TRIBOLOGICAL INVESTIGATION OF NEW SYNTHETIC METAL SULFIDES IN PEEK, PPA AND PPS-COMPOUNDS
合成金属硫化物在改性PEEK, PPA, PPS塑料中的摩擦学研究

Tribotecc
...more than performance

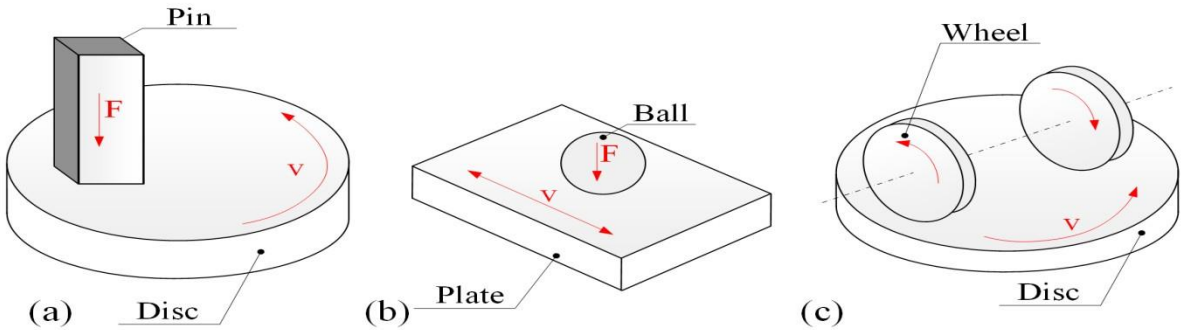
CONTENT 内容

- Scope of the work 研究内容
- Tribotecc at a glance 特博科简介
- Solid lubricants in polymers 聚合物应用固体润滑剂
  - Mechanisms of metal sulfides 金属硫化物的机械属性
  - Synthetic metal sulfides for polymers 聚合物应用之合成金属硫化物
- Examples / Setup / Results 案例/配置/结果
  - PEEK – Bruker UMT-2
  - PPA – OFT 2000
  - PPS – Tabor tester
- Conclusion and Outlook 结论

SCOPE OF THE WORK 研究内容

- Effect of metal sulfides as solid lubricants in high engineered polymers
  金属硫化物在高性能改性工程塑料应用中的固体润滑作用
- Tribological investigation in 3 different polymer compounds: PEEK, PPA, PPS

  通过三种聚合物进行摩擦研究: PEEK, PPA, PPS
- Principle of test set ups 实验设置的原则



Bruker UMT-2 OFT 2000 Tabor tester

- *Preselection of metal sulfides due to modelling testing*
  根据模型测试预选择金属硫化物

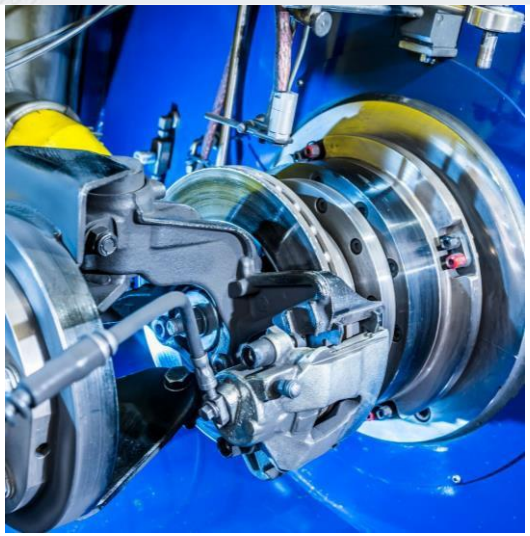
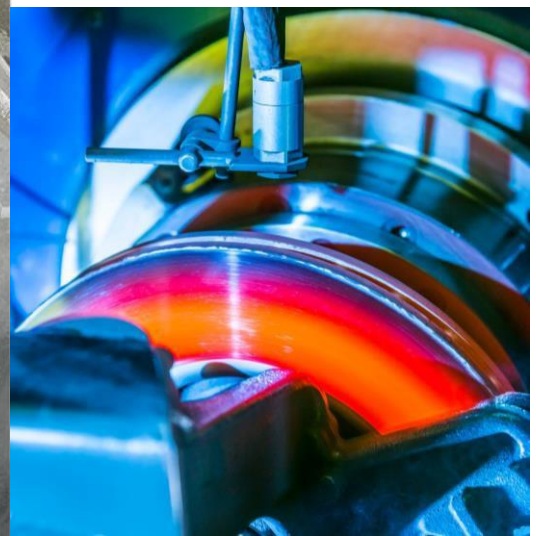
TRIBOTECC AT A GLANCE 特博科简介
THE EXPERT ON METAL SULFIDES 金属硫化物专家

- Global Market and Technology leader of high performance speciality metal sulfides 全球领先的高性能金属硫化物生产商
- Largest production capacity worldwide of synthetic metal sulfides ~ 25.000mt 合成金属硫化物产量 25,000吨/年
- Close and long lasting R&D cooperation in core businesses 持续地研发投入用于核心业务
- Member of Treibacher Group ~800 employees, global sales: 500 Mio EUR; Tribotecc ~ 80Mio EUR (2017)

  特里巴赫集团成员 约800名员工, 5亿欧元销售；特博科 ~8000万欧元销售（2017）

blue: Buildings of Tribotecc GmbH

TRIBOTECC AT A GLANCE 特博科简介
RESEARCH AND DEVELOPMENT – FRICTION 研发 – 摩擦


Testing and manufacturing equipment
实验和生产设备

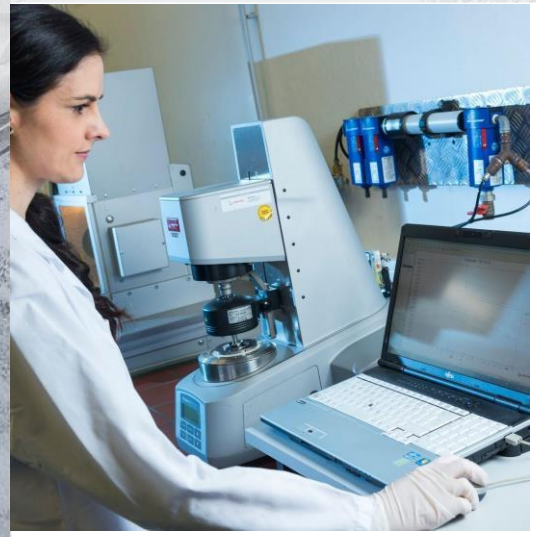
- Mixers, presses and curing units for manufacturing disk brake pads

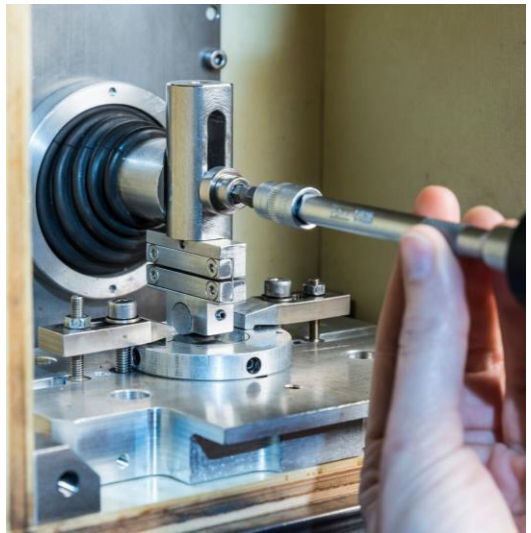
  用于制造盘式制动器的混合器，压力机和固化装置

- Inertia Brake Dynamometers

  惯性制动测功机

TRIBOTECC AT A GLANCE 特博科简介
R&D – LUBRICANTS AND POLYMERS 研发 – 润滑及工程塑料



Testing and manufacturing equipment
实验和生产设备

- Three-Roll-Mill 三辊轧机
- Oscillating Tribometer SRV IV 振荡摩擦机 SRV IV
- Four-Ball-Tester 四球测试机
- Oscillating Friction Tribometer OFT 2000
  振荡摩擦计 OFT 2000
- Rotational Rheometer MCR 301
  旋转流变仪 MCR301
- Brugger Lubricant Tester 布鲁格润滑测试机

- External: Bruker UMT-2 (PCCL, AT)
  外部：布鲁克UMT-2（PCCL, 奥地利）
- External: Tabor tester (DJK institute, JP)
  外部： 泰伯测试机（DJK研究所，日本）

TRIBOTECC AT A GLANCE 特博科简介

MAIN APPLICATIONS OF METAL SULFIDES FROM TRIBOTECC 主要应用

Friction
摩擦

Lubricants
润滑

Polymers
工程塑料

Powder
Metallurgy
粉末冶金

Abrasives
研磨

SOLID LUBRICANTS IN POLYMERS
工程塑料中的固体润滑剂

Use 应用

- In high engineered polymers such as PI, PEEK, PPA, PPS, PAI, PPA, PTFE, POM and many more
  用于改性工程塑料，如PI, PEEK, PPA, PPS, PAI, PPA, PTFE, POM, 及其他

