The properties of Ultraform®

In view of its property profile, Ultraform® belongs to the engineering plastics. It can be thermoplastically processed and has a partially crystalline structure with a high degree of crystallization. Ultraform® is produced by the copolymerization of trioxan and another monomer. It consists of linear chains in which the co-monomers are firmly incorporated in a statistically distributed manner. These co-monomer units account for the high stability of Ultraform® during processing and when exposed to long-term heat and to chemicals. It surpasses by far the resistance of homopolymeric polyoxymethylene.

Mechanical properties

The special aspect of Ultraform® is its ideal combination of strength, stiffness and toughness, all of which can be ascribed to the structure of the product. Owing to its high crystallinity, Ultraform® is stiffer and stronger than other engineering plastics, especially within the temperature range from 50 °C to 120 °C. Ultraform® does not undergo any transitions between the low glass-transition temperature of approximately -65 °C and the melting temperature of approximately 170 °C. This translates into relatively constant mechanical properties over a fairly wide temperature range that is very attractive from a technical point of view (Fig. 1).

At room temperature, Ultraform® has a pronounced yield point at about 8-12 % strain. Below this limit, Ultraform® exhibits good resilience, even under repeated loading, and is therefore especially suitable for elastic elements.

In addition, it has high creep strength and a low tendency to creep (Fig. 2).

This combination of characteristics in association with good tribological properties makes it very suitable for engineering applications.

Ultraform® absorbs very little water: approx. 0.2 % under normal conditions (DIN 50014-23/50-2) and only approx. 0.8 % on complete saturation with water at 23 °C. Its physical properties are so slightly affected by this that it is of little importance for practical purposes.

The mechanical properties can be widely varied by employing suitable elastomeric additives, mineral fillers and glass fibers. Elastomer-modified Ultraform® grades largely retain their POM-like properties but exhibit a substantially higher level of impact resistance and a higher energy absorption capacity. Depending on the degree of modification, the rigidity and hardness of these grades is reduced.

Mineral-filled and especially fiberglass-reinforced Ultraform® grades, in contrast, exhibit increased strength, stiffness and hardness.

Fig. 7 shows the impact strength versus rigidity for selected grades.

Behavior under long-term static loading

The tensile creep test in accordance with ISO 899-1 and the stress relaxation test in accordance with DIN 53441 provide information about extension, mechanical strength and stress relaxation behavior under sustained loading.

The results are illustrated as creep modulus plots (Fig. 2) and creep curves (Fig. 3).

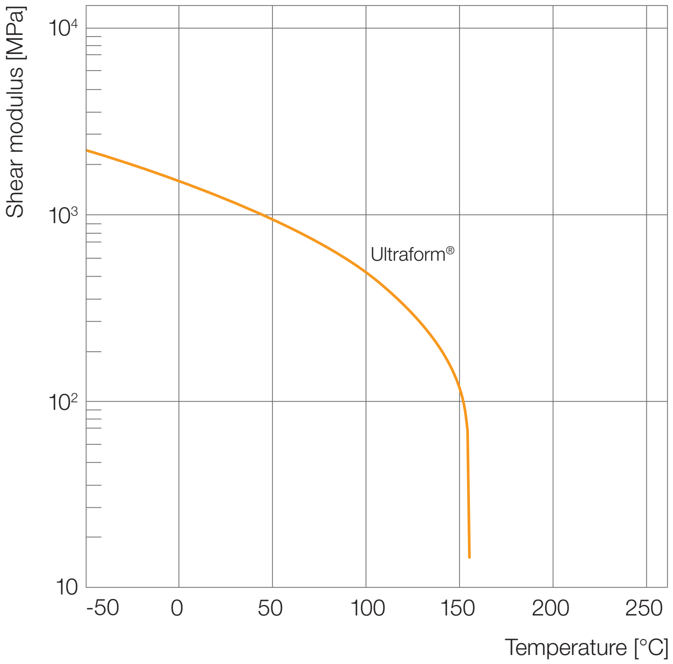


Fig. 1: Shear modulus as a function of the temperature (measured according to ISO 6721)

