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PLATEAU-HONING SEMI-EMPIRICAL MODEL

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ABSTRACT
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. The analytic models developed until date does not provide quantitative results enough goods for to establish the machining process parameters to get a desired surface quality.
In this article it is presented a methodology to obtain a semi-analytical plateau-honing model. The starting points are the results of a DoE of rough and finish honing. They are mathematical functions that relate the metal removal rate, stone wear, and surface finish with the main process parameters: Tangential velocity, longitudinal velocity, working pressure, grit size, grain density and work-material hardness.
Matching the curves of material quantity – Abbott-Firestone curves - of the roughing and finishing processes that give a desired surface quality, it is estimate the quantity of work material to be removed and the work-time of the finish honing process to get it down according with the related metal removal rate function.
Keywords: Plateau-honing, analytic model, DoE, material ratio curve

1. INTRODUCTION
In the tribological studies on the interaction among sliding metal surfaces, it has been established that the roughness surface is one of the determining factors for the friction reduction.
In studies carried out basically in explosion engine cylinders, it has been defined as optimum those roughness profiles made up by very flat plateaus alternated with valleys. These are the profiles obtained after working periods in which wear has filed peaks.
Plateaus provide a good sealing and valleys, full of oil, reduce friction. It is better that valleys should be interconnected among them in order to achieve a good uniformity of temperatures.

2. PLATEAU-HONING PROCESS
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).

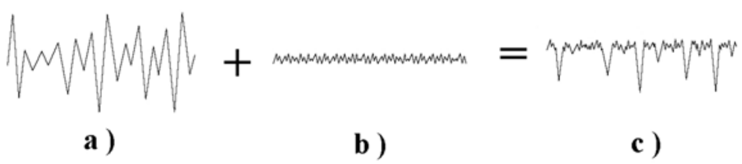


Figure 1. Roguhness Profile: a). Rough, b). Plateau, c). Plateau-Honing.

3. SURFACE ROUGHNESS PARAMETERS
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).

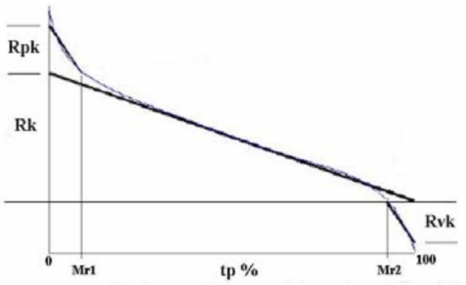


Figure 2. Abbott-Firestone Curve and parameters.

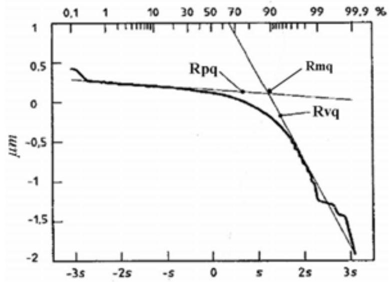


Figure 3. Curve Material probability curve and parameters.

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).

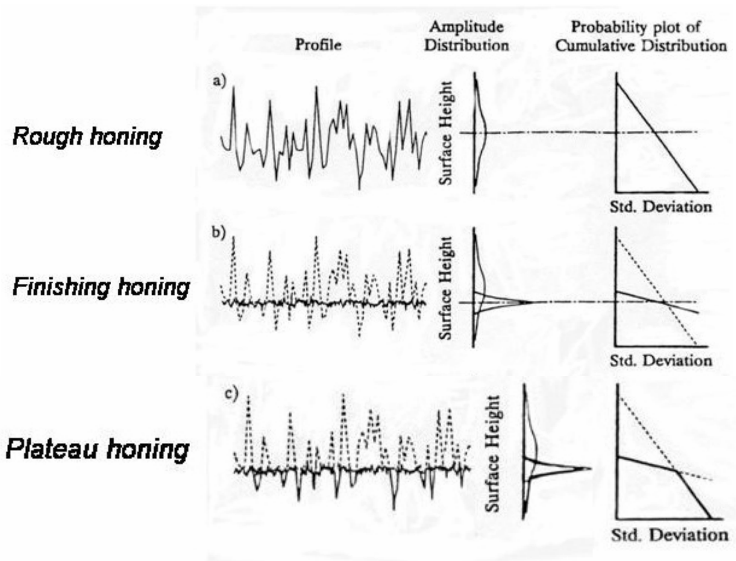


Figure 4. Combination of processes of honing.

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.

4. METHODOLOGY FOR THE OBTAIN SEMI-EMPIRICAL MODEL OF PLATEAU-HONING

Several researchers have looked for an analytic relation among the variables of the honing process and the roughness parameters obtained, but none of them offer quantitative results in processes with abrasives [1-

2]. Experimental studies, always based on the correlation of very few variables, refer to the most usual roughness parameters, and none has used the parameters corresponding to probability curves [3-4].

This study presents a methodology to obtain a mathematical model for the plateau-honing from experimental results in honing processes.

Depending on the experience of manufacturers and users of honing machines, a design of experiments –DoE– has been defined, based on a complete two-level factorial development that includes five variables of the process with the following values:

Honing Stick	TG Grit size	20 micron	400 micron
	TD Abrasive density	50%	90%
Process	VL Longitudinal velocity	20 m/min	40 m/min
	VT Tangential velocity	20 m/min	40 m/min
	PE Specific pressure	50 N/cm2	150 N/cm2

The remaining variables will remain fixed in the test carried out on steel tubes ST 152 with hardness 160-187 HB, using Borazon honing stick with metal binder, under controlled lubrication and temperature conditions.

