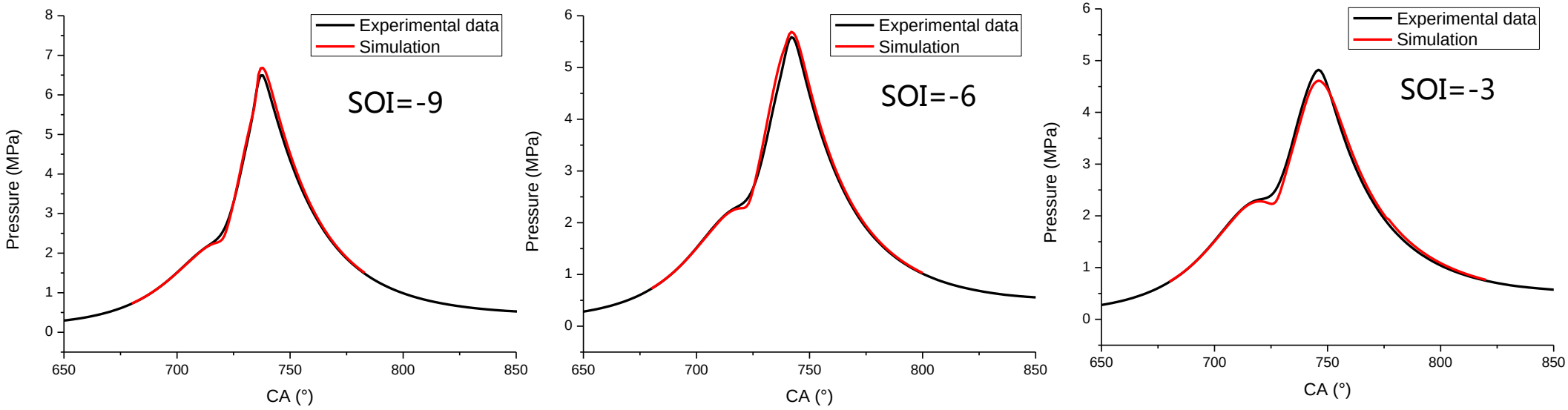




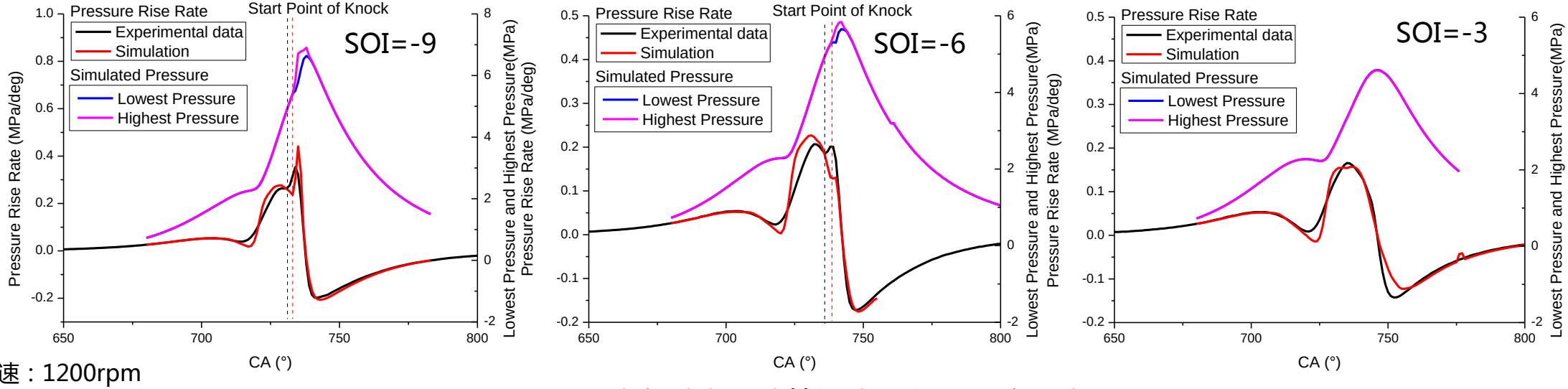
转速：1000rpm
负荷：外特性

压升率对比、计算缸内最低和最高压力

缸内燃烧爆震



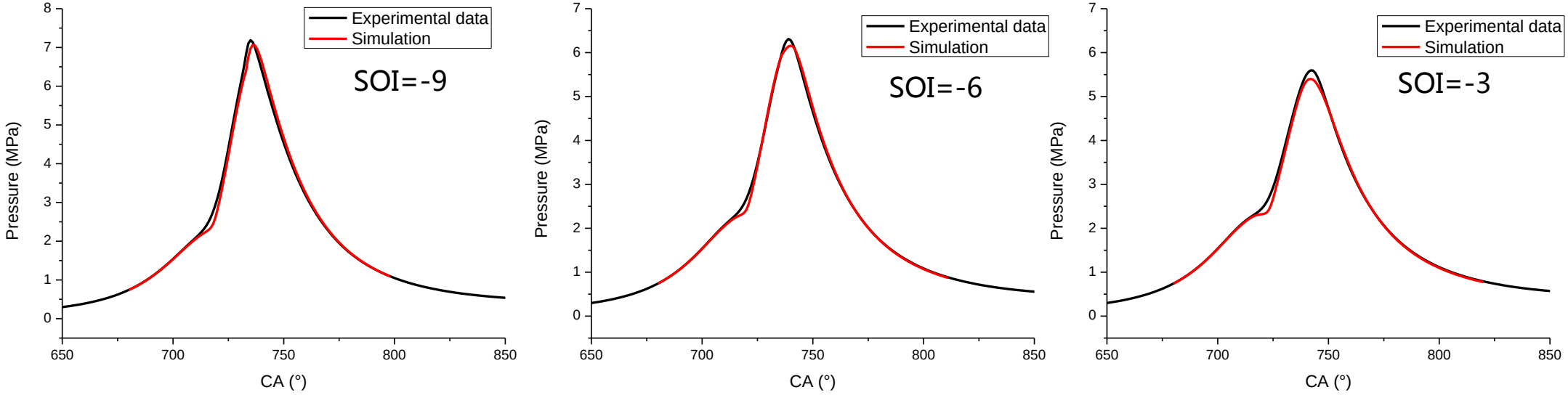
缸压曲线对比



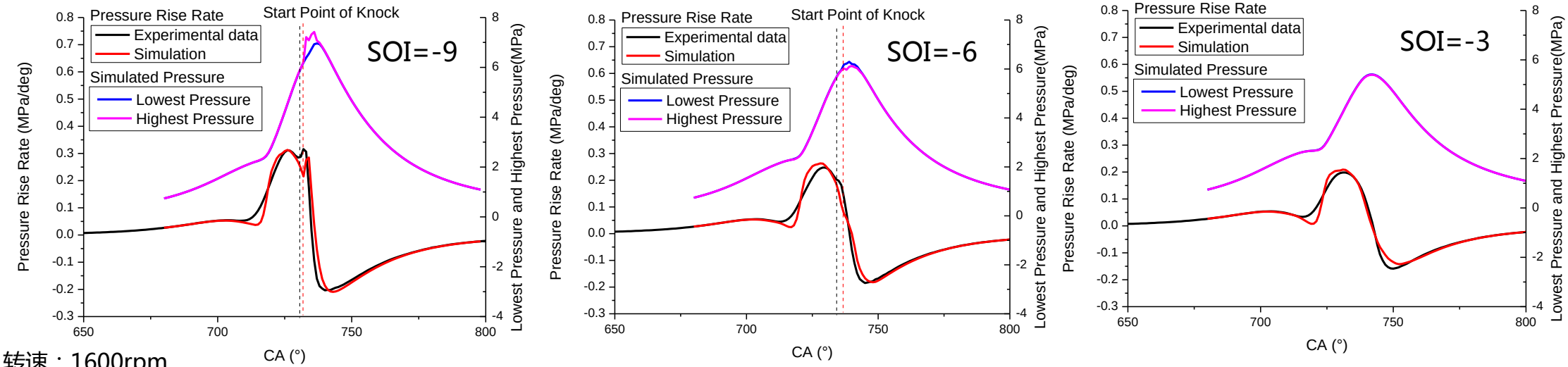
转速：1200rpm