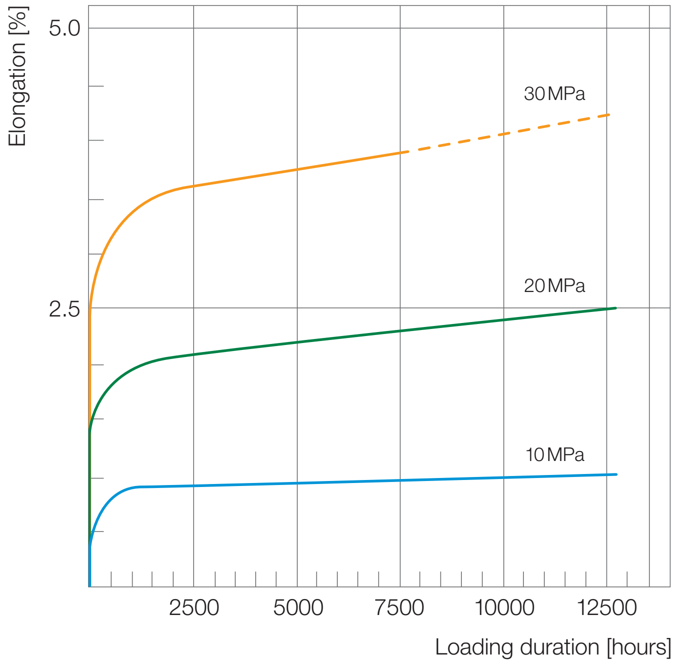


Fig. 3: Creep curves for Ultraform® N2320 003 at 23 °C, measured in accordance with ISO 899-1

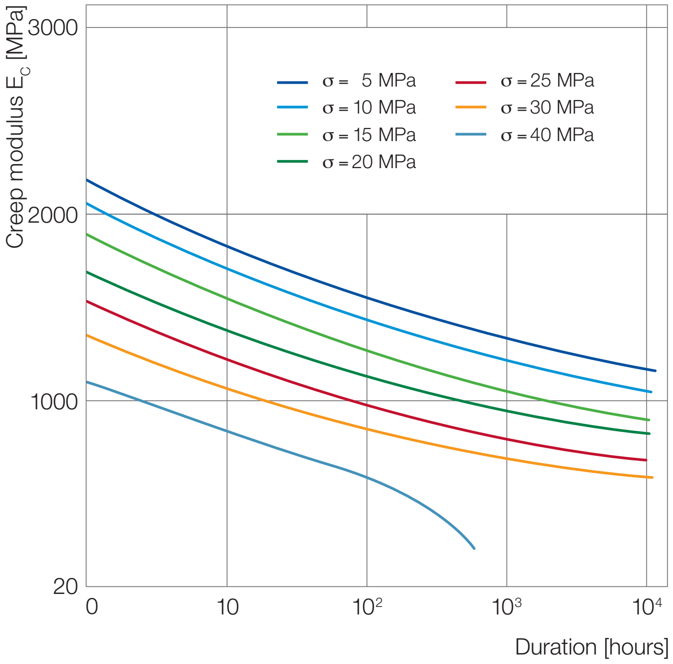


Fig. 2: Creep modulus E_C of Ultraform® N2320 003 as a function of loading duration (measured in accordance with ISO 899-1 under standard climatic conditions, 23°C / 50% r.h.)

Figs. 4 and 5 show the isochronous stress-strain curves for standard and glass-fiber reinforced Ultraform®.

The graphs reproduced here are just a selection from our extensive collection of test results. Further values and diagrams for different temperature and atmospheric conditions can either be obtained from the Ultra-Infopoint or from the plastics materials database “Campus” on the internet.

Design data obtained from uniaxial tensile loading tests can also be used to assess a material’s behavior under multiaxial loads.

The PC programs “Snaps”, “Screws” and “Beams” developed by BASF can be used for the analysis of construction elements such as snap and screw connections and beams subjected to flexural stresses

The creep strength values determined for pipes made from Ultraform® reflect a multiaxial stress condition and the all-round action of water (Fig. 6).

Impact strength

Parts made from Ultraform® stay impact-resistant over a wide range of temperatures. Due to its very low glass transition temperature (about -65 °C) Ultraform® still exhibits outstanding impact resistance and adequate notched impact resistance at temperatures as low as -30 °C.

Impact-resistant grades with graduated modification are available for applications with high demands on toughness. Fig. 7 shows a plot of impact strength versus rigidity for these and other grades. A substantial gain in impact strength is obtained at the expense of a moderate loss in rigidity.

