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Analysis of the Repeatability and Reproducibility (R&R) in the Surface Roughness of the "Alloy X" in Milling Process

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Abstract: At present, the factors involved in the machining processes have advanced very quickly. But the results and efficiency of the final product is a very important point during the milling process. In the case of final finishing of a piece that goes through a milling process, there are characteristics such as the surface roughness that are factors of great importance due to the final finishes and tolerances required by each specific piece given by the customer. A repeatability and reproducibility analysis are a great help when verifying if our measurement system is reliable or not. Repeatability and reproducibility are the two precision components in a measurement system. In this case the repeatability is the variation that we would have for the measuring device and in the case of reproducibility it would be the variation caused by the measuring system.

Keywords: Analysis of the repeatability, Surface roughness, Alloy X

1. Introduction

Maintaining a quality improvement program in manufacturing processes requires, among other things, a reliable measurement system, machine tools with adequate capacities and conditions for the production demanded, and qualified specialists to operate the machines.

The quality control in the manufacturing process will be executed on the basis of a reference that indicates that the obligation must be the typical behavior of the characteristic associated with the quality of the manufacturing process and that reference, together with the measuring system and must be stable for a prolonged period of time.

The stability of the system must guarantee manufacturing and control measures in the established functional ranges, using the same manufacturing and measurement methods, with the same technicians and equipment, in time intervals commonly greater than one year.

When a manufacturing process does not meet the required quality control standards, it is necessary that the causes that generate this variability between the quality of production obtained and the required quality be reviewed. It is known that stability in measurement systems is evaluated with repeatability and reproducibility indicators (R&R). These indicators consider variations in the measurements due to the technician who carries out the process and variations awarded to the measuring equipment.

2. Literature Review

2.1 Repeatability and Reproducibility Study (R&R)

Repeatability and reproducibility (R&R) are standardized terms adopted by ISO and ASTM to assess the stability of measurement systems and are related in principle to the accuracy and stability over time of measurements made with a set of instruments that measure the same magnitude.

The different methodologies for assessing repeatability and reproducibility (R&R) in measurement systems, known as RRG, were developed in the 60's of the last century to address the estimation of the variation of a measurement system applied to the manufacturing industry.

Currently, RRG is a standard practice in many fields of industry and processes. The average and range method is used for the analysis of repeatability and reproducibility (R&R) in the measurement systems, and allows the variation of the measurement system used into two separate components (repeatability and reproducibility).

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This method allows to specify the influence of the technicians and the equipment on the stability of the system based on a processing of data obtained and classified according to the measuring instruments, the measured measures and the technicians who execute the measurements.

It is known that the results of manufacturing and the measurements required for quality control of production are always subject to a dispersion of the measurements of the pieces made in the range of tolerances admitted as functional, and to the uncertainty of the measurements for random errors that must be evaluated by means of a statistical analysis of samples that typifies the process that is controlled. These indicators allow to evaluate together the variation that occurs in a manufacturing process due to machines and technicians under controlled and specific conditions.

The repeatability and reproducibility studies of the measurements determine what part of the variation observed in the process is due to the measurement system used.

Repeatability can be expressed quantitatively in terms of the characteristic dispersion of the results (Figure 1). It is defined, according to the VIM (International Metrology Vocabulary), as the proximity of agreement between the results of successive measurements of the same measuring under the same measurement conditions, where:

1. These conditions are called repeatability conditions.
2. Repeatability conditions include: the same measurement procedure, the same observer, the same measuring instrument, used under the same conditions, the same place, repetition in a short period of time.

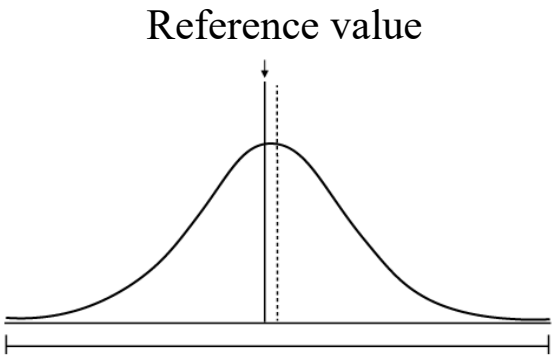

Figure 1. Graphic representation of the concept of repeatability.

