The experimental research strategy of the end-milled aluminum alloys

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Abstract. In this paper, the most important aspects of the research methodology of the resulted surface quality by aluminum alloys end-milling, are presented. The first part of the paper includes a short presentation of the cutting processes aluminum alloys evolution. In the second part, the research problem was defined by setting a fundamental objective and identifying the specific objectives which contribute to achieve the fundamental objective. In this context an experimental study, was performed, starting with the organization and conducting the end-milling process, in which the cutting regime were established, then the characteristic measured parameters were determined, so that the research factors and parameters will result.

1 Introduction

Each science has its own history that marks its development stages. Paul H. Black's book "Theory of Metal Cutting" has a starting point the paragraph "Metal Cutting - Art to Science" in which assumes that cutting history began with 600000-1000000 years ago, somewhere in Tanganyika, Africa. The cutting processes development started since the 19th century [1], when the first experimental tests were conducted aimed to explain the chip formation [2]. Later, in the 1930s, the sintered metal or mineral-ceramic materials were discovered, than in 1950 the indexable cutting inserts were carried which were widespread in the production, leading to the new tools types development. The machining process has a considerable age with a continuous evolution derived by the progresses occurred in the new materials developing, also by the cutting tools and machine tools improvement. The machining process is closely related to the costs, it is desired to raise the machine tools and machining centers performance, and also the new products continuous development, which also contributes to increase the machined parts precision. Choi [3] presents a fairly detailed theory accompanied by a number of applications related to surface modeling techniques used by different software for computer aided design/computer-aided machining. Following a literature review, conducted on the materials used in the cutting processes [4], it was found that over the last decade, the researches have focused particularly on steels. This statement is supported by the Table 1 [5], in which the percentage comparison of the workpiece materials use frequency is presents.

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Table. 1. A percentage comparison on frequency of raw material use [5].

Steel	Cast iron	Aluminium	Plastic	Other material
64%	1%	23%	1%	11%

In this paper the attention will be focused on aluminum, which has been studied only in 23%. Today, aluminum and its alloys are considered to be the most practical metals due their low cost, low weight and modern appearance. Aluminum has a god electrical conductivity, is a good heat conductor, it is magnetic, it is reflexive and resistant to chemicals. It is commonly used in the construction, marine, and aircraft industry because of the ease in processing, non-toxicity and corrosion resistance. The anodizing increases his strength and also allows iridescent finishes in different colors. Due to the aluminum alloy properties of that make it one worthwhile material, the variety of its applications is continuously growing. The aluminum alloys typically contain alloying elements such as copper, magnesium, manganese, silicon and zinc, the aluminum (Al) is predominantly metal. In [4], the research workability of aluminum alloys depending on the year and the number of papers identified through a literature review (period 2000 to 2014), is highlighted (Figure 1). As it can be seen in Figure 1, the higher percentage research, were performed on Al6061 alloy which occupies a proportion of 32%. The aluminum alloys machinability has been studied and tested most often through milling – 46%, drilling – 7% and turning – 4% [4]. Another important aspect is the main research directions pursued in aluminum cutting processes. Following an analysis conducted by [4], it was found that the surface roughness was the most frequently studied (Table. 2).

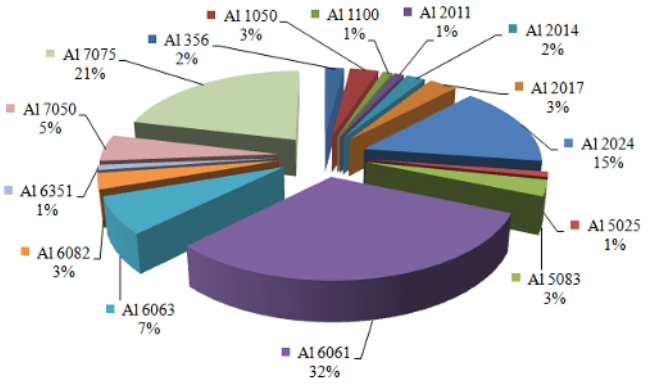

Fig. 1. A percentage comparison on frequency of research on aluminum alloy machinability [5].

Table. 2. Percentage comparison on the research directions.

Friction	7%	Deformations	9%	Temperature	10%	Forces	19%
Tool wear	7%	Stress	13%	Chip formation	14%	Roughness	21%

On the other hand, the most of the identified research paper in order to study these alloys machinability, use for optimization, mathematical methods. The percentage of this method use is shown in table 3 [4]. Starting with this information, the main problem of this scientific work is to present and develop the research methodology of the resulted surface quality by aluminum alloys end-milling.

Table. 3. Percentage comparison on mathematical methods used to optimize the cutting process.