负荷：外特性

压升率对比、计算缸内最低和最高压力

缸内燃烧爆震



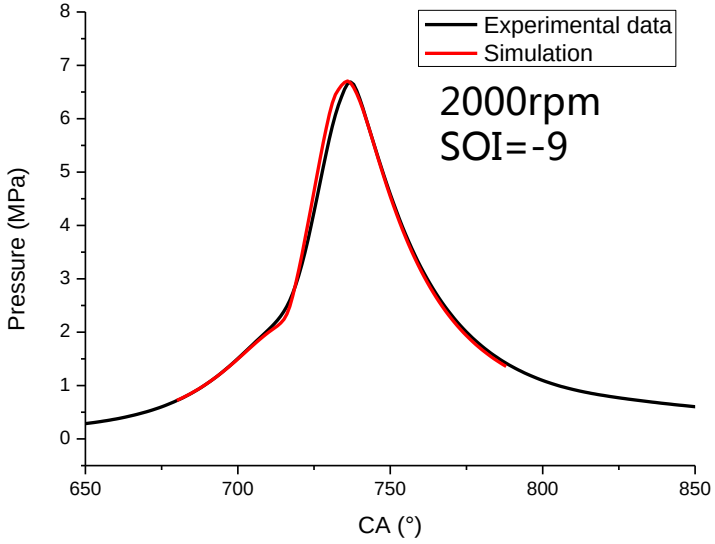
缸压曲线对比

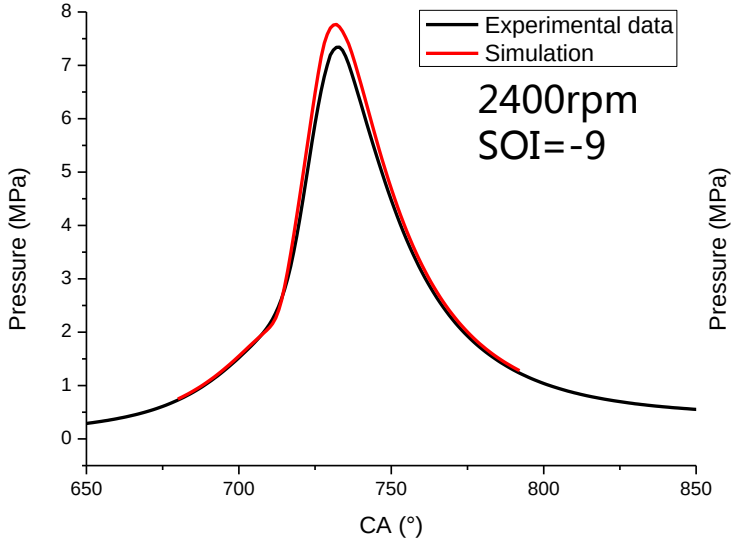


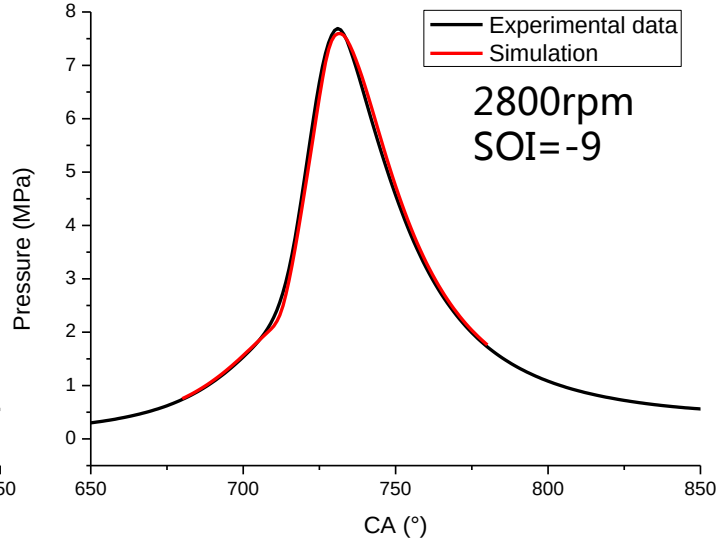
转速：1600rpm
负荷：外特性

压升率对比、计算缸内最低和最高压力

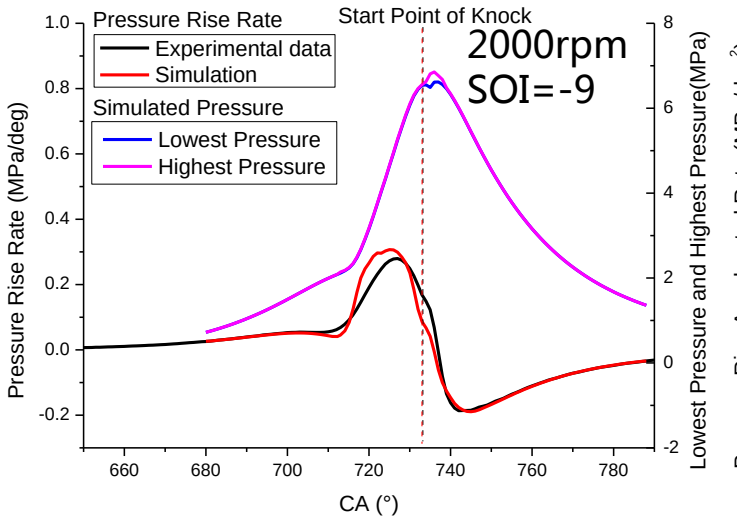
