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DELIVER **INNOVATE** **VISION** MOTIVATION
PERFORMANCE

RELIABILITY

SERVICE **SUCCESS** TEAMWORK EXCELLENCE
RESPECT
INTEGRITY SKILL DUTY **STRENGTH** COURAGE
ACCOUNTABLE MENTOR

Design for Reliability
of 2200bar+ CRS

可靠性设计2200bar+共轨系统

Bosch Powertrain Systems Co. Ltd. 博世动力总成有限公司

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Bosch Powertrain Systems in China 博世动力总成在中国

5200+ associates
名员工

As of Jul. 31, 2022 / 截至 2022 年 7 月 31 日

65 Mio pcs
百万支

injectors for HCV
中重型商用车喷油器

46 Mio pcs
百万支

injectors for PC/LCV
乘用车/ 轻型商用车喷油器

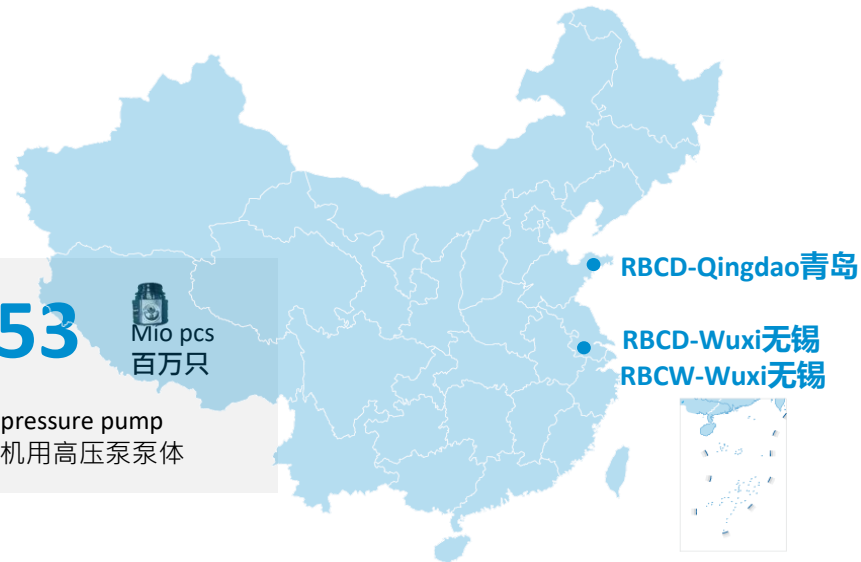
8 Mio pcs
百万只

DNOX
尿素喷射系统

53 Mio pcs
百万只

high-pressure pump
汽油机用高压泵泵体

As of Jul. 31, 2022 (Accumulated Output) / 截至 2022 年 7 月 31 日 (累计生产量)



