Evaluation of Time Efficiency of High Feed Milling

Ján Duplák [1], Michal Hatala [1], Darina Dupláková [1], Jozef Steranka [1]

[1]Technical University of Košice, Faculty of Manufa cturing Technologies with a seat in Prešov, Štúrova 31, 080 01 Prešov Slovakia

***Abstract* – Nowadays, every manufacturing plant applies technologies, methods and procedures to ensure more efficient and cheaper production. In the manufacturing plant, one way to ensure more efficient and cheaper production is to apply the progressive technology – high feed machining. This article is focused on a description of basic principles of high feed milling and its subsequent application in the practice during the machining of aluminium alloy. This progressive method is considered from the point of view of time efficiency of the manufacturing process. Then a comparison with the time efficiency of the manufacturing process is realised by using conventional milling.**

***Keywords* – High feed milling, Time efficiency, Manufacturing process, Progressive technology.**

1. Introduction

High Feed Machining is a method that is classified as progressive method of machining. This method is three times faster than conventional method of machining. In this method, allowed is a little cutting depth a_p in cooperation with a big feed per tooth f_z by using the suitable tools. As a result of this machining method, there is a greater volume of the material. The maximum cutting depth is 2 mm and the value of feed per tooth is very high (up to 4mm/tooth). [1]

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Corresponding author: Darina Dupláková,
Technical University of Košice, Faculty of Manufa cturing Technologies with a seat in Prešov, Prešov Slovakia.
Email: darina.duplakova@tuke.sk

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This method works on way how to extend the life of the tool which means saving the tool in cooperation with the application of a small cutting depth and high feed utilization. The higher surface quality is achieved by reducing vibration. It is possible to remove 1000 cm3 of volume of material by this progressive method of machining per one minute. The high feed machining is possible to categorize to the roughing methods but it is possible to produce the high quality of surface and clear shapes. [2]

The cutting depths are small but the cut width is optional considering the tool geometry during the machining by high feed technology. An edge angle is ranging from 9° to 12° which reduces the effective chip thickness. [3]

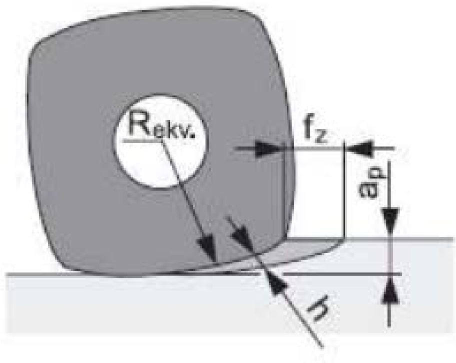

Figure 1. Diameter of chip thickness [3]

The basic advantages of high feed machining are the following [4]:

- without requirements of high spindle speed
- axial direction of cutting forces to the spindle
- reduction of vibration
- improved tool life and more stable cut
- it is possible to achieve up to tenfold feed in comparison with the conventional method of machining
- creation of clear shapes that do not require the semi-clear machining

The basic disadvantages of high feed machining are the following [4]:

- it is not possible to apply this method on the older machines
- raised vibration hazard
- raised noise levels and formation of noise tone component during the cutting process
- invariable work piece clamping

The high feed machining is applicable widely in practice. High percentage of manufacturing plants which are beginning to move from conventional machining methods to progressive technologies to increase efficiency and productivity. [5]
For the application of high feed machining, the CNC machine devices are used. These devices are characterized by high feeds and spindle speed. They are also characterized by short lead time achieving by high feed and short time for exchange of workpieces or tools. [6]

2. Material and Method

The progressive method - high feed milling is widespread method in the field of high feed machining. The high feed milling is a modern progressive technology of machining. Nowadays, this technology has wide application in the engineering industry. It provides the higher efficiency of production and reduces the production costs. [7]

The high feed milling is a method of milling material to achieve the highest possible reduction from workpiece while continually increasing productivity and subsequently shortening the time required to machining each component.

