

# THE CHARACTERISATION OF ENGINE LINER WEAR USING NOVEL BEARING AREA CURVE PARAMETERS

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## Introduction

The problems of increased oil consumption, blow-by, and scuffing have frequently been encountered and reported in heavy duty turbo-charged diesel engines [1]. One cause, first reported in the 1960s [2], is a wear phenomenon known as bore polishing which entails the generation of a bright mirror-like appearance on the cylinder liner surface along with full or partial loss of the honing pattern. Bore polishing has been attributed to either hard carbonaceous deposits, formed on the top land, or contaminants in the lubricating oil (or even both) [3].

Since the lubricating oil plays a major role in controlling these factors, bore polishing can be suppressed or even controlled by suitable oil formation. A number of engine tests have been developed for evaluation of the bore polishing tendency of lubricating oils. However, problems exist in the standardisation of testing due to design changes in test engines and models being withdrawn from production or becoming obsolete. Quantifying the amount of bore polish area present on a liner has involved manual inspection of the engine. This can be either destructive with removal and splitting of the liner or non-destructive with the inspector peering inside the engine block. The subjective nature of human inspection coupled with an obstructed view of the lower part of the liner has led to variations between inspectors' results of as high as 20%.

In order to minimise the variation between inspectors and to provide a more rapid, automated and repeatable polish detection system, the University of Birmingham, in conjunction, with a UK engine testing company embarked on the development of a 2<sup>nd</sup> generation laser bore scanner. As part of this research it was necessary to comprehensively characterise the topographic change occurring as the surface began to wear. This paper presents an attempt at characterising bore polish using surface parameters derived from the bearing area curve.

## Bore polishing

Bore polish involves the removal of the honed topography, by two- or three-body abrasive wear, to generate a mirror-like surface finish. There are varying levels of polish depending on how much of the original honed topography is remaining. The Co-ordinating European Council (CEC)[4] defined bore polish as being "... evidenced by clearly defined areas of bright mirror finish. It is caused by local mechanical wear of the surface." It went on further to categorise the visual rating of bore polishing as either light/low, medium, or heavy/high, the definitions are given in *table 1* and illustrated in the surface axionometric plots in *figure 1*.

CATEGORY	DESCRIPTION
Low Polish	A mirror finish overlaid on the original honing pattern
Medium Polish	A mirror finish showing faint traces of the original honing pattern.
Heavy Polish	A mirror finish showing no traces of the original honing pattern.

*Table 1. Definitions of bore polish*

As the bore polish progresses through these classified conditions, a very smooth surface is produced which leads to lubrication starvation. With insufficient boundary lubrication solid contact is made between the surfaces which can lead to welding and material transfer between the piston rings and liner, ultimately, complete engine failure can occur.

## Experimentation

For this analysis a number of engine liners which had been subjected to a standardised 400 hour bore polish test were used. Areas of polish were detected using the laser bore scanner and these regions were then categorised using the classifications defined in *table 1*. Surface measurements were carried out using a number of 3-D stylus instruments, sample spacing was 12 microns (both x- and y-direction) and an assessment area of 2mm by 2mm was employed. Over 150 measurements were undertaken.

