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# Laser Surface Texturing (LST) on Piston Rings for Friction Power Reduction- A Technical Review

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## ABSTRACT

*This paper reports technical review related to engine tribology in internal combustion engine. The understanding of tribology plays an important role in automotive sector in reducing friction of an Internal Combustion Engine. Piston Ring Assembly is the key component of the Internal Combustion Engine. Knowledge of tribological factors is important for reducing frictional losses, emission level and improving the fuel economy in the I.C. engine. The frictional losses are in the piston ring vary from approximately 25 to 30%, in cylinder liner 15% and face seal 10% of the total mechanical losses as reported in the literature. LST are used on various components to reduce the friction. Due to reduce in friction between two matching parts in I.C. Engine, reduces fuel consumption, increased power output of the engine, reduced oil consumption, a reduction in exhaust emissions in the engine. The literatures revealed that the most important parameter in the engine is load, speed and lubricant.*

***Keywords:—*** *Friction force, Internal combustion Engine (I.C.Engine), Laser surface texturing (LST), Lubrication, Piston rings.*

## I. INTRODUCTION

Internal combustion engine (I.C. Engine) has gained the name and frame in serving the society in many ways. Its main attractions are ruggedness in construction, simplicity in operation and ease of maintenance. But due to friction, we may not be able to avail its services for long time. So efforts are made to make global efforts to reduce friction between parts of the internal combustion engine.

The friction loss in an internal combustion engine is the most important factor in determining the fuel economy and performance of the vehicle utilizing the power of the engine. About 50% friction loss in the internal combustion engine is due to the piston / cylinder system, of which 70-80% comes from piston rings. Proper lubrication and surface formation are the main issues of reducing friction in piston / cylinder systems and therefore, have attracted much attention in related literature. Surface structure is known for many years as an instrument for increasing the tribology properties of mechanical components. Perhaps the most familiar and early commercial use of surface texting in the engine is cylinder liner honing. As a potential new technology to reduce friction in mechanical components, surface texting has emerged in general and laser surface texting (LST) in recent years.

In this work, the surface micro structure of piston rings is changed by Laser Surface Texturing method, in order to change lubrication regime of surface, and wear resistant. Comparison with base data, compared to the piston ring with fully textured, partial textured and friction data, non-textured piston rings.

## II. REVIEW

Number of research papers and studies has been conducted on the use of Laser Surface Texture and effect of Texturing on Engine Friction and fuel economy and studied the effect of changes in parameters like friction force, texture pattern, viscosity of oil, load capacity etc. Number of reviews has been taken below to complete the present study.

### *1. Laser Surface Texture on Piston Rings*

G. Ryk and I. Etsion [1] Testing piston rings with partial surface texturing. Tested on the revised test rig with realistic piston rings and cylinder liner segments. A reference was made between performance of non-textured traditional barrel shape rings and a performance of the maximum partial LST cylindrical shape rings. Friction tests were conducted with many values of normal load fits corresponding to normal contact pressure range of 0.1 to 0.3MP. Special results were found for a representative case with a nominal contact pressure of 0.2MPa.

The average friction force is presented in reference to the non-textured barrel shape rings, and for the partially LST cylindrical face rings, against the rotational momentum of the crank. As such, the average friction increases with both speed and weight, such as hydrodynamic lubrication rule is expected.

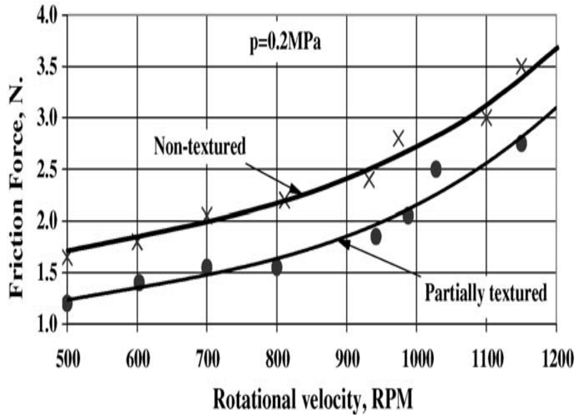


*Figure 1.1 The average friction force vs crank rotational for external normal pressure of 0.2 MPa.*

Clearly the LST has a substantial effect on friction reduction compared to the non textured reference rings. The average friction reference obtained with partially LST cylindrical facial rings is about 20-25% lower than the barrel facial rings, ranging from 500 to 1200 rpm in the entire speed range. They also concluded that the percentage difference between non-textured and partial LST rings is almost independent of minor contact pressure, and slightly decreased with increasing rotational velocity. It should be noted that above 900 rpm the vibrations level of the test rig starts to increase and above 1200 rpm it reaches such a level that prohibited testing in this speed range. Hence, the friction measurements at 1200 rpm can be considered less reliable than at the 500–900 rpm range. Finally, some real engine tests were partially made with LST barrel-shaped rings, which reduce much less friction at lower speeds below 2000 rpm.