Effect 作用

- Reduce wear 减少磨损
- Reduce friction coefficient 降低摩擦系数
- Increase conductivity 增加电导率
- Increase life time of high stressed parts 延长高应力部件寿命

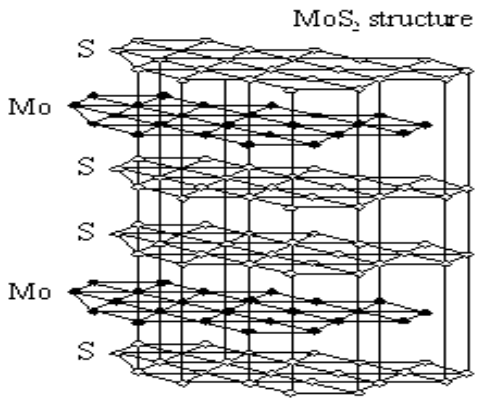
Application 最终产品

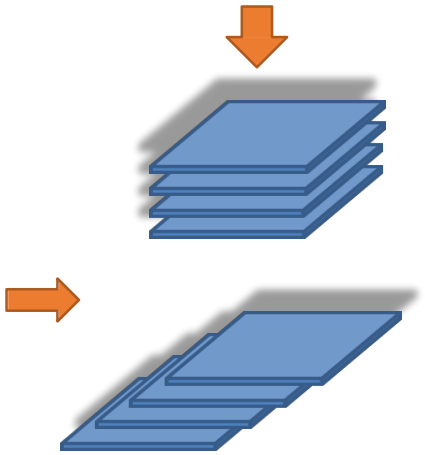
- Bearings, gears, valves, bushings, fuel pump parts, turbo chargers... 轴承，齿轮，阀门，衬套，燃油泵零件，涡轮增压器...

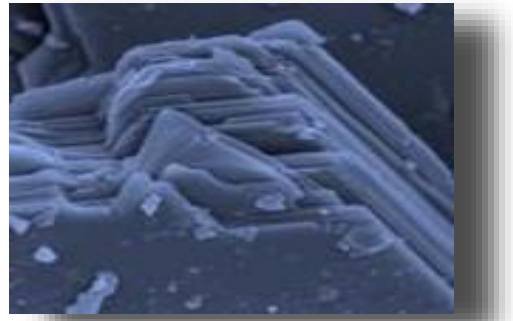
SOLID LUBRICANTS IN POLYMERS 工程塑料中的固体润滑剂
MECHANISMS OF METAL SULFIDES 金属硫化物机械属性

Structural Lubrication 结构性的润滑

- MoS_2, WS_2, SnS_2 have a layer lattice structure 二硫化钼，二硫化钨，二硫化锡都具有层晶格的结构
- Atomic layers are easily movable against each other (Van der Waals forces) 原子层很容易相互移动（范德瓦尔斯力）
- Soft material, good metal adhesion 柔软的材料，良好的金属附着力
- Formation of stable tribofilms/interfaces, high load capacity 形成稳定的润滑膜/界面，高负载能力
- high thermal resistancy >400°C 高热稳定性>400°C







SOLID LUBRICANTS IN POLYMERS工程塑料中的固体润滑剂
SYNTHETIC METAL SULFIDES FOR POLYMERS 改性工程塑料中的合成金属硫化物

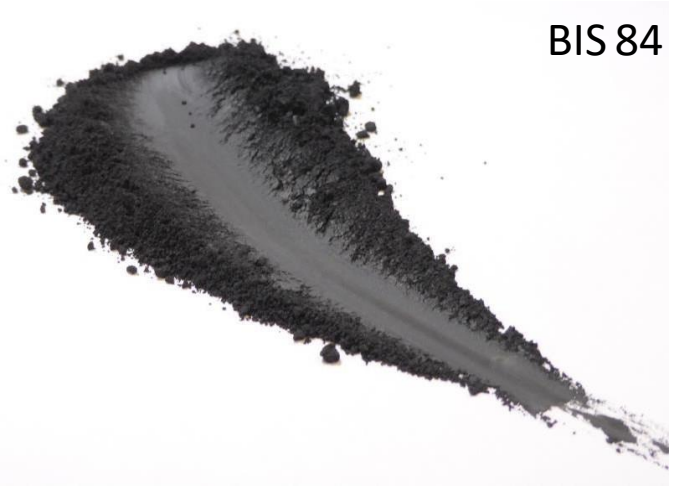
Product description 产品描述：

- **MOS XF**, natural molybdenum disulfide grade, d50 ~8µm (Reference) 天然二硫化钼等级，d50 约8µm
- **WS 2 & WS 5**, pure synthetic tungsten disulfide grades, d50 ~2µm & 12µm 纯合成二硫化钨等级，d50 约2µm & 12µm
- **WS 31 & WS 31F**, new synthetic multiphase-sulfide based on Mo and W, d50 ~6µm & 2µm 基于钼和钨的新型合成多相硫化物，d50 约6µm & 2µm
- **WS 44S**, new synthetic multiphase-sulfide based on Mo, W and Mn, d50 ~6µm 基于钼，钨和锰的新型合成多相硫化物， d50 约6µm
- **SNS2 Grade A**, pure synthetic tin disulfide grade, d50 ~3µm 纯合成二硫化锡等级， d50 约3µm
- **SLS 22 & SLS 22F**, new synthetic lubricant system based on Tinsulfides, d50 ~8µm & 2µm 基于硫化锡的新型合成润滑系统， d50约8µm & 2µm
- **BIS 84**, synthetic bismuth sulfide grade, d50 ~2µm 合成硫化铋等级， d50约2µm
- **CB 500**, synthetic copper sulfide (CuS), d50 ~25µm 合成硫化铜， d50约25µm

Different particle sizes were chosen to investigate the influence of the grain sizes.
同时，选择不同的粒度来研究粒度的影响。

SOLID LUBRICANTS IN POLYMERS工程塑料中的固体润滑剂

SYNTHETIC METAL SULFIDES FOR POLYMERS 改性工程塑料中的合成金属硫化物



EXAMPLES – GENERAL PROCEDURE
案例 – 一般程序

- Compounding 配料
- Injection moulding 注塑成型
- Sample preparation 样品制备
- Tribotests 摩擦实验

EXAMPLE NO. 1: PEEK – BRUKER UMT-2
COMPOUNDING AND SAMPLE PREPARATION
案例 No. 1: PEEK – BRUKER UMT-2
配料和样品制备

Compounding of 10 materials with 10% w/w solid lubricant 按照10%的比例配置10种材料

The compounding was made at APC Advanced Polymer Compounds (AT), materials used:

配料在APC先进聚合物配料公司完成（奥地利），材料使用的是：

- PEEK (VESTAKEEP 4000G)
- Solid lubricant 固体润滑剂：
  Tribotecc® - MOS XF, WS 2, WS 5, WS 31, WS 31F, SLS 22, SLS 22F, SNS2 Grade A,
  CB 500 and BIS 84

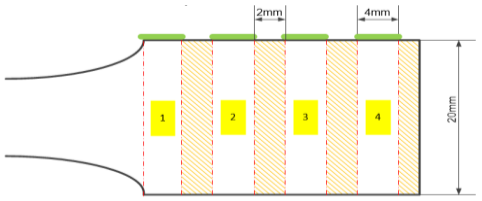
Injection moulding 注塑

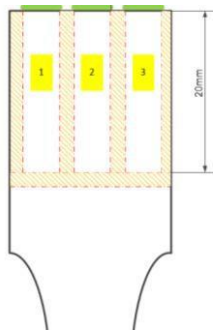
Injection moulding was made at TCKT in Wels (AT)