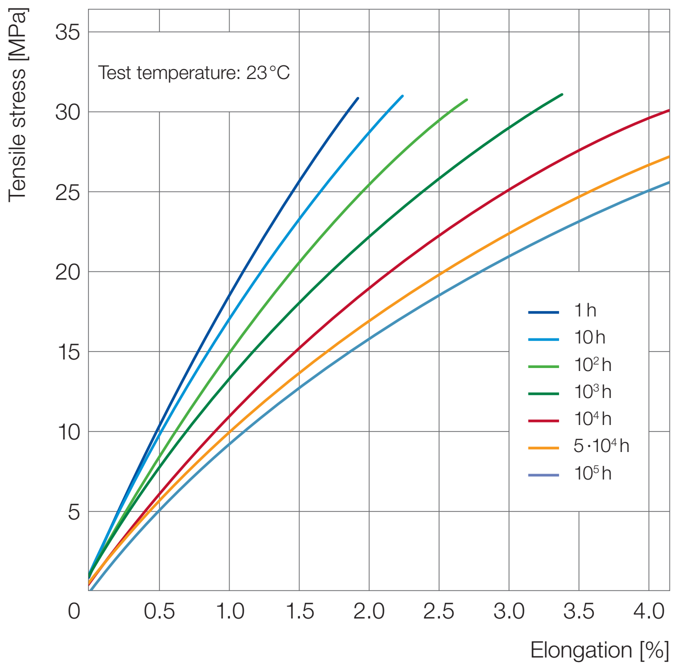


Fig. 4: Isochronous stress-strain curves for Ultraform® N2320 003, measured in accordance with ISO 899-1

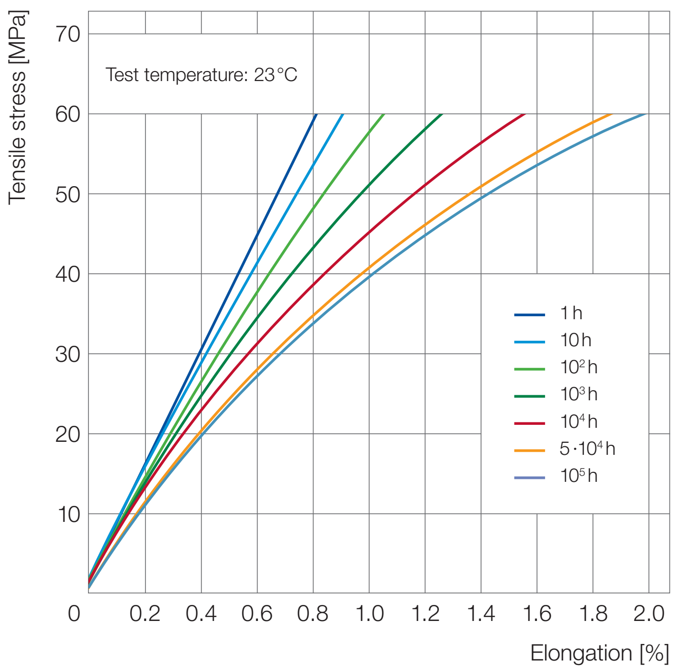


Fig. 5: Isochronous stress-strain curves for Ultraform® N2200 G53, measured in accordance with ISO 899-1

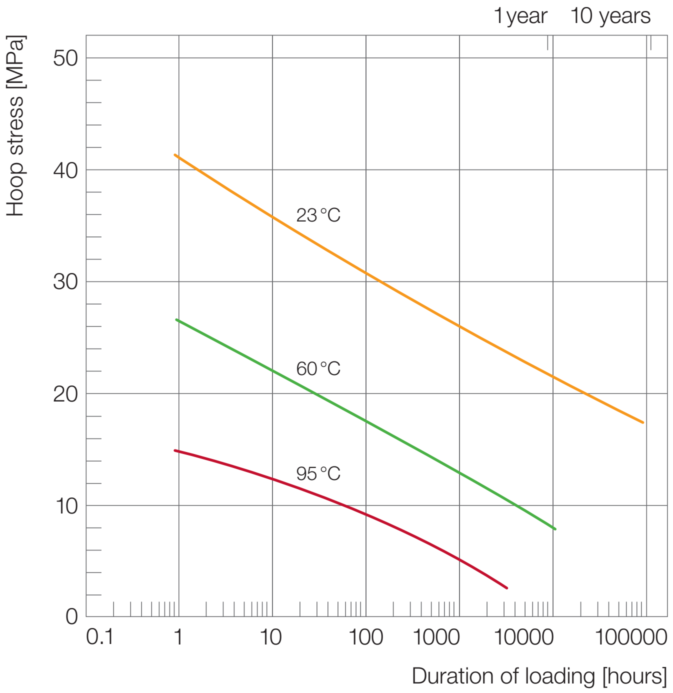


Fig. 6: Creep strength of pipes made from Ultraform® H4320 at various temperatures, with water inside and outside

