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Introduction

Introduction: What does GUR® UHMW-PE Stand For?

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Granulate

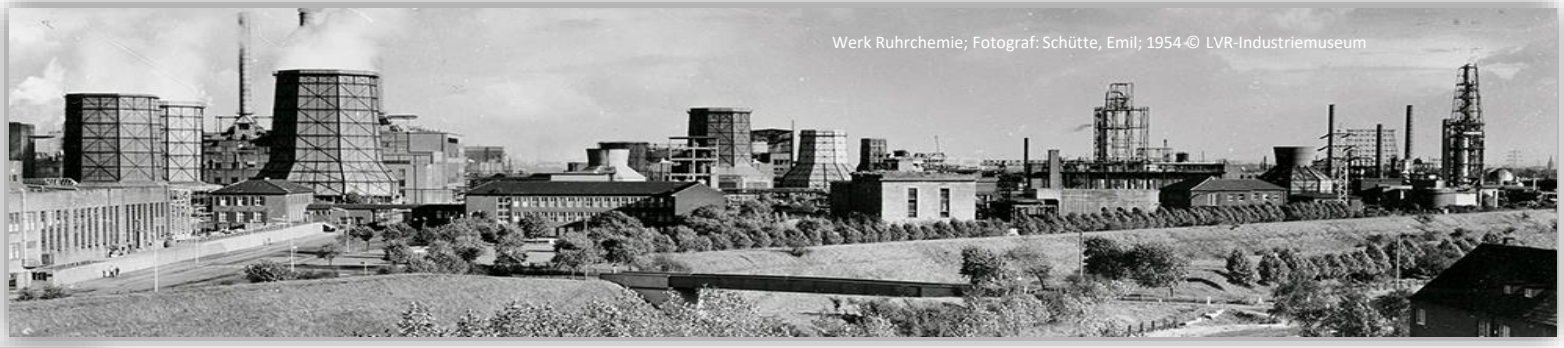
≠

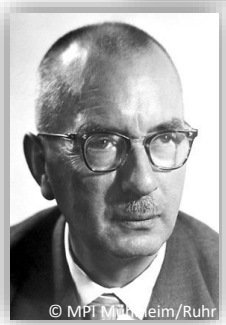
Ultra-high molecular weight

Ruhrchemie

GUR® UHMW-PE - an ultra high performance polyethylene powder encompassing both ultra high and very high molecular weight polyethylene

Introduction: A Short History of GUR® UHMW-PE



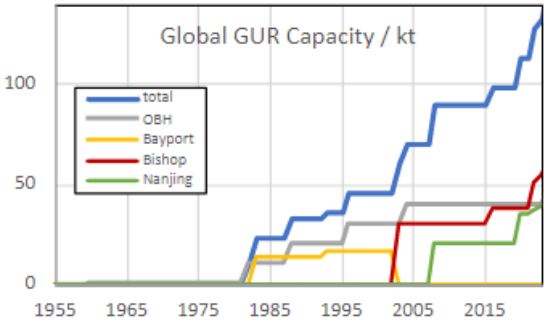


Karl Waldemar Ziegler
1898-1973

1953	Catalyst discovered by Karl Ziegler (Nobel prize for Chemistry in 1963)
1955	First pilot plant at Oberhausen
1955	GUR® UHMW-PE introduced at K-Fair
1960s	First manufacturing unit and development of processing technologies and applications
1981	Process modernization with new catalyst system
1982	3rd line built in Oberhausen

1983	Opening of Bayport, Texas plant
1988	4th line built in Oberhausen
1992	European ISO 9001 certification
1996	Expansion of 4th line in Oberhausen
1998	Global ISO 9001 certification
2002	Opening of Bishop, Texas plant
2004	Oberhausen capacity expansion
2008	Opening of Nanjing, China plant

2016	Bishop debottle necking
2020	Nanjing expansion
2021	Bishop expansion



Introduction: GUR® UHMW-PE - Global Presence

Introduction: What is UHMW-PE?