Parameters to be studied are:

- *Qm*; Material removal rate in mm^3 of material removal per second and per mm^2 of honing tool
- *Qt*; Ratio of the tool wear with respect to the material removed from the workpiece in mm^3 of tool wear per mm^3 of material removal
- *Ra, Rz, Rt, Tp, Rk, Rvk, Rpk*; values of roughness profile parameters.

The correlation between parameters and variables will be obtained:

$$Qm, Qt, Ra\ldots..Rpk = f\,(TG, TD, VL, VT, PE)$$

At the same time, experiments of hydraulic cylinders are carried out on testing benches in order to determine which value intervals of the parameters of the probability curve *Rmq*, *Rpq*, *Rvq*, offer a good functional behaviour regarding wear and sealing.

From the results of all these experiments, a rough honing process is defined by maximizing the material removal, and minimizing the tool wear, keeping the *Rvq* values within the established limits.

Once the rough honing and the acceptable values of roughness *Rmq* and *Rpq* have been defined, it is developed a model to define the plateau-honing process based on determining the volume of material to be removed from the evaluation of the area within the Abbott curves or probability curves of the roughing and finishing processes (fig.5).

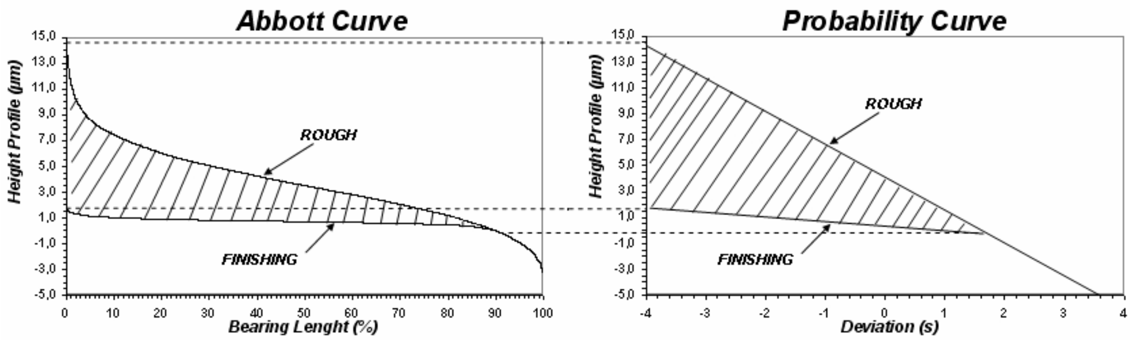
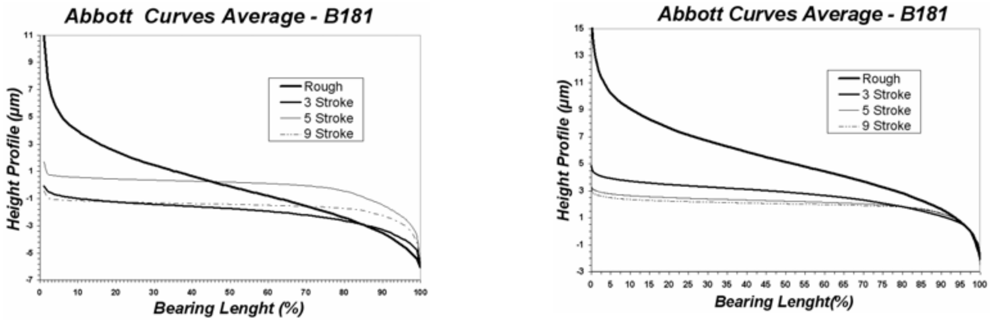


Figure 5. Comparison volume of material from Abbott Curve and Probability Curve.

It is necessary to study the correlation between the areas defined from the corresponding Abbott curves [5], and those defined from the corresponding probability curves.

Due to the randomness of the values of peaks and valleys [6], for comparing the Abbott curves it is necessary to look for an appropriate reference point as regards the reference of heights [7] (fig. 6).



a) Abbott Curve to comparison point valley. *b) Abbott Curve to comparison point in 97.5%.*

Figure 6. Different referent point of comparation curve.

A study with 180 measurements in different tubes is carried out, with various finish grades, and analyzing the residual areas among Abbott curves by taking different points of origin of heights, it is established that the best results are obtained taking as origin the height value corresponding to the point of 97.5% of material (fig. 7).

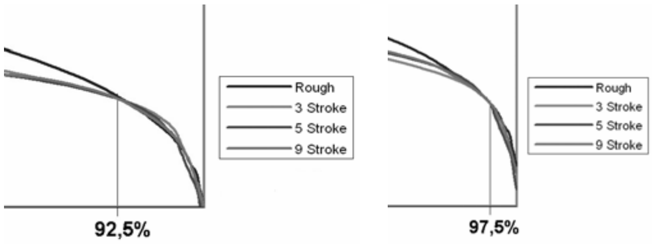


Figure 7. Different point of origin height.

Know the slope *Rvq* of the roughing straight line and the acceptable values for finishing, *Rmq* and *Rpq*, it is possible to determine the area to be removed. Knowing the material removal rate and since the specific pressure is a function of the working area, and this change according to height, the corresponding differential equation is set out. The integration will allow calculating the necessary time *Ta* of the finishing operation according to the process parameters:

$$Ta = \quad (TG, TD, VL, VT, PE)$$

From the equations of *Qm*, *Qt* and *Ta* of finishing, the values of the variables of the process are determinate maximizing the removed material and minimizing the tool wear and the work-time.

5. CONCLUSIONS

The presented methodology allows obtaining the parameters for the plateau-honing process from the parameters of the corresponding rough and finishing honing processes.

6. REFERENCES

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