All Toyota Tribological Innovation to Realize “Zeronize” and “Maximize” Society

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While environmental and energy issues are increasingly attracting global attention, the world is heading towards a sustainable society in which limited resources are used effectively. In these circumstances, the Toyota group is aiming for the realization of “Zeronize”, a term coined to represent the minimizing of negative impacts, and “Maximize”, meaning to maximize positive impacts. Our current, and future, tribological innovation of vehicle and process technology to realize these will be described in this report.

Keywords: automotive, zeronize, maximize

1. Introduction

When looking at the global energy situation, we can see that coal consumption is set to steadily increase, due to growing consumption in China and India. Conventional oil will run out in approximately 2050, and will be replaced by non-conventional oil production. In accordance with this, the demand for cheap coal, and the use of renewable energy, such as hydropower, sunlight, solar heat, biomass and wind power, will all increase. On the other hand, it is expected that the number of vehicles in the world will double by 2030, with half of this increase in Asia. The markets of developed countries will be close to saturation point. As described above, the environment surrounding the automobile is expected to change significantly.

“Today for Tomorrow” is a philosophy of Toyota since the establishment. The vision of business solutions based on this philosophy is referred to as “Zeronize” and “Maximize”. “Zeronize” is used to symbolize our determination to persevere in our efforts for the minimization of the negative aspects of motorization, such as environmental loads, traffic congestion and traffic accidents. At the same time, we must not forget to maximize the positive aspects of the automobile, such as the enjoyment of driving, the excitement and the comfort. The word coined to symbolize these aspects is “Maximize”. The point we aim to reach, and the vision we hope to realize, is the high-dimensional simultaneous realizations of “Zeronize” and “Maximize”.

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This report will introduce our tribological technologies for vehicles, including vehicles currently in the manufacturing process, which we have developed based on our vision of “Zeronize” and “Maximize”.

2. Vehicle Technology

Many tribological parts are used in an automobile, especially in the engine and the power-train transmission. The cost in relation to effect is not high, but the fuel efficiency has improved by around 16% in the past 20 years.

The first example of our developments is DLC (Diamond-like carbon) technology. Fig. 1 is of a JTEKT's 4WD coupling, called ITCC, which uses DLC

Fig. 1 Structure of ITCC

Fig. 2 Over-time change of μ -v grade

coating. (ITCC stands for Intelligent Torque Controlled Couplings.) DLC-Si is applied to the outer control clutches. These clutches, coated with the DLC-Si film with high adhesion treatment, have improved the μ -V grade durability, as shown in Fig. 2¹⁾.

The second example is of a titanium nitride (TiN) coated shim. It has been adopted for use in the engine valve operating systems of Toyota Motor Corporation (Fig. 3). Micron-size projections of droplets are present on the surface of the shim and lap the relative surface. Fig. 4 shows the friction torque of a camshaft employing a TiN coated shim when the engine is started. The friction torque reduces by around 40% in a few minutes, and the figure shows the results when running for a long distance under the same conditions. The friction torque remains constant²⁾.

The third example is of an applied technology for seat cover material, which may at first seem unrelated with the tribological technology that Toyota Boshoku Corporation has been working on. Fabric is generally used for the seat cover material, and vehicle seats must be smooth and comfortable enough to allow passengers to get in and out of their seat easily. They are also required to have adequate stability to keep passengers seated in the correct posture, which is necessary for safe driving. These characteristics depend largely on the static friction coefficient of the seat cover. When coefficient is 0.6 or less, passengers may not be able to maintain a stable posture, causing inappropriate steering or braking operations. In cases of static friction torque of 1.5 or more, passengers find it difficult to get out of the vehicle, because their clothing, especially skirts, cling to the seat cover.

