ANALYSIS OF THE POLISHABILITY AND REFLECTIVITY OF STEEL AISI 304 UF, VP20 AND VP80

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Abstract. *The process of polishing dies and molds for plastic injection is done manually in the industries and control of the final finish is done with the naked eye through the experience of the polisher. This study aims to examine the polishing of automated way to avoid dependence on the experience of polishing and enable quality control to the finish on the production line. Polishing was carried out in three materials: steels AISI 304 UF, VP80 and VP20 that are used in the manufacture of molds and dies. The polishing was done in a controlled manner through a machine polisher and polishing time and stated the same for the three materials. Fifteen samples of each material, totaling forty-five samples that were cut and embedded in Bakelite. The polishing of the samples was preceded by the same grinding with abrasive paper of 400, 600 and 1000, leaving three samples of each material after each sanding, for later analysis of reflectivity and roughness. After sanding, the samples were polished on polishing cloths with diamond pastes, DPNAP of 3µm and 1µm. The samples polished with the paste of 1µm were first polished with 3µm folder for better finishing final polishing. In the process, were also left three samples of each material in the two stages of polishing, 3µm and 1µm. In polishing, every five minutes was measured roughness of the samples in order to observe improvement or deterioration of the finish as the polishing was done. The purpose of these measurements in each time period was to detect whether or not occurred over polishing, which is when the roughness begins to rise from a certain polishing time. After preparation of all forty-five samples, they were subjected to roughness measurements, using a laser interferometer that there was no contact between a probe and the sample surface, thus avoiding risks arising from the measurement and not from sanding and of polishing. The reflectivity measurements were made using a laser beam with a wavelength of 504ηm that ran a light path to the point where it focused on the sample surface. The reflectivity of the incident light was captured by a camera calibrated by a standard mirror reflectivity of silver and then measured in a comparative way between the mirror and standard samples by the acquisition system. Finally, the roughness and reflectivity data were compared in order to find any relationship between them, a relationship that would enable the future production of an apparatus for use in the production line to replace the analysis of the finish to the naked eye, made by polisher. The results showed that the ratio of reflectivity has a good relationship with the roughness, especially for steel VP80.*

Keywords*: Polishing, reflectivity, roughness.*

1. INTRODUCTION

The Polish is an increasingly important factor in the process of mold manufacturing. In addition to the final aspect of the play he can still contribute in reducing the corrosion (parts of PVC, for example), facilitate the extraction of parts, reducing the risk of breaking them. In general, the polishing is evaluated with the naked eye, and the surfaces analyzed should be completely free of risks and porosities.

In polishing mirrored, the final evaluation can be accomplished through the use of optical instruments. Often a polishing, as seen through these instruments, show risks that may be acceptable to the naked eye. Indeed an analysis of the final amount of sanding will depend heavily on the experience of the polisher.

The surface is quite strict in molds and dies (Ra usually less than 0.1 µm) and quite critical especially in injection molding. The quality of finish required on the surfaces of molds for injection is greater than those required in the forging and stamping dies, in addition, its complex geometry prevents the application of automatic polishing.

There are few studies related to the process of polishing dies and molds. A survey conducted by Sandvik (2002) showed that the main manufacturing process is machining. Characterized by material removal, this process is responsible for approximately 65% of the cost of a mold.

According Fallbohmer et al (1996) combinations of manual polishing with automatic polishing have long been used, reaching 70% of mold and die shops in the United States and Japan.

There is the economic importance of polishing in the manufacture of molds and dies, even without considering the finish. According to Machado (2003), the finish can influence the performance of a component, for example, changing the resistance to fatigue. The roughness can cause micro structural changes and consequently, the existence of residual stresses will be related to fatigue.

2. MACHINING OF MOULDS AND MATRICES

In the manufacture of molds and dies machining processes for milling, grinding, machining and electrical discharge or spark erosion (EDM or Electrical Discharge Machining) are the most used. The tools used for shaping metal sheets flat finish machining is performed mainly by grinding or a combination of milling and grinding. Since the forging dies are machined at the stage of completion, by milling or a combination of milling and EDM. This latter process is used almost solely in the polish. Die-casting are also machined in the finishing, for milling and EDM-milling (Ramos, 2004).

The matrices of hardened steels are widely used for forging, casting and injection molding. The material of these matrices has traditionally been machined in its soft condition, ie annealed, followed by heat treatment to achieve the necessary hardness, and finish machining. This finish can be accomplished by using spark machining and / or correction. A final manual polishing is used on most surfaces of complex profiles, further increasing the delivery time and charging the costs of production (Ramos, 2004).

