Analysis of Super-Finishing Honing Operation with Old and New Plateau Honing Machine Concept

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Abstract: In this paper, an attempt was made to study the dependencies between average and maximum roughness in relation to long-stroke honing to different abrasive grain size tools and honing speeds using old and new plateau honing concept. A study to investigate the effect of cylinder liner honing angle on hydrodynamic lubrication between piston ring and cylinder liner. Honing angles between 25-75° were investigated to find the effect of honing angle on film thickness. The plateau-honing is an ultra-finishing process as a result of two machining processes: rough honing with big size abrasive grains and finish honing with very small size abrasive grains to eliminate peaks on the surface of the piece. It is a very complex process depending on many parameters.

Keywords: Plateau Honing, Honing Angles, Piston Ring, Cylinder Liner, Crankshaft honing

1. Introduction:

Typically a machining process known as honing is used to apply the desired finish to the cylinder liner surface. The grooves that the honing process leaves behind are crucial in controlling the amount of oil available in the contact, by both retaining oil on the liner surface and improving the distribution of oil. Another function of the honing texture is to allow wear debris, generated during boundary lubrication around TDC, to be channeled away from the conjunction so as to cause only minimal damage and scratching to the smooth plateau which are crucial for fluid film generation. In this study the effect of applying the honing to hydrodynamic lubrication is investigated.

Very few studies have investigated the effect of honing parameters, and in particular honing angle, on lubrication performance. Therefore this may be an area that has great potential for optimization, and changing a parameter such as honing angle should not add any significant costs to cylinder liner manufacture.

1.1 Honing technology:

Honing is a precision stock removal process for practically all raw materials. The main application is the machining of bores, but it can also be used for plane surfaces, waves or untrue bores. The goal is improving size and shape, or rather, optimizing the tribological characteristics. This means defined surface properties which arise during friction processes, such as in bearings, engines, transmissions and machine elements. With honing, bore accuracy of less than 1 µm diameter tolerance and surface accuracy of less than 0.04 µm are achieved. As a comparison,

a human hair has a diameter of about 60 µm, and a paper clip is about 1,000 µm. Compared to other processes such as internal grinding, honing is not only easier, faster and more cost-effective, it is also more precise.

1.2 Plateau Honing:

One way to obtain this roughness profile is the mechanical process of plateau-honing. It consists of a rough honing with big size abrasive grains followed by a finish honing with very small size abrasive grains until peaks on the surface of the piece have been partially eliminated (fig. 1).

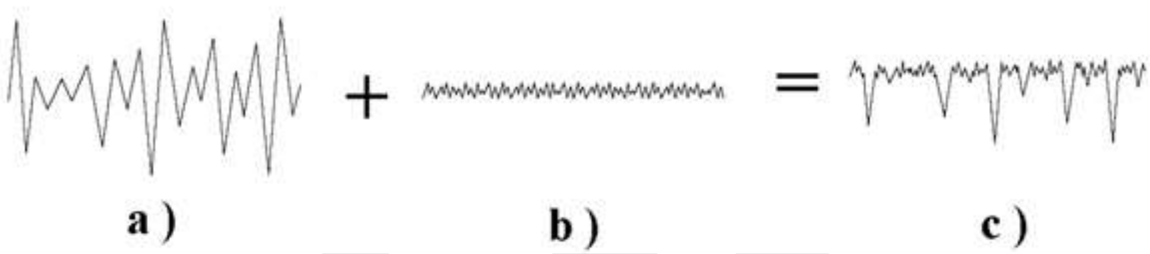


Figure 1. Roughness Profile: a). Rough, b). Plateau, c). Plateau-Honing.

2. Honing Surface Parameters:

2.1 Surface Roughness:

To characterize surface roughness, the following average roughness heights parameters are used *Ra*, *Rz*, and the Abbott firestone curve. But these parameters depend on the characteristics of the two machining processes and, therefore, they are not suitable for planning or controlling each of them separately (Fig. 2).