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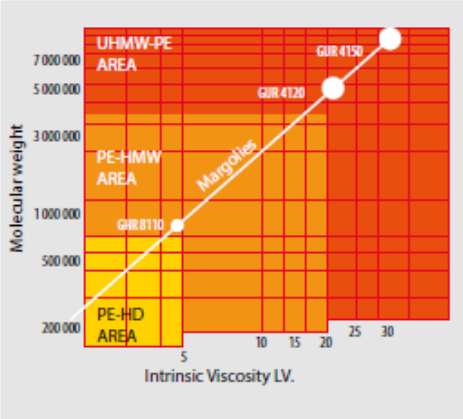
The Polyethylene Family



$CH_2=CH_2$ —(Heat, Pressure / Catalyst)→ $-CH_2-CH_2-$, $-CH_2-CH_2-$, etc.

Ethylene — Rearrangement of primary covalent bond

(H) $^{***}CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-H$

Polyethylene Polymer

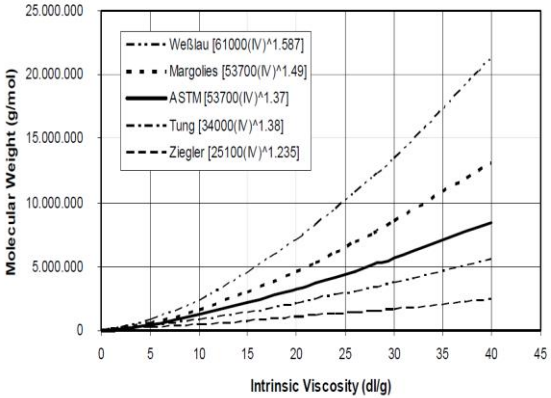
What is UHMW-PE?

- Ultra-high molecular weight polyethylene.
- Definitions of UHMW-PE:
  - ISO 11542-1: MFR < 0,1 g/10 min (190°C / 21,6 kg)
  - ASTM D4020: VN > 2200 ml/g; IV > 1941 ml/g
- Please note: UHMW-PE is not defined by molecular weight in the standards! The molecular weight can be calculated by different equations, which leads to different ranges of molecular weight.
- The common conception of what is UHMW-PE and what is not varies by region, test method and equation used:
  - > 5 million g/mole (ASTM method /NA region)
  - > 3 million g/mole (ISO method/ Europe region)
  - > 1.5 million g/mole (China region)
- Avg. MW of melt processable PE's are typically between 10,000 to 500,000 g/mole

Typical Molecular Weight Ranges of Low Pressure Polyethylene

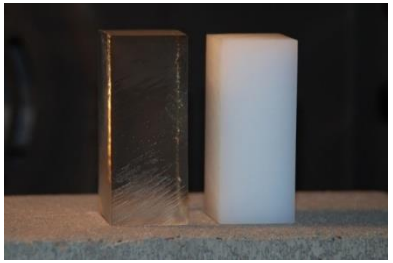
❑ HDPE:	30 000 – 300 000
❑ HMW-PE:	300 000 – 3 Million
❑ UHMW-PE:	3 – 12 Million

Figure 3 Known Molecular Weight Equations
(Correlating with Intrinsic Viscosity)