Technical Center
研发中心

~600
qualified employees
名员工

2万 20,000m²building
平方米的建筑面积

8 engine test benches incl. 2 NG dynos
个发动机测试台架 · 包含两个天然气发动机测试台架

4 cooling boxes
个低温环境实验室

3 chassis dynamometers
台转毂

52 system & components test benches
个系统和零部件的测试台架

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Contents 内容

Reliability Process 可靠性过程

Bosch diesel product portfolio
博世柴油产品组合

Reliability development process
可靠性开发流程

Proof of Reliability
可靠性证明

Challenges 挑战

Market trend
市场趋势

Challenges from market requirement
来自市场需求的挑战

Approaches 方法

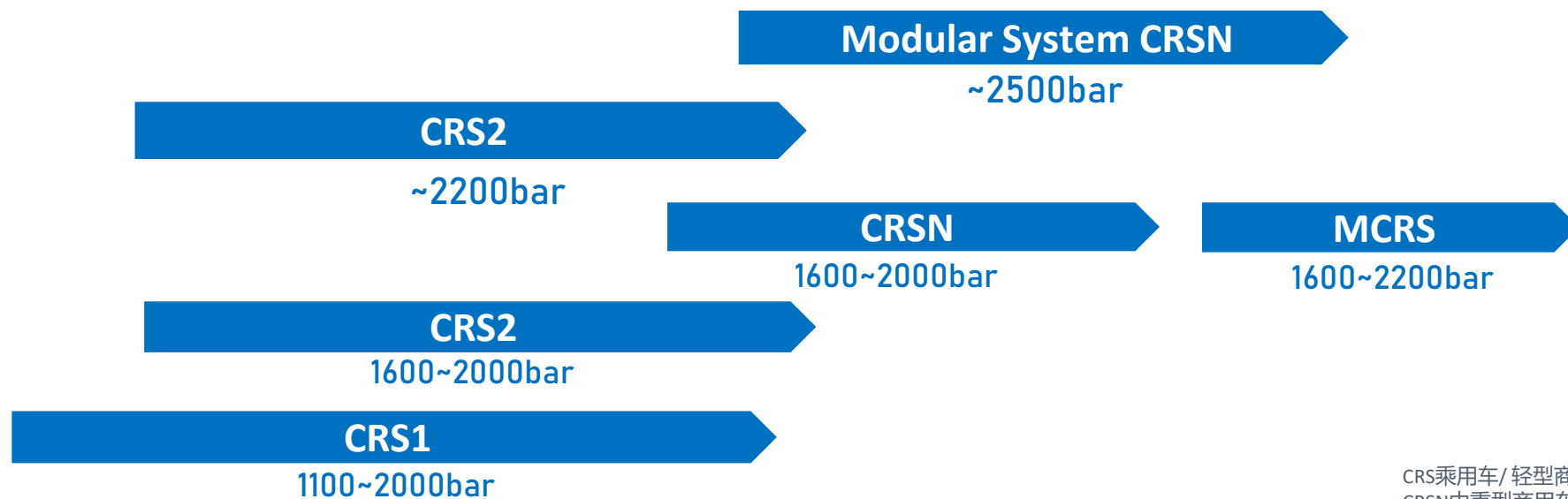
Design for reliability
可靠性设计

Verification test
验证试验

Validation with connectivity
车联辅助验证

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Bosch Diesel CRS Product Portfolio 博世柴油共轨产品组合



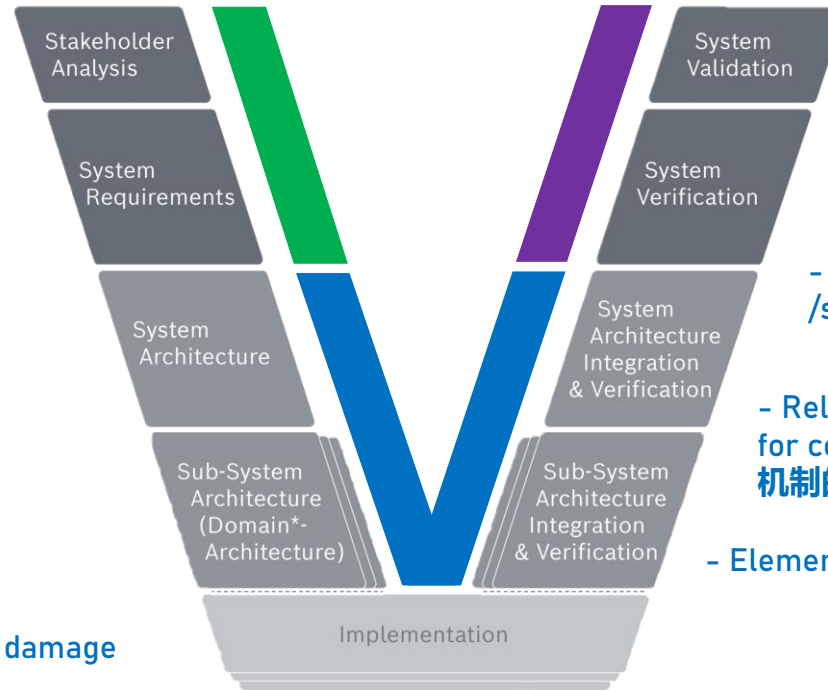
CRS乘用车/ 轻型商用车共轨系统
CRSN中重型商用车共轨系统
MCRS模块化共轨系统

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

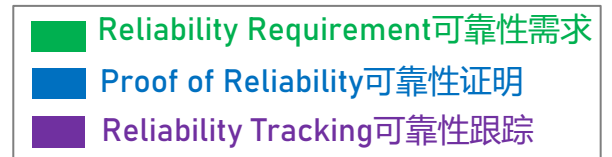
Bosch reliability development process 博世可靠性开发流程

