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Tribology

Friction and Wear

Barcode zu Ansprech-partner und Infomaterialien

Motivation

Tribological systems are technical structures with a function based on contact processes of interacting surfaces in relative motion. Polymers are used successfully in tribological machine elements, like gears and plain bearings, due to their benefical properties, which include good dry-running capability, high freedom of design and highly efficient production processes. Increasing mechatronization causes the market for polymers in tribological applications to grow steadily. New manufacturing processes such as additive manufacturing also open up new application potentials. The research on polymers in tribological systems at the Institute of Polymer Technology (LKT) is focused on the complex interactions of material properties, process and system design, which determine the part properties and the related system behavior (Fig. 1). A large number of model and component test benches are available at the LKT, allowing the analysis of tribological parameters such as friction and wear under real world operating conditions and load collectives.

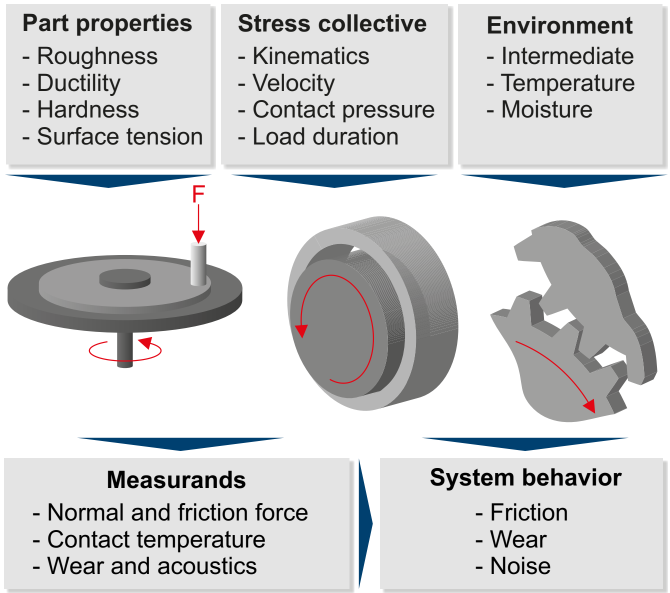

Fig. 1: Analysis of a tribologic system

Polymer Gears

Polymer gears are tribologically stressed parts with a wide array of applications. Uses include actuating drives in cars, drives for electric bikes, medical devices like drug dosage systems, and applications in consumer electronics. The production by injection molding easily allows to adapt the gear geometry to fulfill the needs for mechanical load capacity, tribologic properties or acoustics. To determine the interdependency between material, process and system design and operational behaviour, the LKT has special equipment to test polymer gears for tooth wear and load capacity, as well as friction induced temperature development. There also is newly developed in situ measurement equipment for polymer gears to determine time-dependent wear and tooth deformation in operation. This allows deeper research of the wear behavior (Fig 2.), especially differentiating between the run-in phase, which is characterized by higher instationary wear rates, and the stationary wear phase. An application-specific combination of rotary encoders, sampling at 80 MHz, is used in the new test stand to evaluate the time-dependent angular displacement between drive and output shaft with an accuracy of 0.005°, corresponding to 0.5 µm for a gear with 39 mm pitch diameter (Fig. 3). The load cycle-dependent angular displacement is then combined with signals from predefined, successive teeth of the gears to calculate the deformation in each of these tooth pairings. To determine the wear component of the tooth deformation, the braking torque is released at defined intervals, thus allowing a reset of the mechanical deformation, while the wear persists.

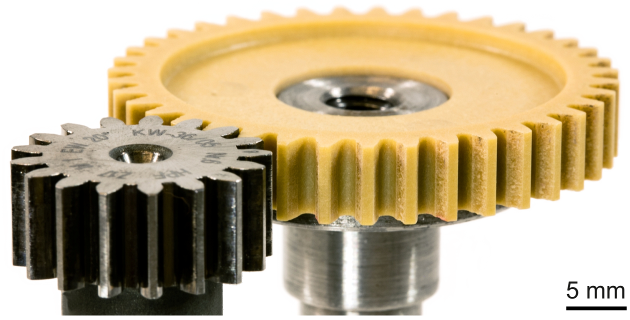

Fig. 2: Wear of dry-running polymer gear with steel pinion

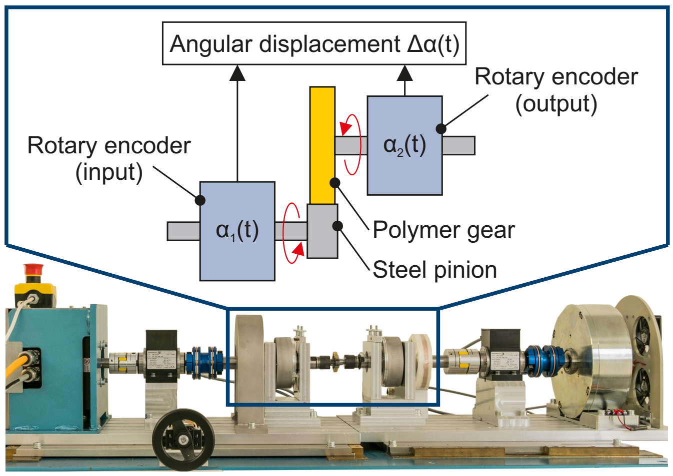

Fig. 3: Newly-developed in situ gear test stand at the LKT

Material, Process and System Design

One central challenge in the design of tribologically loaded polymer parts is the definition of adequate wear allowances to ensure keeping functional tolerances throughout product lifetime (Fig. 4). If a certain tolerance is to be kept during opertation, the resulting wear directly reduces the available manufaturing tolerances. Therefore, one research area of the LKT is the thourough understanding of the underlying wear behaviour in dependence of material, part and process design in order to develop strategies for optimized system designs. With the new in situ testing equipment, fundamental questions regarding the material, process and tolerance design of polymer gears are researched.