GUR® UHMW-PE Properties

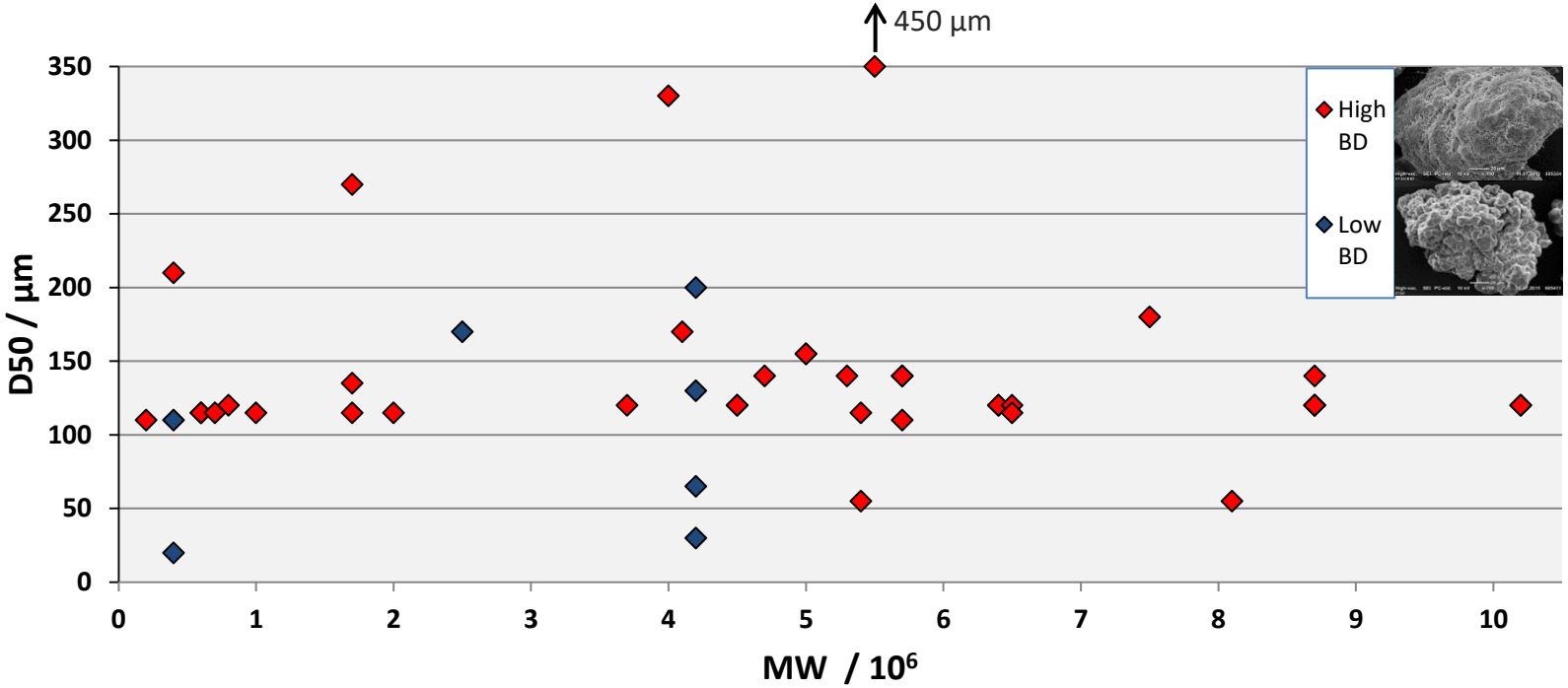
- **GUR® UHMW-PE is a white powder**
- Melts but does not flow
- Outstanding abrasion resistance
- Highest impact strength of any polymer
- Non-stick, self-lubricating surface
- Physiologically safe (FDA compliant)
- Lightweight and low density
- Excellent dielectric and insulating properties
- Low temperature range
- Flexible form factor: sheet / rod / tube, porous block / film, membrane, fiber
- Superior chemical resistance
- Naturally hydrophobic



Limitations:

- Creep resistance
- Processability
- Softening temperature 80°C
- Tensile modulus < 1000 MPa

GUR® UHMW-PE Portfolio Overview



GUR® UHMW-PE sales grades cover a big range in terms of PS and MW

In addition there are pelletized and hydrophilic grades as well as grades including additives (mostly carbon or AO)

Industrial: Processing Methods

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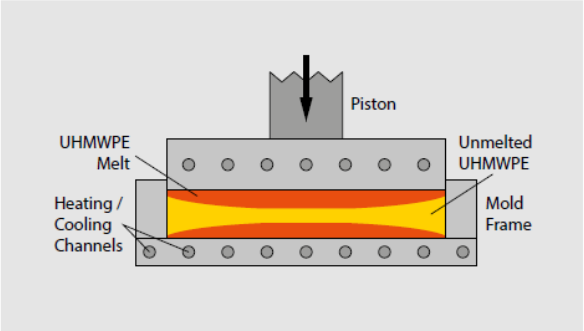
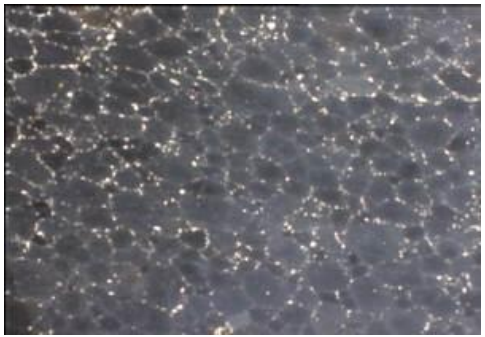
Compression molding of sheets