Toy

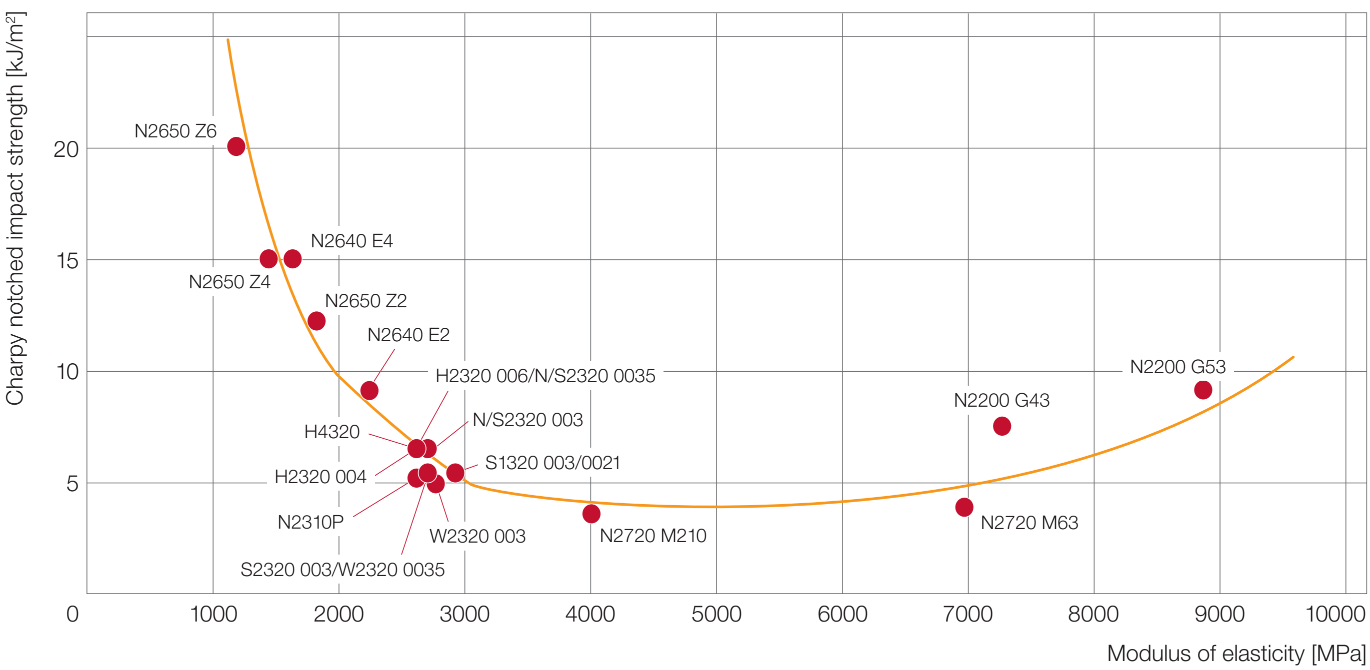


Fig. 7: Impact strength vs. stiffness for selected Ultraform® grades

Behavior under cyclic loads, flexural fatigue strength
Engineering parts are frequently subjected to stress by dynamic forces, especially alternating or cyclic loads, which act periodically in the same manner on the structural part. The behavior of a material under such loads is determined in fatigue tests in flat bending or rotating bending tests (DIN 50100) up to very high load-cycle rates. The results are presented in what are known as Wöhler diagrams obtained by plotting the applied stress against the load-cycle rate achieved in each case (Fig. 8).

The flexural fatigue strength is defined as the stress level a sample can withstand for at least 10^7 cycles.

It can be gathered from the graph that in the case of Ultraform® N2320 003 the stress remains practically constant above about 10^7 load cycles.

When the test results are applied in practice, it has to be taken into account that at high load alternation frequencies, the workpieces may heat up considerably due to internal friction. In such cases, just as at higher operating temperatures, lower flexural fatigue strength values have to be expected.

