Applying Taguchi method to control the thermal expansion effect on machining process of aluminium alloy extruded profile

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Abstract. In this paper we present a technological problem encountered in the machining accuracy of the parts for aerospace, made of aluminium alloy extruded profile with 7 meters length. Those parts have very tight tolerances and on milling process appear deviations due to thermal expansion effect, that influence the repeatability of machining processes. Through several tests and recording all values during the milling process, was defined through Taguchi method the main factors which have impact on the machined parts.

1. Introduction
The application methodology for this research is to analyse and control the thermal expansion influence in the machining process of the parts for aerospace industry made of aluminium alloy extruded profiles with 7000 mm length (figure 1).

Figure 1. Aerospace part

Machining process for those parts are define thorough next steps:
• Drill the middle top holes with the diameter 19.7 mm;
• Drill the sides’ top holes with the diameter 7.3 mm;
• Milling the pocket’s sides from front view.
2. Defining the parameters which influence the thermal expansion
The environment temperature has a major role to define the parameters which have impact on the thermal expansion.

The first parameter which influence the thermal expansion on the extrusion is the machine frame temperature. The temperature was track in different days and different hours of the day to can have a bigger range of results, the record values are: 21°C, 22°C and 23°C.

The second parameter is the extrusion temperature which the same is tracked in different days and different hours of the day, the record values are: 20°C, 22°C and 25°C.

For this experimental research we used the Taguchi method, selecting an orthogonal matrix, on Table 1. The total number of experiments made on this research are equal with 9.

| Experiment number | Frame temperature (°C) | Extrusion temperature (°C) |
|-------------------|------------------------|-----------------------------|
| 1                 | 21                     | 20                          |
| 2                 | 21                     | 22                          |
| 3                 | 21                     | 25                          |
| 4                 | 22                     | 20                          |
| 5                 | 22                     | 22                          |
| 6                 | 22                     | 25                          |
| 7                 | 23                     | 20                          |
| 8                 | 23                     | 22                          |
| 9                 | 23                     | 25                          |

3. Experimental procedure
The experimental configuration consists through using [5]:
- CNC machine Handtmann PBZ NT 1000;
- extruded profile from aluminium alloys;
- digital control thermometer;
- sensors installed on machine frame to can record the frame temperature;
- CMM (coordinate measuring machine).

3.1. Handtmann PBZ NT 1000 machine
This 5 axis machine is used in special for the profile materials up to 10000 mm length, having a flexible clamping system allowing to machine different profile cross sections (figure 2) [3].
3.2. Temperature measurement
The measurement equipment used to define and verify the temperature fluctuation are:
- Digital thermometer used for reading, monitoring and recording the raw material fluctuations (figure 3);
- Sensors used for frame temperature reading, mounted inside of the CNC machine.

![Figure 3. Digital thermometer](image)

3.3. Machined parts control
The machining experimental results are made by CMM (coordinate measuring machine), placed in a room with temperature control environment.

The CMM have orthogonal axes to each other in a typical three-dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. The machine then uses the X, Y, Z coordinates of each of these points to determine size and position with micrometre precision typically (figure 4) [4].

![Figure 4. CMM machine](image)
4. Taguchi analysed

4.1. Experiment preparation

The Taguchi method is efficient because allows quickly to achieve 70–90% from desired optimizations with minimum costs. The rest of 10–30% could be achieve using one or two complementary experiments limited on 2–4 parameters, considered to be most important [1].

The principles with need to be respected to choose the factors are:
- Identifying the factors which influence assure reproducibility of results.
- Factors quality needs to be checked.
- Factors which are truly independents.
- The values of the factors level which needs to be checked.

4.2. Experimental planning

The aim of this experimental research is to realize stability for this technological process. From big amount of parameters which influence have been chosen:
- Frame temperature $T_b$ - measured in [°C];
- Extrusion temperature $T_p$ - measured in [°C].

Based on the customer requirements the geometrical deviations is ±0,2 mm. In Table 2 are presented the factors and the level on which is working.

| Table 2. Factors and workings levels |
|-------------------------------------|
| Factors                           | Minimum | Maximum |
| Frame temperature (°C)             | 21      | 23      |
| Raw material temperature (°C)      | 20      | 25      |

The research is to create a plan which all possible combinations (table 3).

| Table 3. Taguchi orthogonal matrix |
|------------------------------------|
| Experiment number | Frame temperature (°C) | Extrusion temperature (°C) | Maximum deviations obtain (mm) |
|-------------------|------------------------|----------------------------|--------------------------------|
| 1                 | 21                     | 20                         | -0.095                         |
| 2                 | 21                     | 22                         | 0.264                          |
| 3                 | 21                     | 25                         | 0.715                          |
| 4                 | 22                     | 20                         | -0.147                         |
| 5                 | 22                     | 22                         | 0.158                          |
| 6                 | 22                     | 25                         | 0.622                          |
| 7                 | 23                     | 20                         | -0.258                         |
| 8                 | 23                     | 22                         | 0.090                          |
| 9                 | 23                     | 25                         | 0.563                          |

The average deviations based on the defined parameters are shown in figure 5.

Using the incoming dates was created also the residual diagram for the distribution probability, histogram, fits numbers and measurement order, 4 in 1 diagram (figure 6).
5. Conclusions
It is visible that the extrusion temperature has the biggest impact on the holes positioning deviations. How long the extrusion temperature is close to the normal temperature (20°C) the deviation is smaller. Experimental research brings a solution to can track and correct the deviations due to the thermal effect. This research methodology improves the machining process control [2].
6. Acknowledgments
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References
[1] Taguchi G 1991 Taguchi Methods: Research and Development Quality Engineering Series vol. 1 ASI Press Dearborn MI
[2] Tîtu M, Oprean C and Boroiu A 2011 Cercetarea experimentală aplicată în creşterea calităţii produselor şi serviciilor Editura AGIR Bucureşti
[3] *** Training Guide PBZ NT Ver. 2010
[4] *** Metris Bridge CMM User Guide 2016
[5] ***https://www.handtmann.de/en/machining-centres/products/pbz-profile-machining-centres/pbz-nt/ 2016
[6] *** http://www.universalalloy.com/Manufacturing-Capabilities.html 2016