Above 2000 rpm this little benefit of the partial LST vanished completely. It seems that the barrel shape, which presumably was arrived at by trial and error experience over many years, is not a good for partial LST. The ring provides a strong hydrodynamic effect to the facial crown, which usually hides the weak hydrodynamic effects of surface composition at high speeds. Hence, in the future a more appropriate comparison with firing engine test should be made, similar to the present rig test, between the performance of optimum non-textured barrel shape and optimum partial LST cylindrical shape rings. It has been found that approximately 25% of partial LST piston rings are found in lower conflicts.

E.Share & I.Etsion [2] has evaluated the effect of partially laser surface textured piston rings on the fuel consumption and exhaust gas composition of a compression-ignition I.C. engine. Dynamometer tests with Ford Transit were naturally placed on the speed of the engine under roughly half the load conditions for the 2500 cms3 engine. The effect of the LST applied to the four top piston rings of the engine was verified by the following process: To reduce the random effect in order environment fluctuations, each set of rings was tested in three different days. At each day, the same sets of engine loads and engine speeds were tested in two different procedures; an engine speed increasing test procedure, and an engine speed decreasing test procedure. Each procedure was repeated three times. At each point the engine was allowed to reach steady-state conditions, which were typically attained after 20 min.

The non-textured reference to conventional barrel-shaped rings and the maximum partial laser surface texting (LST) was compared to cylindrical-shaped rings. It was found that the partial LST piston rings exhibited up to 4% lower fuel consumption, while no traceable change in the exhaust gas composition or smoke level was observed.

Y. Kligerman et al.[3] Partly LST develops an analytical model of flat face piston rings where only one part of the ring face width is textured. Partially based on the so-called "collective" effect of LST Dimples, which usually provides an equal clearance between parallel breeding surfaces. The behavior of the force of friction comes under pressure in the composite liquid film and time-wise clearance. An intensive parametric investigation is performed to identify the main parameters of the problem. The best LST parameters like the piston ring's diminished contact surface depth, texture area density and textured part are evaluated. It was observed that the friction for the maximum partial LST piston rings is much less than the optimal full LST ring.

The difference varies from about 30% reduction for narrow rings to about 55% reduction in wide rings.

Aviram Ronen and Izhak Etsion [4] examined the piston-cylinder system with laser surface textured piston rings. The authors studied the possible use of piston ring micro-surface structures in the form of spherical segment micro dimples to reduce the friction between rings and cylinder liner, where the full ring surface in contact with the cylinder liner was textured. It showed that significant hydrodynamic effects can be produced from the surface. The time difference between the piston ring and the cylinder liner and the friction force between any operating conditions was obtained by solving the Reynolds equation and dynamic equation simultaneously. The main parameters of the problem were identified. These were the area density of the dimples, dimple diameter, and dimple depth. An optimum value of the micro dimple depth over diameter ratio was found, which yields a minimum friction force. It was found that with textural surfaces it is possible to reduce the 30% and more friction.

G.Ryk, Y.Kligerman, I.Etsion & A.Shikarenko [5] Experimental studies have been introduced to evaluate the effect of partial laser surface texting (LST) on the reduction in friction in piston rings. In the previous study, a 30% friction reduction can be achieved with a complete LST, where the full width of the piston ring is textured with a large number of micro-dipples that acts individually as micro-hydrodynamic bearings. In partial LST, only part of the piston-ring width is textured with high dimension density, which affects "collective" of Dimples, which equally provides equal clearance with parallel fertility surfaces.

Experimental results obtained with flat and parallel test specimens with partial LST are presented, confirming a previously published theoretical model and the advantage of partial over full LST. Friction reduction by LST with actual production-crowned piston rings and cylinder liner segments is not easy and requires further investigation.

