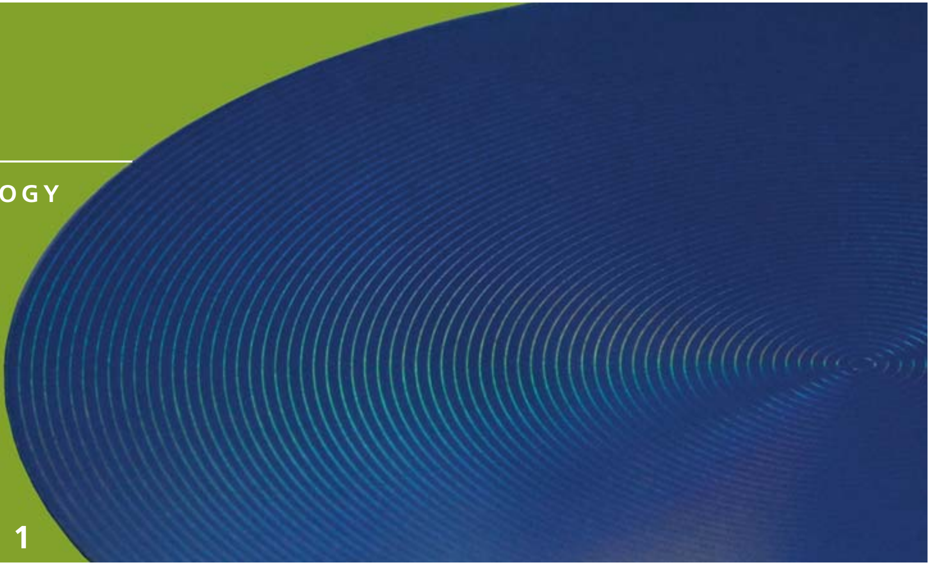

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MICROSTRUCTURED SURFACES TO CONTROL FRICTION AND WEAR

THE TASK

Losses due to friction represent energy quantities that go unused when two moving surfaces interact. Wear on these surfaces reduces the life time of components or the entire system. It is estimated that an average economic loss of approximately 2 to 7 percent of the annual gross domestic product is due to friction and wear.

Significant savings potentials in energy and materials arise for systems that are otherwise technically mature when the tribological, i. e. friction- and wear-related, parameters of mechanically interacting surfaces are influenced by patterning. Prominent examples are common in vehicle manufacturing.

Power train components subjected to endurance stress, such as piston rings, have to be modified on their surfaces on a microscopic scale, without impairing their macroscopic functionality, such as their impermeability to oil and dissipation of heat. Since, as a rule, friction and wear influence one another, in almost all cases the influence of the lubricant has to be considered. An optimal solution for the customer has to be developed.

OUR SOLUTION

The characteristics of metallic surfaces in the automotive industry are modified using several strategies. Functional structures can be generated in partial areas by several laser techniques, but also over entire surfaces, whereby super hard, diamond-like coatings are deposited. The two variants have different goals. Patterning super-fine pocket structures with pulsed laser systems extends the functionality; reservoirs for lubricant emerge, and components sliding across the surface float. Thus, dry friction or mixed friction phases, as well as wear, are minimized. Coating entire surfaces with low roughness and hardness also aims at minimal wear and offers per se less frictional resistance, which, in turn, saves lubricant.

What is fascinating in this approach is the combination of functional microstructures with the advantages of a functional layer over the entire surface. These coatings frequently are subject to high internal stresses and are optically transparent (i. e. lower absorption to laser irradiation). To be able to process them at all in a defined manner and with minimal damage, ultrashort pulsed laser systems with highly flexible beam deflection were used. Customized manufacturing strategies were engineered for each application.

RESULTS

The group of technologies known as "Laser texturing of power train components with hard material coatings, subjected to friction" is consistently focused on (ultra) short pulsed laser systems. Longer pulsed lasers typically result in thermal influences that are hard to avoid, such as the formation of throw ups, increased hardness, and flaking. Another disadvantage is the risk of insufficient absorption. The range of base and layer materials to be addressed can be extended when using (ultra) short pulses and laser wavelengths that are shorter than the infrared wavelength widely in use.

Cavities without burr, of defined component-constant depth with minimal tolerances (Fig. 1), are generated when brittle-hard materials are impacted by laser pulses with pulse durations of 500 fs to10 ps. Diameter and depth, as well as functional layout, are designed for each purpose: piston rings, for example, were functionalized radially with an offset point lattice, with an approximately 2 µm thick diamond-like carbon coating. Point-to-point distances ranged from 50 to 150 µm, the diameters from approx. 15 to 50 µm, and the depth values from approx. 2 to 5 µm (Fig. 2 and 3). Laser structuring in this way retains the sealing capabilities of the piston rings and significantly contributes to minimizing friction by floating on a lubricant film that is dynamically generated. The frictional coefficient can ultimately be diminished by up to 25 percent (as a result of laser structuring).

Life time was significantly increased for other vehicle components without additional sealing functionality, by introducing cavities in a rotationally symmetrical configuration down to a depth of approximately 1 µm (Fig. 1).

Comparing unstructured or conventionally structured and coated components with laser structured and coated ones under the influence of a lubricant, is very complicated. Tests with (ultra) short pulsed laser systems, combined with highly flexible beam deflection devices, demonstrated that customized functional microstructures positively and controllably affect wear characteristics, as well as the frictional parameters of the hard-material-coated components.

1 Rotationally symmetrical laser functionalized surface

2 Laser microstructured piston ring coated with hard material

3 Detail of structure - "piston ring functionalization"

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