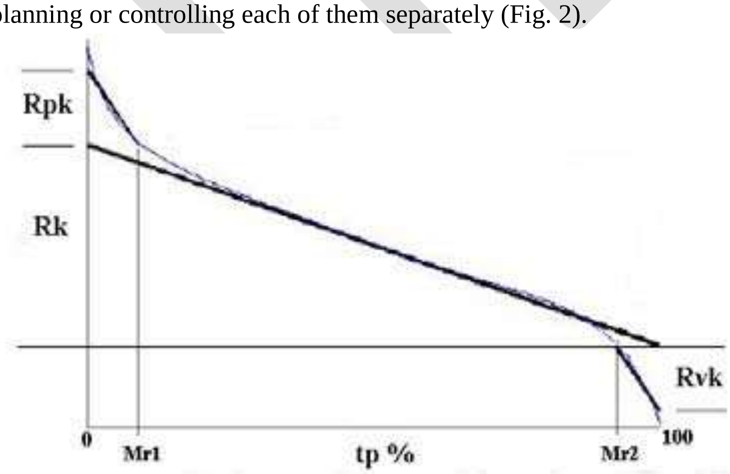


Figure 2. Abbott-Firestone Curve and parameters.

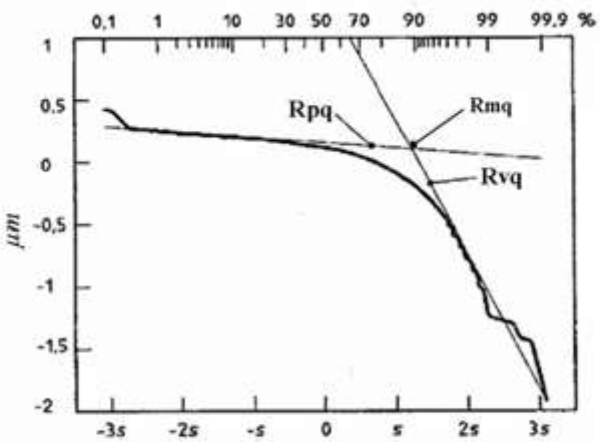


Figure 3. Curve Material probability curve and parameters.

A large number of procedures and parameters have been investigated for a better characterization of roughness. Those with the probability curve defined by the standard ISO 13565-3 stand out among those that offer a better capacity of correlation with each roughing and finishing processes (fig. 3).

Supposing a Gaussian behaviour of the heights of roughness on a honed surface, given that the Abbott material curve is a form of representation of the accumulated probability, this curve represented by semi-logarithmic axis is a straight line: heights in ordinates and standard deviation in abscissas, or what is the same, heights in ordinates and the logarithm of the percentage of material in abscissas. The slope of the line corresponds to the quadratic average roughness *Rq* of the roughness profile (fig. 3).

In the plateau-honing, result of two honing processes, the probability curve will be formed by two straight lines, each one with the *Rq* of the corresponding roughness profile (fig. 4).

