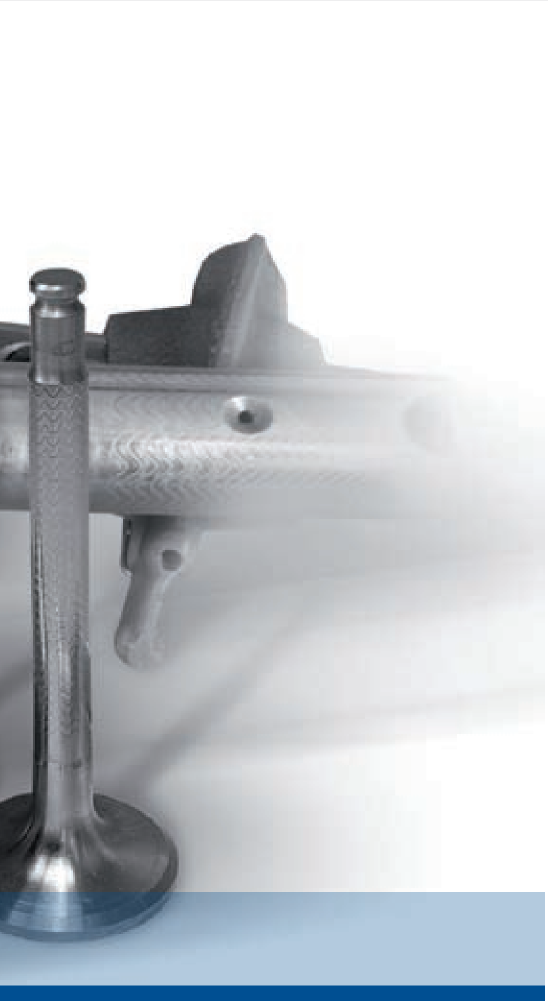
# Reduced Friction Using a Nanolayer-based Environmentally Friendly Technology

For years now the industry has been searching for solutions whereby friction between mechanical parts can be significantly reduced. FriCSo's technology – a simple mechanical machining process using polymer devices – could be an answer. During the machining process with the polymer tools, the topography of the part is significantly improved and the surface is "activated." The oil retaining properties of the surface is optimized. The results of the treatment are increased part life-time due to wear reduction and a decrease in mechanical losses. The process could, under certain circumstances, also be used as an alternative or optimization to existing coatings.



## 1 Introduction

Currently global regulations to reduce emissions, energy and fleet consumption rates in the automotive industry are becoming more stringent. Existing surface finishing processes and coatings such as chrome and nickel are being targeted by environmental protection agencies as they are toxic and detrimental to the environment. The overriding trend in the automotive industry is towards higher engine performance whilst achieving minimum consumption. In addition guarantee and service intervals are increasing and price pressure is ever-present. Therefore car manufacturers and machine builders are being forced to find new ways to reduce wear and increase the working life of their products. One of the main focuses therefore in manufacturing is to find a surface finish where chemical or toxic processes can be avoided.

## 2 FriCSo's Surface Engineering Treatment

FriCSo has developed a technology which can meet these challenges. The technology, Surface Engineering Treatment (SET), and the parts treated by it, significantly reduce the friction between moving parts in all tribo-environments using a polymer-based machining process. In addition to creating a better mechanical surface topography SET creates an oil-retaining nano structure chemically bonded to the metal surface, which improves the affinity of the lubricant to the contact surface: thereby increasing the surface energy and reducing the wetting angle.