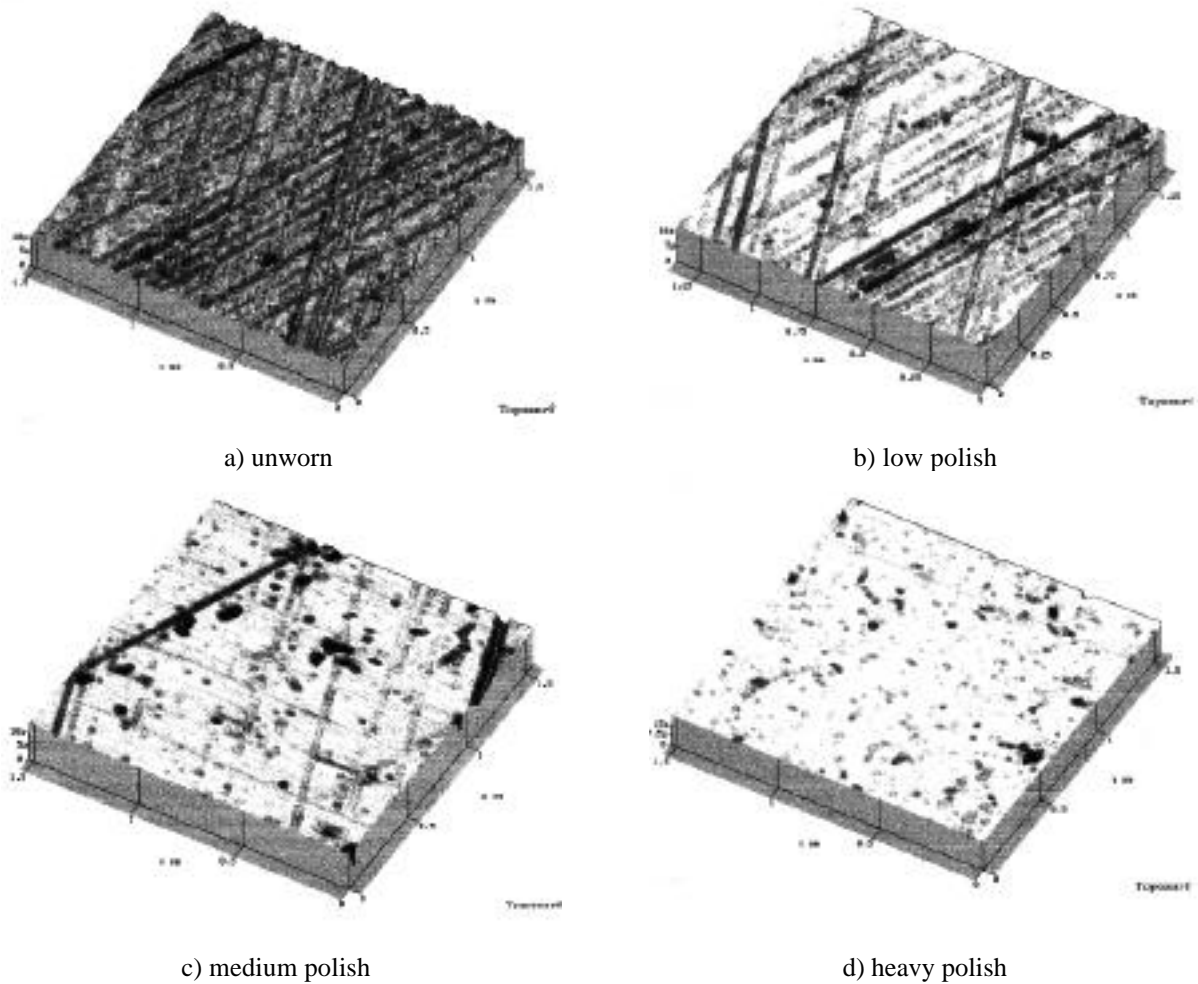


Figure 1. Axionometric plots of bore polish

### Parameters

Originally, an analysis was performed on the surface data employing a number of suites of parameters derived from the bearing area curve. The common theme throughout each suite is the classification of the surface and bearing area curve into peak, core, and valley regions. Unfortunately, although the parameters followed the expected pattern as the surface approaches a smooth valley-sparse topography the actual statistical analysis were not so promising. Both at the 90% and 95% level of confidence no set of parameters were significant. A method was required which could better characterise the subtle topographic changes occurring in the plateau region.