- Used to fabricate semi-finished forms

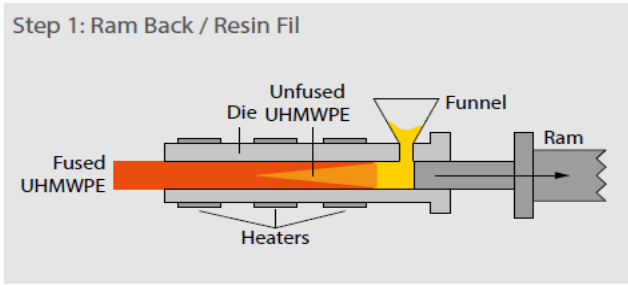


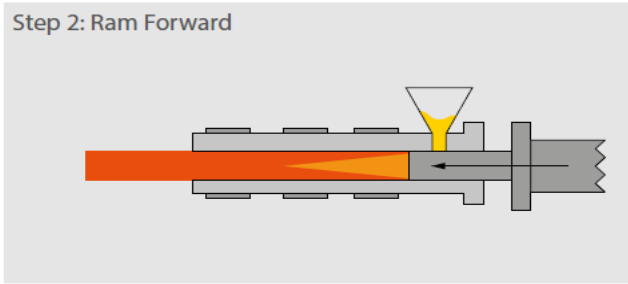


Microscopic picture of thin section from a GUR plate

Ram extrusion of continuous profiles

- Used to fabricate semi-finished forms





Reasons for Using GUR® UHMW-PE as an Additive

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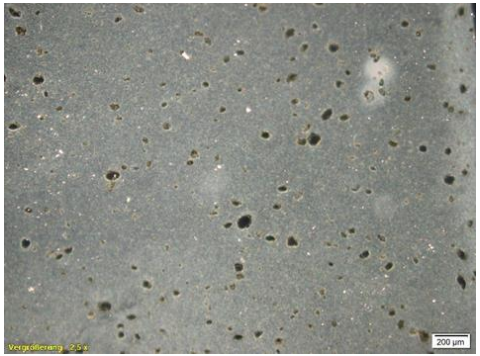
Benefits of GUR® UHMW-PE as an additive
▪ Increases scratch/abrasion/cut resistance of matrix
▪ Increases crack propagation strength of matrix
▪ Improves coefficient of friction (sliding properties) of matrix
▪ Improves mechanical properties, e.g. impact strength and flexural modulus of matrix
▪ Gives unique surface texturing, e. g. anti-slip properties, anti-stick properties, matting effect
▪ Good chemical compatibility with many matrix polymers
▪ Good matrix adhesion due to unique grain morphology
▪ No melt flow. Keeps particle shape during processing
▪ Biocompatible & no fluorine content. FDA approval.
▪ Very good chemical resistance



Microtome of GUR® UHMW-PE dispersed in PP

Additive Segmentation by Application

Rubber additive

Examples for rubbers: NBR, EPDM, TPE, TPU

Effects achieved: increased abrasion resistance, increased crack propagation strength, anti-sticking properties

Mode of action: the GUR® UHMW-PE grains are homogenously distributed in the rubber part.

Film additive

Base materials of blown film: PP, PE

Effects achieved: surface structuring effect (gets rough)

Mode of action: the GUR® UHMW-PE grains do not get stretched with the film because of their high melt flow. Therefore, they generate surface roughness in the film.

Thermoplastics additive

Examples for technical polymers: POM, PA, Polyesters and more

Effects achieved: increased abrasion resistance, improved tribological properties

Mode of action: the GUR® UHMW-PE grains are homogenously distributed in the thermoplastics part.

