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Optimization of process parameters for machining of Al 7075 thin-walled structures

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A B S T R A C T

The aim of this paper was focused on research in order to improve the manufacturing of aluminium alloy thin-walled components through the optimization of milling process parameters. The methodology for optimization of milling parameters is developed and presented. The influence of the tool path strategy, wall thickness and feed rate on the machining time, dimensional accuracy deviation, shape and position accuracy deviation, and surface roughness in the case of line-type thin-walled parts machining were analysed. Based on the analysis of experimental results, the corresponding empirical models of responses were identified. Optimization of results was conducted using response surface methodology. Verification of optimization results was executed using two additional experiments. The results from experimental verification show a satisfactory matching with calculated optimal values. The basic scientific contribution of the paper relates to the development of a methodology for optimization of machining parameters for milling of thin-walled structures of aluminium alloy using an ANOVA method, Central Composite Design experiment and empirical modelling. Practical implications are related to the correct selection of the tool path strategy and feed rate value for machining of thin-walled aluminium components in order to achieve the required output techno-economic effects.

A R T I C L E   I N F O

Keywords:
Thin-walled structures;
Aluminium alloy Al 7075;
Optimization;
Response surface methodology;
Machining process parameters;
Milling

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1. Introduction

Due to its homogeneity, corrosion resistance, and excellent ratio between load capacity and weight, thin-walled aluminium components are increasingly being used as structural parts in the aerospace, automotive, military and other branches of electrical-mechanical industry [1, 2]. New designs of these components are focused on monolithic parts rather than a larger number of components that require to be assembled after machining. In this way, the result is a design with good mechanical characteristics, better quality and accuracy, lower weight and less production time and costs [3]. The design of thin-walled structures can vary from simple line and rectangular form to more complex geometric forms [4].

The manufacturing process of thin-walled parts is mainly performed by removing the material from blanks, in a large percentage from their original volume and mass, making it a time-consuming and challenging process [5, 6]. Consequently, machining demands are directed to high productivity, causing in turn the occurrence of issues related to machining vibrations and elastic deformations of thin-walled structures that affect the surface roughness, as well as dimensional and shape accuracy [7, 8]. In addition to this, permanent deformations of the structure can occur, and this may cause the incidence of rejected parts [9, 10]. Numerous factors of process planning are affected by the aforementioned issues, such as the elements of the machining system (machine tool, tool, and fixture), cutting parameters, tool-path strategy, cutting fluids, etc. [11-14].

In parallel with the increasing market demands for aluminium alloy thin-walled components, there is a number of accomplished researches focused on optimizing the structure in order to reduce mass, deformation, and vibration, i.e. increase load capacity and strength. Also, researches are focused on optimization of process planning of these components aiming to reduce the machining time and costs, and increase the accuracy of shapes and positions, and improving surface roughness, etc. [3, 4, 15, 16].

Novak-Marcincin *et al*. [17] investigated the possibility of a quick analysis of the appropriate tool path in the process of milling different features (rectangle, circle, L-shape and T-shape). Based on the obtained results, a software solution is developed to assist in the selection of optimal milling strategy on the basis of the minimal processing time. Pandian *et al*. [18] analysed the influence of the cutting forces on the deformation during the machining of thin-walled parts which results in different wall thickness, larger at the top and smaller in the root. Authors applied the developed Artificial Neural Network (ANN) and Particle Swarm Optimization (PSO) for prediction of the cutting force during machining of thin-walled parts. Msaddek *et al*. [19] represented the methodology for the optimization of machining strategies implemented for machining complex shaped pockets. For this purpose, authors developed the analytical model which is used for modelling feed rate value regarding the tool path strategy. Denkena and Schmidt [20] defined an improved simulation model which predicts a form of unsuitable deviation occurring during the milling of the ends of thin-walled structures. Their paper analyses the effect of cutting forces that causes the deflection of thin-walled structures and the occurrence of errors on machined parts. Peripheral milling of thin-walled structures is modelled in Budak and Altintas [21]. The developed model provides satisfactory predictions of cutting forces and dimensional surface defects throughout the deflection of cutting tool and thin-walled structures during the milling process. Baranek *et al*. [22] emphasized the influence of material removal on the surface roughness of thin-walled structures during the milling process. Experimental research on the stability of milling the thin-walled aluminium structure, as well as the measurement of cutting forces and acceleration, was conducted in Rusinek *et al*. [23]. The analysis was performed through the stability diagrams and recurrent quantification analysis. Kanchana *et al*. [24] used the finite elements method approach and the analysis of frequency response for machining of thin-walled components for aerospace industry purposes. Arnaud *et al*. [25] investigated the stability of machining the thin-walled aluminium structures. The system was modelled using a dynamic mechanistic model, while the dynamic system parameters were obtained using the finite element analysis. Masmali and Mathew were used an analytical approach to predict dynamic chip thickness variation during machining of thin wall workpieces [26]. Pare *et al*. [27] implemented metaheuristic methods for selecting optimum process parameters in high speed CNC end-milling of composite materials. They compared Gravitational Search Algorithms (GSA) with Genetic Algorithm (GA), Simulated Annealing (SA) and Teaching-Learning-Based Optimization (TLBO) methods. Ratchev *et al*. [28] represented a virtual environment for the simulation and prediction of the deviation of the thin-walled structures during the machining process. The model for material removal was based on an iterative voxel transformation algorithm.