► Reliability related work in development V-model 产品开发v模型中可靠性相关的工作

- Lifetime definition 寿命定义
- Reliability target definition 可靠性目标定义
- Mission profile (load) definition 载荷谱定义
- Damage mechanism identification 损伤机制的识别
- Reliability target partitioning to element 可靠性目标的分解
- Load conversion on element as load path 按载荷路径分解载荷到元件上
- Design for Reliability based on concerned damage mechanism 基于相关损伤机制的可靠性设计



- Vehicle monitoring in field 场地车辆监控
- Engine and vehicle validation at customer 客户发动机和车辆验证
- Program endurance test on component /system 组件/系统的程序耐久性试验
- Reliability lifetime test on element/ component for concerned damage mechanism 针对相关损伤机制的元件/组件的可靠性寿命试验
- Element test 元件试验



Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Proof of Reliability 可靠性证明

Requirement Engineering 需求工程

Legislation 法规需求
Customer 客户需求
Standard 标准需求
...

Focus Analysis 焦点分析

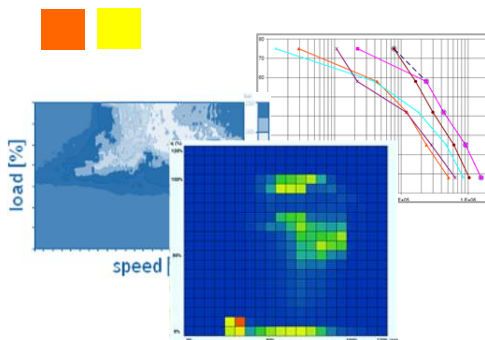
Requirement 需求	Elements, Functions 功能	
	High risk 高风险	Low risk 低风险
...

Main concerns 主要关注点

- High pressure fatigue 高压疲劳
- Cavitation 穴蚀
- Mechanical fatigue 机械疲劳
- Wear 磨损 ...



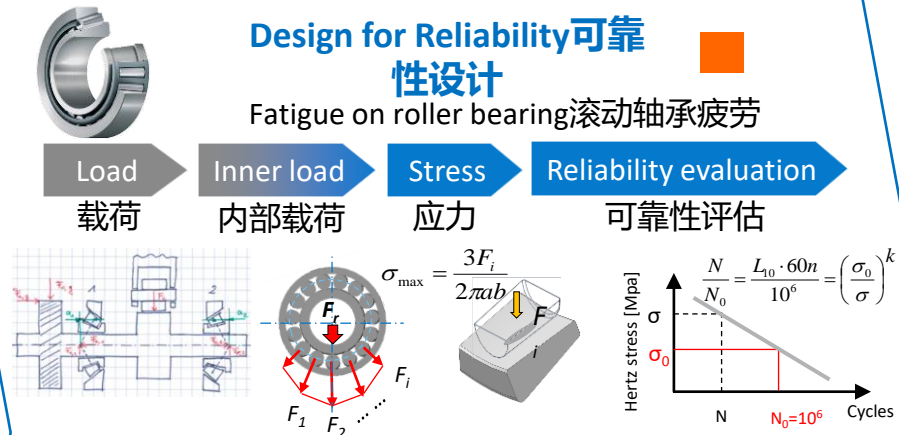
Load profile 载荷谱



Proof of Reliability 可靠性证明

Design for Reliability 可靠性设计

Fatigue on roller bearing 滚动轴承疲劳



Verification and Validation 检验和验证

Standard test 标准试验

Vehicle validation 车辆验证

Tailored lifetime verification 量身定制的寿命验证

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Diesel FIE system world-wide requirement trend 柴油喷射系统全球需求趋势



Low fuel consumption
低油耗
(CO₂ target)



Increasing pressure高
压力
(CN6 → post CN6)



Long lifetime长寿命
(within tolerance)