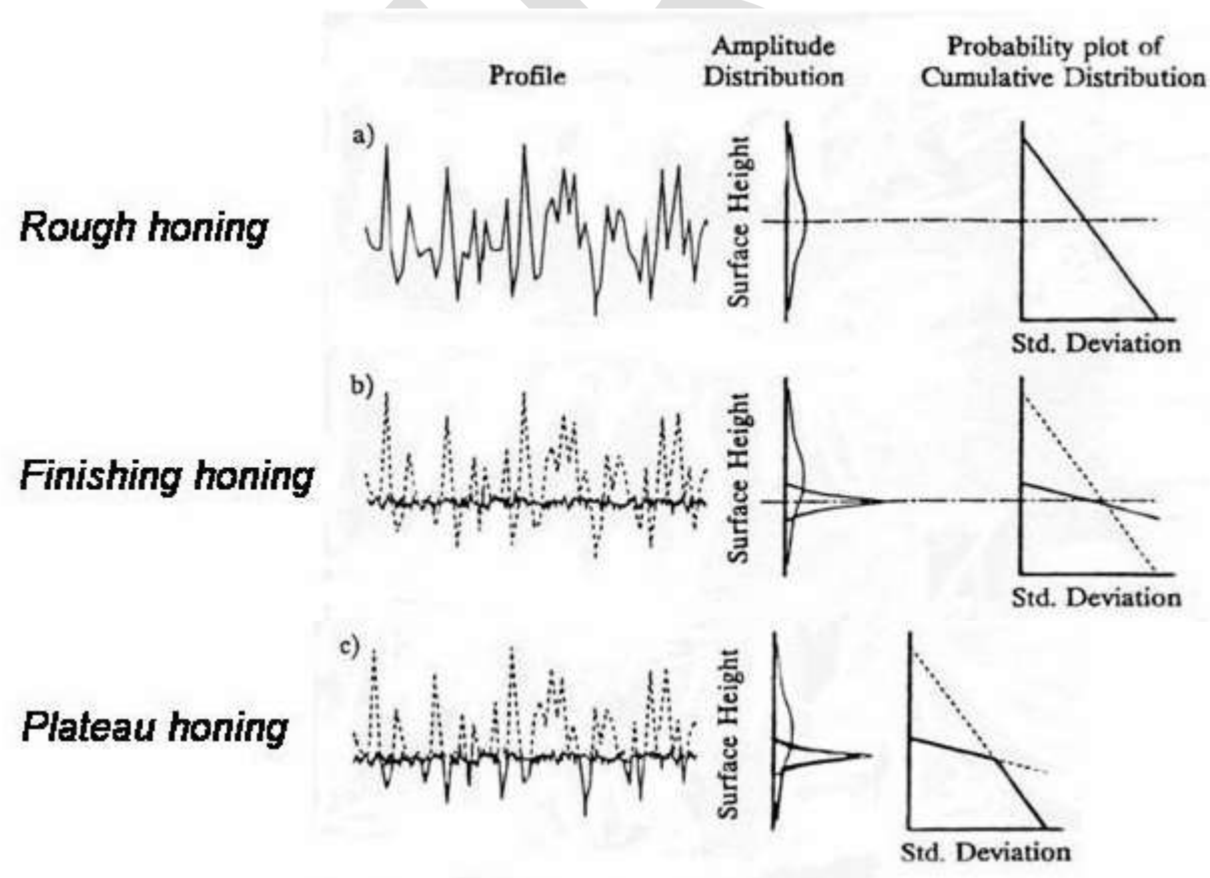


Figure 4. Combination of processes of honing.

Using the probability curve, the surface roughness is defined by three parameters:

- *Rpq*: Quadratic average roughness of the finish honing
- *Rvq*: Quadratic average roughness of the rough honing
- *Rmq*: Percentage of material eliminated by the finishing process

Using these parameters, it is possible to control each process separately. For this, it is necessary to relate roughness parameters with the variables that characterize the tools and working conditions for each honing process.

2.2 Lubrication:

Plateau honing is a process that improves cylinder wall surface finish by removing tiny peaks of torn or folded material and increasing bearing area. This type of finish allows lubricant to collect in the remaining valleys, improving lubrication control and retention. It also extends the life of components such as piston rings and seals because there are no peaks of material for them to remove during initial break-in. This reduces the time it takes to seat a new set of rings as well as initial ring wear, blow by and oil consumption. The engine delivers good compression right away, there is no blue smoke in the exhaust, emissions and oil consumption are reduced, and the rings last longer because they have not had to wear to conform to the bores. A plateau bore surface also provides increased bearing area to support the rings while retaining enough depth in the crosshatch for good oil retention and lubrication.

3. Relation Of These Surface Parameters With Pollution Norms:

To ensure reliable performance and prolonged service life of products, its components require to be manufactured not only with high dimensional and geometrical accuracy but also with high surface finish. The surface finish has a vital role in influencing functional characteristics like wear resistance, fatigue strength, corrosion resistance and power loss due to friction. In case of auto components, surface parameters become more and more stringent to meet the norms in terms of noise levels, pollution, etc. necessitating closer control of surface integrity. Significant progress has been made, in recent years, in wide varieties of surface-finishing technologies including micro finishing, honing, lapping and Burnishing. Since, each process is designed to generate a particular geometrical surface and to correct specific irregularities, selection of a right kind of finishing process is very important to achieve the potential benefits.