注塑在TCKT公司完成(奥地利）

Sample preparation 样品制备

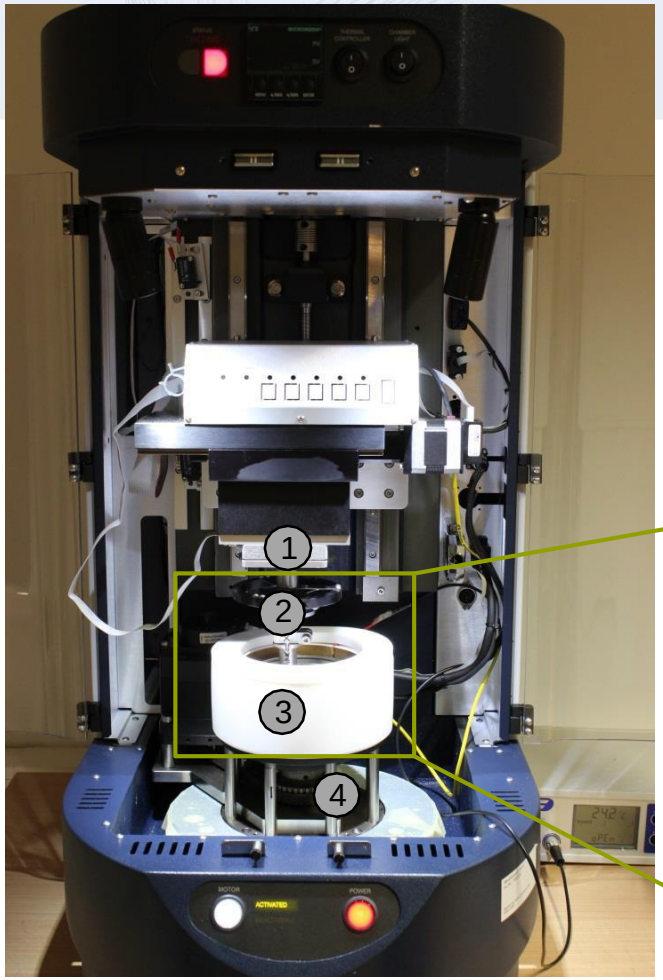
at PCCL (AT)





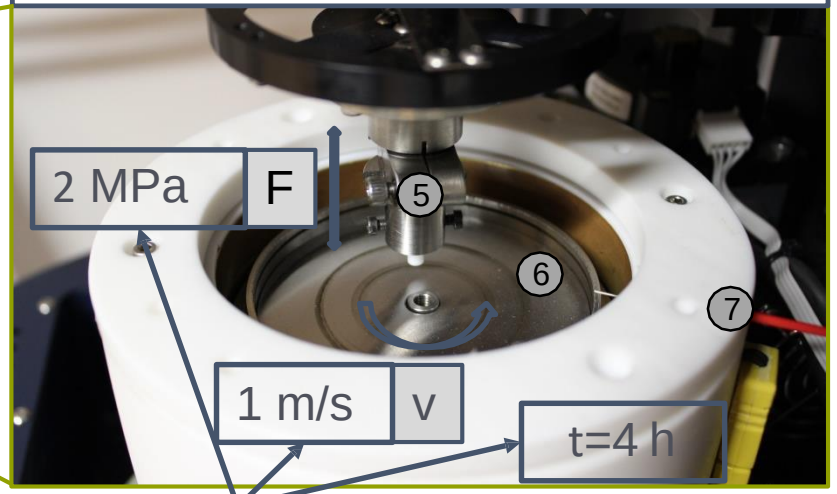
EXAMPLE NO. 1: PEEK – BRUKER UMT-2 案例 No. 1

TRIBOTEST ACCORDING TO ASTM G99 摩擦实验依据ASTM G99



UMT-2, Bruker Nano

1. Measuring box 量盒
2. Suspension system 悬挂系统
3. Medium chamber 中室
4. Engine 发动机
5. Sample holder (Pin holder) 样品架（针座）
6. Disc holder 盘片架
7. Temperature sensor 温度计



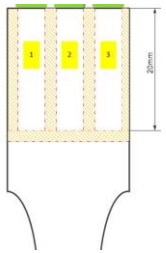
Parameters
参数

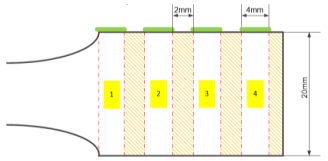
Sliding counterpart: 34CrNiMo6, Ra: 0,4µm
滑动对应物: 34CrNiMo6, Ra: 0.4µm

