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Experimental Study of the Effect of Cutting Processes on the Roughness of ASTM A36 Steel

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Abstract

This article analyses the roughness of ASTM-A36 steel both in its delivery state and after various cutting processes. The material was cut with different methods conventionally used in the metal-mechanic and construction industry, in addition to other non-conventional processes used to a lesser extent in the industry. Similarly, similar cuts were made to maintain test homogeneity and to analyze the faces of the cut on each specimen in a similar manner. Among the conventional cuts made to the specimens are the milling machine, oxy-cutting and cutting machine, while the non-conventional ones were applied by EDM and plasma, maintaining as far as possible similar cutting and working parameters. Subsequently, the roughness of the cut surface of each of the specimens was studied using a BAKER K130/8 analog tape roughness meter, which allowed quantifying the changes that occur in the material depending on the cutting method used and defined according to each method that can affect the surface finish and therefore the final application of the material. The graphical results allowed a comparative analysis of all the methods used, as well as the differences found between them and to obtain important conclusions that can be used in the new techniques of the manufacturing processes.

Keywords: Roughness, Testing, Surface finishing, Cutting processes

1. Introduction

The constant progress in the industrial area demands more and more efficient methods to obtain more and more sophisticated products. The design of new mechanisms requires increasing perfection and manufacturing tolerances are becoming increasingly tighter, so much so that the shapes previously accepted due to their method of obtaining through machine tools can no longer be applied without prior verification of their geometry and surface texture [1].

Real surfaces, no matter how perfect they may be, have particularities that are a mark of the method used to obtain them, for example: turning, milling, grinding, honing, stoning, among others [2]. The surfaces thus produced are presented as a set of irregularities, regular or irregular spacing and that tend to form a characteristic pattern or texture in their extension. In this surface texture two distinct components are distinguished: roughness and waviness [3].

The surface quality of a part is measured with the surface integrity which, apart from the surface topology, considers the mechanical and metallurgical properties, very important in fatigue, corrosion resistance or service life of the part [4].

The surface finish of a mechanical component must not only consider the aesthetic aspect as a specific function but must also be produced at the lowest possible cost, considering that there is a direct relationship between the degree of finish and the time required to achieve it [5].

Some techniques for measuring surface integrity such as X-ray diffraction or metallurgical inspection are very sophisticated and need to be performed in laboratories. These post-processing techniques involve considerable time and cost consumption [6]. The surface roughness as a representative parameter of the easiest surface texture to measure is what has been the focus of much of the current work [7].

To measure the roughness of the parts, electronic instruments called roughness meters are used, which measure the depth of the average roughness (Rz) and the value of the average roughness (Ra) expressed in microns and show the reading of the measurement on a screen or in a graphic document [8].

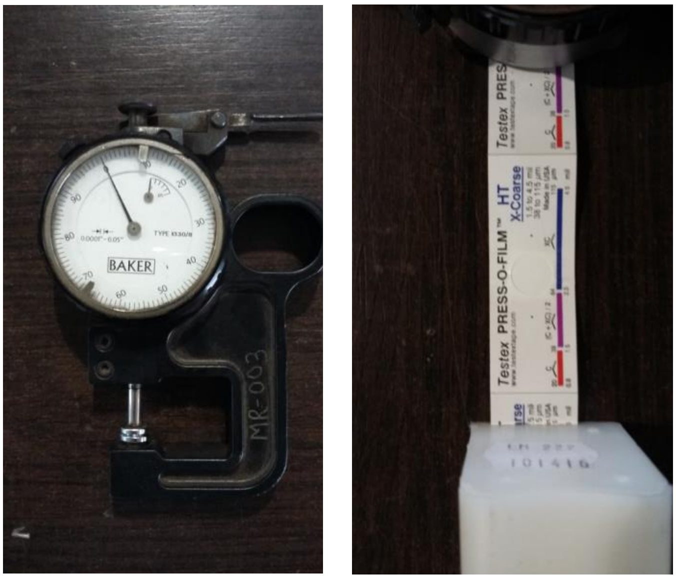
To quantitatively evaluate the mechanized surface roughness, many characterization parameters have been defined. Among the different characterization parameters, surface roughness parameters are most commonly used in practical applications. According to ISO standard [9], [10]. The main contribution of this paper is present the experimental study results of the effect of cutting processes on the roughness of ASTM A36 steel, which can be use to predict the mechanical properties of this material after the cutting processes.