The process enables a performance which is similar to the known and well-tried coatings but in a much shorter processing time, for a fraction of the cost and using a significantly less complex production technology. There are three main arguments which promote this technology:

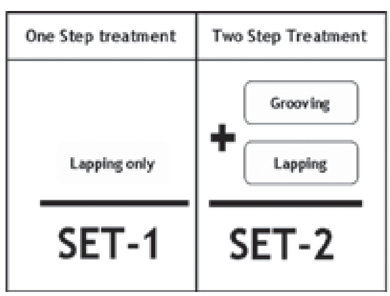



**Figure 1:** Overview of the possible methods of treatment

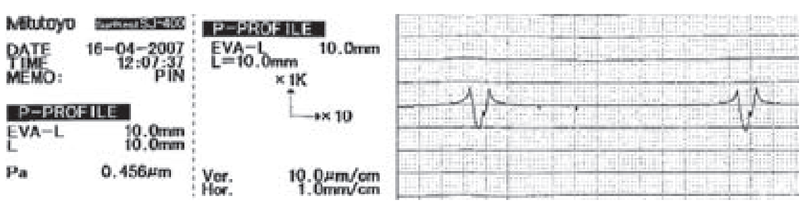



**Figure 2:** Surface characteristic after texturing – the shoulders are clearly visible

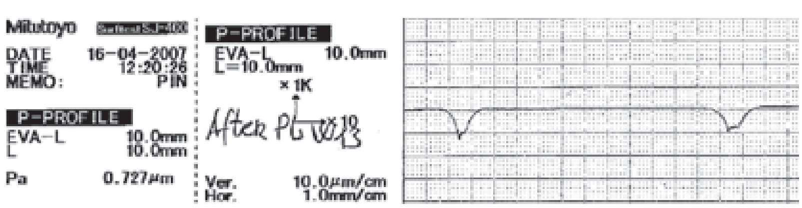



**Figure 3:** Surface characteristic after polymer lapping – the shoulders are rounded


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**Figure 4:** Honing head with polymer tools

- It improves efficiency – SET reduces friction and thereby the mechanical losses by creating strong oil retaining properties on the surface of the treated part.
- It can replace or promote the effectiveness of coatings – SET can replace toxic or highly complex coating processes by using environmentally-friendly polymer devices on existing surface finishing machines.
- It improves wear resistance - SET enables a significant extension of wear resistance up until seizure under extreme working conditions.

## 3 Variations in the FriCSo Treatment

The SET process can be either a 1 or 2-step procedure, **Figure 1**.

### 3.1 The Process (SET-1)

SET works in a similar way to an existing mechanical process (lapping/honing) – however instead of using GG-lapping tools it uses the patented polymer-based consumable devices. The process creates an organic nano structure that is chemically bonded to the surface of the moving part. The newly formed nano structure bonds into the top 2-3 microns of the surface and once there – due to its special characteristics – acts to minimize friction and wear over the total lifetime of the tribo-system.

### 3.2. Surface Texturing (SET-2)

During surface texturing indentations are created in the metal surface. These indentations could be grooves made by plastic deformation or laser dimples. The indentations are used to create oil reservoirs on the surface which can release the oil into the tribo-system in case of insufficient lubrication.The friction pair is therefore also sufficiently lubricated in boundary conditions such as start-stop.

Creating a groove by texturing creates bulges, meaning - shoulders on each side of the groove. To remove these bulges using existing super finishing methods (fixed particle or hard stones) would create a sharp edge which in turn is highly damaging to the micro-hydrodynamics of the friction pair. In fact the sharp edge can become an abrasive itself.

In contrast to existing methods, the polymer lapping process uses a “soft” polymer tool, which rounds the shoulders of the groove to the advantage of the micro-hydrodynamics of the friction pair and in addition creates the characteristics of the nano-structure as mentioned above, **Figure 2** and **Figure 3**.

An important performance increase has been shown when using the correct texturing pattern together with polymer lapping when compared to super finishing or simple polymer lapping. Through FriCSo’s experience and the database of texture patterns it is possible to recommend a specific geometry for various applications.

## 4 Polymer Lapping in Detail

As the polymer devices, **Figure 4** and **Figure 5**, are used together with an abrasive lapping paste it is possible to get from Ra 0,2 μm to Ra ≤ 0,02 μm in one single machining step. During the lapping process with the polymer tool a chemical reaction takes place between tiny polymer particles with reactive polar groups which are torn from the polymer tool and the active areas on the metal surface. The result is the creation of an unique surface whose affinity and adhesion to lubricants is significantly improved. The nano-structure is formed during the polymer lapping process (with relatively little mechanical pressure) and held by strong ionic forces to the metal substrate, which means that it also remains active even at seizure. The polymer tools are so designed that they can be used on existing prototype and series machines. The cycle time remains virtually the same despite the change of tool.