缸内燃烧爆震

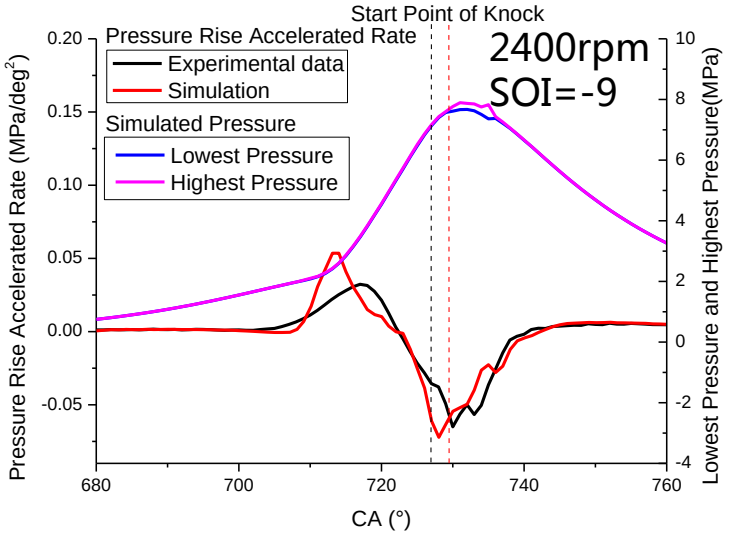


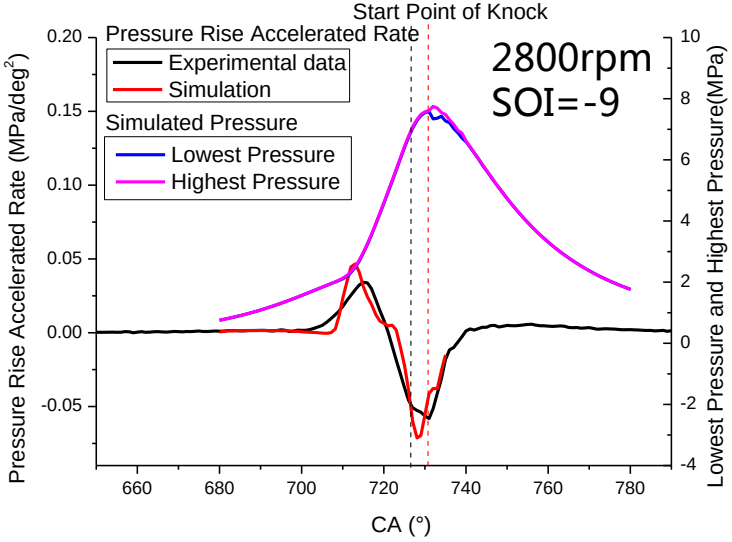




缸压曲线对比



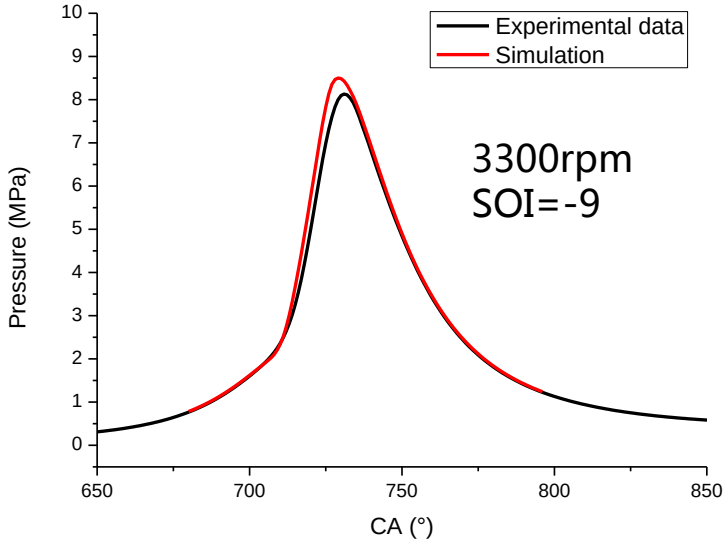


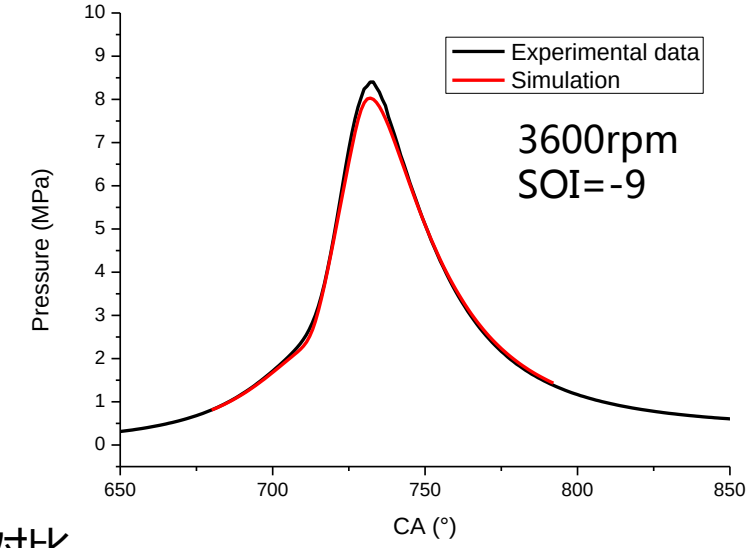


负荷：外特性

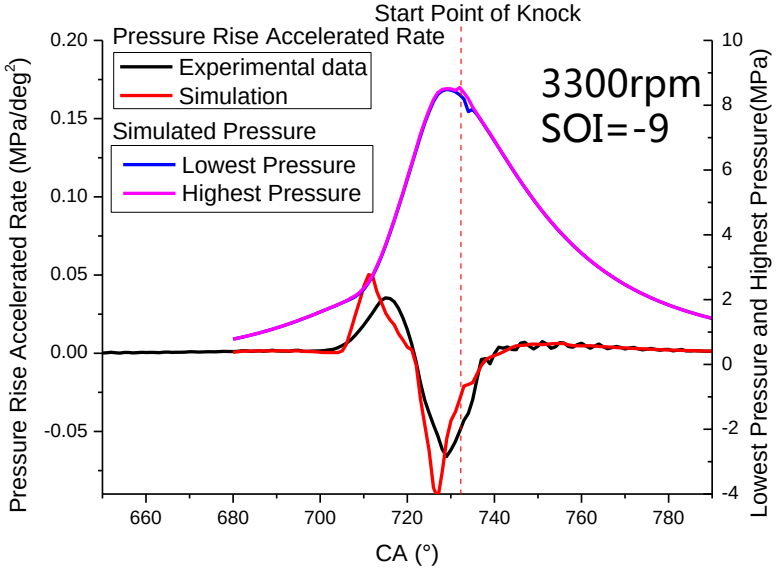