Cost reduction
低成本



Short time to market
快上市



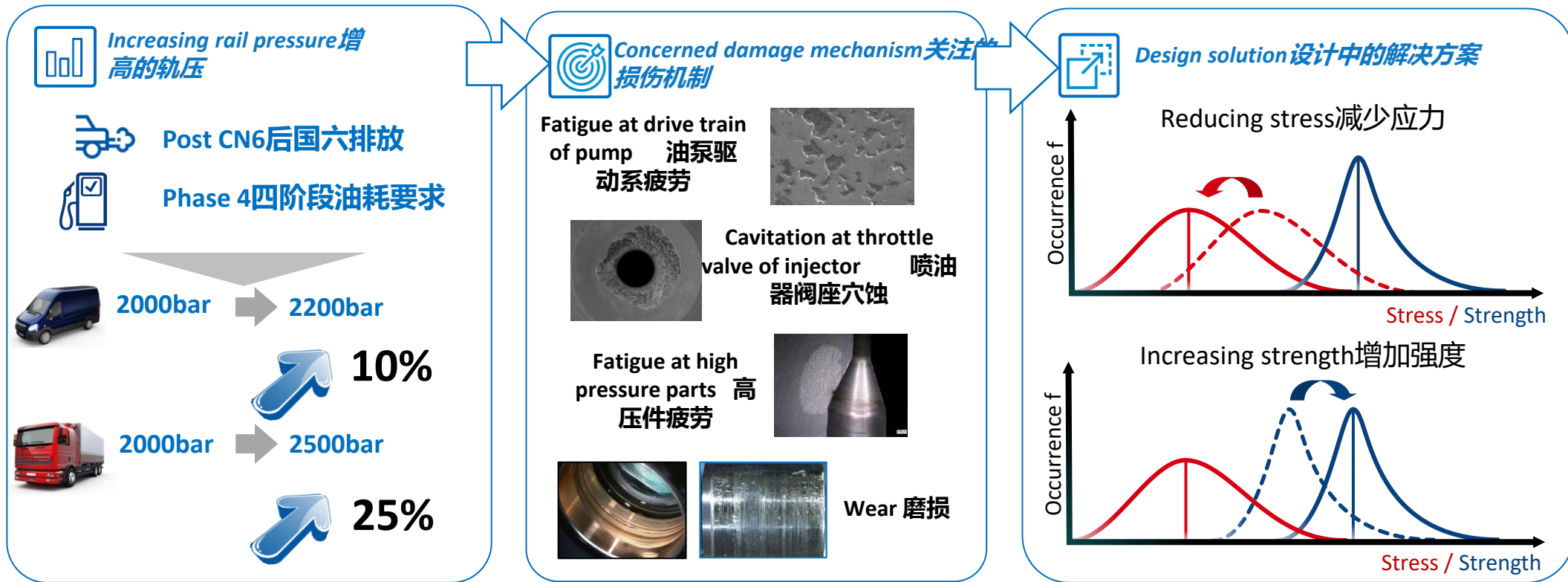
Diversification
多样化
(On-HW, Off-road, HEV)



Design with lower reliability reserves 设计较低的可靠性储备
Fewer iterations during the design phase, fewer recursions during verification/validation
设计阶段和验证阶段的迭代次数更少

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Challenges from market requirement 来自市场需求的挑战



Fatigue, cavitation, wear are main concerns due to pressure increasing,

Design solution is to reduce stress and increase strength of design element.

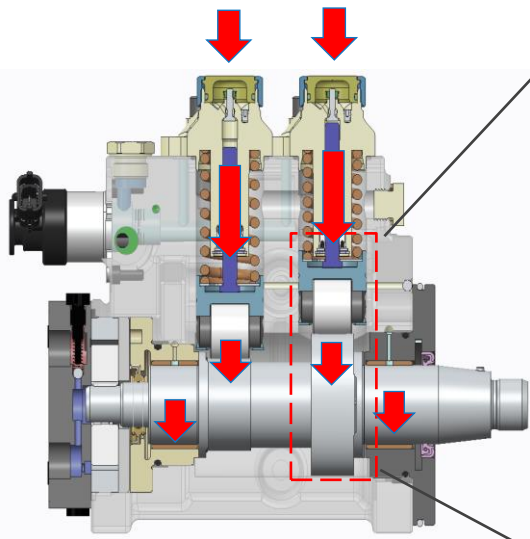
轨压增加导致的疲劳、穴蚀、磨损是主要问题，设计解决方案是减少元件的应力和增加强度。

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Design for Reliability in pump development 油泵开发中的可靠性设计

Working load 工作载荷:

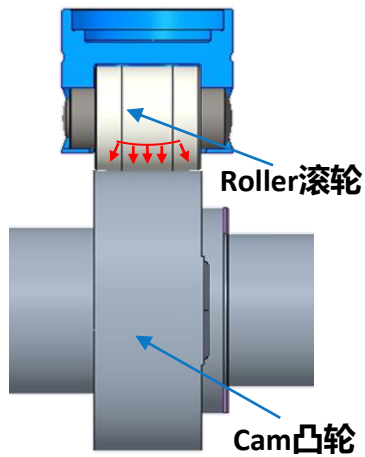
2000 bar → 2500 bar



Concern point 关注点:

High contact stress 高接触应力
→ fatigue probability increase 疲劳可能性增加

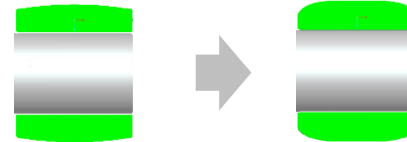
Drive train parts 驱动部件



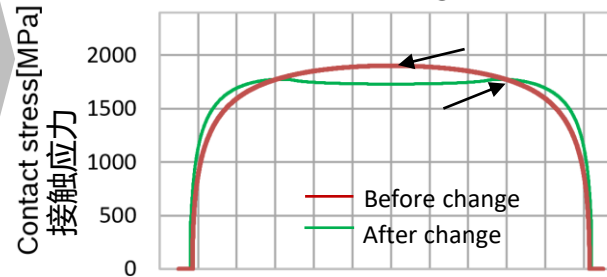
Design optimization 优化:

设计

Roller profile optimized 滚轮轮廓优化
→ contact stress decrease 接触应力下降



roller axial length

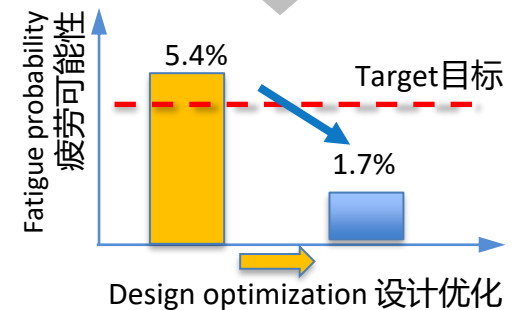


Reliability evaluation 可靠性评估:

Stress v.s. strength 应力强度
→ fatigue probability 疲劳可能性

	500	700	900	1100	1300	1500	1700	1900
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
60	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
70	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
90	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
110	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
120	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
130	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
140	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
150	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
160	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
170	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
180	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
190	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
200	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
210	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
220	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
230	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
240	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Load profile 载荷谱



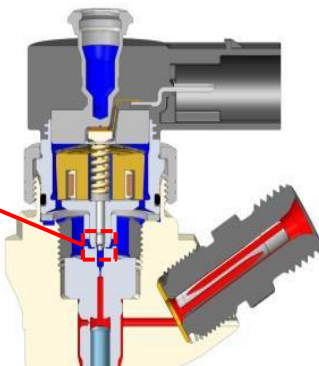
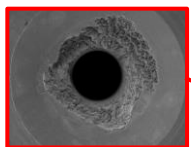
Contact stress on roller decreased by optimizing roller profile to reach reliability target, although pressure increased by 25%. 虽然轨压增加了 25%， 但通过优化滚轮轮廓以降低接触应力从而达到可靠性目标。

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Verification Test in injector development 喷油器开发中的验证试验

Concern point and design solution 关注点和设计方案:

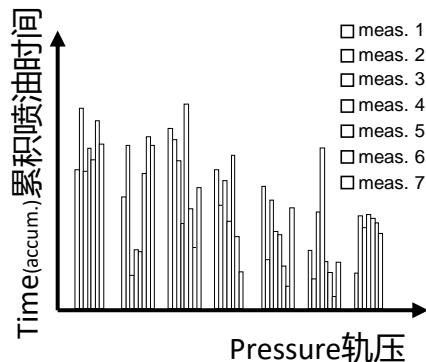
Cavitation, wear at valve throttle 阀座的穴蚀和磨损