Taking into consideration the conclusion from listed literature above, it can be concluded that the field of machining the thin-walled structures has been the research subject around the world for many years now. It was identified that there is no universal model or unique approach that could be implemented in this field. The aforementioned researchers were oriented to individual input/output parameters of process plan for the machining of thin-walled parts, with different techniques applied, such as simulation methods and models, predictive models, stability diagrams, finite element method, and so on. The main goal in this research relates to the development of the methodology for optimization of machining parameters for thin-walled structures. In this way, the focus is put on the improvement of process planning function which currently represents a bottleneck in the production environment, and the integration of product design and manufacturing. The methodology is based on the simplicity and generality of application with a quick and easy way of reaching reliable data for the process planning for machining of thin-walled parts. It can easily be applied to other shapes of thin-walled structures, other materials, with the inclusion of other input/output parameters of machining process.

The primary hypothesis of this research was that the change of a tool path strategy and cutting conditions of aluminium alloy thin-walled structures affects the machining time, surface roughness and dimensional, shape and position accuracy of workpieces. According to the given hypotheses, the aim of this research was focused on the selection of an optimal tool path strategy, wall thickness and feed rate value of line type aluminium thin-walled structures for the best machining responses. The target responses which were selected include: the shorter machining time, the smallest wall thickness, perpendicularity, flatness deviation and the smallest surface roughness.

2. Materials and methods

Optimization theory as a scientific discipline is more frequently used in solving engineering problems, where, on the basis of criteria and the appropriate optimization method, the best solution is being found for a selected object of the optimization in line with machining requirements. The main phases in the proposed experimental procedure of the process parameters optimization methodology for the machining of aluminium alloy thin-walled structures are shown in Fig. 1 and described below. Optimization methodology was performed using ANOVA method within Design Expert Software [29].

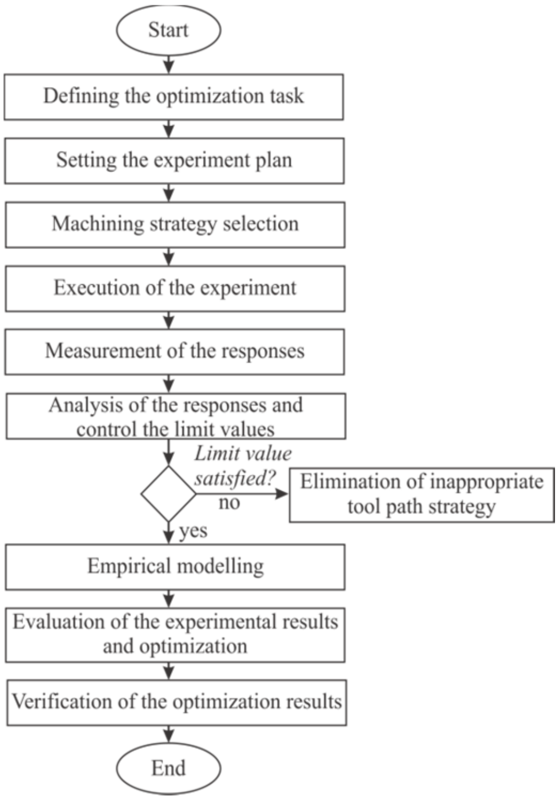


Fig. 1 Flowchart for the optimization methodology

2.1 Defining the optimization task

The object of the research was the line-type aluminium alloy thin-walled structure machining, having wall thickness *a* from 0.5 mm to 1.5 mm, which is moderately low compared to wall height *L* (*L*:*a* = 30:1).