压升率（压升加速度）对比、计算缸内最低和最高压力

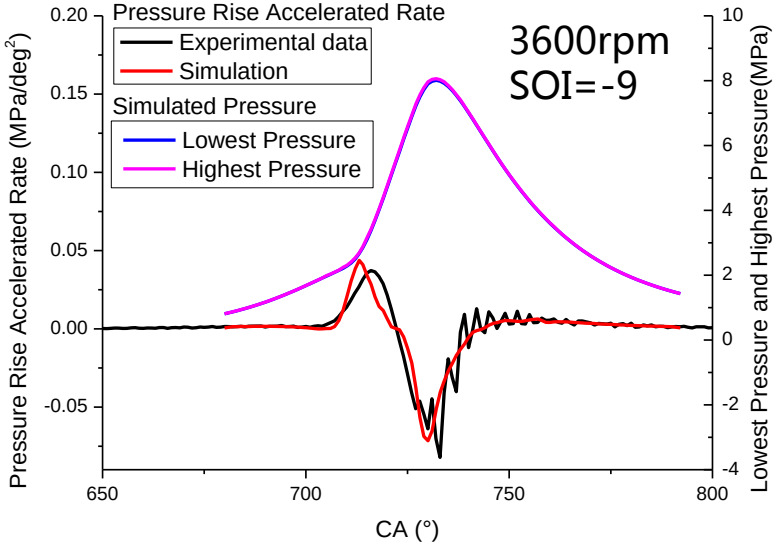
缸内燃烧爆震





缸压曲线对比

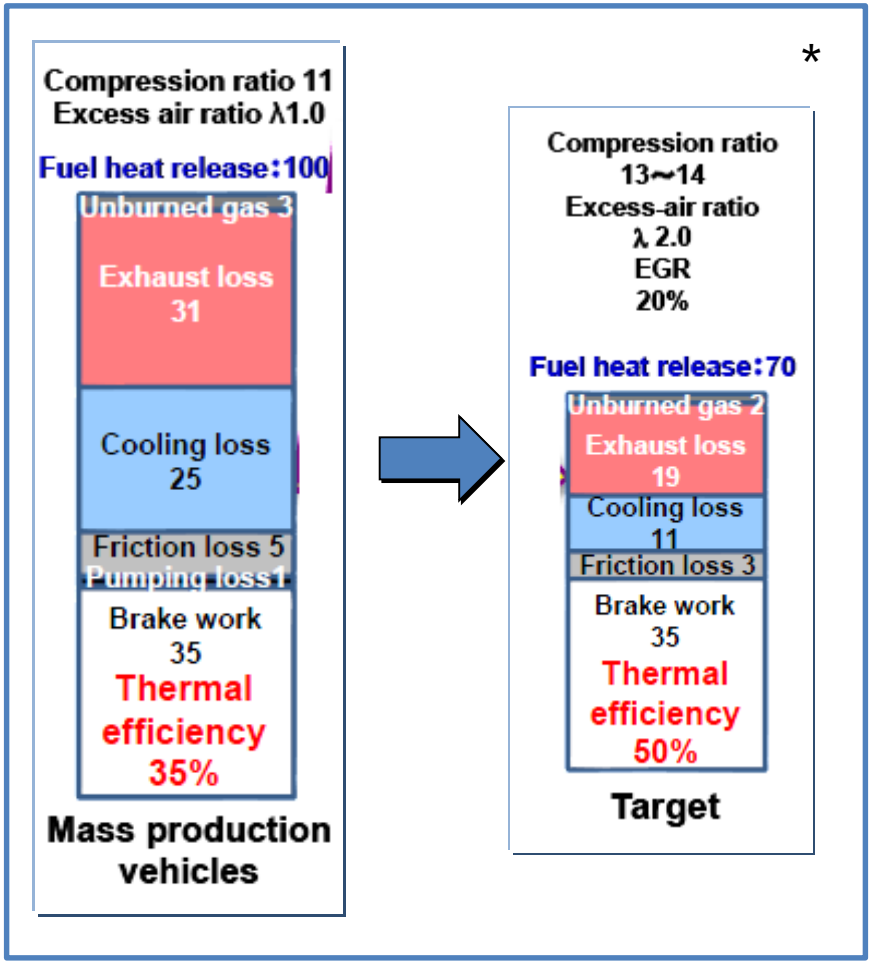


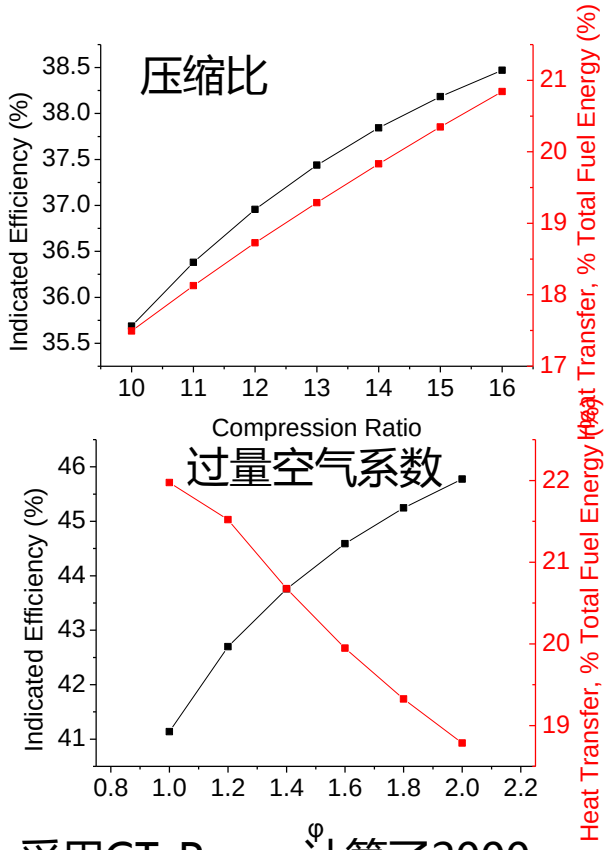


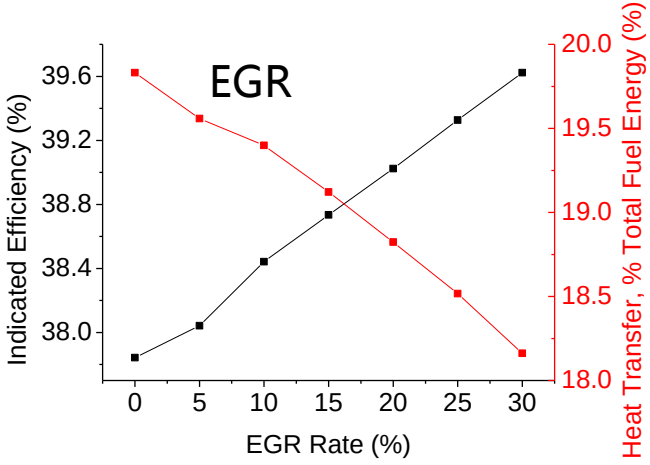
负荷：外特性

压升加速度对比、计算缸内最低和最高压力