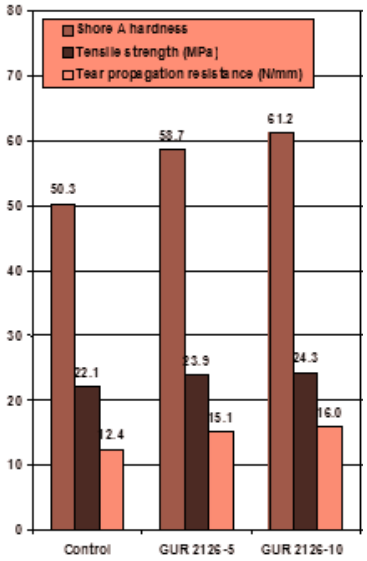
Additives for paints and coatings

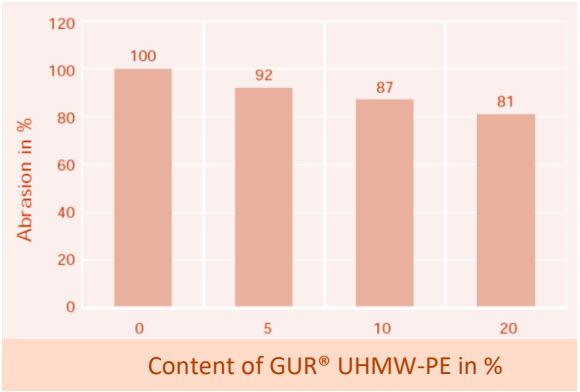
Example: baking paints, UV-curing coatings

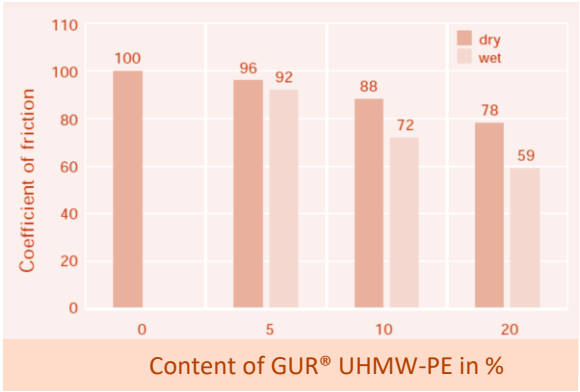
Effects achieved: surface structuring, improved tribological properties, surface matting

Mode of action: GUR® UHMW-PE grains are added to paint or coating formulations. These are coated on a substrate.