2.1. Characterization of molds and dies

Most of the cost of a mold concerning the aspects of its manufacture. For example, are extremely important added values during the construction process of the mold, especially in the steps of machining and polishing. The life of the molds in general is high and its replacement is due mainly to change the project and, more rarely, to wear the cast. Therefore, the performance properties of the steel used to be regarded as sufficient only for application. The properties of manufacturing, by contrast, must have a prominent role in order to reduce the total cost of the mold produced. And especially, should be considered the interactions between the steel and the process employed to manufacture. In many cases the largest investment in the steel used can be converted into future earnings, in terms of reducing total cost of manufacture or repair of mold (Mesquita & Barbosa, 2007).

The mold surface is key to finishing the piece produced, and the degree of polish application dependent. Perfectly polished may be needed for many applications such as injection of glasses or car headlights. In the case of forming textured plastic, the mold surface also needs proper polishing. The polishability measures the ease of completing the polishing of a steel mold, being affected by several metallurgical factors. Non-metallic inclusions such as oxides and sulfides can reduce polishability depending on the size and distribution. The answer to texturing measures the ease of applying a texture to the steel tool used in the mold (Mesquita, 2007).

According to Barbosa (2001), the definition of steel to be used for the manufacture of moldings are made prioritizing certain features. Table 1 shows these such features.

Table 1. Desired characteristics of steels for manufacturing dies and molds (Barbosa, 2001).

For the use	**Desirable characteristics for manufacturing**
Mechanical properties (hardness, etc.)	Machinability
Answers nitriding	Weldability
Polishing Facility	Reproducibility
Responses texturing	Dimensional stability (to heat-treat)
Thermal conductivity	Minimal risk and complexity (if heat-treat)
Corrosion resistance (Inoxibilidade)	
Reproducibility	
Low cost	

2.2. Characterization Methods Polishes

The polished surfaces are generally characterized by measurements of roughness, and molds for plastic injection roughness measure does not always reflect the overall quality of the mold. Any deficiency in this step can be transmitted to the final product. Therefore, it has currently under study as well as measurements of roughness, a measure of reflectivity of the polished surface. The actual measurement of roughness should be determined by the most appropriate parameter.

3. METHODOLOGY

For the measurement of reflectivity, we used three different types of steels for plastic injection molds, which are: AISI 304 UF, stainless steel VP80 and VP20 ISO. In Figure 1 below is the micrograph of the steels used.

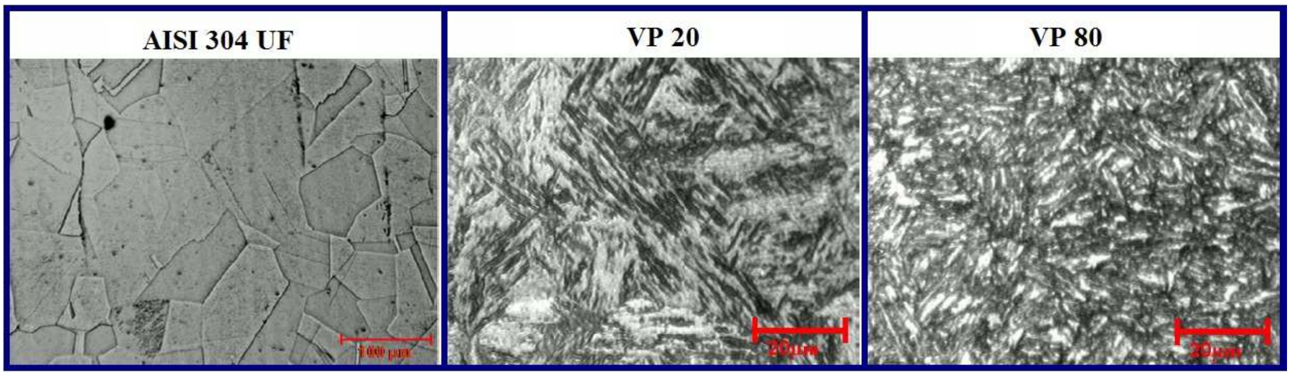


Figure 1. Micrographs of the steels used.

First, we carried out sample preparation, which we used to cut the samples an abrasive disc in an electric cutter. Then we used Bakelite for the inlay hot. Done inlays held sanding with sandpaper 400, 600 and 1000 and finally polishing using abrasives with three and one micron. For each new grinding or polishing always remained three samples for each material. Therefore, the analysis was performed in a total of 45 samples for the three steels. The polishing tests were performed in LTM (Laboratório de Tribologia e Materiais) and the testing of inlay and sanding performed in the laboratory of non-traditional machining, Universidade Federal de Uberlândia. The Table 2 below shows how the samples were distributed by type of steel and finish.