EXAMPLE NO. 1: PEEK – BRUKER UMT-2 案例 No.1

RESULTS: COEFFICIENT OF FRICTION

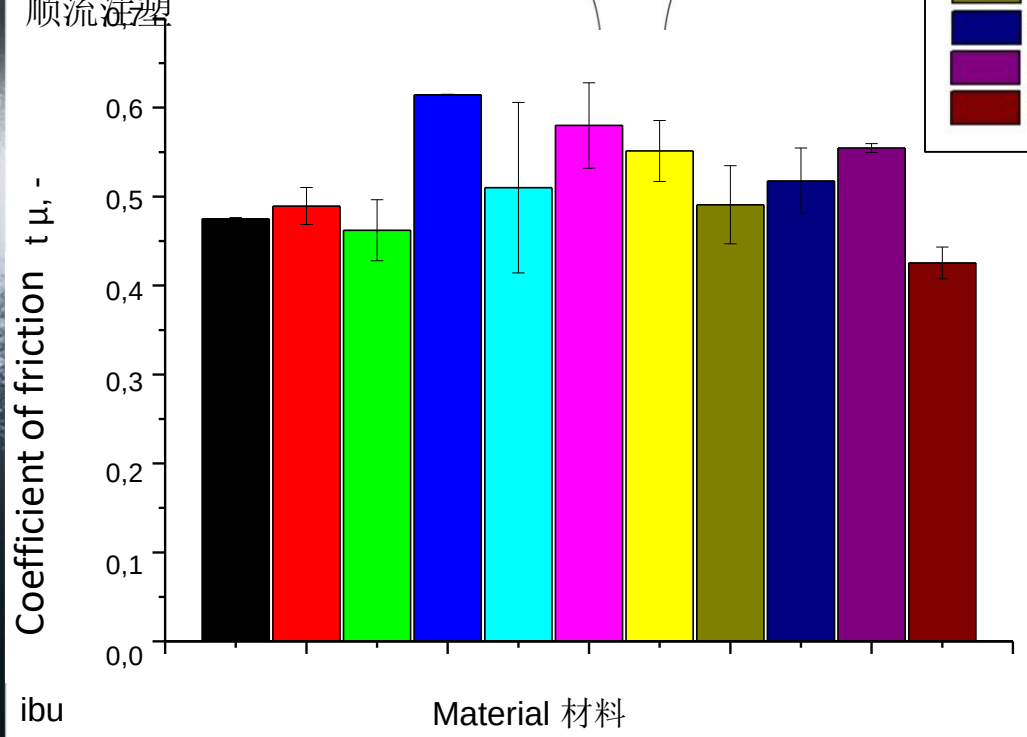
结果：摩擦系数



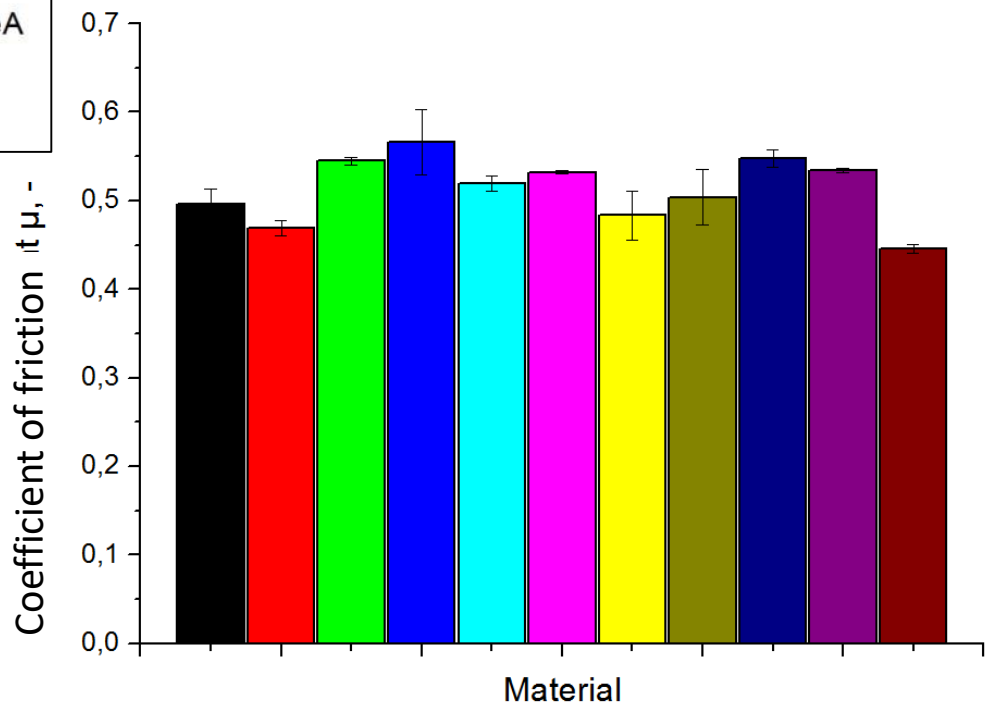


IN injection direction

顺流注塑



CROSS injection direction 交叉注塑



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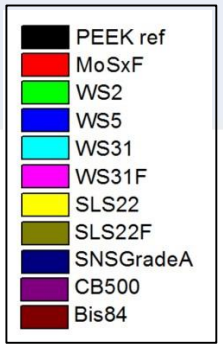
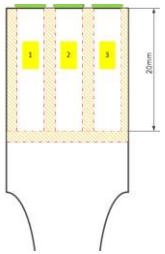
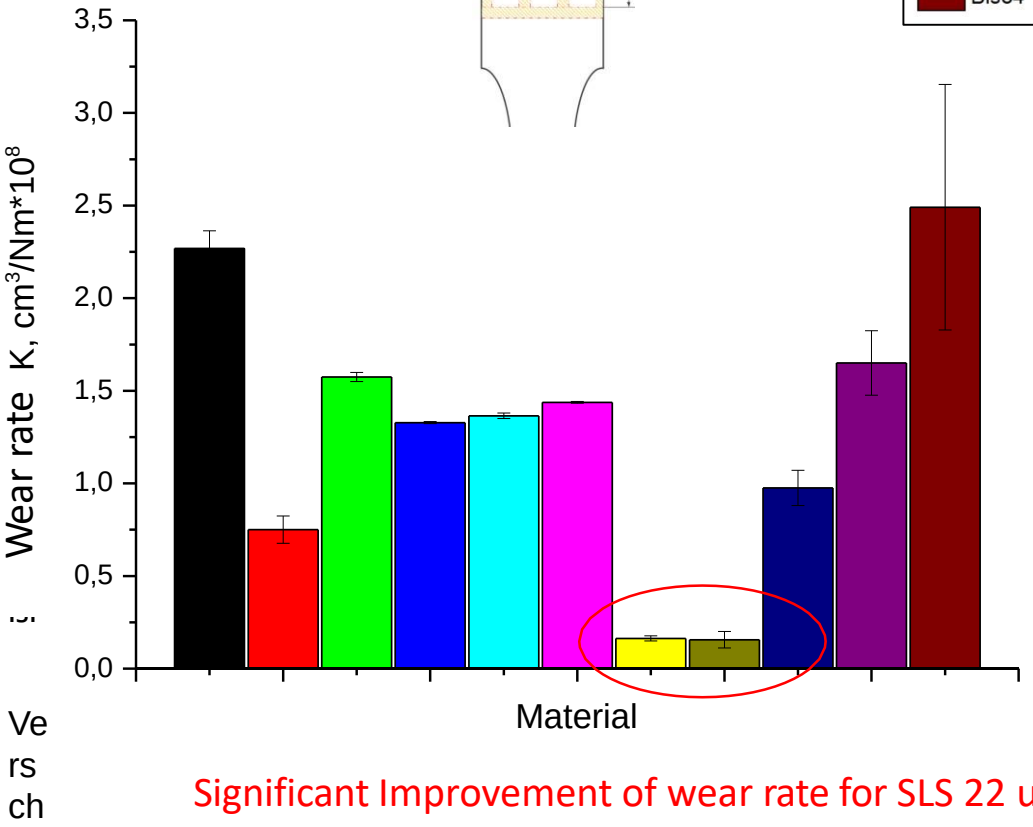
EXAMPLE NO. 1: PEEK – BRUKER UMT-2 案例 No. 1