Examples for Property Improvement: GUR® UHMW-PE as Additive for SBR Rubber

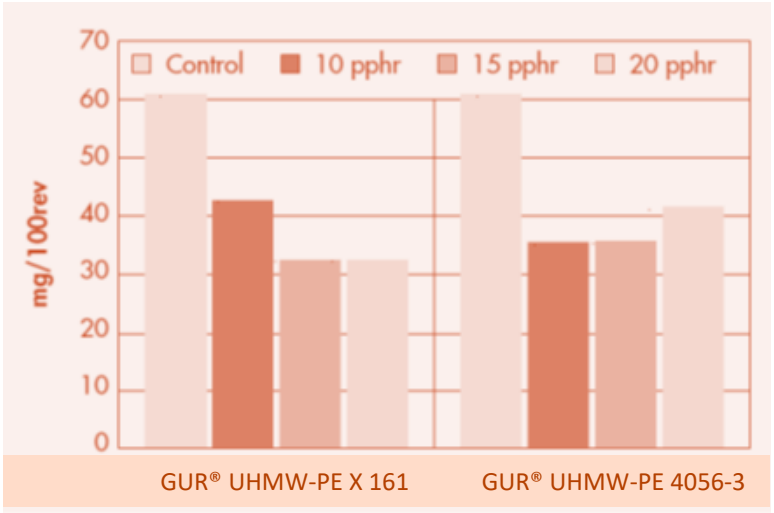




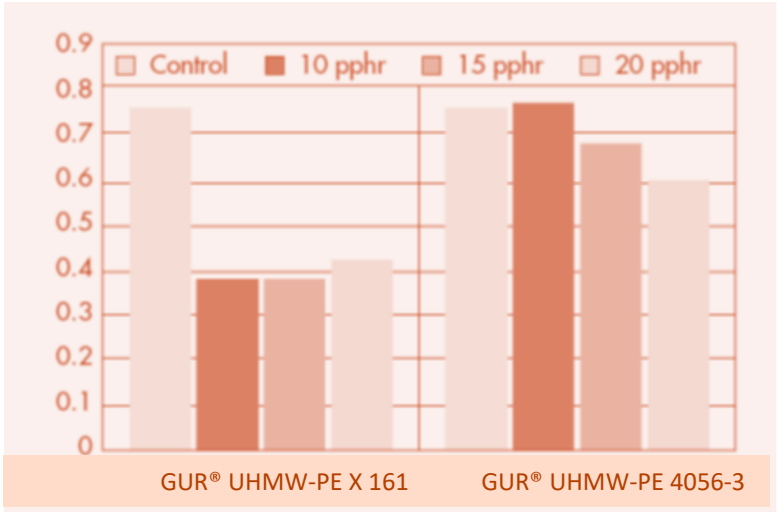


Significant improve in abrasion resistance, sliding properties and tear propagation resistance. The effect becomes stronger with higher loading ratios (within certain limits)

Examples for Property Improvement: GUR® UHMW-PE as Additive for Polyurethane



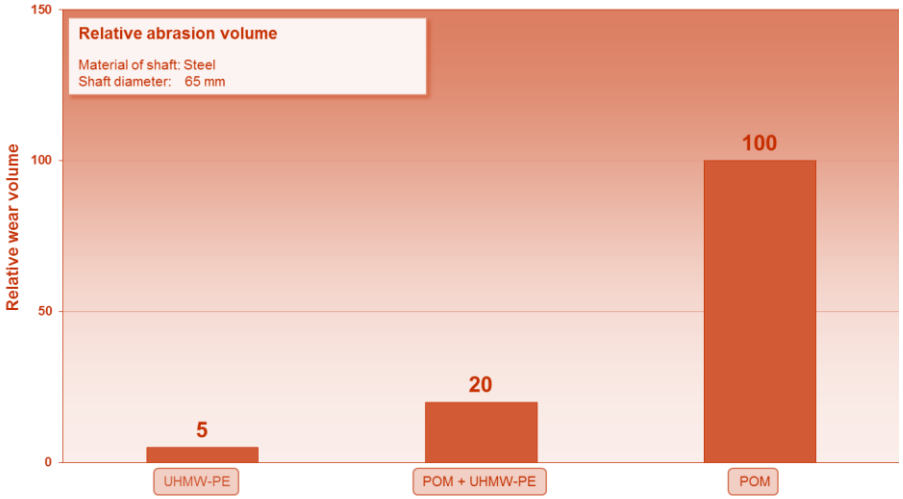
Taber wear resistance

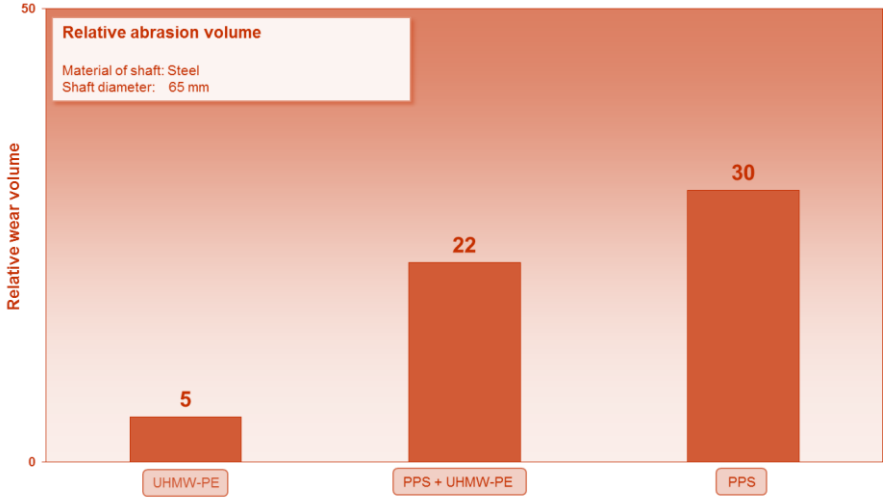


Coefficient of friction versus steel

Clear improvement in wear resistance and CoF.
Hydrophilic grades show best performance.