Table 1. Distribution of samples per material and workmanship

Finish	Steels			Total
	AISI 304 UF	VP 20 ISO	VP 80	
Sanding 400	3	3	3	9
Sanding 600	3	3	3	9
Sanding 1000	3	3	3	9
Polish 3µm	3	3	3	9
Polish 1µm	3	3	3	9
Total (samples)	15	15	15	45

Each sample was performed two types of measures, with a reflectivity held in LNMIS (Laboratório de Novos Materiais Isolantes e Semicondutores), Universidade Federal de Uberlândia and the roughness tests performed in the LTM. For tests performed in LNMIS, we used a laser (Fig. 2 (a)) with a wavelength of 504 nm. The laser went through a light path (Figure 2 (b)) covering the sample surface, where the reflectivity of light was captured by a camera (Figure 2 (c)).

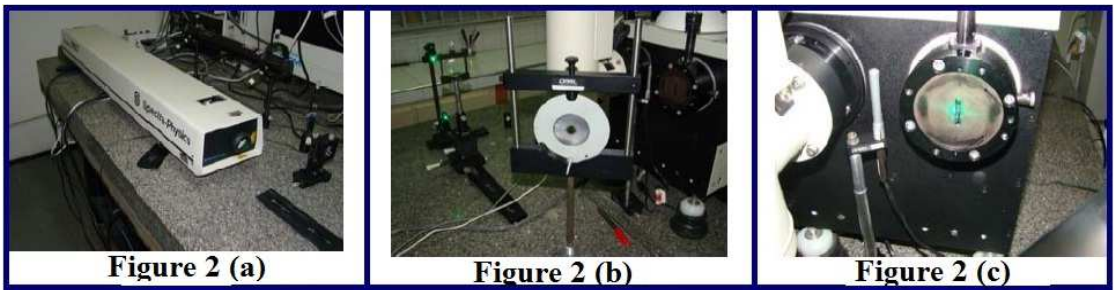


Figure 2. Distribution of the arrangement of equipment for obtaining the reflectivity of materials using the method of photoluminescence.

Figure 3 shows the schematic of the method used photoluminescence.

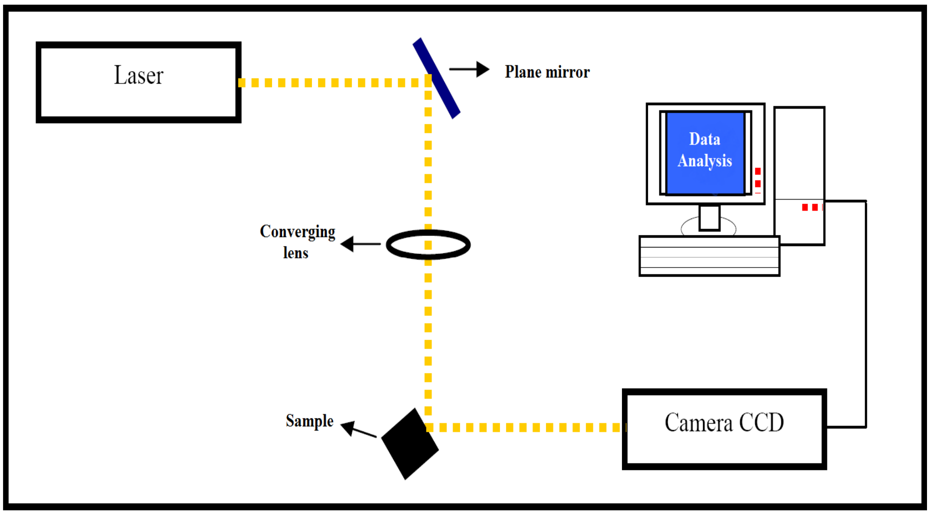


Figure 3. Function diagram of the method of photoluminescence.

The laser interferometer used for the characterization of the surface is able to recognize imperfections in the surface up to 100 ηm in vertical direction. The interferometer in question is able to capture surface irregularities of about 500 µm in depth of the valleys and 500 µm in maximum height of the peaks. From these values become inaccurate measurement results.

4. RESULTS AND DISCUSSION

The results of measurements performed in Laser Interferometer for steel VP80 showed that the surface roughness decreases with the level of polish. The caveat is that the sample was scraped with a particle size of 600, where an increase in roughness in relation to the sanding of 400. Figure 4 (a) shows the values of roughness (Ra) (obtained by the method of interferometry) in nm for sanding (number 400, 600 and 1000) and polishing (3µm and 1µm).