RBFN	Taguchi	Regression	ANOVA	RSM
2%	24%	14%	38%	22%

2 Research Methodology

2.1 Experimental Methods Used in Research

The scientific research involves the theoretical studies development combined with the experimental research. The theoretical studies enable to underline the laws of the studied phenomena by using the mathematical equipment and the achievements in the respective field or in other fields [6], [7]. The methods used in the experimental research are [6]: - *The hypothesis testing* using: χ^2 test, Fisher - Snedecor test, Cochran test or Bartlett test.- *The anomalous result elimination* involves the measurement results reading and it allows highlighting the data that are inconsistent with reality - Chauvenet test, Romanovski test, Grubbs test, Student test etc. - *Check the randomness data string* is often carried out using test Young. - *To check the normal distribution of experimental data,* the Gauss's law in the experimental results processing obtained by measurements, is more accepted, χ^2 test, Massey test, Shapiro-Wilk test, Kolmogorov test. - *When determining the range and level of trust* - the arithmetic mean and the dispersion are the main parameters describing a statistical set. - *To choose the confidence level value* the measurements made in: industry, laboratories, some operations control, reception, testing, expertise, etc., take the 95% confidence level; the measurement of high quality and responsibility in science and technology, one of the values: 99%, 99.5%, 99.73% and 99.99%. In this context, the research presented in this paper were conducted using the above mentioned methods of covering the requirements of processing / modeling of experimental data held.

2.2 Research Problems Defining

For the beginning, the *fundamental research objective* was defined: the study of the arithmetic mean deviation of the surface profile Ra, resulted from the 7136 aluminum alloys end milling process, depending on the cutting process parameters.

Specific objectives helps to fulfill the fundamental objective. These must identified and consists in answers to the following research questions [4]:

Question 1: What is the influences percentage of each cutting parameter on the arithmetic mean deviation of the machined surface profile Ra?

Question 2: How is the arithmetic mean deviation of the surface profile Ra, influenced by the each cutting process parameter?

Question 3: It is possible to get a valid mathematical model of Ra, depending on the cutting process parameters?

Question 4: It is possible to make some determined settings on the cutting process parameters in order to obtain a predetermined Ra?

The answers of these questions represent the following specific objectives:

Specific objective 1: Calculation of the percentages influences of the cutting process parameters to attain the performance on obtaining an arithmetic mean deviation of the machined surface profile Ra, as good as possible and also, to have a minimum sensitivity of the uncontrollable factors.

Specific objective 2: The Ra experimental determination of the Al7136 end milled surface profile, and the data analysis and the interpretation of the measured results.

Specific objective 3: The establishing of the mathematical model to determine the arithmetic mean deviation Ra according to the studied cutting parameters in one established experimentally field.

Specific objective 4: The mathematical model validation and the experimental data optimization.

2.3 Research Design

The research design stages summarized and adapted by [8] are: first to conducting a rigorous bibliographic study, then the research problem definition, setting the input data entry: raw material, the cutting operation, the research factors and their variation levels, cutting tools, CNC Machine, instruments and measurement devices; setting the output data: the choice of the responses tracked in research and the methods of their determination; choice of the experimental method so the information progressive acquiring is allowed, and finally the system knowledge (phenomenon).

The experimental method must to be efficient, and allows to obtaining the maximum information with a minimum experiments number. Also, the required number of measured values, samples and tools used will be established; the experiment; analyzing, interpreting and validating the results analysis, is facilitated by the initial choice of the experimental method, which also must achieve the objectives; the information gradual acquisition is necessary because if a phenomenon is studied, the experimenter did not know the results, so he must forward progressively and reorient the research based of the obtained results. First experiments lead to primary conclusions and based on these conclusions can be make another series of experiments. The experiments series allow obtaining more comprehensive information about the phenomenon. If it is necessary, depending on the obtained results in the first experiments series, it can be carried out another experiments series. In this way the experimenter seeks the needed answers and he stops when he obtained them; knowledge of the studied system.

2.4 Research Planning

The research planning, pursue the expected results in the maximum efficiency terms. The measurements volume will be based: on the accuracy, on the timing of the instruments for measuring purchase, on the results processing timing and on the research cost. A low measurement volume has a negative effect on their accuracy, and a too big volume charges the research program useless. The excessive repetition of the measurement data may lead to measure some parameters variation tendencies as a result of the unavoidable data dispersion, resulting incomplete or erroneous conclusions.

Table 4. Al7136 Chemical Composition Standard AMS4415A.