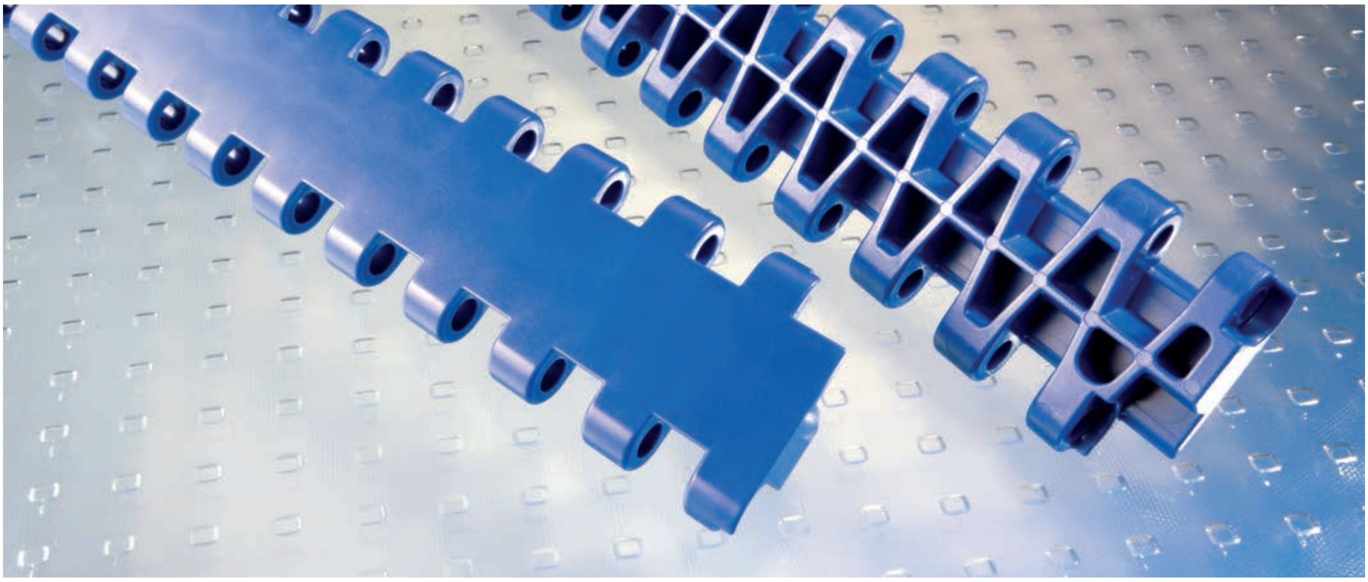
Tribological properties
The smooth, hard surface and highly crystalline structure of this material allow its application for functional parts subjected to sliding friction. Even in the case of solid friction only slight wear is to be expected at the coefficients of sliding friction likely to be in operation. The coefficient of sliding friction of Ultraform® becomes smaller as the surface roughness of the paired material increases, but wear caused by sliding friction will increase.

The special grades of Ultraform® N2310 P, N2770 K and N2720 M210 display a marked improvement in their sliding and abrasion behavior. N2720 M210 exhibits optimal properties, even at elevated surface pressures or greater roughness of the sliding counterpart. Generally speaking, N2310 P and N2770 K are best suited for applications in precision mechanics.

Figure 9 shows the coefficient of sliding friction and the rate of wear due to sliding friction of Ultraform® N2320 003 and N2310 P as a function of the average roughness height. The properties of Ultraform® N2310 P prove to be particularly favorable at low roughness heights of the sliding counterpart (Figure 10).

Wear and friction are system properties which depend on many parameters such as the nature of the paired materials, temperature, speed, loading, etc. While results obtained from tests allow some assessment of tribological properties, they are no substitute for performance testing carried out under practical conditions on the pair of materials actually planned.

