Establish the CNC machining strategy in relation with geometric complexity of the parts made from aluminum 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 aluminum alloy extruded profile with length up to 10 meters. Those parts have very tight tolerances and on milling process appear several factors that influence the repeatability of machining processes. Several factors must be considered when developing the machining process for a specific part, including: establishing the machining strategy in relation with piece geometric complexity, analysis of machined parts through coordinate measuring machine and statistical analysis, to determinate the proper machining strategy for obtaining parts in tolerance. Through several tests and recording all dimensions changes during the milling process, will be modified the machining strategy. By analysing the machining strategy at different lengths of extrusions and records of dimensions fluctuations along the processing chain has been created a proper machine strategy which will obtain a repeatability of the machining process.

1. Introduction
The application methodology for this research is to solve a technological problem encountered in the machining accuracy of the parts for aerospace industry made of aluminum alloy extruded profiles with length up to 10000 mm (Figure 1).

Those parts have very tight tolerances and on milling process appear several factors that influence the repeatability of machining processes [1].

Figure 1. Examples of aerospace parts used in researches
In this research is an analysis of the machine-tools system [2] and the main contributions are: measurements and collecting geometrical deviation values from machined parts on X-axis direction, creating a solution based on CNC machining strategy to solve the deviations problem and achievement the experimental tests.

2. The main elements that are part of the machining process

2.1. CNC machine definition
The machining process is performed in a normal processing unit, without climate control and the CNC machine used is Handtmann PBZ NT (Figure 2).

![Figure 2. Handtmann PBZ NT](image)

The PBZ NT is a profile machining center features impressive maximum flexibility and great cost effectiveness in machining aluminum and steel.

A flexible clamping system for machining different profile cross sections and up to 90 tool slots allows for a wide range of applications up to 25 meters in length. An integrated sawing unit for spatial cuts completes the highly efficient PBZ NT machine concept [3].

2.2. Aluminum alloy extrusion
The research was conducted on extruded aluminum alloys work pieces used in aerospace industry, with a wide range of alloys and treatments (Figure 3).

With thin walls and the section represents a high resistance to shock and breakage, develop from advanced alloys tailored for specific applications to help find the right balance of strength, damage tolerance, and corrosion resistance.
2.3. Parts complexity
Manufacturing process of those parts are define through: drilling holes with 19.7 diameter on middle side, holes 7.3 diameter on both sides of the raw material (Figure 4) and additional milling pockets from the front side (Figure 5). All holes have tolerance ±0.2 up to 10000 mm length. On the CNC machine tests we use extrusion with 4000 mm length [4].

![Figure 3. Extrusion tolerance](image)

2.4. Problem detection
All machined parts specific for aerospace industry needs to be validated by CMM (coordinate measuring machine), placed in a room with temperature control environment.

These axes are orthogonal 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 micrometer precision typically [5].

Metris is an high quality and innovative metrology solutions to a wide range of industries (Figure 6). The geometrical deviation was determined based on holes position (Figure 7).

**Figure 6.** Metris CMM, 3 "bridge" used for parts control

**Figure 7.** Measuring holes position

### 3. CNC machining strategy

**3.1. First machining approach**

The CNC machining strategy was determinate in following way (Figure 8):

- First drilling the TOP holes, 19.7 mm diameter and 7.3 mm diameter.
- Second operation will machine the front pockets.

**Figure 8.** First machining approach

After processing six pieces with the first machining approach, they were measured in CMM, on Table 1 are represented the measurement results [6].
### Table 1. Measurement results from first machining approach

| X-axis position | X-axis value position (mm) | P1  | P2  | P3  | p4  | P5  | P6  |
|-----------------|---------------------------|-----|-----|-----|-----|-----|-----|
| 1               | 0                         | 0   | 0,021 | 0   | 0,048 | 0 | 0,006 |
| 2               | 76                        | 0,009 | 0,039 | 0,07 | 0,116 | 0,061 | 0,08 |
| 3               | 152                       | 0,042 | 0,07 | 0,099 | 0,142 | 0,085 | 0,099 |
| 4               | 228                       | 0,016 | 0,022 | 0,089 | 0,118 | 0,063 | 0,077 |
| 5               | 304                       | 0,012 | 0,004 | 0,088 | 0,104 | 0,049 | 0,067 |
| 6               | 380                       | 0,021 | 0,009 | 0,083 | 0,101 | 0,061 | 0,065 |
| 7               | 456                       | 0,021 | 0,007 | 0,084 | 0,095 | 0,065 | 0,056 |
| 8               | 532                       | -0,025 | -0,019 | -0,099 | -0,098 | -0,064 | -0,056 |
| 9               | 608                       | -0,064 | -0,048 | -0,128 | -0,127 | -0,095 | -0,08 |
| 10              | 684                       | -0,031 | -0,016 | -0,092 | -0,105 | -0,057 | -0,052 |
| 40              | 2964                      | -0,256 | -0,263 | -0,315 | -0,349 | -0,298 | -0,378 |
| 41              | 3040                      | -0,22 | -0,232 | -0,291 | -0,318 | -0,274 | -0,344 |
| 42              | 3116                      | -0,181 | -0,207 | -0,25 | -0,284 | -0,241 | -0,328 |
| 43              | 3192                      | -0,18 | -0,216 | -0,245 | -0,286 | -0,238 | -0,326 |
| 44              | 3268                      | -0,217 | -0,235 | -0,272 | -0,32 | -0,256 | -0,338 |
| 45              | 3344                      | -0,22 | -0,229 | -0,279 | -0,308 | -0,253 | -0,318 |
| 46              | 3420                      | -0,246 | -0,255 | -0,317 | -0,34 | -0,286 | -0,343 |
| 47              | 3496                      | -0,248 | -0,238 | -0,318 | -0,338 | -0,284 | -0,285 |
| 48              | 3572                      | -0,241 | -0,242 | -0,268 | -0,292 | -0,251 | -0,298 |
| 49              | 3648                      | -0,235 | -0,25 | -0,244 | -0,268 | -0,253 | -0,291 |
| 50              | 3724                      | -0,248 | -0,255 | -0,249 | -0,27 | -0,261 | -0,283 |
| 51              | 3800                      | -0,262 | -0,261 | -0,244 | -0,258 | -0,26 | -0,275 |
| 52              | 3876                      | -0,258 | -0,267 | -0,259 | -0,245 | -0,26 | -0,268 |
| 53              | 3952                      | -0,261 | -0,273 | -0,268 | -0,235 | -0,259 | -0,26 |