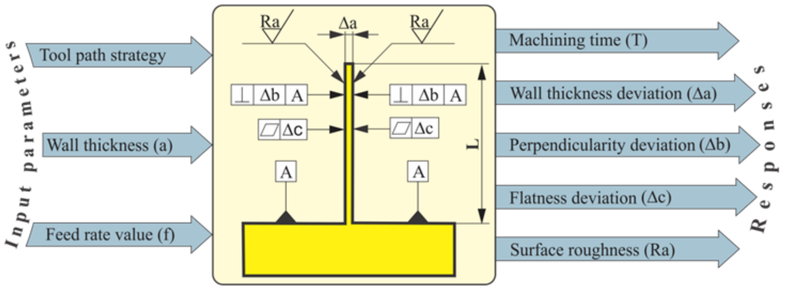


Fig. 2 Scheme of input parameters and responses

Basic optimization task refers to the determination of the influence of tool path strategy, wall thickness *a* and feed rate value *f* on machining time *T*, wall thickness deviation *Δa*, perpendicularity deviation *Δb,* flatness deviation *Δc*, as well as surface roughness *Ra*. This task was solved using the experimental optimization method, which scheme is shown in Fig. 2. The parameters *T, Δa, Δb, Δc* and *Ra* can be observed as measured outputs, i.e. responses.

2.2 Setting the experimental plan

The stage of setting the experimental plan was carried out using the Design-Expert Software. The software supports a large number of experimental designs, while for the present case the Central Composite Design was selected. Three factors, two numerical and one categorical all on three levels generated the total of 33 experiments. The first numerical factor was the thickness of the line-type thin-walled structure *a*, with the lowest limit of 0.5 mm, and the highest limit value of 1.5 mm. Second numerical factor was milling feed rate *f*, with the lowest limit at 150 mm/min, and the highest limit value at 350 mm/min. For the third, categorical factor, three different tool path strategies were chosen. Tool path strategies for machining the thin-walled structures were selected based on the recommendations from the literature [4, 18, 21]. These tool path strategies are as follows:

- Tool path strategy No. 1 (Parallel spiral) 
- Tool path strategy No. 2 (Zigzag) 
- Tool path strategy No. 3 (True spiral) 

2.3 Machining strategy selection

This phase encompasses the selection of the machining strategy in the terms of machining passes sequencing during machining process of thin-walled structures. Selected machining passes sequence for this experiment was adopted from [30]. Selected machining passes sequence implies that the first machining pass was executed at the left side of thin-walled structure, then the second and the third machining pass were executed at the right side of thin-walled structure. Next, the fourth and the fifth were executed again at the left side, and so on up to the twentieth pass at the bottom of the structure as shown in Fig. 3. Machining of thin-walled structure was performed with the following fixed parameters: depth of cut a_p = 3 mm, step over distance a_e = 8 mm for each machining pass and spindle speed n = 2000 min^{-1}.

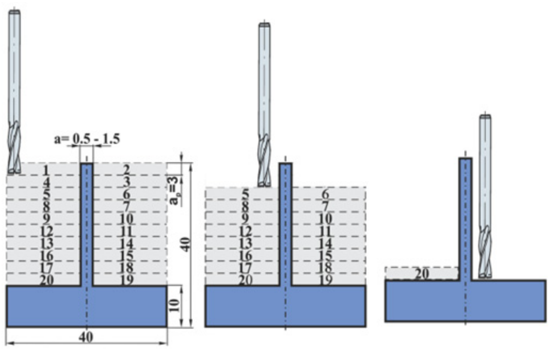


Fig. 3 Selected machining passes sequence for the machining of thin-walled structures

2.4 Experimental procedures

Realization of the experiments

Block samples (33 pieces) with dimensions of 70×40×40 mm from Al 7075 alloy (AlZnMgCu1.5) were chosen and prepared. This Al-alloy has very good mechanical properties, as well as high resistance to fatigue and corrosion, which makes it suitable for use in the milling of thin-walled structures. The chemical composition of this alloy is Al (87.1–91.4 %), Cr (0.18–0.28 %), Cu (1.2–2 %), Fe (≤0.5 %), Mg (2.1–2.9 %), Mn (≤0.3 %), Si (≤0.4 %), Ti (≤0.2 %), Zn (5.1–6.1%). Basic mechanical characteristics are: tensile strength (560 MPa), $Rp_{0.2}$ (500 MPa), yield strength (7 %), and hardness (150 HBW).