RESULTS: WEAR RATE
结果：磨损率

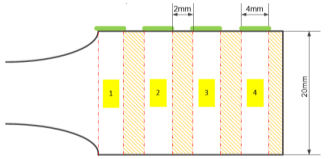


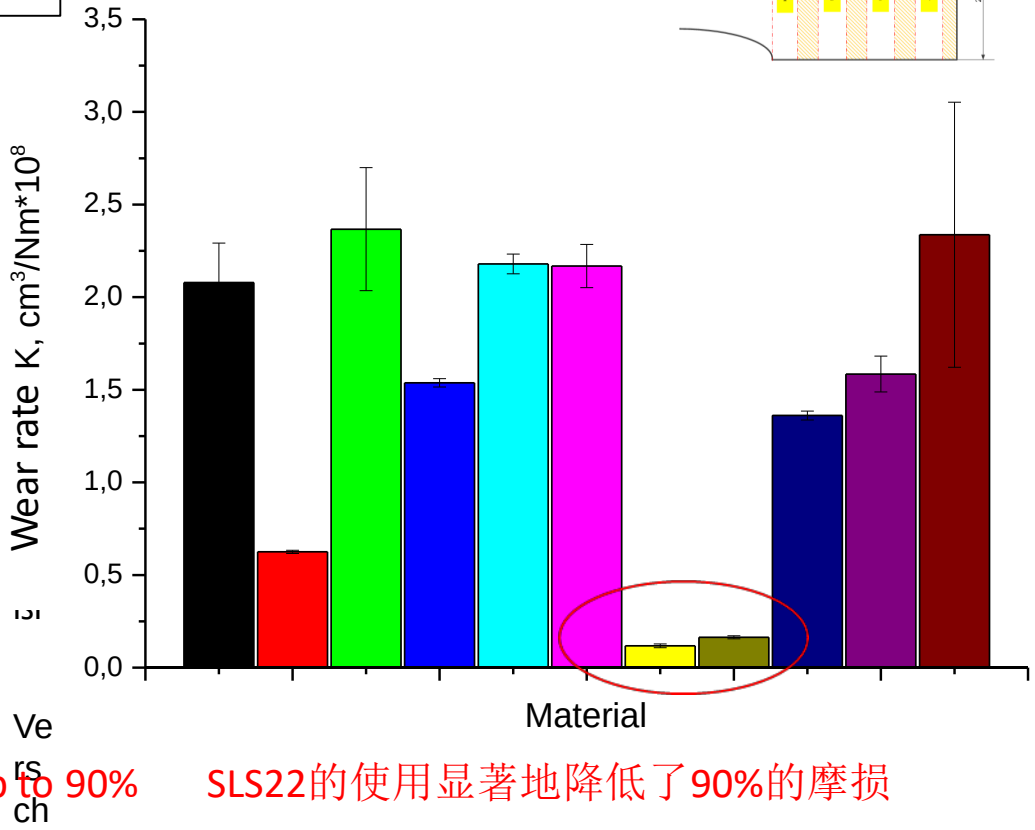
IN injection direction
顺流注塑





CROSS injection direction
交叉注塑



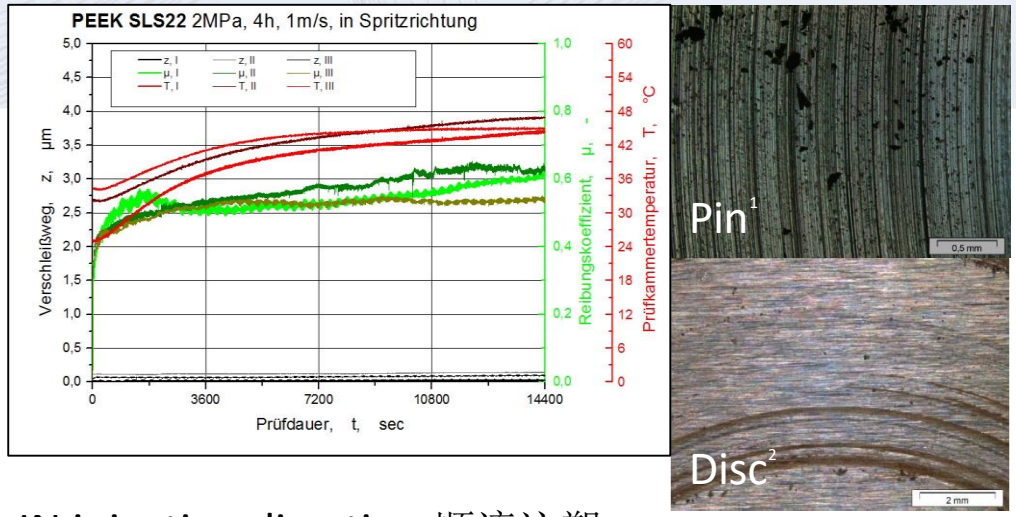


Significant Improvement of wear rate for SLS 22 up to 90%

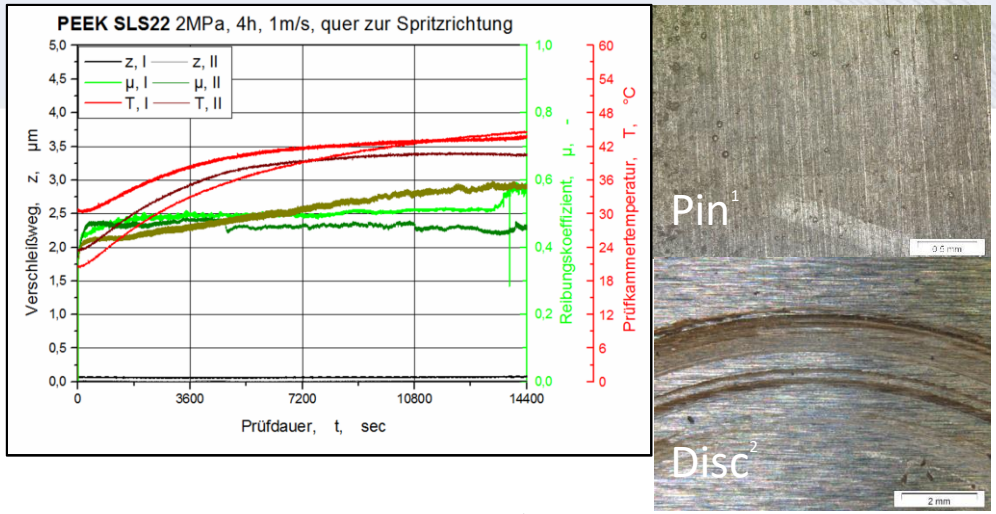
SLS22的使用显著地降低了90%的摩损

EXAMPLE NO. 1: PEEK – BRUKER UMT-2 案例 No.1

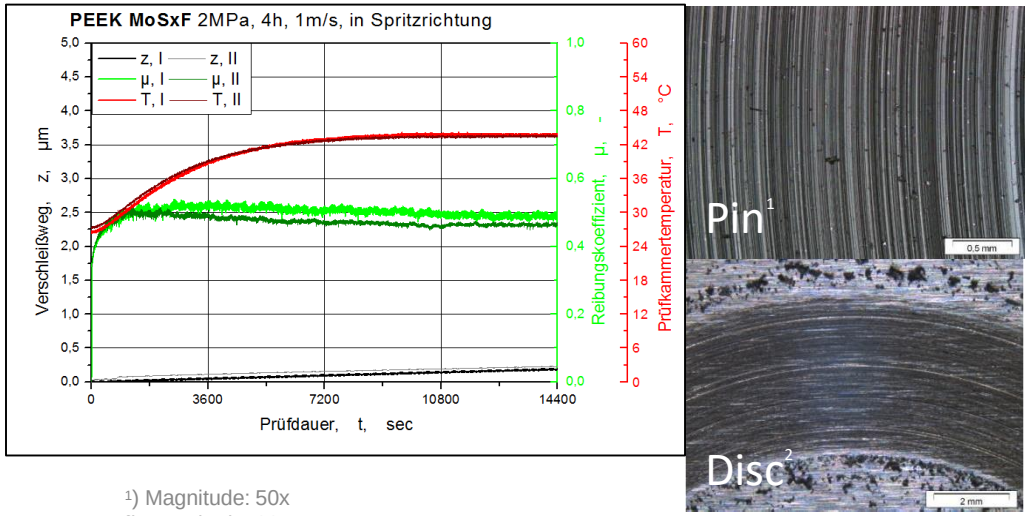
RESULTS: DETAILS 结果：明细

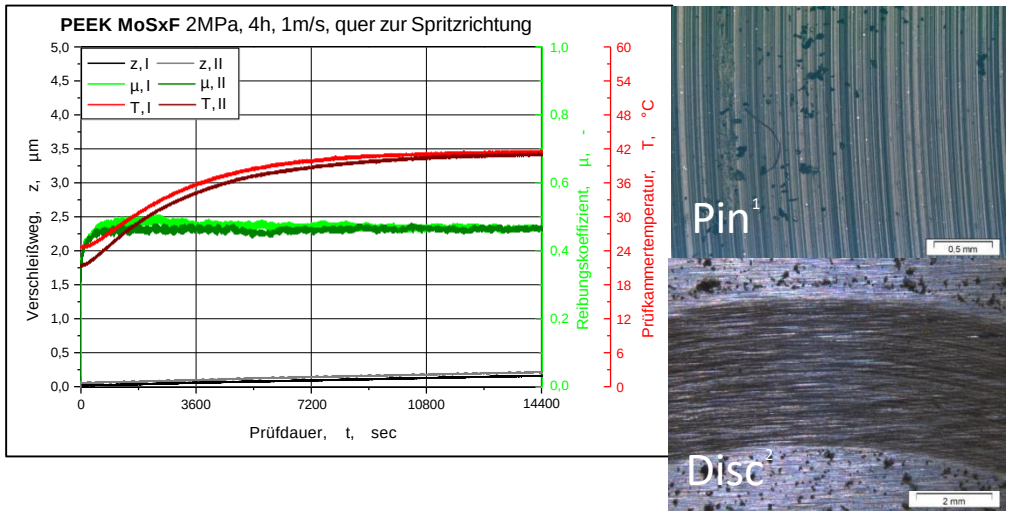


IN injection direction 顺流注塑



CROSS injection direction 交叉注塑





[1]) Magnitude: 50x
[2]) Magnitude: 20x

EXAMPLE NO. 2: PPA – OFT 2000 案例No. 2 PPA
COMPOUNDING AND SAMPLE PREPARATION 配料和样品制备

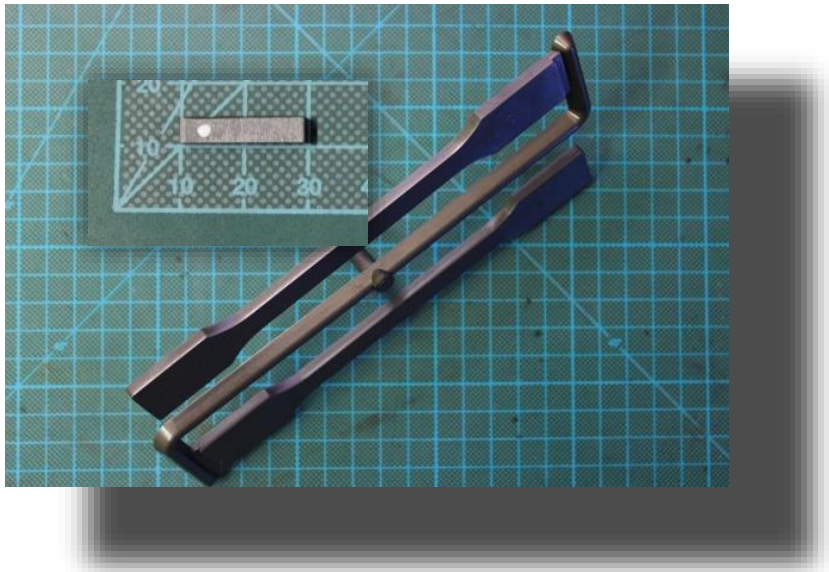
Compounding of 5 materials with 5% and 10% w/w solid lubricant 将5种添加剂按照5%和10%的比例配料

The compounding was made at APC Advanced Polymer Compounds (AT), materials used:

配料在APC先进聚合物配料公司完成（奥地利），材料使用的是：

- PPA
- Solid lubricant 固体润滑剂：

  Tribotecc® - MOS XF, WS 2, WS 31, SLS 22, WS 44S



Injection moulding 注塑

Injection moulding was made at TCKT in Wels (AT)
注塑在TCKT公司完成(奥地利）

Sample preparation 样品制备

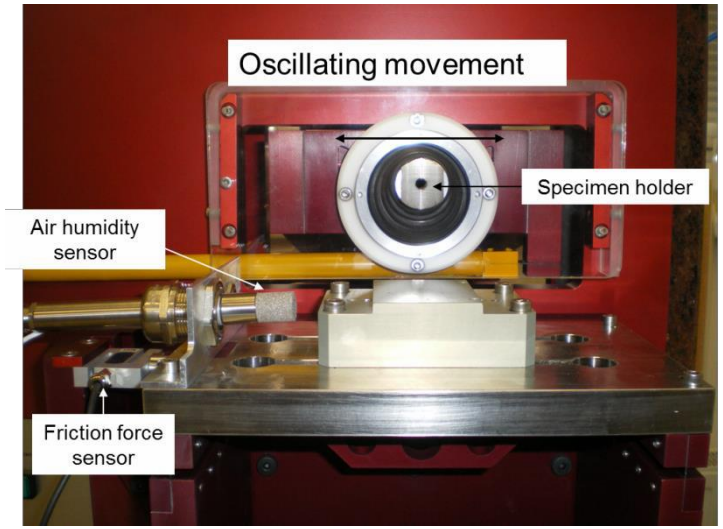
Tensile specimen cut into pieces to fit into the OFT 2000 将拉伸试样切片以适合放入 OFT 2000

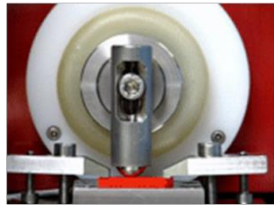
Reference made to tests from PPA-test series performed by PCCL (presented at the PolyTrib 2016, Hausberger A.) – Bruker Nano UMT-2, according to ASTM G99, Pin-on-Ring, 2MPa, 1m/s, 4h
参考奥地利PCCL公司进行的PPA系列测试(Hausberger在PolyTrib 2016展示), Bruker Nano UMT-2, 根据ASTM G99, Pin-on-Ring, 2MPa, 1m/s, 4h