The SET-process offers real advantages in friction reduction as the surface created is reliable and durable. The reduced friction from breakaway in bounadry or mixed lubrication up to hydrodynamic

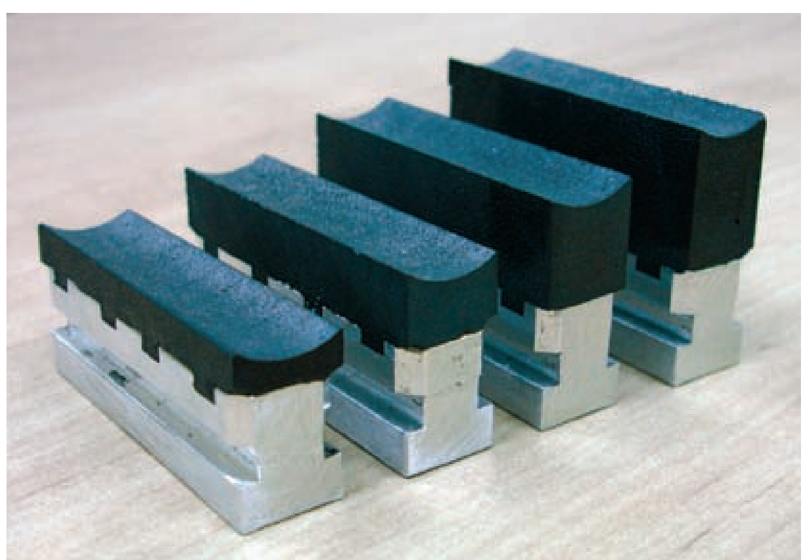

**Figure 5:** Polymer tools for outer diameter

**Table:** Abrasion in the SOP system for two different material combinations

| Conditions | | | |
|---|---|---|---|
| Shaft on Plate | ISO7148 / 2 | Speed | 18,8 mm / s (30 rpm) |
| Contact line | 9 mm | Duration | 50 Hrs |
| Movement | Rotation | Temperature | Room temperature |
| Lubrication | 100 µl parafinic mineral oil without additives | | |
| **Case 1** | Shaft against brass Plate<br>Steel / brass combination | **Case 2** | Shaft against brass Plate<br>Steel / Steel combination |
| **Reference Material** | | | |
| without | Test piece without treatment | W13 | W13, W32 and Y4 are different polymer tool compositions |
| cast iron | Current machining process | W32 | |
| | | Y4 | |