CNC machining centre – EMCO Concept Mill 450, and the milling cutters with the identification R216.32-10025-AK32 from the Sandvik Coromant were used for the realization of the experiments. The positioning and clamping of the samples in the milling process were carried out using a pneumatic clamp with pre-set limiter.

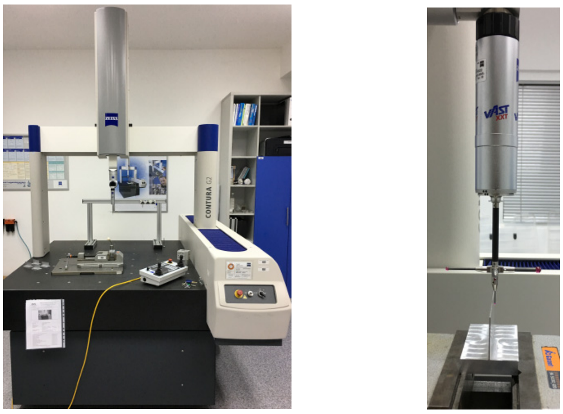
Measuring of the responses

According to the experiment plan, the following responses of the thin wall structure machining process were measured:

- Machining time – T,
- Wall thickness deviation – Δa,
- Perpendicularity deviation – Δb,
- Flatness deviation – Δc,
- Surface roughness – Ra.

The measurements of the dimensional parameters were performed using the coordinate measurement machine Zeiss Contura G2 (Fig. 4a) together with sensor touch probe Zeiss Vast XXT shown in Fig. 4b. The Maximum Permissible Error MPE = 1.9 µm for size measurement according to ISO 10360-2:2009 is specified for this machine.

Surface roughness measurements were conducted with the INNOVATEST contact device, in direction perpendicular to the cutter movement on both sides of the wall. The device has the ability of measuring the parameters Ra and Rz. The roughness measurements were performed with a stylus radius of 2 µm and resolution of 0.01 µm.



a) b)

Fig. 4 Measuring of parameters Δa, Δb and Δc on machined parts by CMM

Analysis of the responses and control of the limit values

At this phase, the intervals of responses values obtained from the measurements of all three tool-path strategies were analysed (Fig. 5). Limit values of responses were predefined as follows: maximal wall thickness deviation $max\Delta a$ = 0.2 mm, maximal perpendicularity deviation $max\Delta b$ = 0.1 mm, maximal flatness deviation $max\Delta c$ = 0.1 mm and maximal surface roughness *maxRa* = 1.6 µm. The analysis of the limit value intervals of all responses shows that the values of wall thickness deviation Δa, perpendicularity deviation Δb, flatness deviation Δc and surface roughness Ra for tool path strategy No. 2 do not fall into the predefined limit values, causing the tool path strategy No. 2 to be excluded from further research. Tool path strategies No. 1 and No. 3 satisfied the limit values, and therefore both were taken into consideration for determining the optimal strategy.