Reproducibility is defined as the proximity of concordance between the results of successive measurements of the same measuring under changing conditions of measurement (Figure 2). Where:

1. A valid reproducibility statement requires that the changing condition be specified.
2. Changing conditions may include: measurement principle, measurement method, observer, measuring instrument, reference standard, location, conditions of use, time.
3. Reproducibility can be expressed quantitatively in terms of the characteristic dispersion of the results.
4. It is understood that the results are usually corrected.

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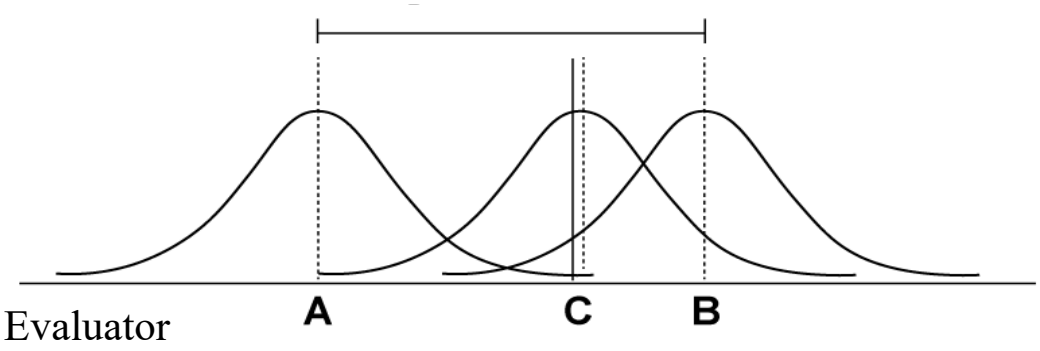

Figure 2. Graphic representation of the concept of reproducibility.

3. Experimentation

3.1 Description Problem

Identifying the problem and finding a solution to it is not an easy task. The super alloy of Alloy X is a material with multiple favorable qualities, but at the time of making the machining of parts in this type of material, different questions arise about the final quality of the product that goes through a machining process.

For this investigation, we performed Milling tests of Alloy X, taking as main parameters Speed (RPM), Feed (mm/rev) and Depth (mm) which are shown in table 1 as experimental data.

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	

Identify the quality of the product in terms of roughness, this is the problem posed and thus perform the measurement of this condition, thus conducting a repeatability and reproducibility study (R&R) to verify the reliability of the roughness results.

3.2 Methodology

The purpose of the R&R studies is to verify that the variability of the system evaluated is insignificant with respect to the variation of the product that is controlled in its quality parameters. The methods for determining the repeatability and reproducibility of processes in manufacturing systems, as well as in measurement system processes, are based on the statistical evaluation of the dispersions of the results. The said dispersion is considered as the difference between the dimensions of the manufactured part and the accepted reference value with the functional dimensional tolerances.

Stage 1: Data collection. Data collection was performed, measuring roughness values in the different grooves of the milling tests performed. The measurements were carried out in each of the machined slots with the previously established parameters, performing roughness measurements with a surface roughness tester Mitutoyo model sj-210 (Figure 3).

Stage 2: Statistical calculations. The statistical analysis of repeatability and reproducibility (R&R) was carried out in the Minitab statistical analysis program, which is a reliable tool to perform this type of analysis.

Stage 3: Analysis of the results. The results of this repeatability and reproducibility analysis (R&R) are shown in the results section.

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Figure 3. Surface roughness tester Mitutoyo model sj-210.

4. Results

A study of repeatability and reproducibility (R&R) was carried out with the variables of speed, advance and depth for the machining of Alloy X, obtaining roughness results for each of the tests according to the machining parameters proposed.

With the experimental data presented at the beginning, the machining tests were carried out and after that the roughness measurement was made in each of the slots of each test performed.