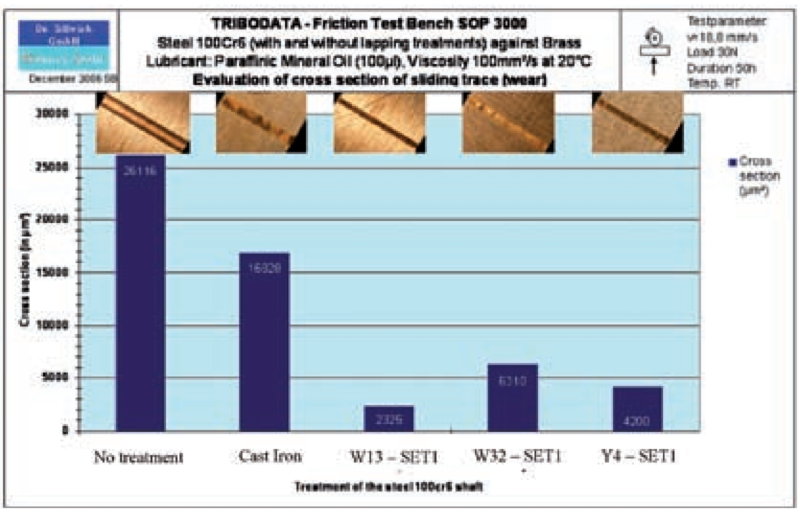


**Figure 6:** SOP test – material combination steel / brass

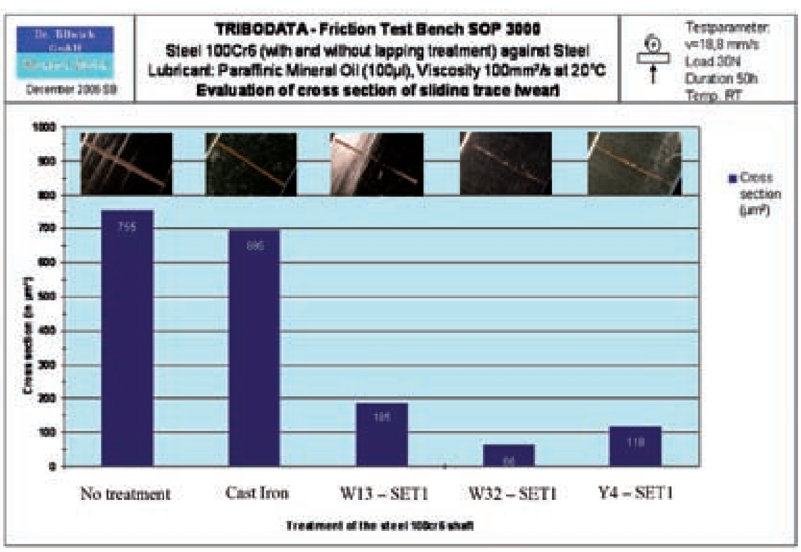


**Figure 7:** SOP test – material combination steel / steel

conditions means energy saving without performance loss over the whole life-time of the friction pair. Wear is reduced and the performance criteria improved. When measured, the metal surfaces treated by SET show improved oil-retaining characteristics (even in boundary conditions),a lower surface roughness, (Ra, Rpk, Rz etc) and what is more, an optimised surface topography with gently-rounded peaks giving a radically improved bearing area curve. A better sliding contact has been created for all lubrication conditions with less friction and this has lead to some rethinking in terms of simplifying existing systems – for example replacing bearings or even bronze / steel friction pairs with steel / steel friction pairs, **Table**.

The production process uses existing mass-production machines; centerless through feed machines and honing machines. FriCSo's polymer devices simply replace the cast iron or abrasive stones being used for finishing and honing. The production time will be similar to the one being used by manufacturers, with a clear advantage in friction reduction when treated parts are assembled. The newly formed surface delivers consistent, reliable performance. The resulting low friction during breakaway torque and during hydrodynamics translates into energy savings without compromising performance. Wear is reduced, efficiency is improved, and the solution provides a safe, cost-effective and reliable alternative to coatings and durable metal parts.