■当量比燃烧汽油机面临受爆震限制的压缩比、部分负荷节流损失、高传热、低比热比等限制热效率提高的不利因素
■提高压缩比、稀燃、高EGR、强湍流、增压等是提高汽油机热效率的有效手段。







Pin=1.8bar
EGR=20%
Φ=2.0
CR=14.0

ITE=47.8%

采用GT-Power计算了2000rpm外特性j均质燃烧提高压缩比、稀燃、EGR对指示热效率的影响，不考虑SOI、放热率形状的变化，假设点火能量足够高，足以在形成直径2mm的初始火核。

*Norimasa Iida , Super-Lean Burn Concept for High Efficiency SI Engine, ERC 2017 Symposium

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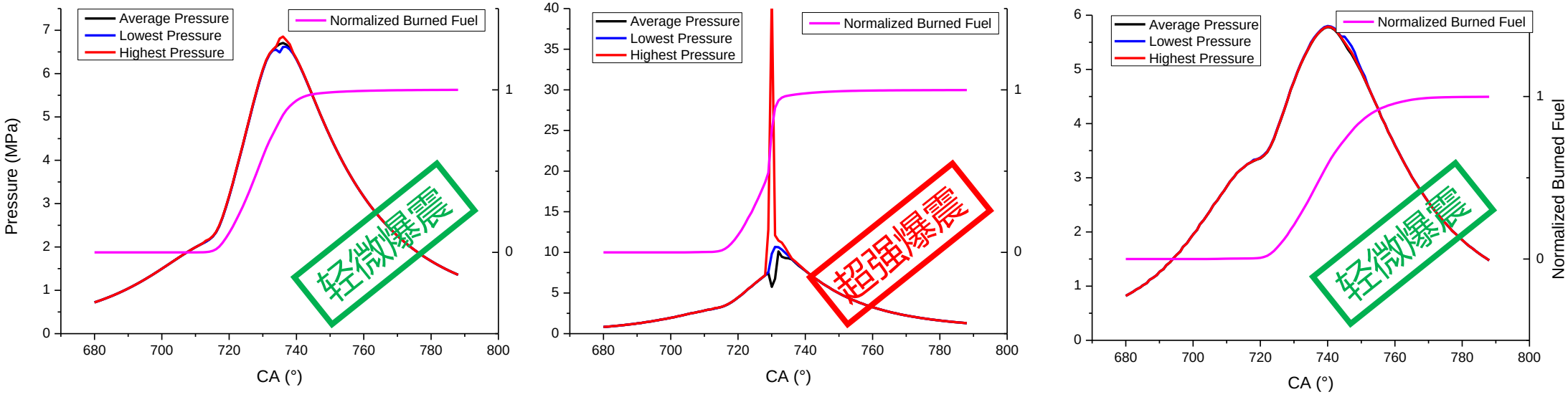
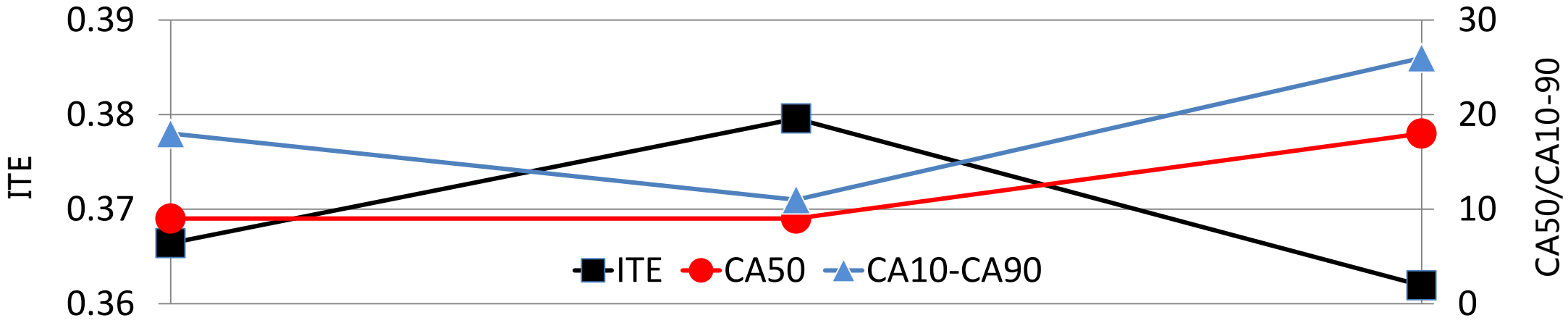
提高压缩比