It is visible an improvement on the holes positions, there are in tolerance (Figure 9).

![Figure 9. X-axis deviation chart from first machining approach](image)
If the side pockets are machined first the residual stress from extrusion is eliminated and holes drilled after are in tolerance.

3.2. Second machining approach

The CNC machining strategy was changed with a new approach made in following way:

- First milling the front pockets.
- Second drilling the TOP holes, 19.7 mm diameter and 7.3 mm diameter.

Based on the next six pieces machined, we have the following CMM measurement results (Table 2).

| X-axis value position (mm) | P7  | P8  | P9  | P10 | P11 | P12 |
|---------------------------|-----|-----|-----|-----|-----|-----|
| 1                         | 0   | 0   | 0,019 | 0   | -0,047 | 0,034 | 0,036 |
| 2                         | 76  | 0,004 | 0,015 | -0,007 | 0,010 | 0,035 | 0,027 |
| 3                         | 152 | 0,028 | 0,019 | -0,033 | 0,019 | -0,009 | 0,017 |
| 4                         | 228 | 0,02 | 0,018 | -0,015 | 0,001 | 0   | 0,023 |
| 5                         | 304 | 0,038 | 0,016 | -0,039 | -0,007 | 0,017 | 0,039 |
| 6                         | 380 | 0,003 | 0,011 | -0,045 | -0,010 | 0,015 | 0,027 |
| 7                         | 456 | 0,019 | 0,019 | -0,038 | -0,013 | 0,023 | 0,03 |
| 8                         | 532 | 0,059 | 0,006 | -0,002 | -0,001 | 0,014 | 0,044 |
| 9                         | 608 | 0,031 | 0,013 | -0,007 | 0,035 | 0,005 | 0,022 |
| 10                        | 684 | 0,059 | 0,018 | 0,033 | 0,011 | 0,011 | 0,026 |
| 40                        | 2964 | 0,037 | 0,048 | -0,024 | 0,046 | 0,007 | 0,026 |
| 41                        | 3040 | 0,058 | 0,048 | -0,004 | 0,013 | 0   | 0,012 |
| 42                        | 3116 | 0,027 | 0,055 | -0,009 | 0,014 | 0,015 | 0,006 |
| 43                        | 3192 | 0,027 | 0,055 | -0,004 | -0,04 | 0,009 | 0,018 |
| 44                        | 3268 | 0,073 | 0,052 | 0,018 | -0,004 | 0,034 | 0,04 |
| 45                        | 3344 | 0,06 | 0,052 | 0,003 | -0,006 | 0,027 | 0,046 |
| 46                        | 3420 | 0,032 | 0,062 | -0,02 | -0,033 | 0,032 | 0,041 |
| 47                        | 3496 | -0,009 | 0,069 | -0,002 | 0,029 | 0,011 | 0,04 |
| 48                        | 3572 | 0,034 | 0,061 | -0,004 | -0,008 | 0,02 | 0,036 |
| 49                        | 3648 | 0,021 | 0,069 | -0,003 | 0,036 | 0,023 | 0,038 |
| 50                        | 3724 | 0,048 | 0,061 | 0,011 | 0,06 | 0,024 | 0,034 |
| 51                        | 3800 | 0,008 | 0,07 | -0,02 | -0,016 | 0,069 | 0,048 |
| 52                        | 3876 | 0,008 | 0,073 | -0,039 | -0,004 | 0,052 | 0,017 |
| 53                        | 3952 | 0,031 | 0,069 | -0,049 | -0,008 | 0,063 | 0,008 |

It is visible an improvement on the holes positions, there are in tolerance. If the side pocket are machined first the residual stress from extrusion is eliminated and holes drilled after are in tolerance (Figure 10).
4. Conclusions
Experimental research bring a solution using different approach on CNC machining strategy, which is a major concern for processing repeatability of specific parts from aerospace industry. This research methodology improve the machining process control.

The original contribution for this research is: creating a solution based on CNC machining strategy to solve the deviations problem.

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