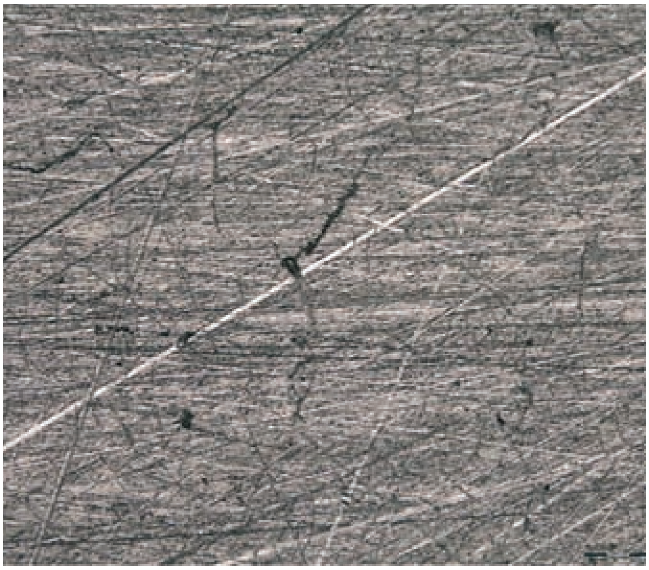

Figure 8: Grey cast iron – standard honing

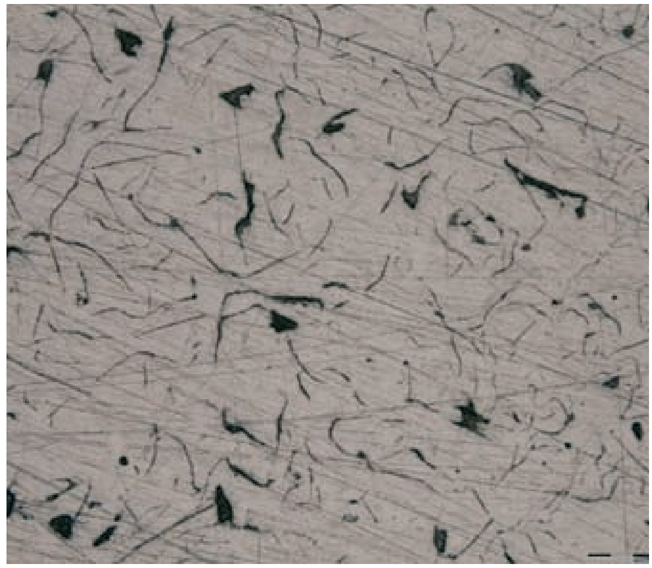

Figure 9: Grey cast iron – graphite revealed by polymer lapping

## 5 Basic Research and Tests

The industry has developed various standard tests such as shaft on plate (SOP) or pin on disc with which a tribosystem can be checked as a first step. In the following table the results of wear measurements are shown for two different metal pairs.

The results of the standard SOP test shows that treating the parts with FriCSo gives a clear advantage in terms of wear over the standard process (cast iron stones). This is the effect of the "active" surface. The lubrication adheres better to a surface which has an improved topography and better bearing curve characteristics.

In case 1, **Figure 6**, a pairing of Steel / Brass is tested whereas in case 2, **Figure 7**, the pairing Steel / Steel is checked. It can be seen in addition that the differing polymer tool compositions (W13,W32 and Y4) also give differing "effects". It can be seen that not only is an applications-specific machining concept possible (SET-1, SET-2), but also that polymer compositions can also be adapted for specific material pairs.

## 6 Combustion Engines

An ideal application for the SET technology is the cylinder with its complex tribological environment and demands: minimum friction losses by creating hydrodynamic conditions over a large area with a fine running surface. The special polymer lapping process leaves the established and necessary rougher honing structure in place. The peaks on the contact surface, which promote friction and wear, however are rounded. (while removing few microns of material). This alone reduces friction losses and piston ring wear. The plateau surface created by the polymer lapping process has a large oil retaining capability, **Figure 8** and **Figure 9**.

When treating piston pins with polymer tools, **Figure 10**, the roughness was reduced by up to 30 % compared to the same machining time using standard processes. The friction and wear results were improved so much that in certain constructions it can be considered an alternative to costly con rod bushings in bronze. In test conditions a steel / steel concept achieved a 40 % reduction in friction losses compared to a steel on bronze bearing.

When considering a cam shaft, **Figure 11**, the SET-1 and SET-2 machining concepts were used. In this instance only the bearing areas were treated with FriCSo SET. The lobes were not treated for this test. The results have shown that the SET treatment reduced the friction losses by up to 26 %

## 7 Engine Test in the Technion Institute

A test, carried out in the Technion has shown that using the SET-process reduces oil consumption and particle