Examples for Property Improvement: GUR® UHWM-PE as Additive for POM and PPS





GUR® UHMW-PE strongly improves the abrasion resistance of Polyoxymethylene (POM) and Polyphenylensulfide (PPS)

List of Typical Additive Products and Relevant Properties

GUR® UHMW-PE Grades	Elongational Stress /MPa	Molecular weight /g/mol	Bulk density /g/cm³	Grain morphology	Median grain size (d50) /µm	Surface Energy	Comment
4120	0,24	$4,7*10^6$	0,45	Potatoe	120	Hydrophobic	Multi purpose grade
4150	0,52	$8,7*10^6$	0,45	Potatoe	120	Hydrophobic	Similar to 4120 but higher MW
4050-3	0,50	$7,3*10^6$	0,44	Potatoe	60	Hydrophobic	Fine grade
4056-3	0,50	$7,3*10^6$	0,44	Potatoe	60	Hydrophilic	Same as 4050-3 but hydrophilic
2126	0,19	$4,2*10^6$	0,28	Popcorn	30	Hydrophobic	Low bulk density and very fine
2126-2	0,19	$4,2*10^6$	0,28	Popcorn	30	Hydrophilic	Same as 2126 but hydrophilic
2105-1	< 0,05	$0,4*10^6$	0,30	Popcorn	20	Hydrophobic	Low bulk density, low MW and ultra fine
X 160	< 0,05	$0,4*10^6$	0,30	Popcorn	20	Hydrophilic	Same as 2105-1 but hydrophilic
2122	0,21	$4,2*10^6$	0,25	Popcorn	130	Hydrophobic	Low bulk density

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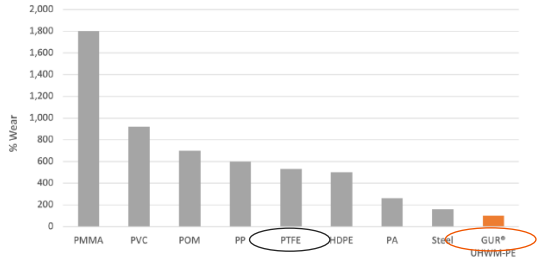
PTFE Replacement

PTFE Replacement

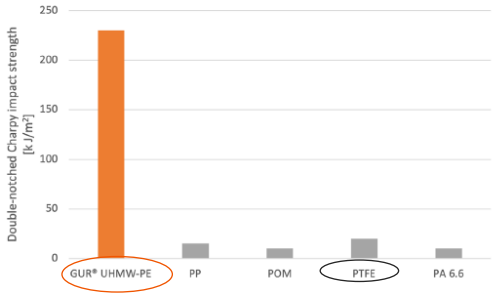
PTFE Replacement – Comparison of Properties

Abrasion resistance



Material loss performance is relative to GUR® UHMW-PE grade 4120 (=100) for different materials determined by the sand slurry method. The sand slurry method rotates specimens in a sand-water mixture under defined conditions for several hours.

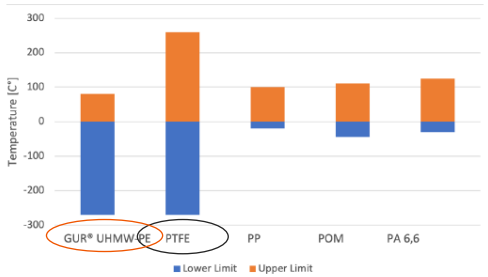
Impact strength



e double-notched Charpy impact strength test results show the amount of energy absorbed a material at the breakpoint. This graph illustrates that the impact strength performance of R® UHMW-PE is much higher than that of other thermoplastic polymers.