Table 2 shows the results of the ANOVA of our repeatability and reproducibility study (R&R). The results show that in the part category there is no difference, as well as in the relation operator*part does not show differences. While the category of operator does show a difference, the values are shown in the table.

Table 2. ANOVA Table (Roughness)

ANOVA				Alpha
	SS	*df*	*MS*	*F*
Part	0.574835	8	0.07185438	0.14370827
Operator	33.7203627	1	33.7203627	67.440498
Operator*Part	0.574835	8	0.07185437	0.14370827
Repeatability	18.0000607	36	0.50000169	
Total	52.8700933	53	0.99754893	

Table 3 shows the results for the study variations, showing a 100% variation in Tot Gage R&R which indicates that we must perform a better training when taking the roughness readings. On the other hand, repeatability presents a variation of 50.5%, that the measurements of the different parts show a marked difference. While reproducibility shows 86.3% variation, which indicates that the measurements do not show an accurate replica.

In the Op * Part category it shows us 0%, which is a favorable result, as well as Part-to-Part of 0%, which indicates a favorable result since it is below the expected 10%.

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Table 3. Model variation table

VARIATION

	Var	*%*	*Std Dev*	*%*
Tot Gage R&R	1.65542361	100.0%	1.28663266	100.0%
- Repeatability	0.42215672	25.5%	0.64973588	50.5%
- Reproducibility	1.23326689	74.5%	1.1105255	86.3%
-- Operator	1.23326689	74.5%	1.1105255	86.3%
-- Op*Part	0	0.0%	0	0.0%
Part-to-Part	0	0.0%	0	0.0%
Tot Variation	1.65542361	100.0%	1.28663266	100.0%

Figure 4 shows a graph with the roughness readings of each of the replicas performed. This graph shows the roughness data against the test number, thus showing the variation between each of the readings.

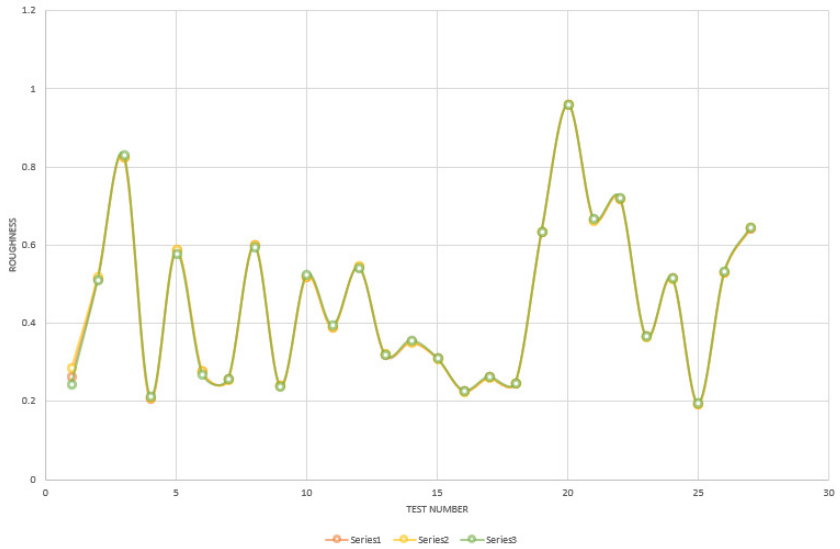

Figure 4. Roughness measurement graph.

5. Conclusions

The procedure presented is oriented to the analysis of the repeatability and reproducibility (R&R) of a manufacturing system based on dimensional measurements made in one piece. When the analysis shows that the repeatability rates are higher than the reproducibility indicators, it is necessary to improve the precision capabilities of the measuring machines; In case the reproducibility indexes are higher than the repeatability indicators, it is very likely that the skills of the technicians need to be improved.

Through the analysis of R&R oriented to manufacturing processes, as it was shown in this case, the instability of a manufacturing process can be detected by machining that might seem appropriate when observing that the dimensions of the pieces are admissible for the range of established functional tolerance.

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