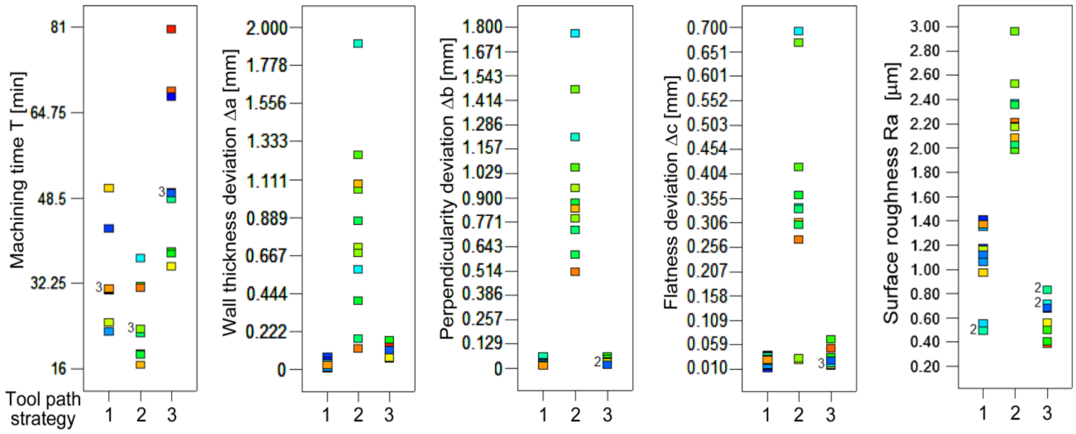


Fig. 5 Intervals of the values *T, Δa, Δb, Δc* and *Ra*

3. Results and discussion

3.1 Empirical modelling

After manual elimination of inadequate tool path strategy No. 2, responses of both other strategies, No. 1 and No. 3 were empirically modelled. Results from this stage are empirical models of responses for both tool path strategies, which are listed in Table 1. All models were obtained using quadratic polynomial modelling with some transformations for better model results.

Table 1 Empirical models of responses

Tool path	Empirical model	Responses
No. 1	$lnT = 4.89861 + 2.14456 \cdot 10^{-3} \cdot a - 7.7971 \cdot 10^{-3} \cdot f + 7.84629 \cdot 10^{-6} \cdot f^2$	Machining time
No. 1	$\sqrt{\Delta a} = 0.66044 - 0.32615 \cdot a - 2.34118 \cdot 10^{-3} \cdot f + 1.68538 \cdot 10^{-3} \cdot a \cdot f$	Wall thickness deviation
No. 1	$ln\Delta b = 1.51485 - 5.24519 \cdot a - 0.020474 \cdot f + 2.29188 \cdot a^2 + 4.12498 \cdot 10^{-5} \cdot f^2$	Perpendicularity deviation
No. 1	$\frac{1}{\sqrt{\Delta c}} = 3.20174 + 3.36622 \cdot a$	Flatness deviation
No. 1	$\sqrt{Ra} = -0.80634 + 1.80076 \cdot a + 5.71813 \cdot 10^{-3} \cdot f - 1.67948 \cdot 10^{-3} \cdot a \cdot f - 0.44182 \cdot a^2 - 8.04146 \cdot 10^{-6} \cdot f^2$	Surface roughness
No. 3	$lnT = 5.437 - 0.02208 \cdot a - 8.04091 \cdot 10^{-3} \cdot f + 7.84629 \cdot 10^{-6} \cdot f^2$	Machining time
No. 3	$\sqrt{\Delta a} = 0.85989 - 0.44928 \cdot a - 1.96566 \cdot 10^{-3} \cdot f + 1.68538 \cdot 10^{-3} \cdot a \cdot f$	Wall thickness deviation
No. 3	$ln\Delta b = 1.70287 - 5.24519 \cdot a - 0.020474 \cdot f + 2.29188 \cdot a^2 + 4.12498 \cdot 10^{-5} \cdot f^2$	Perpendicularity deviation
No. 3	$\frac{1}{\sqrt{\Delta c}} = 2.52262 + 3.74762 \cdot a$	Flatness deviation
No. 3	$\sqrt{Ra} = -0.78597 + 1.57972 \cdot a + 5.71813 \cdot 10^{-3} \cdot f - 1.67948 \cdot 10^{-3} \cdot a \cdot f - 0.44182 \cdot a^2 - 8.04146 \cdot 10^{-6} \cdot f^2$	Surface roughness

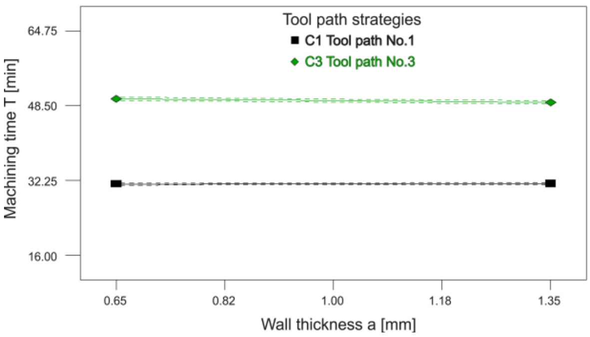


Fig. 6 Machining time *T* for tool paths

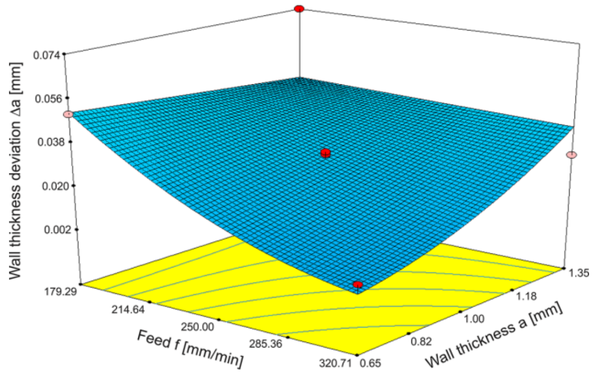


Fig. 7 3D surface diagram for the thickness deviation *Δa* with tool path strategy No. 1

Based on the carried experiments and empirical modelling, graphical results, i.e. 3D surface diagrams were obtained and discussed below.