High feed milling combines a shallow cutting depth and a larger shape radius or small lead angle (Figure 2.). This angle is achieved by setting big radius on the cutting edge. This connection provides directing of cutting forces into the spindle with the result of high tool stability in the axial direction. [7]

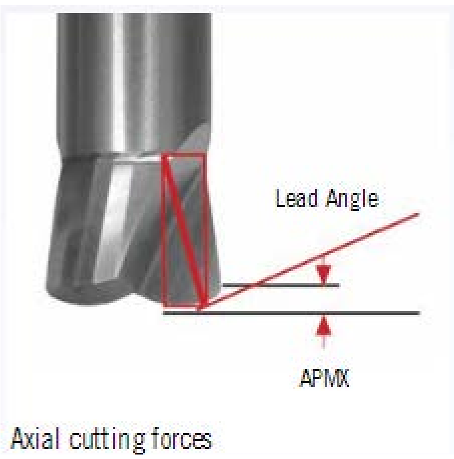

Figure 2. Lead angle – High feed milling [7]

The main cutting forces act in the lower part of the cutting edge. From this reason, the angle of cutting forces at a large radius is closer to the spindle axis. This distance is smaller than for the tools that have a small shape radius. [7],[8]

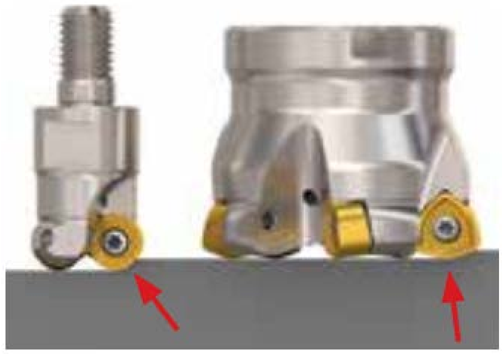

Figure 3. Direction of cutting forces – high feed milling [7]

On the basis of requirements from the practice, it was machined the aluminum alloy (EN AW-AlZn5,5MgCu) on machine – HAAS VF 2 – vertical machine tool with three axes (Figure 4.). This material is characterized by high strength and very good machining ability. From the metallurgical point of view, this material can be classified as heat-curable and precipitating.

Figure 4. HAAS VF-2

The basic properties of EN AW- AlZn5,5MgCu material:

- high strength
- Tensile strength: 360-540 MPa
- HB: 104 – 160
- Modulus of elasticity: 71GPa
- Modulus of Resilience: 98 to 1850 kJ/m^3
- Thermal conductivity: 130-160 W/m.K

The nomenclature - EN AW- AlZn5,5MgCu describes:

- marking according to EN
- aluminium alloy (A)
- wrought material (W)

Combination of words and numbers behind the dash denotes the quantity and the type of additive substances. This alloy is used in the engineering industry, the automotive industry and the aircraft industry.

The experiments were realised by using the following tools (Figure 5.):

- Milling head ISO 90P
- Monolith milling cutter Φ12
- Milling cutter Φ32

The basic parameters of the above mentioned tools are provided in the following table.

Table 1. Specification of tools

Milling cutter	Diameter of milling cutter [mm]	No. of teeth [mm]	Maximum cutting depth [mm]
Milling head ISO 90P	40	4	9
Milling cutter Φ32	32	3	15
Monolith milling cutter Φ12	12	4	1.5

Figure 5. Cutting tools

Legend to Figure 5:

I. Milling head ISO 90P
II. Milling cutter Φ32
III. Monolith milling cutter Φ12

3. Application of high feed milling in practice

Two experiments for evaluation of time efficiency were realised:

- Experiment No. 1 – application of high feed milling
- Experiment No. 2 – application of conventional milling method

These experiments were realised by producing a component (Figure 6.) from a semi-finished product (sizes: 115 x 35 x 20mm).

Figure 6. Product

In both experiments, the basic cutting conditions were calculated with respect to the machined material and the used tools. The specific values of cutting conditions are stated in the following table for the operations (1 – roughing of the workpiece face; 2 – smoothing of the workpiece face; 3 - roughing of the contour).

Table 2. Cutting conditions – Experiment No. 1

operation	diameter of milling cutter [mm]	No. of teeth	cutting speed [$m.min^{-1}$]	feed rate [$mm.min^{-1}$]	cutting depth [mm]	operating speed [min^{-1}]	feed per tooth [mm]
1.	40	4	180	480	1.8	1500	0.08
2.	12	4	120	768	1.5	3200	0.06
3.	32	3	500	2160	2	6000	0.12

In the Experiment No. 1, the milling cutter Φ32 was used for roughing of the contour. It was taken 15 mm of material during the roughing of the contour (Figure 7.).

