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Implementation of Statistical Model in the Machining of Superalloys

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Abstract: Machining processes have now become very important processes in the manufacturing industry, but also the technological advances and the demands of the current industry, they have required much more advanced and precise processes, which has led to the development of new machining methodologies to meet current requirements.

From its beginnings to the present, the machining processes have had great advances and technology has played an important role in this and the current requirements have undoubtedly been an important factor in their progress. With the development in large part of the aerospace, automotive and other industries, manufacturing processes require even greater advances, so the development and research in them are a priority in today's industry.

The current machining processes have changed significantly compared to years ago, to develop processes that allow us to have a better product with shorter machining times and the same quality, they are important factors in the investigation and it is sought to advance with it.

Keywords: Milling Process, Superalloys, Statistical Model

1. Introduction

Nowadays superalloys have reached relevant importance in industry and it is the case of aerospace industry that have had experimented a considerable grew in recent years. The machining of parts for this kind of industry is very important, because the materials are exposed to extreme conditions under daily operations therefore the resistance to those conditions have become key aspect in aerospace industry. Superalloys can resist most extreme required conditions in the aerospace industry. The most representative case is the material Inconel 600 that have become a material with high demand for its excellent mechanical properties for this reason exists a special interest in the study of this material.

Inconel 600 is a nickel-base superalloy with excellent properties such as high oxidation resistance, excellent corrosion resistance even at high temperatures and it keeps high strength under these conditions, thus the Inconel 600 has been widely used for many applications such as aircraft gas turbines, reciprocating engines, metal processing, spacecraft, and nuclear power plants, etc.

2. Literature Review

2.1 Superalloy Inconel 600

Alloy 600 is a nonmagnetic, nickel-based high temperature alloy possessing an excellent combination of high strength, hot and cold workability, and resistance to ordinary form of corrosion. This alloy also displays good heat resistance and freedom from aging or stress corrosion throughout the annealed to heavily cold worked condition range.

The high chromium content of alloy 600 raises its oxidation resistance considerably above that of pure nickel, while its high nickel content provides good corrosion resistance under reducing conditions. This alloy exhibits high levels of resistance to stress and salt water, exhaust gases, and most organic acids and compounds.

Alloy 600 is not an age hardening alloy; cold working is the only available means of hardening. Softening by annealing begins at about 1600°F (871°C) and is reasonably complete after 10 to 15 minutes of heating at 1800°F (982°C). Above this temperature, grain growth may be objectionable, although very brief heating at 1900°F will cause complete softening without undue grain growth. Since the rate of cooling has no effect on the softening, the material may be water quenched or air cooled.

Alloy 600 is machinable in both the hot worked and annealed conditions. Because considerable heat is generated in machining this alloy, high-speed steel, cast nonferrous or cemented carbide tools should be used. The tools should be kept sharp.

Lathe turning speeds with high-speed and nonferrous tools are 35/45 sfm (0.18/0.23 m/s); speeds with cemented carbide tools are 100/175 sfm (0.51/0.89 m/s). (This data should be used as a guide for initial machine setup only. The figures used are averages. On certain work, the nature of the part may require adjustment of speeds and feeds.)

Sulfur-based oil should be used as a lubricant but should be completely removed before the machined part is exposed to elevated temperatures, as in welding.

2.2 Statistical Methodology of Regression Analysis

Regression analysis is a technique used for modeling and numerical data`s analysis, consists of a number of independent and dependent variables. The model is a group of independent variables and one or more parameters. The parameters are adjusted to give more approximate value, it is using to obtain the best fit with the least-squares method, but also may use other criteria. In the dependent variable is assumed that this is a random variable with observation`s errors.

The data consist of "r" values taken from "y" observations which are response or dependent`s variable. The dependent variable is subject to error. This error is assumed that a random variable with mean zero. The independent variable x is called predictor o regressor´ variable. In a simple linear regression model is described by the following equation 1 [Montgomery, 2004].

$$y_i(t) = \sum_{j=1}^{n} x_{ij} \beta_j + \varepsilon_i \qquad y_i = \sum_{j=1}^{n} x_{ij}\beta_j + \varepsilon_i \quad y_i = \sum_{j=1}^{n} x_{ij}\beta_j + \varepsilon_i$$

(1)

The constant's coefficients are x_ijor functions of the independent`s variable, x. And this is under the following scenarios.

• Residual ε_i is normal with mean zero and unknown common variance σ^2 σ^2;; addition, these residuals are independent.

• The number variables that explain the problem (m) is lower than observations (n); this hypothesis is called full range.

• There is not exact linear relationship between the variables used to explain.

Using linear regression is to decide if the response variable y is linear function of the x variable.