2. Methodology

The steps used to measure the roughness of materials are presented below, along with a description of the instrument used to measure the mechanical property and the steps taken in the study.

2.1 Roughness measuring instrument

To measure the roughness, the instrument used is a roughness meter, which is used to quickly determine the roughness of surfaces or holes. The instrument displays the average roughness depth Rz and the average roughness value Ra in µm. Measuring the roughness is very simple.
For this study we used a BAKER K130/8 analog tape roughness meter shown in Figure 1a, this equipment allows to measure the anchor profile of the part with the use of the Testex PRESS-O FILM tapes shown in Figure 1b, which is used to measure the picovalle height of a surface profile molded into the Testex replica tape. The adhesive tape is rubbed onto the prepared surface forming an exact replica of the surface profile, this replica is measured by a spring to determine the maximum peaks and heights.
Among the most representative features of the equipment are the 0.2" scale, 0.1 mil resolution and anvil pressure as required by the standards.



(a) (b)

Figure 1. Equipment for measuring roughness, a) Roughness meter BAKER K130/8, b) PRESS-O-FILM

2.2 Roughness test

In the roughness test, a procedure was carried out on the specimen to measure the surface anchorage profile of the material using as a guide the procedure to verify this profile in hydrocarbon transport pipes, which must have a specific anchorage profile to apply the coating to them.

The PRESS-O-FILM was placed and pressed on the surface of the material, so that the surface profile was captured on it, as shown in Figure 2a, then the tape was placed on the roughness meter as shown in Figure 2b and it indicated the roughness value.

(a) (b)

Figure 2. Roughness test, a) Application of PRESS-O-FILM, b) Application of the roughness meter.

3. Results and discussion

3.1 Roughness results

The results obtained after measuring the roughness of each of the specimens can be seen in the figure. The average value calculated for each cut shows a greater roughness in the plasma and oxyfuel cuts compared to the specimen without cutting, in the other cuts there is a decrease in the roughness values, on the contrary, the decrease obtained after cutting with wire by EDM is notable, which due to its characteristics generates a clean cutting surface with a very good surface finish.

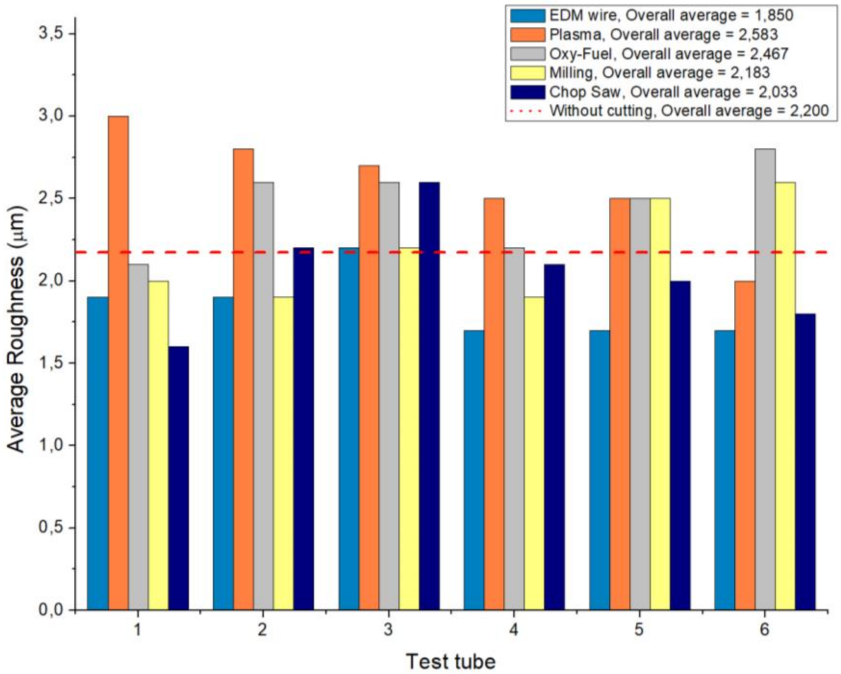


Figure 3. Comparison of individual roughness.