Figure 4 (b) shows the values of reflectivity (obtained by the photoluminescence method) depending on the trim level of the samples. You can see a relation with the roughness, when the results are compared with the results presented in Figure 4 (a). In relation to the measures taken by the laser interferometer, it can be seen that increasing the roughness in the sample with 600 sandpaper for finish sanding with 400 sample Fig. 4 (a) is also seen in reflectivity, for the same samples have a worse reflectivity for sample with 600 sandpaper finish.

With increasing roughness the reflectivity of a surface tends to decrease due to increased scattering of the laser when reflected by a sample with rough surface (Shimizu and Fuji, 2003).

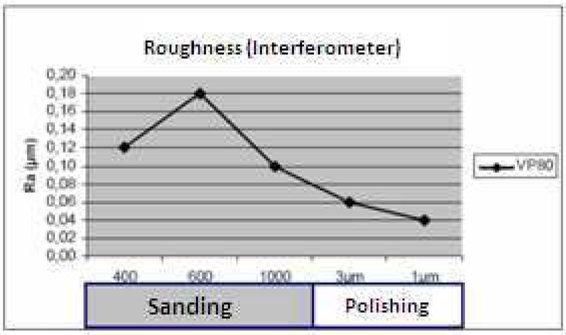


Figure 4 (a)

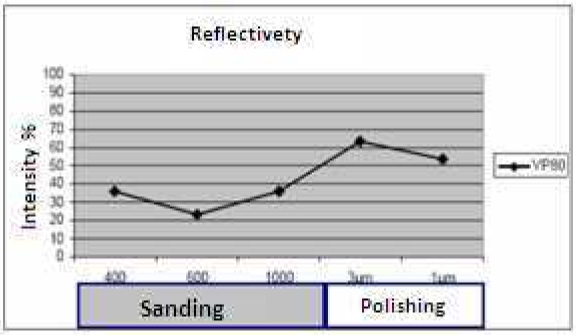
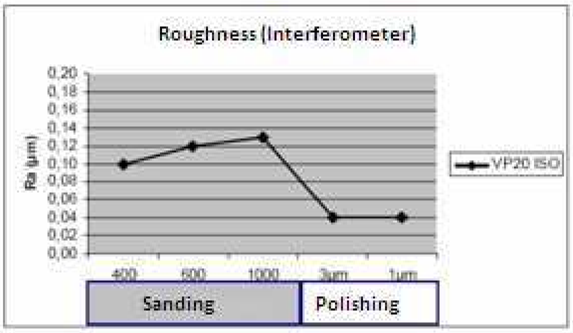


Figure 4 (b)

Figure 4. Roughness values (Fig. 4 (a)) and reflectivity (Fig. 4 (b)) obtained for 80açoVP through the methods of photoluminescence and interferometry, respectively.

For VP 20 ISO steel is observed in Figure 5 (a) an increase in roughness from samples craped with sandpaper up to 400 sample scraped with sandpaper 1000. The samples polished with diamond paste have lower roughness but there is no significant difference between the polishing with 3 and 1 µm. Figure 5 (b) shows the results for the reflectivity method by photoluminescence. In this case the reflectivity increases with surface preparation to sample equivalent to 1000 sandpaper and the have a short fall.



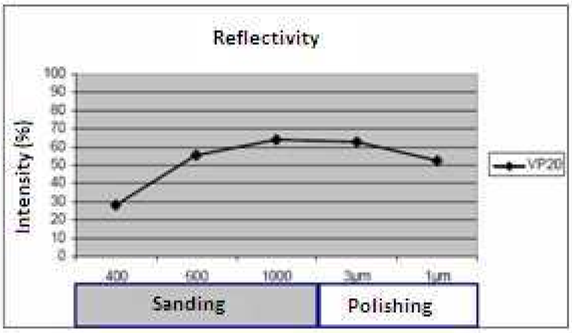
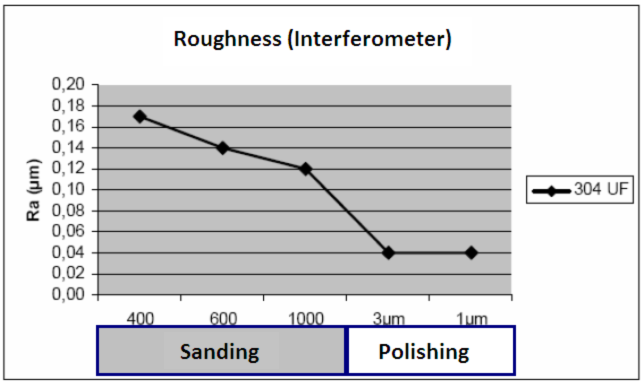


Figure 5 (a) Figure 5 (b)

Figure 5. Roughness values (Fig. 6 (a)) and reflectivity (Fig. 6 (b)) obtained for steel 20VP isomethods photoluminescence and interferometry, respectively.