Surface Improvements (India) Limited, in association with Nagel, Germany and Nagel, India have been able to successfully establish plateau honing parameters in a wide range of IC engine cylinders, mostly cast iron. This is particularly important in view of the strict pollution control norms in automobiles. Appropriate use of conventional or diamond rough honing followed by the right grades of base and plateau honing combination has yielded excellent results. This has brought a new level of achievement in critical surface finish and geometry parameters, so important to meet Euro norms. It is well known that achieving the correct grade of plateau honing brings in the twin benefits of both vastly reduced oil consumption and more importantly vastly reduced harmful emission. This makes conformity with Euro norms and easier tasks.

3.1 Basic norms for heavy duty commercial engines:

Deterioration Factor

I) Vehicle manufacture may opt for fixed deterioration factor

Engine Type	Test Cycle	CO	HC	NMHC	CH4	NOx	PM
Diesel Engine	ESC	1.1	1.05	----	----	1.05	1.1
Diesel Engine	ETC	1.1	1.05	----	----	1.05	1.1
CNG,LPG or Gaseous fulled engine	ETC	1.1	1.05	1.2	1.2	1.05	----

ii) Alternatively, vehicle manufacture may opt for evaluation of deterioration factor by minimum service accumulation period

Category of vehicle	Min. service accumulation period in km
Category N1 vehicles	100000
Category N2 vehicles	125000
Category N3 vehicles with GVW ≤ 16000kg	125000
Category N3 vehicles with GVW > 16000kg	167000
Category M2 vehicles	100000
Category M3 vehicles with GVW ≤ 7500kg	125000
Category M3 vehicles with GVW > 7500kg	167000

International Journal of Engineering Research and General Science Volume 3, Issue 2, Part 2, March-April, 2015
ISSN 2091-2730

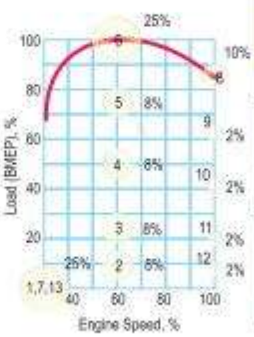
Heavy Duty Vehicles (GVW>3500 kg) Emission Regulation History

	Effective date	CO (g/kWh)	THC (g/kWh)	NOx (g/kWh)	PM (g/kWh)[d]	Free accl. smoke (m-1)	Remarks
Diesel, CNG or LPG Engines	1.4.1991 -1.4.1992 **(1991 -1992 Norms)**	14.00	3.50	18.00	NA	2.45	Exhaust gas opacity standard was effective from 01.04.1991
	1.4.1996 **(1996 Norms)**	11.20	2.40	14.40	NA	2.45	
	1.4.2000 (**BS I**)	4.50	1.10	8.00	0.36[a]	2.45	For diesel vehicles with GVW >3500
		4.50	1.10	8.00	0.36[b] 0.61[c]		For diesel vehicles with GVW ≤ 3500
	24.10.01 in NC Territory of Delhi (**BS-II**)	4.00	1.10	7.00	0.15	2.45	For diesel vehicles with GVW >3500 & For diesel vehicles with GVW ≤ 3500

a- For engines with power exceeding or not exceeding 85 kw.
b- For engines with power exceeding 85 kw.
c- For engines with power equal to or less than 85 kw.
d- Only for Diesel engines

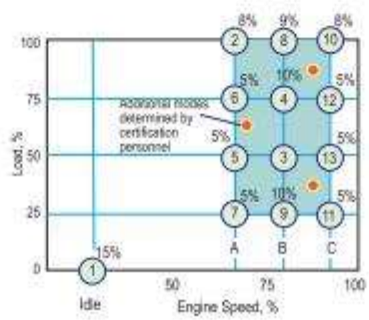
TEST CYCLES

Indian 13 Mode Emission Cycle (BS-I & BS-II)



Mode No.	Speed	Load %	Weighting Factors
1	idle	–	0.25/3
2	Maximum torque speed	10	0.08
3		25	0.08
4		50	0.08
5		75	0.08
6		100	0.25
7	idle	--	0.25/3
8	Rated power speed	100	0.1
9		75	0.02
10		50	0.02
11		25	0.02
12		10	0.02
13		--	0.25/3