### The Normal Probability Scale

A further development to the bearing area curve, first discussed over 30 years ago by both Williamson [5] and Eberle [6] was the plotting of the curve on normal probability paper. On normal probability (NP) paper any Gaussian distribution should fall in a straight line due to the unique horizontal scale. More recently, this technique has been formalised for 2-D profiles in a new ISO standard [7]. The surface of a cylinder liner is normally generated by a number of honing stages (usually two), each which leaves its unique 'fingerprint' on the surface. By plotting the cumulative amplitude distribution on a NP scale it is possible to identify two distinct lines (using the best fit criteria) corresponding to the plateau and base honing processes (*figure 2*). The gradient of each line corresponds to the rms. roughness ( $R_q$  for 2-D and  $S_q$  for 3-D) for that process. In this analysis the roughness of the plateau region is denoted as  $S_{q(\text{upper})}$  and the base-honed region as  $S_{q(\text{lower})}$ .

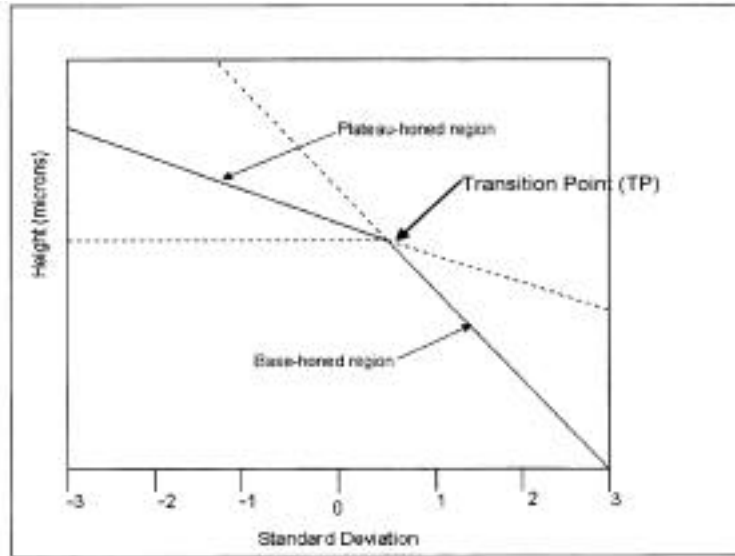


Figure 2. The Bearing area curve plotted on a normal probability scale

**Results**

Table 2 summarises the average parametric values for each degree of bore polishing while figure 3(a-d) illustrates the change in bearing area from an unworn to a heavy polished surface.