There are several ways to reduce wear during operation by material modification. Fibers can be used to increase material strength. Internal lubricants like polytetraflouroethylene (PTFE) decrease frictional heat and adhesion. These two approaches can also be combined in two-component gears with locally optimized properties, e.g. friction-optimized edge layers and mechanically-optimized cores (Fig. 5). Radiation crosslinking is also an option to reduce wear. Materials with added crosslinking agents are injection molded and the resulting part is irradiated using high energy radiation to establish crosslinking bonds between single macromolecules. Thus, mechanical properties are increased, especially at elevated temperatures, allowing the substitution of costly high performance thermoplastics with standard engineering thermoplastic materials. Tests show a reduction in wear by up to 50 % using radiation crosslinking. It can also be combined with conventional material additives. A process-oriented approach to improve mechanical and tribological properties of polymer gears is the optimization of the microstructure. Mechanical strength and wear resistance can be improved by achieving a highly crystalline microstructure and reduction of edge layers. In conventional injection molding, there is a conflict between cycle time and crystallization. To achieve a highly crystalline structure, high mold temperatures are required. This, however, increases cooling and cycle time compared to lower mold temperatures. The pending conflict can be solved using highly-dynamic tempering of the mold. Thus, a highly crystalline structure is achieved in low cycle time.

Plain Bearings

As with polymer gears, thermoplastic plain bearings have significant advantages in comparison to metal based bearings, like dry-running capability, chemical and corrosion resistance, thermal and electrical isolation and high integration ability. Therefore metal based bearings are more and more substituted by thermoplastic ones. By providing knowledge of the links between process, material and part design the LKT enables innovative applications of plain bearings. For example, by using multi-component injection molding (Fig. 6) local part properties can be highly customized and specific functions can be integrated. High mechanical properties to adapt for surface pressure and good tribological properties for support and sliding layer can be combined in one component to accomplish modern component requirements. Additive manufacturing, especially laser sintering, also shows high potential in plain bearing applications. This is due to the high freedom of design and functional integration combined with highly crystalline structures resulting in good mechanical and wear properties (Fig. 7).

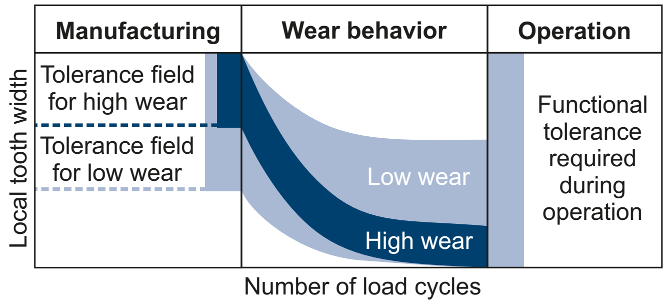

Fig. 4: Manufaturing tolerances are determined by required functional tolerance and wear during operation

Fig. 5: Tribo-mechanically optimized 2-component gear
matrix material: Polyoxymethylene (POM)
inner component: POM with glass fibres
outer component: POM with Polytetraflouroethylene

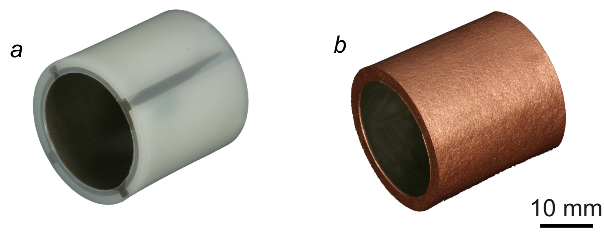

Fig. 6: Plain bearing optimized for different applications
matrix material: Polyamide 6.6 (PA66)
a) mechanical optimization with glass fibers
b) thermal optimization with copper flakes

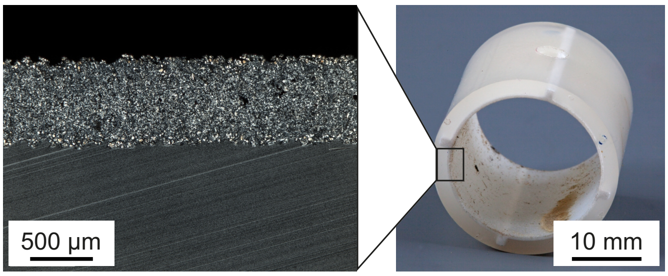

Fig. 7: Highly crystalline structure of a laser sintered Polyamide 12 insert used in a plain bearing

Research Objects and Service for Industry

- Systematic analysis of influences on tribologic properties:
  - Material combination and processing
  - Part design and operating conditions
- Research on the design of tribological compounds
- Gear, bearing and model tests for wear and friction
- Failure analysis of tribo-mechanical systems

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