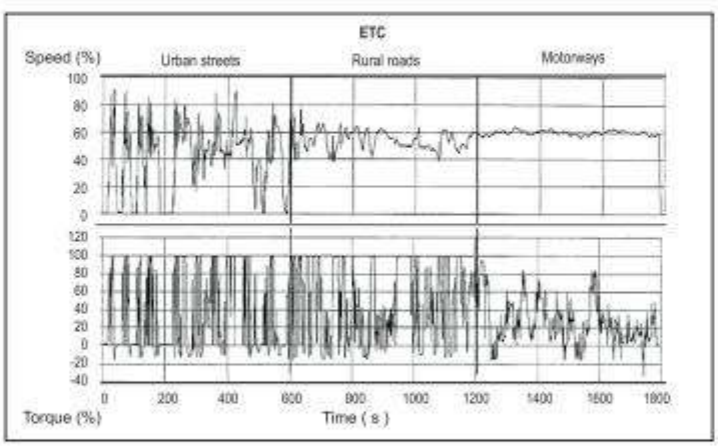
Engine Steady state cycle (ESC) (BSIII & BSIV)



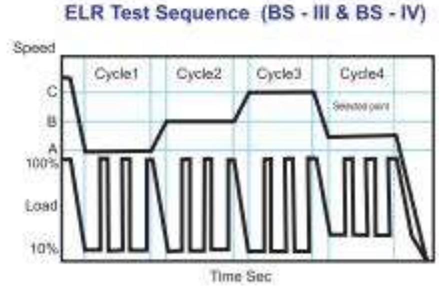
Mode No.	Speed	Load %	Weight Factors
1	Low idle	0	15
2	A	100	8
3	B	50	10
4	B	75	10
5	A	50	5
6	A	75	5
7	A	25	5
8	B	100	9
9	B	25	10
10	C	100	8
11	C	25	5
12	C	75	5
13	C	50	5

Engine Transient Cycle (ETC) (BS - III & BS - IV)

ETC Dynamometer Schedule



ELR Test Sequence (BS - III & BS - IV)



IV) EMISSION STANDARDS FOR CNG & LPG DRIVEN VEHICLES

I) Mass emission standards for vehicles when operating on CNG shall be same as are applicable for gasoline vehicles with the exception that HC shall be replaced by NMHC, where NMHC= 0.3 x HC

II) Mass emission standards for vehicles when operating on LPG shall be same as are applicable for gasoline vehicles with the exception that HC shall be replaced by RHC, where RHC= 0.5 x HC

III) Crank case emission and SHED test are not applicable in CNG/LPG mode.

IV) Applicable emission norms for CNG & LPG driven vehicle

Category	Applicable Emission Norms
OE CNG/ LPG Category M and Category N Vehicles with GVW=3500kg, 3 wheelers and 2 wheelers	Prevailing gasoline norms *
CNG/LPG Category M and Category N Vehicles with GVW= 3500kg, 3 wheelers and 2 wheelers retro fitment from Gasoline	Prevailing gasoline norms
CNG/LPG Category M and Category N Vehicles with GVW= 3500kg, 3 wheelers and 2 wheelers retro fitment from Diesel	Prevailing diesel norms**
CNG/LPG Category M and Category N Vehicles with GVW > 3500kg, manufactured upto 1st April 2010	Prevailing diesel engine norms based on 13-mode steady-state engine dynamometer test or 13 -mode Engine steady state cycle as applicable **
CNG/LPG Category M and Category N Vehicles with GVW > 3500kg, manufactured on and from 1st April 2010	Prevailing diesel engine norms **

* - Vehicle having option for bi-fuel operation and fitted with limp-home gasoline tank of capacity not exceeding 2 liters, 3 liters and 5 liters respectively on 2W, 3W and 4W are exempted from emission test, crankcase emission test and SHED test in gasoline mode.

** - PM limit is not applicable

4. Applications:

- Critical surface finish and geometry parameters.
- Vital importance in reaching the euro norms.
- Prolonged service life of products.

5. New Machine Concept

Presently the honing for cylinder bores is carried out on Nagel Cylinder bore honing machine, where there are three spindles for rough, finish honing and brushing. Here the spindles are fixed and cylinder block is moving.