The last example is of the application of computer chemistry, which Toyota Central R&D Labs have been working on in recent years. Under high pressure, oil film sometimes transmits tractive forces across rolling contacts. When special traction oil of a certain molecular structure is used, traction coefficient, μ , increases (Fig.5). We have therefore developed new molecular dynamics software in order to analyze the reasons for the μ increase. As a further step, we expanded this method by using a massive-parallel super

Fig. 3 Valve train cross-section

Fig. 4 Camshaft friction torque reduction

Fig. 5 Comparison of simulated traction coefficient μ to ball-on-disk measurements

computer where we succeeded to simulate a realistic oil film thickness. We are planning to apply this technology to various solutions³⁾.

3. Process Technology

The first example is of industrial waste reduction by using non-chlorine processing oil, carried out by Toyota Boshoku Corporation. Chlorine processing oil has a feature in which die wear is less than non-chlorine processing oil due to its superior lubricity. It requires

cleaning, however, as it contains chlorine, which causes rusting. We then blended a sulfur compound into it to ensure the same, or better, lubricity as chlorine processing oil, and optimized the viscosity of the oil film. As a result, we succeeded to develop non-chlorine processing oil which doubles the die life. Additionally, the nonuse of chlorine allowed us to cut external liquid waste disposal to zero (Fig. 6).

Fig. 6 Develop non-chlorine processing oil with the same or better performance as chlorine processing oil

The second example is of industrial waste reduction by introducing new lubricants into the forging processes of drive pinion shafts, carried out by Toyota Motor Corporation. Conventionally, a polymerization coating of zinc phosphate and metal soap has been used in the lubricant process for cold forging. This method, however, generates lots of industrial waste, needs large-scale equipment and takes a long time. We therefore developed a lubricant which has the same processing performance as a conventional one, using friction heat during forging to form a coating. By using this method we have succeeded in reducing industrial waste generation to zero and decrease waste by 125 tons a year, per line. At the same time, we have achieved a remarkable reduction in working space and processing time (Fig. 7)⁴⁾.

Fig. 7 New process

The last example of process technology is of energy saving, by applying low friction hydraulic fluid. This is something which Denso Corporation has been working

on. We made a selection of fluids aiming to cut 500 tons of CO₂ by using friction hydraulic fluid. Conventionally, oil A, B and C have been used, but in addition to these we tested 3 types of oil and adopted oil D because the friction coefficient is stable and does not cause seizure under a wide range of pressures (Fig. 8). Applying this hydraulic fluid to all vane pumps will allow CO₂ reduction of up to 3 times the original target, and also the selection of a switching device⁵⁾.

Fig. 8 Lubricity test of various energy-saving hydraulic fluids

4. Expectations for Future Technology

The first expectation is that of the ultimate fuel economy technology. About 40% of energy generated by a car engine is consumed due to engine friction loss, including pumping loss. Also for drive systems a decrease in friction loss and an increase in transmissibility are required. That is to say, we have to vigorously push forward the technical developments of the ultimate tribological technologies such as zero friction, zero wear and μ control in order to realize further fuel economy in the future.

The second expectation is the ultimate sensitivity control technology. Although we have already introduced sensitivity control technology applied to the seat in this report, we regard it as still being in the early stages of development. Ergonomics from a tribological perspective - or “Sensory-Tribology” - however, will be very important in the future and needs to be discussed in more detail.

The last expectation is the “creation of new technology to create dream-inspiring cars”. The one-passenger “i-unit” vehicle, introduced at the World Exposition in Aichi, Japan and the Tokyo Motor Show in 2005, is a wind-powered electric car. It may be the ultimate eco-car because it is powered using natural energy. The i-unit has further developed the concept of “human expansion”; it is “the mobility which allows individuals to move more freely, which is the essence of life. It also expands human possibilities”. Our ultimate aim is “Kintoun” (a flying cloud, in Chinese classical literature) which will allow us to travel fast anywhere at will. Developing this “Kintoun” will be difficult, but we

believe that we will be able to create the technologies need to make it a reality.

5. Rerences

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