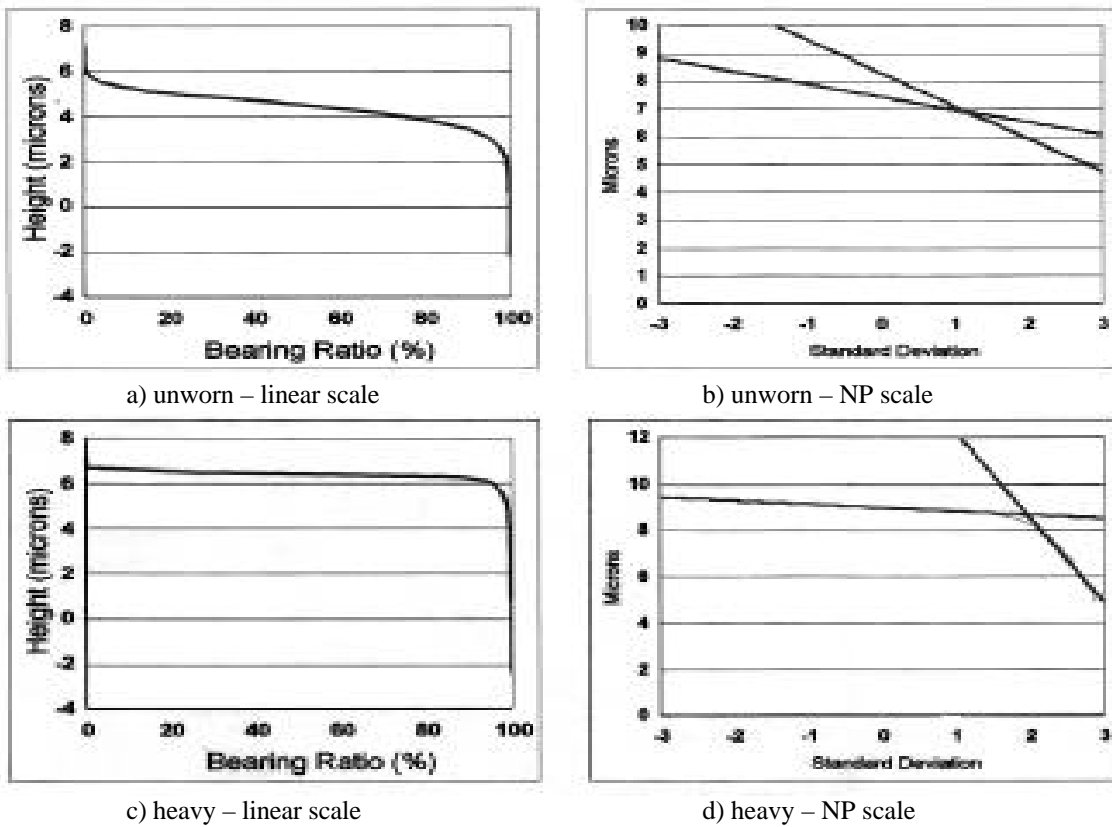


Figure 3. Dual plotting of the bearing area curve

CATEGORY OF WEAR	RMS ROUGHNESS ( $S_q$ )		
	OVERALL	UPPER	LOWER
Unworn	0.81	0.64	1.71
Low Polish	0.68	0.37	3.67
Medium Polish	0.41	0.25	1.89
Heavy Polish	0.26	0.14	1.95

Table 2. Comparison of average  $S_q$  values for overall and separate surface components

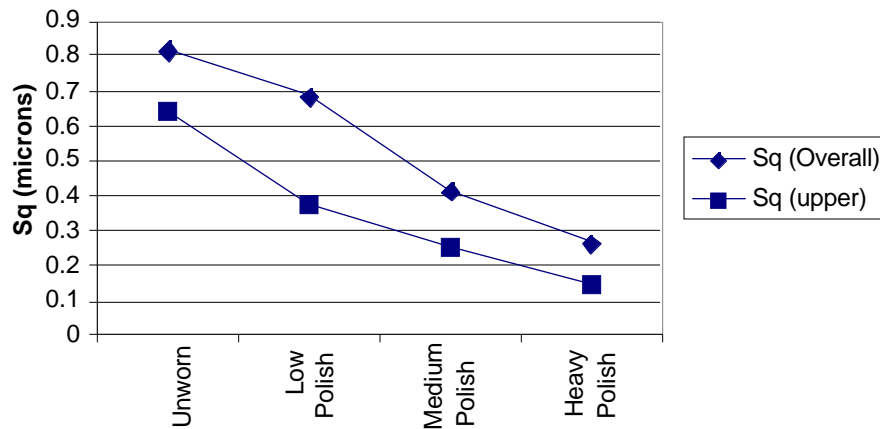


Figure 4. Variation of  $S_q$  with respect to degrees of polish

### Discussion

From table 2 and figure 4 it can be clearly seen that the trend for the areal rms. roughness of the plateau region ( $S_{q(\text{upper})}$ ) is one of decreasing values (as is the trend for the overall roughness). The increase in  $S_{q(\text{lower})}$  could be attributed to pitting or possible scoring in the base-honed region. At the 95% confidence level the  $S_{q(\text{upper})}$  values were significant suggesting that this method could detect subtle topographic changes (attributable to bore polishing) in the plateau zone.

### Conclusions

The plotting and subsequent analysis of the bearing area curve using the normal probability plotting has yielded a technique better adapted to detecting and measuring subtle topographic changes. The next stage of this research is to correlate these parameters with the output obtained from the laser bore scanner so as to provide a rapid, non-subjective, and validated method of polish detection.

### References

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