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Influence of Milling Strategies of Thin-walled Elements on Effectiveness of their Manufacturing

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Abstract

The paper presents an analysis of milling strategies influence of thin-walled elements made of aluminum alloy EN AW-2024 on effectiveness of their production. Two values were adopted as measures of the effectiveness: result of emerging deformation (after removal of samples from clamping fixture) and machining time. The three milling strategies i.e.: HPC, HPC combined with conventional finishing operation as well as HPC and HSC were analysed as a part of experimental study. Each combination was characterized by the different range of technological parameters that have directly impacted on manufacturing effectiveness. On the base of obtained results it has been noted that milling strategies have an impact on the values of emerging deformation. The best result was achieved for combination of HPC with conventional finishing operation. Despite relatively low efficiency, conventional operation application can have a practical use.

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Keywords: machining; aluminium alloy; deformation; effectiveness; machining time; High Speed Cutting; High Performance Cutting; thin-walled elements

1. Introduction

A wide range of application of thin-walled elements in the industry, mainly aerospace, imposes continuous improvement of manufacturing methods and increasing the process effectiveness. According to Lean Manufacturing philosophy, considering necessity of cost reduction of both production and exploitation at a later stage, it is required to decrease the total weight of the final product whilst retaining appropriate strength, dimensional and shape accuracy as well as surface quality [1, 7].

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Thin-walled structures are often referred to as integral elements. They are characterized by low weight in comparison to overall dimensions and solid design, among others. Parts are produced from monolithic plates with different thickness, particularly wrought aluminium alloys, on the new generation of 5-axis machining centres. Large quantity of generated chips, amounting in some cases even more than 95% of the semi-finished product weight, implies to use modern, high-performance technologies such as High Speed Cutting (HSC) and High Performance Cutting (HPC). Now both of these methods are widely used in the manufacturing of thin-walled elements [2, 6, 8, 9].

The machining process used for production of integral structures has to meet high requirements. Its key task is high performance, which can be obtained by removing allowance in the shortest possible time, whilst retaining the specific quality requirements [8].

The big problem is elastic and plastic deformation of thin-walled components, generated during the cutting process. Elastic deformations are the reason of generating shape deviation and vibration, affecting negatively on cutting accuracy. Plastic deformations cause residual stresses, which are difficult to remove from surface layer. They bring on permanent changes of size and shape, increasing cost and time of production, for example by necessity of using additional heat treatment [3, 4, 10, 11].

2. Literature Review

Residual stresses are defined as "stresses remaining in the element after the discontinuation of external forces action which cause its deformation". As a result of external factors: mechanical, thermal and structural, material deforms elastically and plastically. Reversible deformation disappears after removing the load and the remaining irreversible deformation leads to the formation of residual stresses, counterbalancing each other within a specific area. The reason of their manufacturing is to increase the internal energy of the element, leading to the defects of molecular lattice and changes in the properties of the material [8, 10].

The final state of stress in the surface layer during the machining process is the result of overlapping the two main mechanisms, i.e.: mechanical and thermal. However, the size and type of emerging stresses depend on many factors: depth of cut, feed per tooth, cutting speed, angle of back-rake, cooling condition, material properties, wear of cutting tool, etc. [10].

Residual stresses can have both positive and negative effect on how the elements work. Therefore, depending on the analysed case, one tends to produce or remove them. Their beneficial effect is observed e.g.: during shot peening, where emerging stresses have impact on increasing fatigue strength, fatigue corrosion resistance and abrasion as well as prevent the formation of microcracks. Although residual stresses are in the whole volume of the material, they are the largest in the surface layer. The amount of these stresses of the element after machining depends largely on its shape and dimensions. It was noted that in the case of objects with a very small thickness of walls, macroscopic deformations of entire body are formed, while for the materials of significant size, cracks on the surface and changes in the internal structure of the selvage layers are observed [10].

During storage after heat treatment, low-temperature drawback treatment, as well as load of variable forces, stresses relaxation appears and that is defined as "unprompted decrease of stresses in the metal". Experimental studies have confirmed that it occurs in various metals at different temperatures and it is the result of dislocation glide and diffusion. Factors influencing on stress relaxation include: chemical composition of the material and its structure, process conditions, loading and unloading state, time and temperature. Stress relief of large parts is quite uncomfortable, mainly on the grounds of need to use the special chambers for aging, storage costs and energy losses [8, 10].

Machining of integral elements places high performance demands. A key factor is the speed of material removal. In addition, increasingly it has been noticed that there is a tendency striving to simplify the semi-finished products in order to avoid expensive production operations. Another observable trend is the use of modern technology i.e.: HSC and HPC. It is the main direction of growth of production performance by increasing cutting speed outside the area that is dedicated to conventional cutting [10].

Analysing the current state of literature, also own experiences, the manufacturing effectiveness of thin-walled structures can be improved mainly through [5, 7]:

- · improvement the elements producibility
- selection of the proper machining strategies

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