Conveyor belt parts



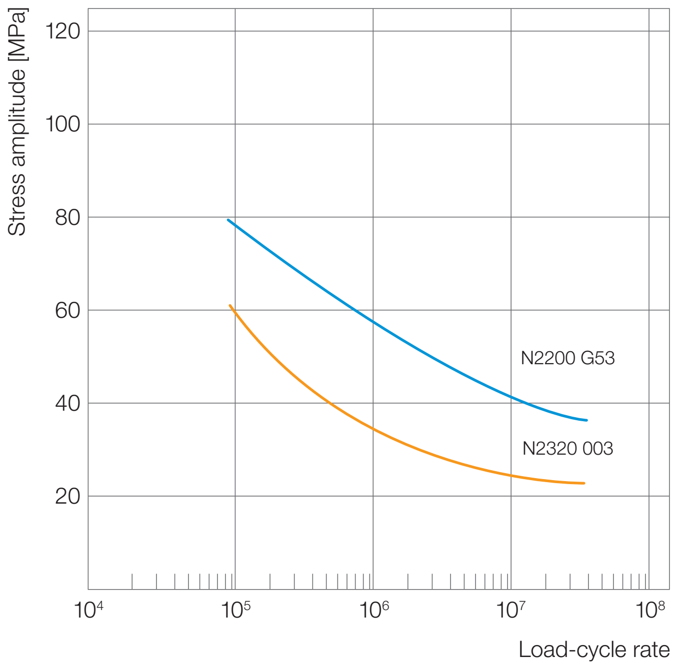


Fig. 8: Wöhler diagram for unreinforced and reinforced Ultraform® determined in the flexural fatique tests in accordance with DIN 50100. Normal climatic conditions 23/50 in accordance with DIN 50014, load cycle frequency: 10 Hz

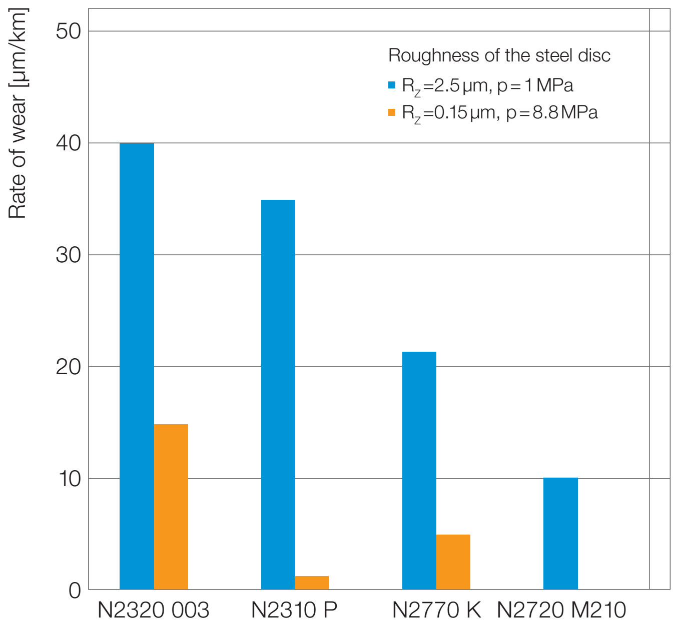


Fig. 10: Rate of wear of modified grades as a function of the roughness of the sliding counterpart (steel disk); v = 0.5 m/s; max. 40 °C

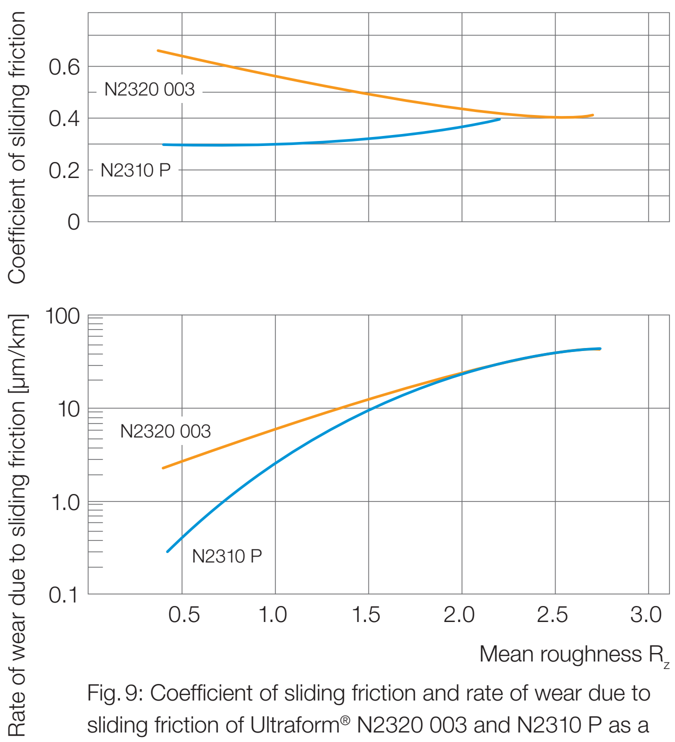


Fig. 9: Coefficient of sliding friction and rate of wear due to sliding friction of Ultraform® N2320 003 and N2310 P as a function of the average roughness height. Sample technically dry. Sliding counterpart: steel disk, HRC 54 to 56, 40 °C, p = 1 MPa, v = 0.5 m/s