3. Experimentation

3.1 Methodology

The methodology that was followed in this study is described with detail in next paragraphs. First data obtained after the classification of recorded results and then were analyzed with Lineal Regression system equations. The identification and optimization of variables involved in the process of manufacturing a product are a challenge the reason is that it is a recent case of study and exist limited information.

3.2 Description Problem

The problem is identified, control and optimized the parameters that influence in the machining of Inconel 600, with the purpose to increase the productivity, efficiency cost of production, first stage was organize the parameters used for the develop of the experiment this numbers are used in the lineal regression (Shown in Table 1). The main focus of this study is obtaining the optimum machine parameters such as the roughness, increase tool life and MRR to Inconel 600 machining process and finally provides appropriate control parameters in the production of this material.

Table 1. Experimental Data

Conditions	Units	Level 1	Level 2	Level 3
Speed	mm/min	500	1000	1500
Feed	mm/rev	50	100	150
Depth	mm	0.5	1.0	1.5

4. Results

A statistical analysis with the variables of speed, feed and depth for machining of Inconel 600 was done, obtaining different optimal results for the machining of this superalloy. With the previously introduced variables the results shown below were obtained.

The speed and feed values in the above table are significant parameters for the analysis of the model, since the value of p is less than 0.05 and thus the regression coefficient values shown in Table 2 are obtained.

Table 2. ANOVA Table and Model Summary (Roughness)

Source	*GL*	SC Ajust.	MC Ajust.	Value F.	Value p	R-Squared	R-Squared	S	R-Squared (Adjjusted)
Regression	3	0.157257	0.052419	32.55	0.000	0.0401287	80.94%	78.45%	71.13%
Speed	1	0.010233	0.010233	6.35	0.019				
Feed	1	0.144005	0.144005	89.43	0.000				
Depth	1	0.003018	0.003018	1.87	0.184				
Error	23	0.037037	0.001610						
Total	26	0.194294							

Table 3. Coefficient Table (Roughness)

Term	Coef.	EE of Coef.	Value T	Value p	VIF
Constant	0.4642	0.0648	7.17	0.000	
Speed	-0.002384	0.000946	-2.52	0.019	1.00
Feed	1.789	0.189	9.46	0.000	1.00
Depth	-0.0518	0.0378	-1.37	0.184	1.00

According to results shown in the regression coefficients we can realize that the values of regression (VIF) of Table 3, are less than 10, which shows a good fit and prediction in the model, so the model roughness shown in equation 2.

$$y_i = \sum_{j=1}^{n} x_{ij}\beta_j + \varepsilon_i \; y_i = \sum_{j=1}^{n} x_{ij}\beta_j + \varepsilon_i$$

$$RA = 0.4642 - (0.002348 * speed) + (1.789 * feed) - (0.0518 * depth) \quad (2)$$

Figure 1 shows the relation between the results obtained in the tests performed of roughness and the prediction analyzed with the regression model. This model for predicts final conditions reflects a good final prediction of efficiency that can be used in industrial production process.

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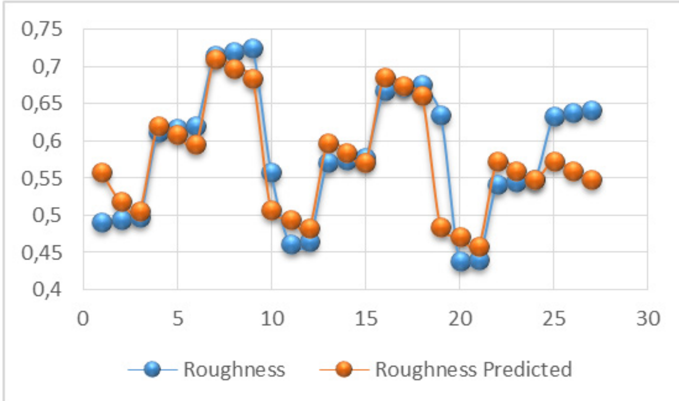

Figure 1. Predicted Roughness Chart

5. Conclusions

Nowadays, statistical analysis takes a fundamental role in the industry, since these are very useful for different types of industries by helping to predict behaviors of different systems and even to predict processes without the need to carry out. The manufacturing industry has been growing in recent years with major advances in machine processes with the appearance of superalloys as in the Inconel 600. Predicting this type of processes as this case is the roughness, it helps us to make specific adjustments with our process prior to the implementation in production.

The simple regression modeling generated reduces the time with its specific adjustments and therefore will provide a view of the parameters in the machining process that were not previously considered in the industry and in the implementation of projects for new materials or new designs for parts in special components for the aerospace industry or another, as well as reducing costs to obtain a better surface quality.

6. References

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