The figure shows the variation of the roughness for the different cuts made with respect to the roughness obtained in a specimen without a cut, which presented a value of 2.2 thousandths. As mentioned above, there were variations in both the increase and the decrease, with the plasma and wire cuts by EDM being opposite poles in this measurement, while the plasma causes a surface finish with greater irregularities, the wire cut allows us to obtain a surface with a better finish and less irregularity.

Types of cutting	Overall average roughness	Variation in roughness (%)
Oxyfuel	2.467	12.1
Milling	2.183	-0.8
Chop Saw	2.033	-7.6
Plasma	2.583	17.4
EDM Wire	1.850	-15.9

Figure 4. Variation of the roughness with respect to a specimen without cutting.

These variations influence the presentation of the material as well as other mechanical properties such as fatigue strength, wear resistance, corrosion resistance, heat transmission and lubrication. In addition, the economic aspect must be considered, since the adequate surface finish must be obtained at the lowest possible cost, considering that there is a direct relationship between the degree of finish and the time needed to achieve it.

3.2 Economic study

Figure 7 shows the commercial costs of each of the cuts made in Colombian pesos, where wire cutting by EDM presents a high cost due to the fact that the equipment used is uncommon in the trade, in addition, it is of a high cost, on the contrary, the other cuts are more accessible and can be found for moderate costs. Plasma cutting also requires special equipment but is more common than the wire-cutting machine and due to the machine's configuration allows large lengths of material to be cut in a single operation.

Types of Cutting	Cutting Value	Observations
Oxyfuel	$ 30.000	Value for 6 specimens
Milling	$ 70.000	Value for 6 specimens
Chop Saw	$ 30.000	Value for 6 specimens
Plasma	$ 12.000	Value for 6 specimens
EDM Wire	$ 225.000	Value per hour $150.00, cutting time 80 min approx.

Figure 5. Costs of the cutting process.

Comparing the variation of the roughness of each of the cuts with respect to the roughness of the material in supply state and the cost of the cutting process, it can be observed that the cutting processes with a cutting machine and a milling machine decrease the roughness value by 7.6% and 0.8% respectively, which can be considered as a slight variation of the value of the roughness of the material with respect to the same in supply state, in addition, both processes are low cost and easy to access in the industry. The wire cut presented a decrease in the roughness of the material by 15.9% with respect to the initial roughness of the material, this greater variation generates a surface finish of higher quality in the material, but the cost of the cutting process is very high with respect to all other cuts and the process is difficult to access in the industry. The oxyfuel and plasma processes showed an increase of 12.1% and 17.4%, respectively, generating a rough and lower quality surface finish, which can affect the final application of the material. However, both cuts are very low cost and easy to access in the metalworking industry.

4. Conclusions

The results obtained allow us to observe variations in the roughness of the material, a greater variation in the specimens subjected to higher temperatures and a better result for wire cutting by EDM.

Taking into account the costs involved in performing each of the cutting processes and comparing them with the roughness observed in each of the specimens, it was established that the cutting processes with cutting machine and milling machine are the ones with the best cost-variation ratio for this property, in addition, they are very low cost and easy to access processes in the industry.
It is recommended that for applications such as the manufacture of components such as gears, pulleys, wedges and power transmission elements, it is recommended to use cutting processes such as the milling and cutting machine to finish these elements, as these processes maintain the roughness of the material after cutting similar to that of the material being supplied. On the other hand, for the manufacture of mechanical components that do not require a very fine surface finish or that will subsequently be machined by another process, it is possible to use cuts such as plasma and oxyfuel cutting that leave a surface with greater roughness.

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