Crankshaft honing is carried out on a Nagel horizontal ream honing machine. Fixed diameter reamer is passed through the crankshaft bearing caps to achieve the required surface finish.

These two operations are carried out on separate machines and hence they occupy more space, more energy is consumed and also prolonged processing time.

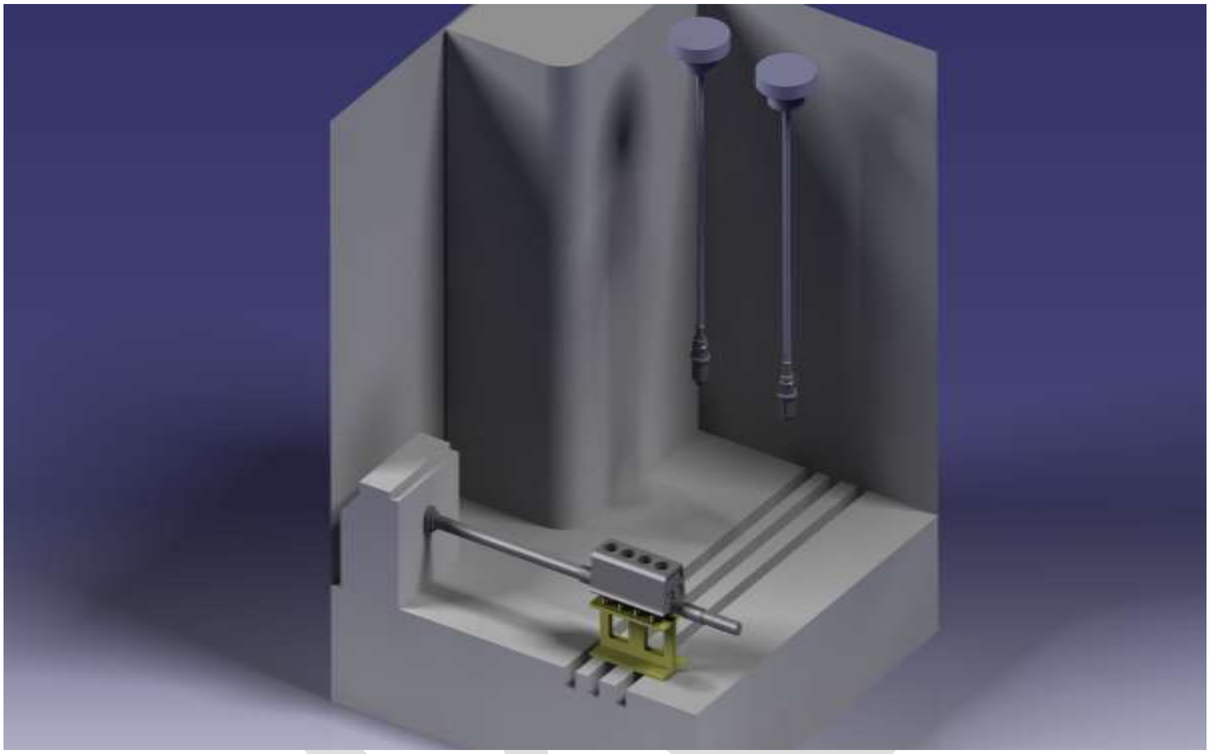
Our suggestion:

Due to these incurred drawbacks we suggest the use of new machine in which is introduced by Nagel itself, which includes a combination of these operations on a single CNC machine i.e. cylinder honing and crankshaft ream honing.

Advantages of new machine:

- Time required for processing both these operations is reduced up to 50%.
- Machine space required will be reduced.
- It is well operated by single operator whereas earlier two operators were required.
- Easy to maintain.
- Reduction in handling damages.
- Total cost required is been reduced due to single controller for both operations.
- Consumption of cutting oil/hydraulic oil/lubricating oil will be reduced.

Catia Model of New Machine



6. Conclusion:

The presented analysis allows obtaining the parameters for the plateau-honing process from the parameters of the corresponding rough and finishing honing processes eventually reaching the required euro norms.

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