The results obtained from analysis of 304 UF in Figure 6 (a) conform to the expected the roughness decreased according to the grain size used in the preparation of samples, therefore the smaller the grain size of sandpaper and diamond paste used less roughness. The exception is for samples of 3µm and 1µm, which present similar roughness values. Figure 6 (b) shows the results obtained for the reflectivity of 304 UF. In this case, the best reflectivity was obtained by samples prepared with 600 sandpaper.



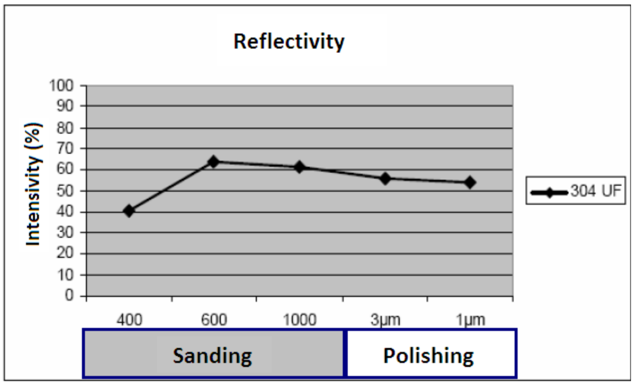


Figure 6 (a) Figure 6 (b)

Figure 6. Roughness values (Fig. 6 (a)) and reflectivity (Fig. 6 (b)) obtained for steel 304 UF through the methods of photoluminescence and interferometry, respectively.

Figures 7 (a), 7 (b) and 7 (c) shows the steels 304 UF, VP 20 ISO and VP 80 respectively. In general, the images obtained for steel VP80 and VP 20 ISO are closer to the same standard which does not occur for 304 UF, it is possible to see in this image a surface with a worst finish, thus demonstrating greatest difficulty in polishing of 304 UF.

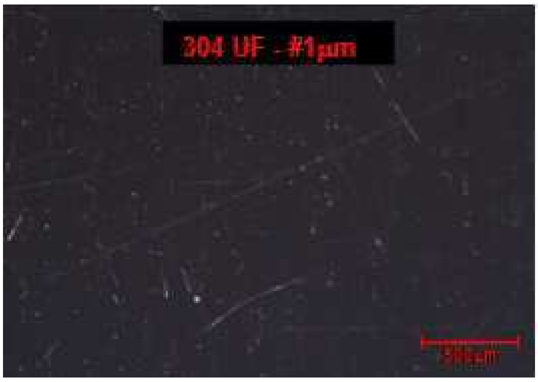


Figure 7 (a)

Figure 7 (b)

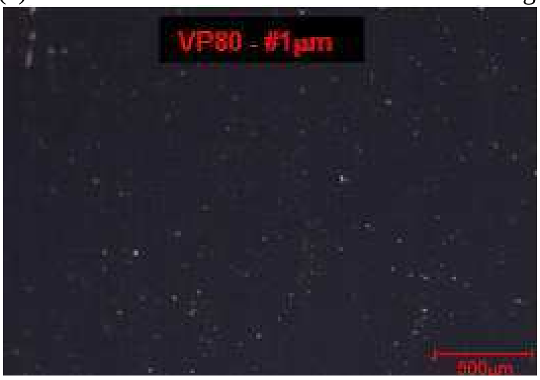


Figure 7 (c)

Figure 7. Images obtained for steels V304 UF, ISO VP 20, VP 80 through the stereo microscope with Olympus software Image Express.

5. CONCLUSIONS

Upon completion of the testing surface roughness and reflectivity of the materials and made the analysis and comparisons for the three materials, it was possible to draw some conclusions about the materials and methods of surface characterization. They are:

- Material VP 80 had a good relationship between increasing roughness and decreasing the reflectivity;
- The reflectivity method photoluminescence has not demonstrated the same relationship for the reflectivity of the roughness for the materials and VP20 ISO and 304 UF;
- The material VP20 ISO roughness had decreased more quickly compared to other materials when compared to the polishing time;
- There was generally a material with higher hardness presented a lower roughness;
- The visual analysis of the material shown to have a V304 UF polishing worse compared to other steels studied;
- There was generally a material with higher hardness had a lower roughness.

6. ACKNOWLEDGMENTS

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