EXAMPLE NO. 2: PPA – OFT 2000 案例 No. 2 PPA
TRIBOTEST ON OFT 2000 在OFT 2000上的摩擦测试

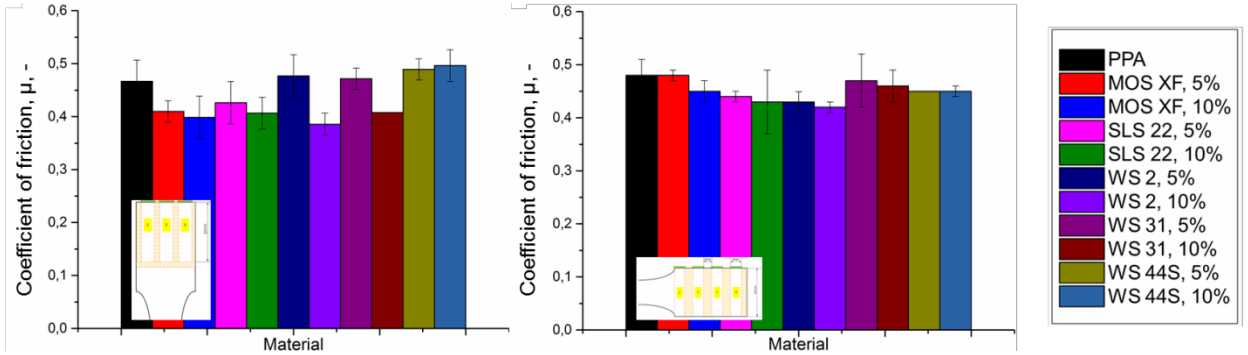
- Oscillating Friction Tribometer - Ball on Disc setup 摆动摩擦试验机 – 圆盘上的球的设置
- Disc material: PPA compounds with Tribotecc® solid lubricants – tests along injection direction
  圆盘材料：含有特博科固体润滑剂的PPA配料 – 沿注射方向进行测试
- Ball material: 100Cr6
  球的材料: 100Cr6

Ball diameter 球直径:	10,0	mm
Amplitude 振幅:	10,0	mm
Frequency 频率:	1,0	Hz
Normal force 法向力:	100	N
Duration 持续时间:	75	minutes
Temperature 温度:	25°C / 180°C	



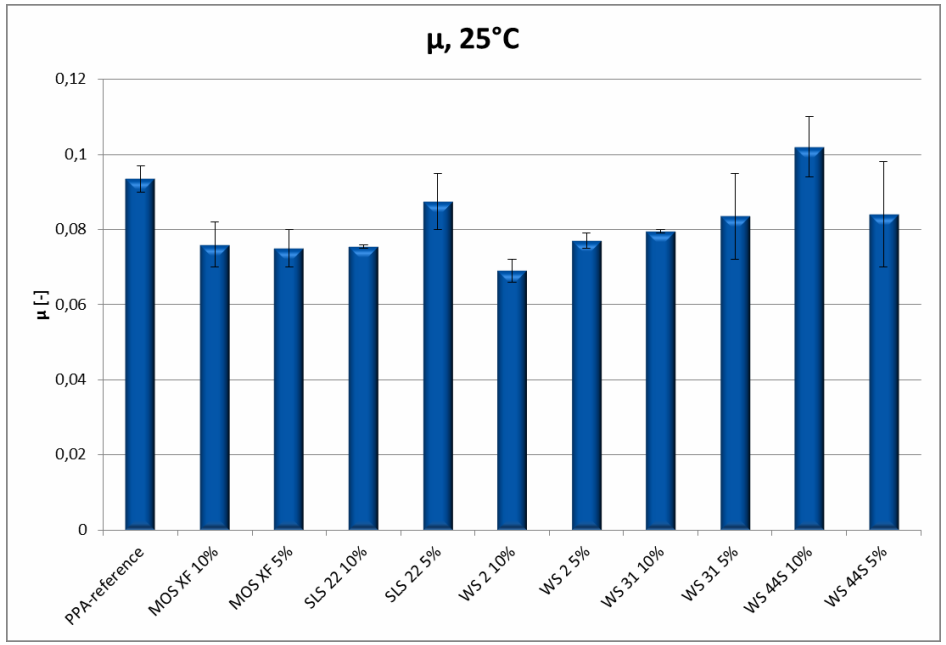


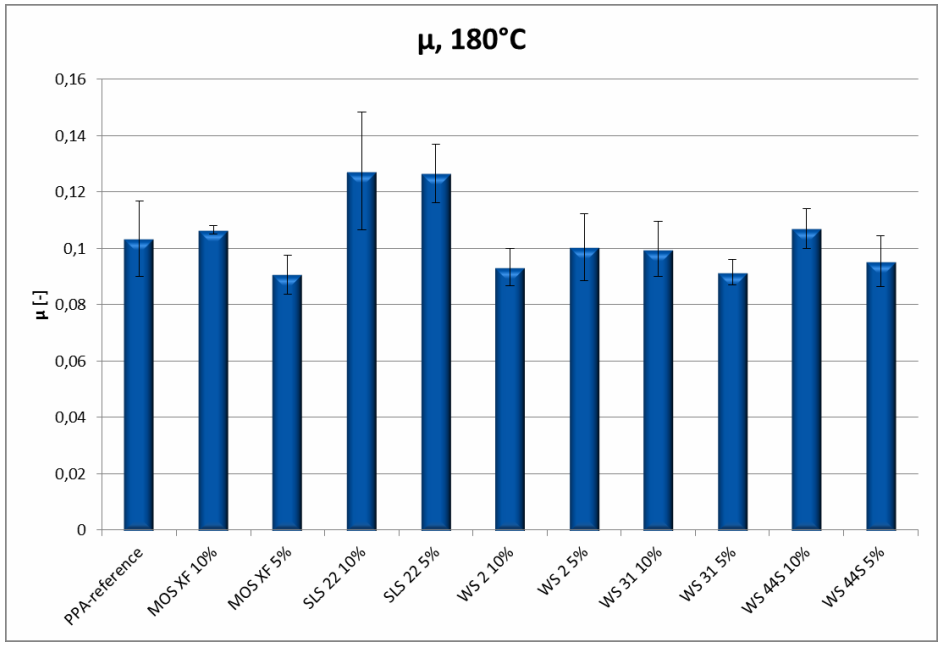
EXAMPLE NO. 2: PPA – OFT 2000
RESULTS: COEFFICIENT OF FRICTION