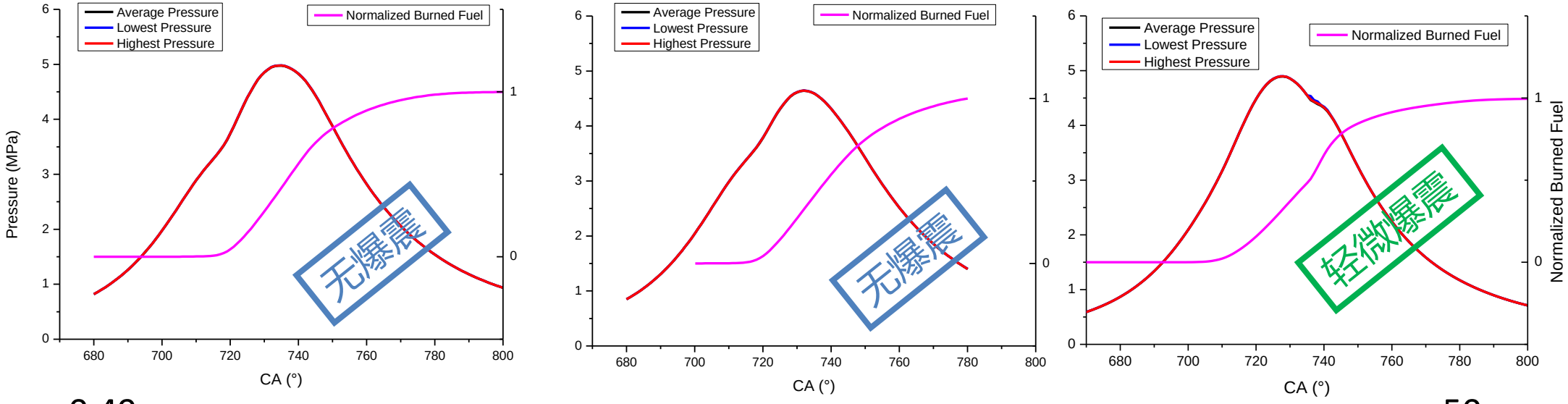
CR=10.8 → CR=14.0 → CR=14.0+SOI推后6°

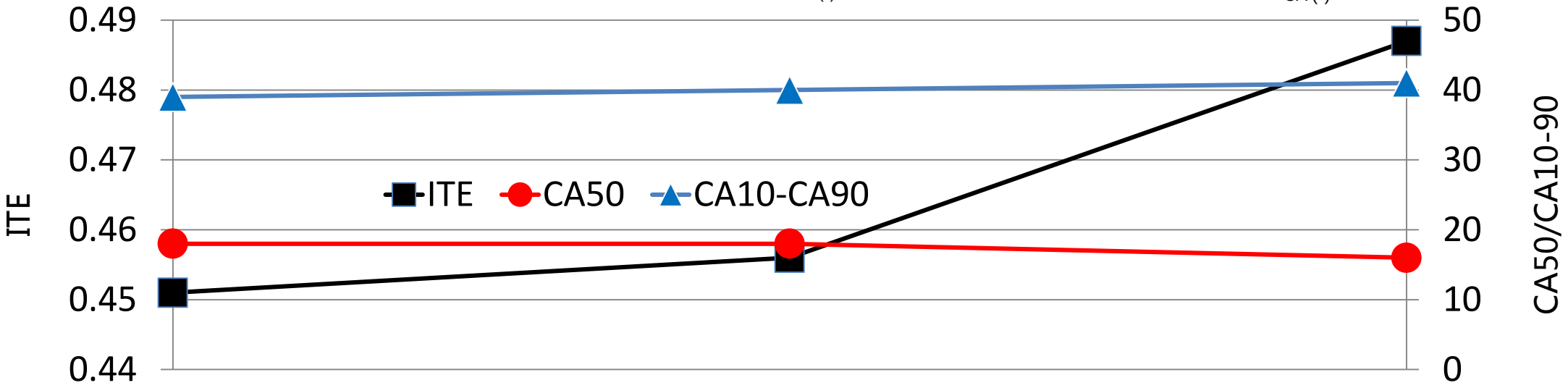




稀燃（CR=14.0，SOI与CR=10.8相同）

Φ=1.35 → Φ=1.55 -40°湍动能提高1.5倍 → Φ=2 SOI提前10° -40°湍动能提高4倍





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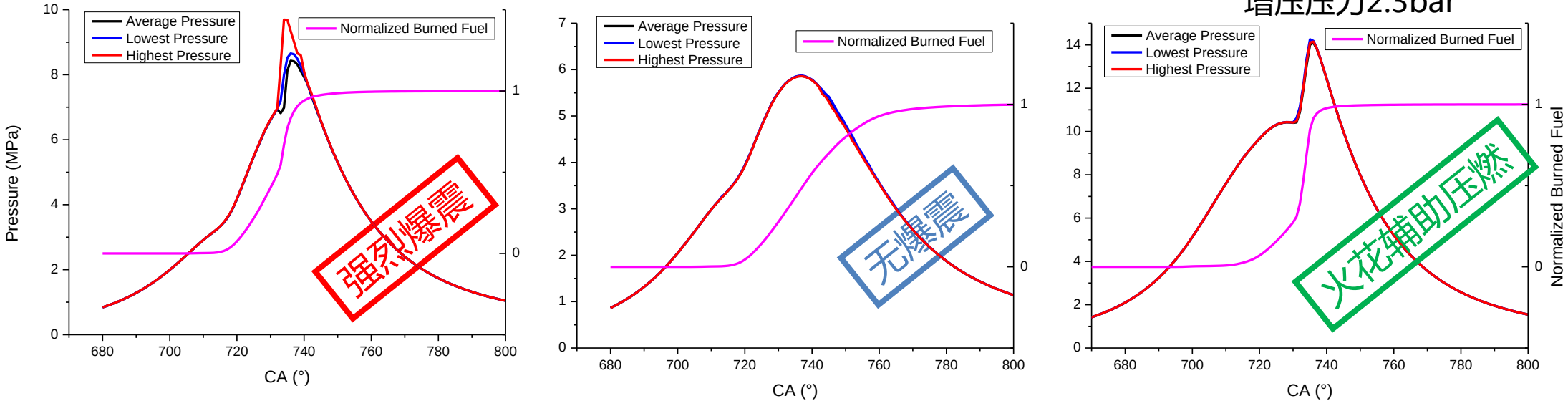