Element	Min	Max	Element	Min	Max	Element	Min	Max
Silicon	-	0,12	Magnesium	1,8	2,5	Zirconium	0,10	0,20
Iron	-	0,15	Chromium	-	0,05	Other elements, Each	-	0,05
Copper	1,9	2,5	Zinc	8,4	9,4	Other elements, Total	-	0,15
Manganese	-	0,05	Titanium	-	0,10	Aluminum	difference	

The effective research planning is based on the material used in the study - 7136 aluminum alloy with the chemical composition indicated in Table 4. The effective experiments will go towards to detailed study of the behavior of Al 7136 according with the proposed objectives taking into account the variation of the cutting regime parameters.

The experiment will be performed using a standard tools set on aluminum machining - SECO R217.69-1616.0-09-2AN - 16 mm End milling cutter with 100% tool engagement - holding two indexable cutting inserts XOEX090308FR-E05, H15.The machine used for the milling tests is a HAAS VF2 CNC. The optical microscope Micro-Vu VERTEX 310 was used to make an optical determination and evaluation of the machined surface. To analyze the surface roughness for different machining conditions it was used the portable surface roughness tester - Mitutoyo SURFTEST SJ-210, with a resolution of 0.002 μm.

2.5 Research Strategy

The research strategy (Figure 2) has as a starting point the fundamental objective initially set. To conduct the research strategy, it is required an experimental study on the defined research problem, based on an experimental plan. To make a rational choice of the experiment to carry out and also, to obtain the most clear and precise results it is necessary to use modeling and optimization techniques of the experimental research.

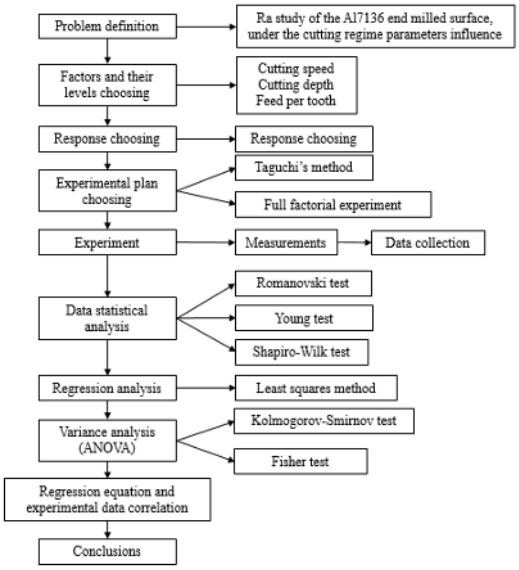

Fig. 2. Research strategy [4].

The Figure 2 requirements will be accomplished according to the producer's recommendations and technological possibilities of the tool, CNC Machine and workpiece materials. In order to identify the influence of cutting speed; cutting depth and feed per tooth on the arithmetic mean deviation of the surface profile Ra, in the chosen experimental field, it is necessary to conduct preliminary screening programs [8]. Then the optimization is used to predict the response value in the experimental field of any factors combination to identifying the optimum to increase the cutting process performance and obtaining a minimum sensitivity to the uncontrollable factors and to determine the influence percentage of the studied factors on the followed response - finally to be able to get a regression model. In this way the methods used are Taguchi, because it can be use a small number of experiments, and a full factorial experiment based on a 7 times experiments replication, to obtain more precise results, according to Montgomery [9] which says that this repetitions can variate between 3 and 7 times for each set of input parameter values to determine the consistency of measurements. A statistical analysis will be performed to certify that the obtained values are real for the studied process. Finally, the regression analysis using the least squares method [6] will be performed to identify a quantitative relationship between the cutting process parameters and the response, which describe the system at any point in the studied experimentally range. The experimental data evaluation related to the regression equation must be done with the Variance Analysis ANOVA, which is focused on the estimation of a various variability types of responses made by Fisher test. By Fisher test the coefficients significance of the regression equation is tested by comparing the ratio of two variances and show the probability that between them exist or not a statistical difference [8]. But the ANOVA analysis of the regression equation can be carried out only under a

normal data distribution. To confirm that, the Kolmogorov-Smirnov test. Finally the proposed regression model will be compared with the experimental results.

Conclusion

Starting from the fundamental objective and specific objectives of this research paper defined in the current chapter, the whole activity is based on the experimental plan settled.

The design, planning, programming and control of processing activities conducted are taking into account the whole range of technologies and methods used to define how products must be manufactured.

The machining activities such: design, planning, programming and control that transform the inputs (workpiece) into finished products was done taking into account the whole range of the technologies and methods used to define how products must be manufactured.

With the experimental stand, it have been fulfilled the main necessary requirements to achieve the sets objectives and also to obtain the experimental data on which can be analyzed the cutting parameters influence (cutting speed, cutting depth and feed per tooth) exerted on the roughness of the end milled surface.

The research strategy was established, beginning with a study that was conducted on the defined research problem, with an experimental design plan using Taguchi's method. For this, it was used modelling and optimizing methods and techniques for the experimental research.

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