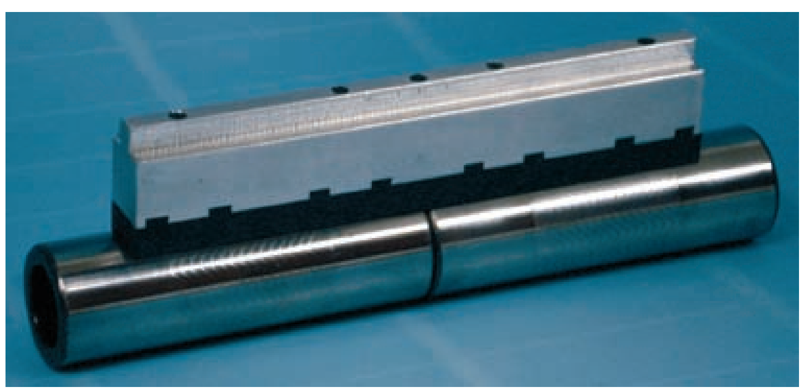

Figure 10: Piston pin with structuring in the con rod bearing area

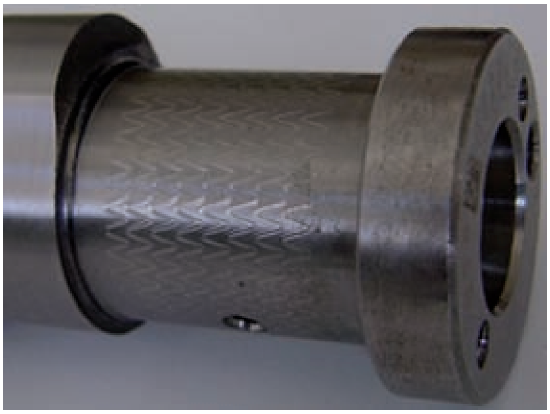

**Figure 11:** Cam shaft with structuring in the bearing area

emissions substantially, leads to a better fuel efficiency and improves engine performance. The test was carried out on an older generation 4-cylinder tractor diesel engine. The tests showed that the SET treated version, depending on applied loads, achieved a fuel consumption reduction between 0,4 to 4 %, 43 to 46 % less particle emissions and a 2 % improvement in power output. **Figure 12** and **Figure 13** show the treated and the untreated cylinder bores.

## 8 Dampers

Damper rods treated by SET (Rpk reduced by nearly 50 %) give a better driving experience as the forces which affect the damper (especially side loads) are reduced and the damping characteristics are improved. Life-time of the damper is extended and wear resistance on the Elastomer seal is improved.

## 9 Hydraulics

In hydraulics systems SET eliminates the adhesive wear problem on many different parts even in severe working conditions. The picture below shows parts from a hydraulic pump which have been finished using standard super finishing tools, **Figure 14**, and tested over 1,2 million cycles at 37 MPa pressure and 2400RPM at 82 °C. There are signs of severe adhesive wear on the surface of the parts with the standard finishing treatment,whereas the FriC-So treated part, **Figure 15**, shows virtually no signs of wear.

**Figure 12:** Series cylinder as base line

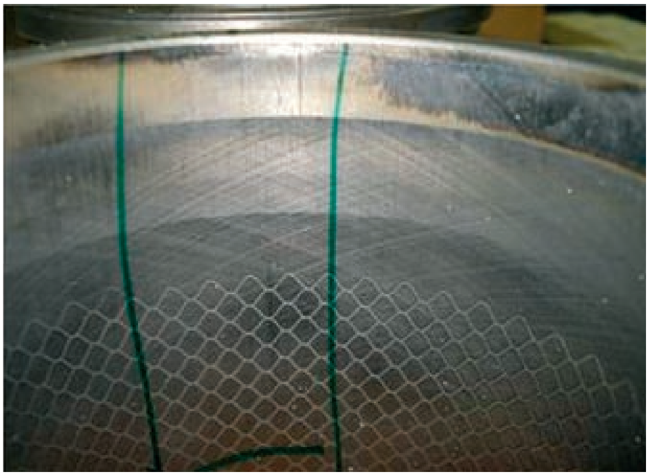

**Figure 13:** Series cylinder with SET2 treatment

**Figure 14:** Series parts after test

**Figure 15:** Polymer lapped parts after test