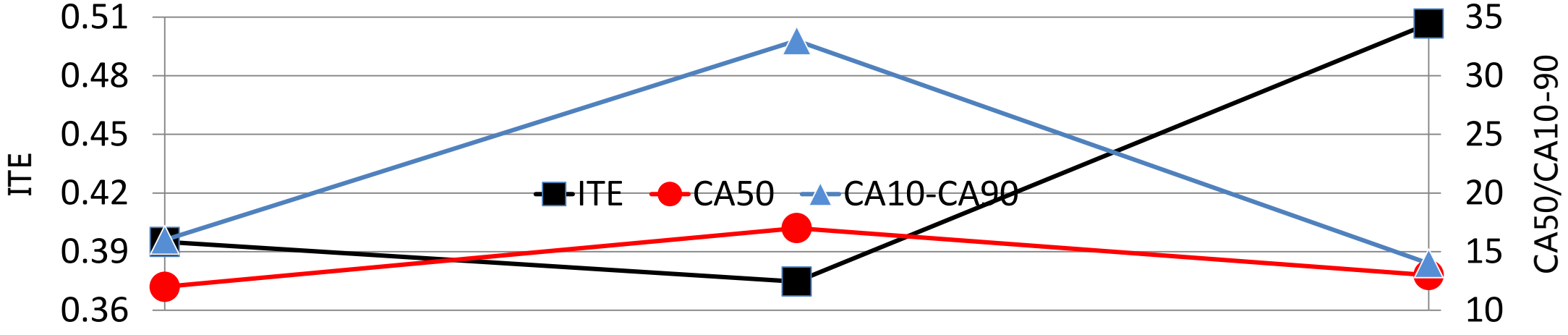
EGR（CR=14.0，SOI与CR=10.8相同）

EGR=10% → EGR=20% → EGR=20%
Φ=2
-40°湍动能提高2.5倍
增压压力2.3bar





●采用激波管和定容燃烧弹开展了商品汽油火焰传播速率和高温滞燃期实验，并标定了反应机理。
●采用发动机缸内燃烧数据进一步标定了反应机理和燃烧模型参数，并验证了模型的普适性，可准确预测缸内燃烧及爆震，包括爆震发生的位置、时刻及点火提前角。
●采用标定后的机理和模型计算了均质燃烧下提高压缩比、稀燃、引入EGR、提高湍动能、增压等措施实现50%ITE的技术路线。最终在14:1的压缩比下采用火花塞辅助压燃的方式可达到51%的ITE。