As it is well-known, machining time is influenced by feed rate value. While wall thickness, on the other hand, does not show almost any significance on machining time. This refers to both tool path strategies. It was recorded that machining time for tool path strategy No. 1 was significantly shorter than for No. 3 for same feed rate values *f*, as can be seen in Fig. 6.

The influence of feed rate *f* and wall thickness *a* on wall thickness deviation *Δa* for tool path strategy No. 1 is shown in 3D surface diagram in Fig. 7. It can be seen that maximum wall thickness deviation for this tool path strategy was lower than 0.05 mm.

Wall thickness deviation decreases with higher feed rates. Model also shows that wall thickness deviation is proportional to the wall thickness, and that with the higher wall thicknesses, feed rate has almost no influence on wall thickness deviation.

3D surface diagram for wall thickness deviation *Δa* using tool path strategy No. 3 is shown in Fig. 8. In this case maximum wall thickness deviation of 0.17 mm and min. deviation of 0.08 mm was achieved. Wall thickness deviation for tool path strategy No. 3 is also strongly influenced by feed rate with lower wall thickness, while less influence of feed rate is noticed with higher wall thickness. It can be seen that tool path strategy No. 1 gives much better results when thickness deviation is considered.

3D surface diagram for the perpendicularity deviation *Δb* using tool path strategy No. 1 is shown in Fig. 9. Models for perpendicularity deviation *Δb* for both tool path strategies show the same trends, i.e. perpendicularity deviation rises with wall thickness reduction, while feed rate does not have significant influence. Best results, i.e. the lowest deviation can be achieved with middle values of feed rate. Maximum perpendicularity deviation *Δb* for tool path strategies No. 1 of 0.04 mm is predicted and it is lower than for tool path strategies No. 3 (0.05 mm).

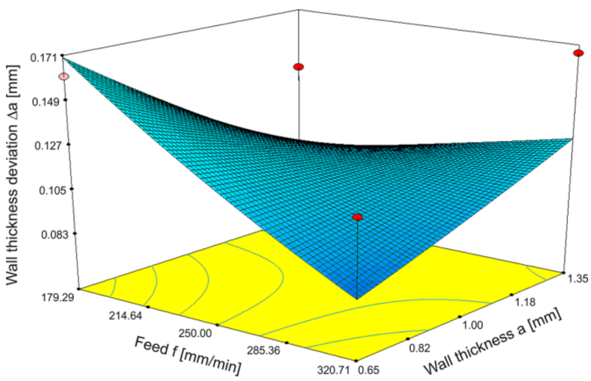


Fig. 8 3D surface diagram for the thickness deviation *Δa* with tool path strategy No. 3

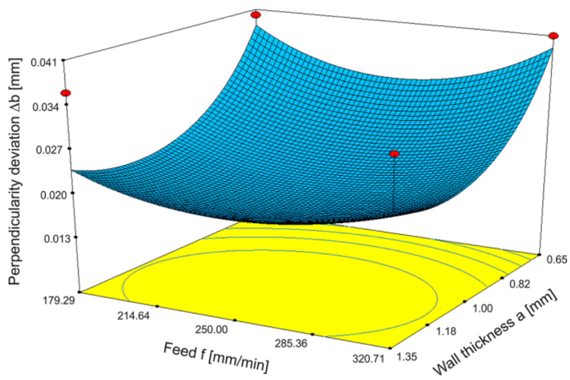


Fig. 9 3D surface diagram for the perpendicularity deviation *Δb* with tool path strategy No. 1

Influence of feed rate and wall thickness on flatness deviation Δc for tool path strategy No. 1 is shown by 3D surface diagram in Fig. 10. Flatness deviation for both tool path strategies (No. 1 and No. 3) shows the same dependence, i.e. flatness deviation is significantly influenced by wall thickness, while feed rate almost does not have any influence.