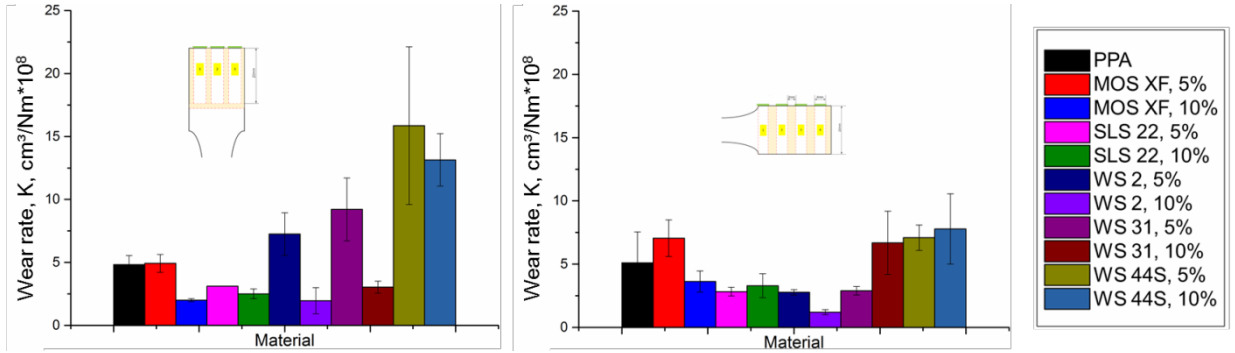
Bruker Nano UMT-2

OFT 2000



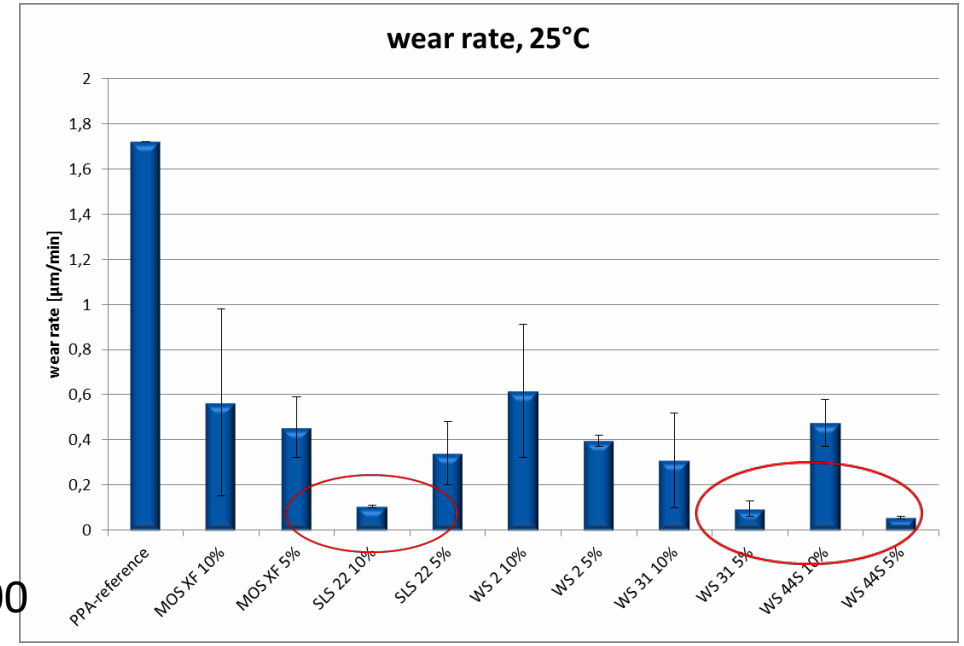


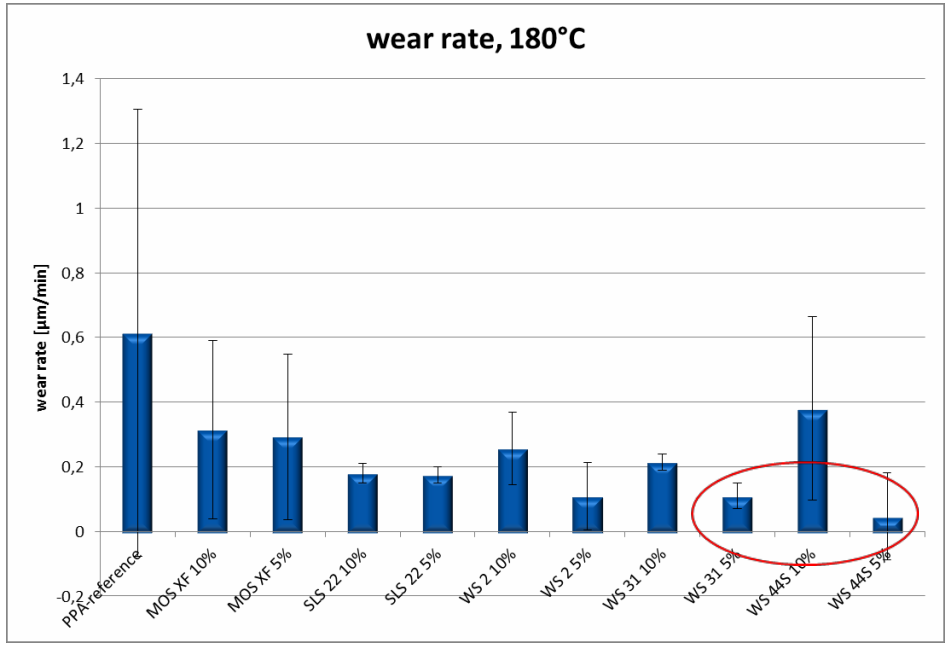
EXAMPLE NO. 2: PPA – OFT 2000 案例No. 2 PPA
RESULTS: WEAR RATE 结果磨损率



Siginificant improvement in wear for both testing models
两种测试模型的磨损均有显著改善

Bruker Nano UMT-2





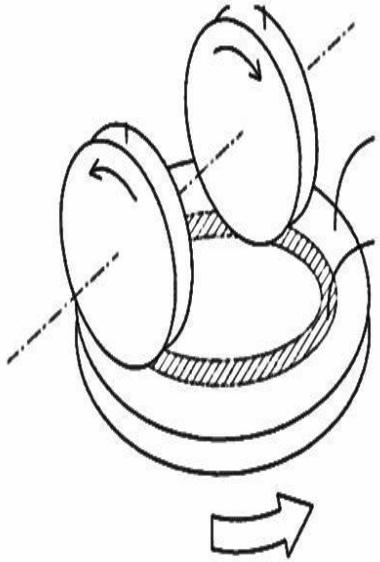
OFT 2000

EXAMPLE NO. 3: PPS – TABOR TEST 案例No.3 PPS
COMPOUNDING 配料

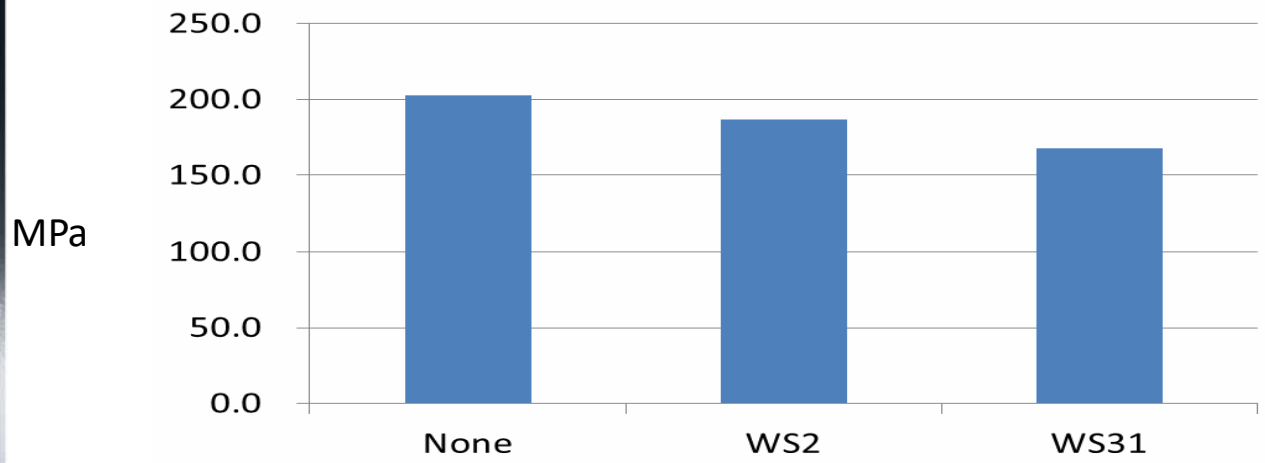
- Tests performed at Japanese DJK institute
  在日本DJK研究所进行的测试

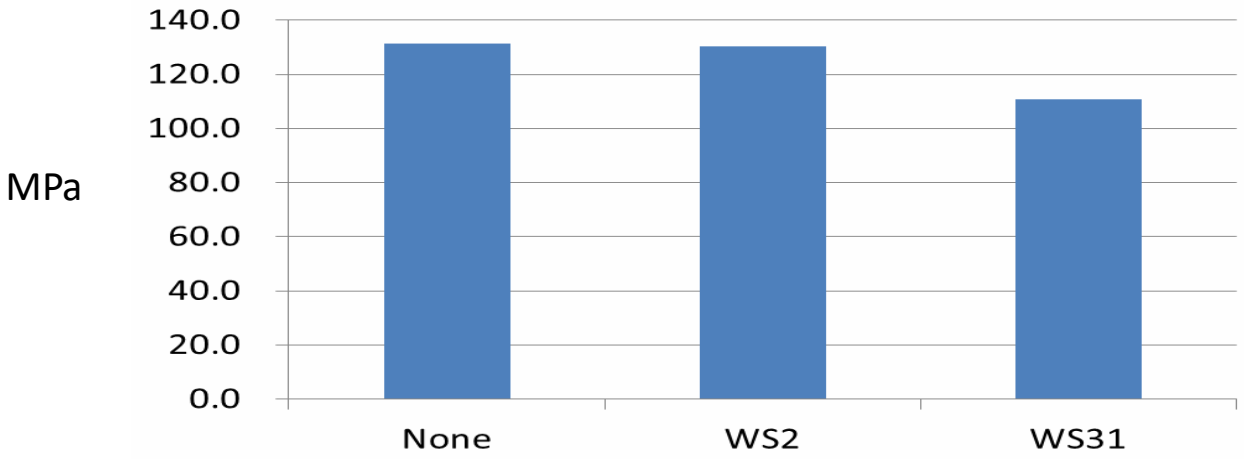
- Polymer used PPS的型号:
  - PPS type A503X05B (Toray), 30% GF

- Variations 变化:
  - PPS reference („none“) PPS基准 （无）
  - 10% addition of Tribotecc® - WS 2 添加10%特博科 WS 2
  - 10% addition of Tribotecc® - WS 31 添加10%特博科 WS 31