It has been found that in the limit of test manipulative speed, the conflicts can be reduced to about 25% with partial LST compared to full LST. Compared with this non-textured case, there is an additional improvement on ≈40% friction reduction, with full LST. Some early manipulation and real engine tests with production piston rings and cylinder liners do not show the same amount of reduction in the friction. However, these tests were done with barrels-shaped piston rings and not with conformal cylindrical rings.

G.Ryk, Y.Kligerman and I.Etsion [6] Impressed by the study of inertial forces, the limitation conditions of the film's action and pressure on the strength of the friction between the laser textured piston ring and cylinder liner surfaces. Two approaches are presented. The first full dynamic force is based on the equilibrium, which takes into account the inertial forces and the squeeze film effects due to the piston ring set and radial speed, respectively. The second is based on a quasi-static force equilibrium that neglects inertia and squeeze film effects. Real time variations during the engine cycle Pressure instead of continuing constant pressure instead of boundary crisis, the result is also studied for the first approach. By solving a quasi-static force balance problem in conjunction with a proper curve fitting it is possible to obtain sufficient accurate results for both the instantaneous and the average friction forces and to save computing time. The main disadvantage of this solution is its inability to predict the time variation of the clearance where the sliding velocity diminishes and clearance is maintained due to squeeze film effect.

The maximum value of the clearance is strongly affected by the real time variation of the cylinder pressure during the engine cycle. The minimum value of clearance is the same for the same ambient cylinder pressure case. Immediate friction force is less susceptible to the actual cylinder pressure and the error in the average friction force is less than 15%.

### *2. Laser Surface Texture on cylinder Liner*

Staffan Johansson et al.[7] In their experiment, the reciprocating tribometer at Volvo technology has been updated so that the friction difference between the content combinations / surfaces is further evaluated. It is possible to evaluate a number of operational parameters in each experiment. The studied components were piston ring running against the cylinder liner. Changes in experiments in friction, wear and surface morphology were studied. It has been shown that dynamic viscosity, acceleration, and contact pressure interaction can be studied in an experiment for the introduced DOE-based tribometer. The results show differences in friction which could be explained as the surface creating beneficial contact conditions for oil film build-up. It is also

apparent that surface roughness is important regardless of material properties. To better understand the correlations between friction and surface roughness a future study should include a study of similar materials with different roughness values.

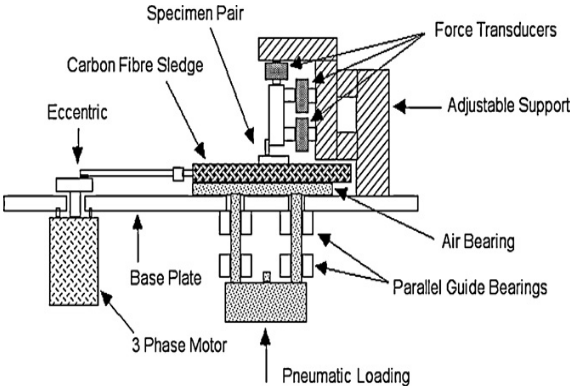


*Figure 2.1 Overview of the reciprocating eccentric tribometer.*

For the materials studied in this work [Gray cast iron] it is apparent that surface roughness is important in the mild wear situation regardless of material properties, this is accurate for boundary and mixed lubrication regime. It can be clearly seen that all part of the surface amplitude should be minimized to decrease friction; however, due to the multitude of surface roughness parameters that shows a significant correlation to friction it is difficult to draw conclusions of what surface characteristic that is of most importance to decrease friction.

Yuankai Zhou et al. [8] In this paper, the capacity to load the first compressed ring and the film's theoretical model were based on the conditions of the dynamic operation of the Reynolds equation and the cylinder liner and the CY6102 type diesel engine's piston ring. Based on the theoretical models, the effects of the texturing parameters on the load carrying capacity and film thickness were investigated under different velocities, and the ranges of optimum texturing parameters were found. The best texting design method was proposed on the cylinder liner. It shows that on the cylinder liner, texting with variable dimensions in different accelerating ranges can produce greater load carrying capacity and film thickness with infrequent parameters.

The texturing with variable parameters in different velocity ranges can produce thicker film than the invariable texturing, the same results can be found at the top and bottom dead center, indicating that it is a good method to improve the hydrodynamic lubrication effect than others.