Flatness deviation is inversely proportional with wall thickness. Maximum flatness deviation Δc for tool path strategies No. 1 has value of 0.035 mm and it was just a bit lower than for the tool path strategies No. 3 (0.04 mm), both for the same wall thickness a = 0.65 mm.

3D surface diagram for the surface roughness Ra for tool path strategy No. 3 is shown in Fig. 11. Also in this case, surface roughness models for both tool path strategies show the same dependence, i.e. surface roughness is proportional to the wall thickness, while feed rate affects roughness inversely proportionally only with higher wall thicknesses. Maximum surface roughness achieved with tool path strategy No. 1 was Ra = 1.41 μm and it was higher than for tool path strategy No. 3 (Ra = 0.83 μm).

Taking into consideration empirical models and 3D surface diagrams, it can be concluded that tool path strategy No. 1 has advantages over tool path strategy No. 3 in the following responses: machining time, thickness deviation, perpendicularity deviation and flatness deviation. Tool path strategy No. 3 has only an advantage in surface roughness. Based on these reasons, tool path strategy No. 1 can be declared as the one which generates the best responses for previously adopted conditions of experiment. For those reasons, the optimization of process parameters for thin wall structures machining was executed only for tool path strategy No. 1, i.e. parallel spiral.

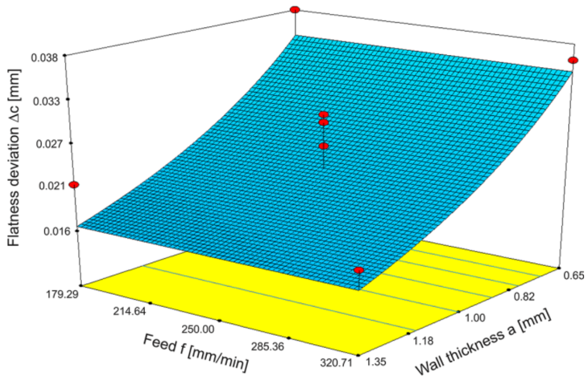


Fig. 10 3D surface diagram for the flatness deviation Δc with tool path strategy No. 1

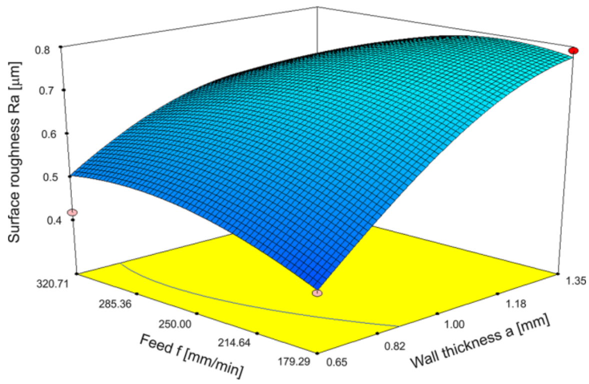


Fig. 11 3D surface diagram for the surface roughness Ra with tool path strategy No. 3

3.2 Evaluation of the experimental results and optimization

Empirical models were then used for machining optimization. As concluded above, the optimization of machining parameters was performed for the tool path strategy No. 1 only. The main objective of optimization was the selection of optimal feed rate values for specific wall thickness between 0.5 mm and 1.5 mm, using the step of 0.1 mm, which would generate the smallest values of responses, i.e. the smallest deviation in thin wall structure machining.

Criteria and goals of optimization process are given in Table 2. As it can be seen, the highest weight coefficient was assigned to wall thickness deviation, because the scope of the experiment was related to machining of thin wall structures, where the main geometrical feature of thin wall structure is its thickness. Other weight coefficients have the same values i.e. other responses have the same level of importance.

The optimal feed rate values for different wall thickness values and corresponding predicted values of responses for the tool path strategy No. 1 are shown in Table 3. Results show that except for the thickest wall, the feed rate should be set at maximum value f = 350 mm/min.