EXAMPLE NO. 3: PPS – TABOR TEST 案例No.3 PPS
FLEXURAL AND TENSILE STRENGTH 弯曲和拉伸强度



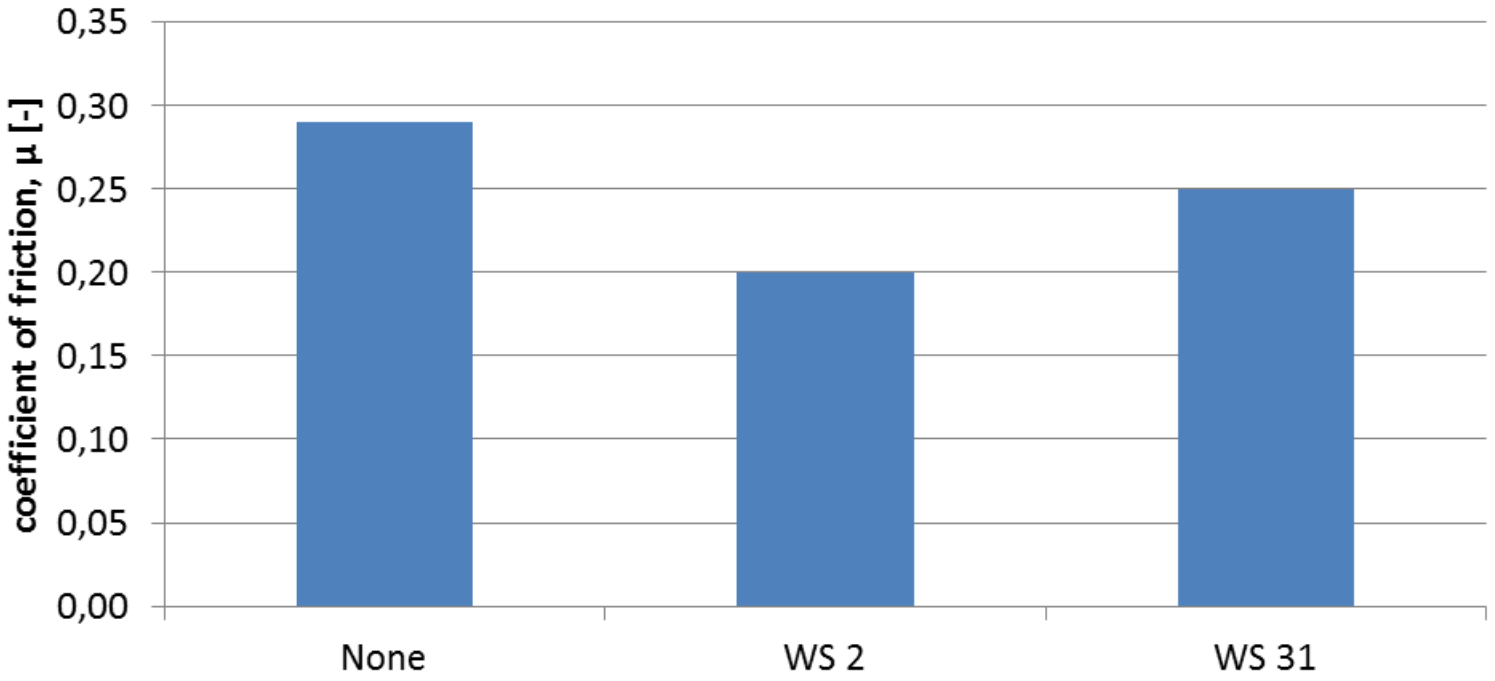


Test 测试	Standard 标准	Conditions 条件
Flexural test 弯曲测试	JIS K7171 ISO 178	Test speed 速度: 2mm/min Span 跨度: 65mm

Test 测试	Standard 标准	Conditions 条件
Tensile test 拉伸测试	JIS K7161 ISO 527	Test speed 速度: 5mm/min Span 跨度: 115mm

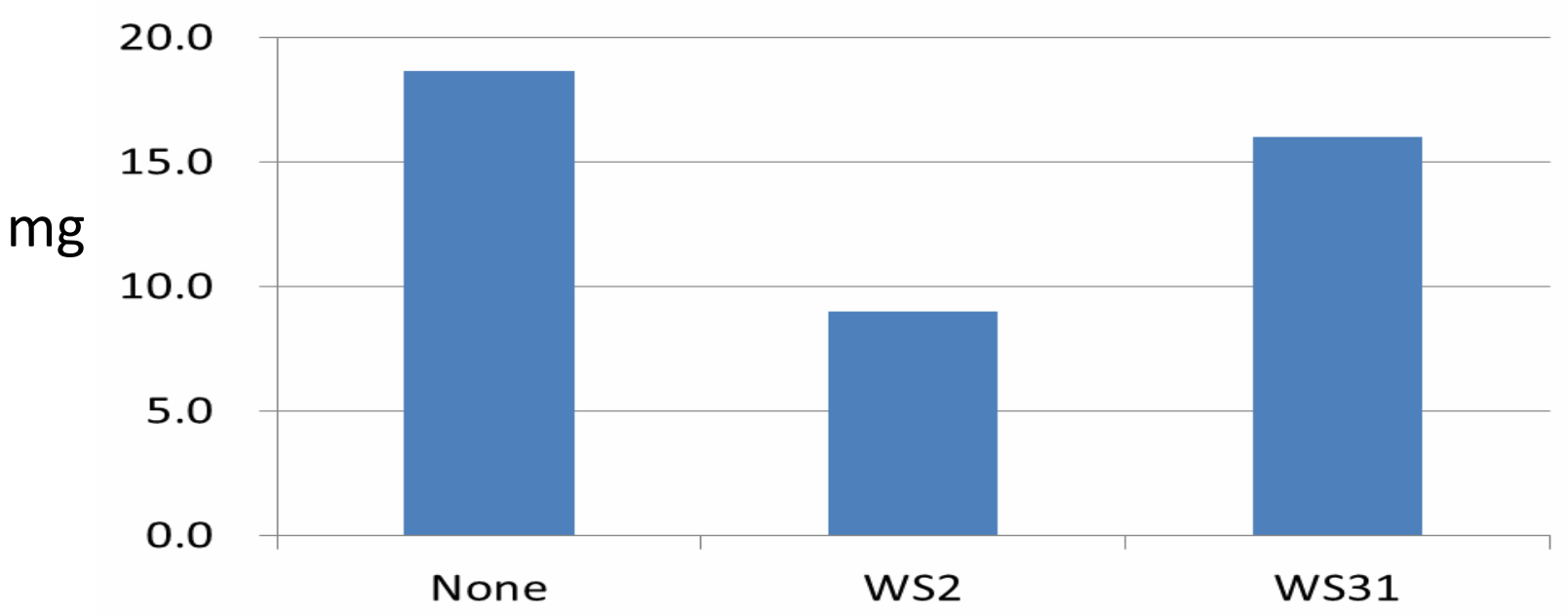
EXAMPLE NO. 3: PPS – TABOR TEST 案例No. 3 PPS
RESULTS: COEFFICIENT OF FRICTION 结果: 摩擦系数

Test 测试	Standard 标准	Conditions 条件
Friction test (coefficient) 摩擦测试（摩擦系数）	JIS K7125 ISO 8295	Load 负荷: 200gF Speed 速度: 100 mm/min



EXAMPLE NO. 3: PPS – TABOR TEST 案例No.3 PPS
RESULTS: WEAR (ABRASION) 结果: 磨损（研磨）

Test 测试	Standard 标准	Conditions 条件
Friction test (weight reduction) 摩擦测试（失重）	JIS K7204 ISO 9352	Load 负荷: 4.9 N Rotation 旋转: 1000 times Ring 圆环: CS10



CONCLUSIONS AND OUTLOOK
结论和展望

- The positive influence of novel metalsulfides on tribological properties can be shown in PEEK, PPA and PPS-compounds in 3 different contact situation.
  通过实验案例可以看出，使用特博科的金属硫化物的改性PEEK，PPA和PPS均表现出积极的摩擦学性能。

- Especially **wear rate** can be improved significantly by using SLS 22F, WS 2, WS 31 and MOS XF compared to blank.
  与无添加相比，使用SLS 22F, WS 2, WS 31和MOS XF可以显著的改善磨损率。

- Concentration level has an impact on COF whereas 5% seems to be a minimum level to see a beneficial impact.
  浓度水平对摩擦系数有影响，而5%似乎是看到有益影响的最低添加量。

- Particle size has an impact on homogenous contribution -> transfer layer
  粒径对均匀分布有影响 -> 转移层

- Preselection by modeling possible but depends on tribo-contact;
  通过建模使得预选变为可能，但也取决于摩擦接触情况

- Big potential for metalsulfides in high engineered polymer compounds.
  高性能改性工程塑料中的金属硫化物具有巨大潜力

- Interaction with other additives to be expected.
  与其他添加剂的相互作用、配合使用也是预期的

Further joint investigations to be done! 乐意与您一起共同开发！

THANK YOU FOR YOUR ATTENTION!
谢谢您的关注！

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