Pressure balanced valve and anti-wear coating 压力平衡阀和抗磨涂层

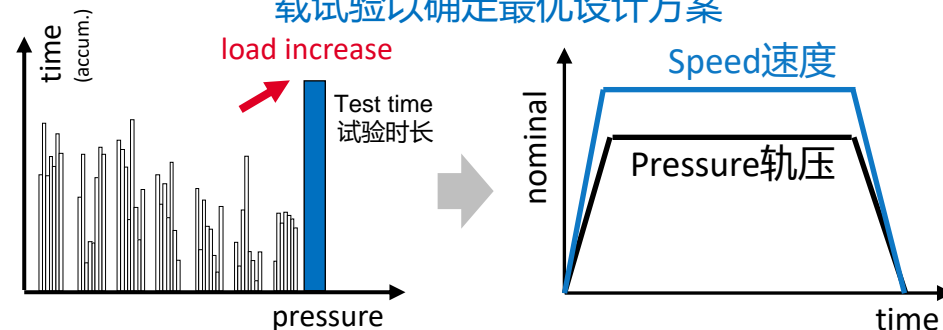
Load analysis 载荷分析:

Loads collected from different vehicles 多种应用收集的载荷数据

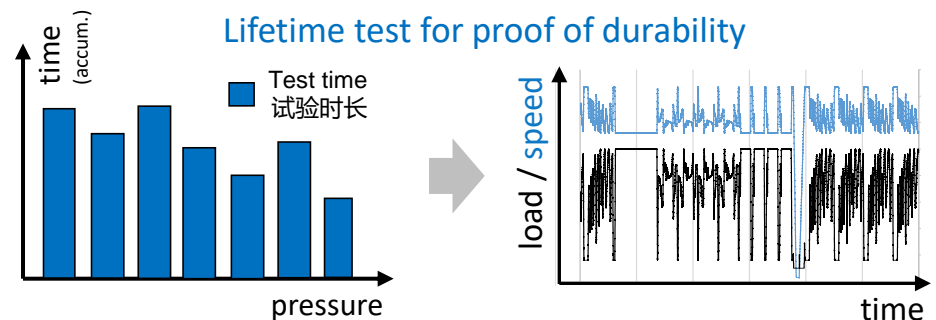


Test program definition: 试验程序定义

Overload test for determination of design solution 超载试验以确定最优设计方案



Lifetime test for proof of durability



Considering cavitation, wear at valve throttle, the overload test defined to determine design solution and the lifetime test defined to prove durability of design.

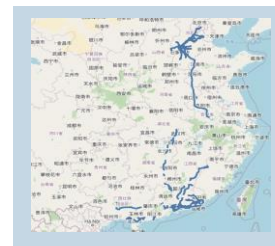
针对喷油器阀座的穴蚀、磨损，定义了超载试验以确定最优设计方案，寿命试验证明了设计的耐久性。

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

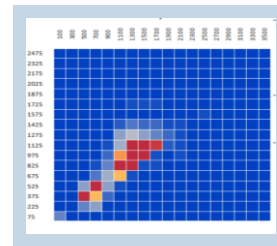
Validation with connectivity 车联辅助验证



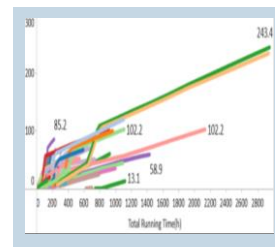
Data automatic analysis and visualization 数据自动分析和可视化



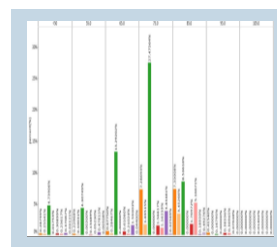
Road condition analysis 路况分析



Operation condition analysis 工况分析



Accumulated injection number 累积喷射次数



Temperature distribution 温度分布

System validation in field with support of connectivity solution.

Large scale monitoring, components status timely tracking, real load data collection.

在车联解决方案辅助下的场地系统验证实现了大范围监控，零部件状态及时跟踪，真实载荷数据采集。

Design for Reliability of 2200bar+ CRS (2200bar+共轨系统可靠性设计)

Summary 总结

- 1 Bosch develops CRS2-22, CRSN25MS to face diesel FIE system world-wide requirements
博世研发CRS2-22、CRSN25MS 应对柴油喷射系统的全球需求
- 2 Systematic reliability working process ensures the reliability of CRS products
系统的可靠性工作流程保证了共轨产品的可靠性
- 3 Design for Reliability to prove the product reliability by evaluation in design phase
可靠性设计通过在设计阶段的评估方法来证明产品的可靠性
- 4 Verification and Validation to prove the product reliability by test in testing phase
检验验证通过在试验阶段的试验手段来证明产品的可靠性

THANK YOU

谢谢!