### *3. Laser Surface Texture on face seal*

Wan Yi et al.[9] In their paper, laser was used to generate micro pores on T8 steel surface and the structure and morphology features of surface micro pores were observed. Tribological experiments were carried out with ring-on-disk testers under various loads and speed.

It is shown that the maximum PV value of face seal can be increased by hydrodynamic effect of micro pores.

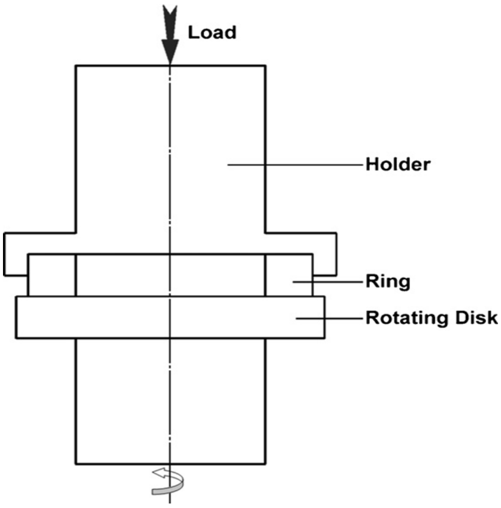


*Figure 3.1 Ring-on-disc friction testing.*

The frictional properties of the laser-micro pored surface were assessed by ring-on-disk tests, corresponding to the face seal contact interface with various loads and speeds.

The findings are concluded as follows: All the surfaces had similar trends with the friction coefficients decreased at the initial stage and increased gradually with load and speed. Compared with the polished surface, the laser-micro pored seal surface can improve the maximum PV value to 2.5 times.

### 4. Laser Surface Texture effect in soft elasto-hydrodynamic lubrication.

A.Shikarenko et al. [10] Theoretical model has been developed to study the potential use of laser surface texting (LST) in the form of rounded micro-dimples for soft elasto-hydrodynamic laboratory (SEHL). This model is a smooth elastomeric and LST rigid surface of mutual, which is progressing simultaneously in the presence of oily lubricant. Fluid film pressure distribution and Elastomer's elastic distortion, together with Reynolds equation, solves and achieves an elastic equation for Elastomer. A comprehensive parametric investigation is done to identify the main key parameters of the problem, which is the density of aspect ratio and area of the dimples. Parametric analysis provides maximum dimensions to surface structure and suggests that LST effectively increases load capacity and reduces friction in SEHL.

It was found that texturing of the rigid counterpart generates a load-carrying capacity that can be maximized by selecting a preferred dimple area density, Sp, and an optimum dimple aspect ratio, Maximum parameters for maximum emphasis reduces friction force. It was observed that Dimple Radius does not affect the tribological performance of SEHL.

The best value of the dimple are a density, Sp, is almost independent of all the other parameters of the problem and is about Sp=0.3.

The optimum aspect ratio depends exclusively on the SEHL stiffness index, E. As E changes from 420 to 6×105, the optimum aspect ratio (e) opt varies from 0.1 to 0.02, respectively. Further increase of E does not affect the optimum aspect ratio, which remains 0.02.

### 5. Laser Surface Textured under lubrication initial point contact.

Andriy Kovalhenko et al.[11] discussed the effect of laser-textured surfaces on the tribological properties under a point ball-on -flat contact configuration. Tribological experiments with dimpled flats were used in pin-on-disk friction machines at speeds ranging from 0.015 to 0.75 m / s, using oil with different viscosity.

Disks with different depths and denser dimples were evaluated. The results show that discs with high dimension density have created more frictional wear on the ball sample.

However, this high-wear rate created a transition for quick production of contacts and mixed lubrication regime, resulting in a rapid reduction in the multiplication of friction, with increased ball wear. As expected, the rate of wear was higher in tests with low viscosity oils. Studies can be beneficial for the optimization of LST technology for industrial applications in friction units.

## III. CONCLUSION

Decrease in the conflicts with partial laser surface texting (LST) was evaluated on repeated test manipulation by measuring the force of friction between piston rings and cylinder liner segments. The results were compared with the non-textured barrel face piston ring. It has been found that, in the speed limit of the test skin, a reduction in about 25% of the friction can be obtained with partial LST cylindrical face rings. Some initial real engine tests do not show the same number of reductions in friction with production (barrel-shaped) piston rings and cylinder liners. Optimum partial LST cylindrical face rings require further investigation with the engine firing.

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