Table 2 Criteria and goals of optimization process

Responses	Goal	Lowest limit	Highest limit	Weights
Wall thickness	Equal to specific value	0.5	1.5	1
Feed rate	in range	150	350	1
Machining time	minimize	10	90	1
Thickness deviation	minimize	0.005	1	10
Perpendicularity deviation	minimize	0.01	1.85	1
Flatness deviation	minimize	0.01	0.7	1
Surface roughness	minimize	0.2	3,2	1

Table 3 The optimal parameter settings and predicted responses for different wall thickness (tool path strategy No. 1)

a [mm]	f [mm/min]	T [min]	Δa [mm]	Δb [mm]	Δc [mm]	Ra [µm]
0.5	350	22.9	0.07	0.042	0.05	0.76
0.6	350	22.9	0.054	0.037	0.06	0.77
0.7	350	22.9	0.001	0.043	0.03	0.7
0.8	350	22.9	0.003	0.036	0.029	0.8
0.9	350	22.9	0.006	0.031	0.026	0.9
1	350	22.9	0.011	0.029	0.023	1.0
1.1	350	22.9	0.017	0.027	0.021	1.0
1.2	350	22.9	0.025	0.028	0.019	1.1
1.3	350	23	0.034	0.029	0.017	1.1
1.4	350	23	0.044	0.032	0.016	1.1
1.5	293	23	0.056	0.037	0.015	1.1

3.3 Verification of the optimization results

The verification of optimization results were conducted on two samples with wall thickness of a = 0.7 mm and a = 1.2 mm. Feed rate f was set according to the optimization at 350 mm/min and tool path strategy No.1 was selected. The other cutting conditions of experiments were kept the same as in the main experiment. After machining of the samples, the process of measurement of responses was conducted in the same manner and with the same equipment.

Verification results are shown in Table 4. It can be seen that results of verification tests deviate from the predicted values for less than 10 %. These results can be accepted as satisfactory, considering the complexity of the machining process of thin-walled structures, the conditions of machining, machine rigidity, the occurrence of vibration, and other influencing factors.

Table 4 Results of verification test

Sample	Tool path strategy	a [mm]	f [mm/min]		T [min]	Δa [mm]	Δb [mm]	Δc [mm]	Ra [µm]
1	1	0.7	350	Predicted value	22.9	0.001	0.043	0.03	0.7
2	1	1.2	350		22.9	0.025	0.028	0.019	1.1
1	1	0.7	350	Measured values	23	0.001	0.041	0.033	0.76
2	1	1.2	350		23.3	0.027	0.027	0.020	1.18
1	1	0.7	350	Deviations of values	0.4 %	0 %	4.6 %	10 %	8.5 %
2	1	1.2	350		1.7 %	8 %	3.6 %	5.3 %	7.2 %

4. Conclusion

The optimization methodology for thin wall structures machining was presented in this research. Significant savings in machining time were achieved by selecting the optimal tool path strategy and feed rate value, and at the same time meeting the quality factors (i.e. responses) in terms of accuracy of wall thickness deviation, perpendicularity deviation, flatness deviation and surface roughness. The determined tool path strategy and feed rate value are suitable for machining the line-type aluminium alloy thin-walled structures. They are also suitable for structures with similar configuration, such as the rectangular-type structures.

Based on these results, it can be concluded that the tool path strategy No. 1, i.e. parallel spiral provides the most satisfactory response values for wall thickness from 0.5 mm up to 1.5 mm. It is also important to highlight the significance of generated empirical models, which give insights into machining process within the considered research.

The verification of the optimization results shows the maximum deviation of 10 % in measured and predicted values, which represents a significant achievement in the field of thin-walled structures machining. The obtained results confirmed the defined research hypotheses. The represented methodology gives reliable data on the input/output parameters of machining process, which can be used for developing a knowledge base within the process planning system. It was proved that the optimization of machining parameters has an influence on improving the manufacturing of thin-walled components, primarily in terms of machining time, machining accuracy and quality itself.

In addition to the presented technological effects, realized optimization has a significant impact on the economic effects, which are easily recognizable here. Based on obtained results, it can be seen that the main machining time for the tool path strategy No. 1 is shorter than the machining time for tool path strategy No. 3, thereby it affects the increase of the manufacturing productivity. On the other hand, using the proposed optimization methodology, it is easy to identify the values of the input parameters that provide the required parameters of accuracy and surface quality. This reduces the possibility of scrapping and additional milling operations, which results in a reduction of production costs.

In order to obtain the generality of the optimization methodology for thin-walled structures process planning, it is necessary to expand the research to other shapes, such as triangular, hexagonal and other more complex shapes.

Researching should also be expanded on machining of other light alloys and composites, as well as thin-walled structures with wall thickness up to 3 mm, and larger height-to-thickness ratio (> 30:1). Monitoring of the cutting forces, occurrence of vibrations in machining and possible deformations of workpiece structures should be taken into consideration as well.

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