Chemical resistance

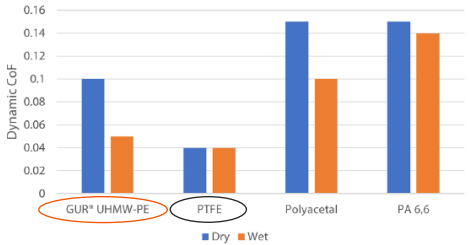
Temperature range



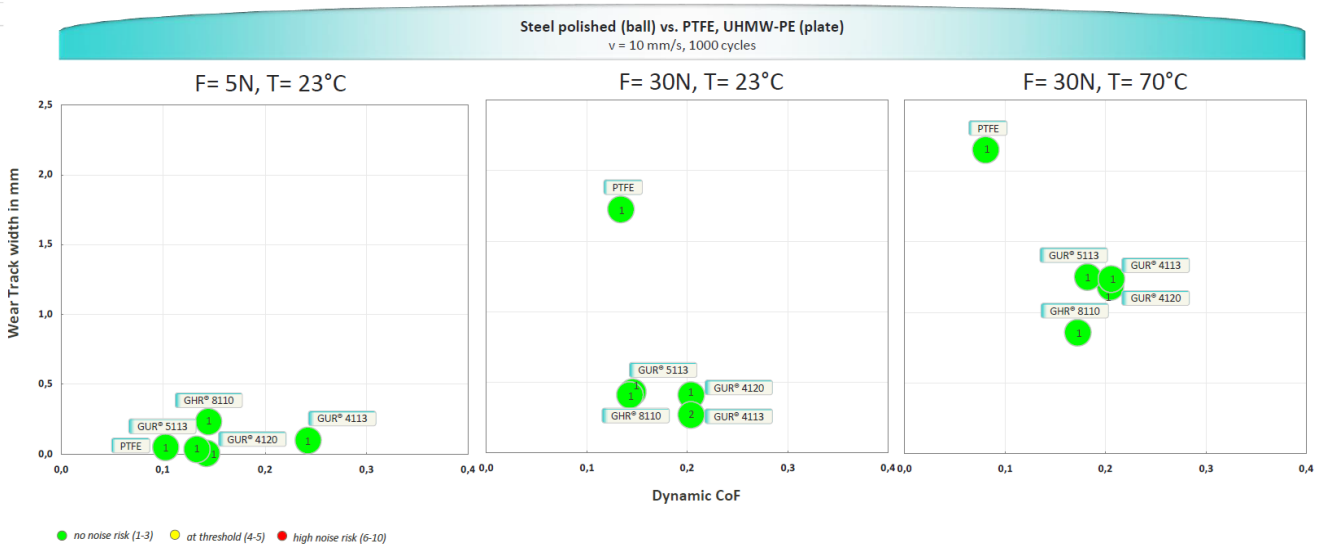
Typical operating temperature ranges for a selection of different materials. At temperatures of -270°C, the material still exhibits a double-notched Charpy impact strength of the order of 10kJ/m².

PTFE Replacement – Tribology

Coefficient of friction (CoF)



Dynamic CoF test results under dry and wet conditions for GUR® UHMW-PE compared to other thermoplastics.



PTFE Replacement – Comparison of Properties

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Typical values	GUR® UHMW-PE	PTFE
Coefficient of Friction	++	++
Wear resistance	++	o
Impact Strength	++	o
Shore Hardness	D60	D55
Density [g/ml]	0,93	2,2
Maximum Usage Temperature [°C]	80	260
Minimum Usage Temperature [°C]	-270	-270
Chemical resistance	+	++
UV Resistance	-	++
Purity, FDA approval,	++	++
Flammability	-	++
Price	+	-

Summary GUR® UHMW-PE

- **GUR® UHMW-PE is a white powder**
- **GUR® UHMW-PE is a unique material with a number of outstanding properties:**
  - Wear resistance
  - Impact strength
  - Low temperature performance
  - Chemical resistance
- **GUR® UHMW-PE usually has no melt flow and is therefore comparably difficult to process with traditional technologies.**
- **GUR® UHMW-PE serves many kind of different applications**
- **Application areas in focus are**
  - Additives
- **Currently hottest topic is**
  - Replacement of PTFE in many kinds of different applications (PFAS discussion)

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