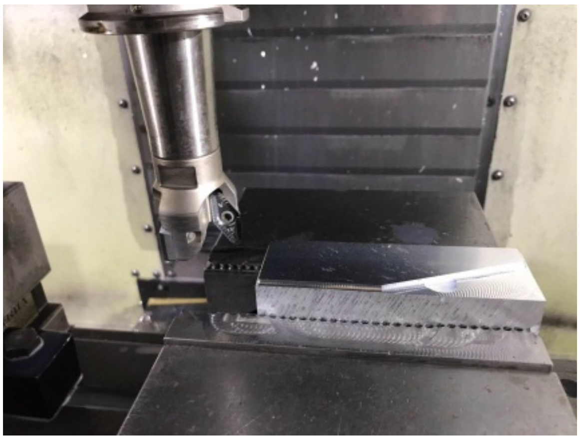

Figure 7. Realization of Experiment No. 1 – Contour milling

The second experiment consisted in machining of the same material but the conventional milling technology was used. The cutting conditions are presented in the following table for the particular operations (1- alignment of the face of the workpiece; 2 - roughing of the contour; 3 – reduction of the material from the face of the workpiece; 4 - roughing with a milling cutter).

Table 3. Cutting conditions – Experiment No. 2

operation	diameter of milling cutter [mm]	No. of teeth	cutting speed [m.min^{-1}]	feed rate [mm.min^{-1}]	cutting depth [mm]	operation speed [min^{-1}]	feed per tooth [mm]
1.	40	4	120	230	1.5	1000	0.08
2.	12	4	120	768	1.5	3200	0.06
3.	12	4	120	768	1.5	3200	0.06
4.	40	4	120	230	1	1000	0.08

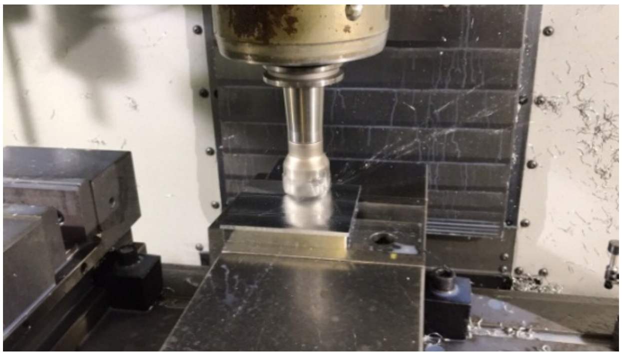

Figure 8. Realization of Experiment No. 2 – Milling of workpiece face

After the realization of experiments, the evaluation of production processes was realised from the point of view of time efficiency. The results are listed in the next section of the article.

4. Results and discussion

The total time efficiency of production process was considered by determination of total production time for one piece of product and production batch in the particular experiments. The total production time is composed of machining time and side time. The side time includes the time for tool change, clamping of the workpiece, loosening of the workpiece, etc. This time was measured by digital stopwatch and its average value was 1.5 min.

When determining the total production time for single piece production, the progressive [9] high feed milling technology is 9.17 minutes more efficient than conventional milling. Numerical results are also confirmed by the chart below.

Table 4. Results – total production time – one piece of product

No. of Experiment	Total production time [min]
Experiment No. 1	3.04
Experiment No. 2	12.21
Time difference	9.17

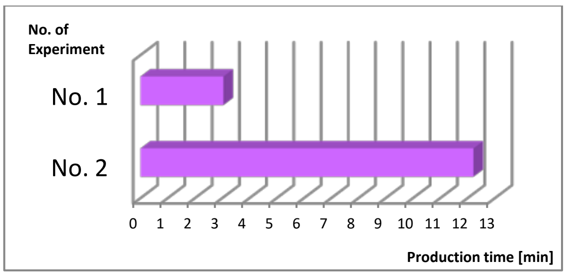

Figure 9. Diagram of total production time - one piece of product

The evaluation of time efficiency is presented in the following table - for one production batch (1200 pcs).

Table 5. Results – total production time - production batch

No. of Experiment	Total production of time [min]
Experiment No. 1	3 648
Experiment No. 2	14 652
Time difference	11 004

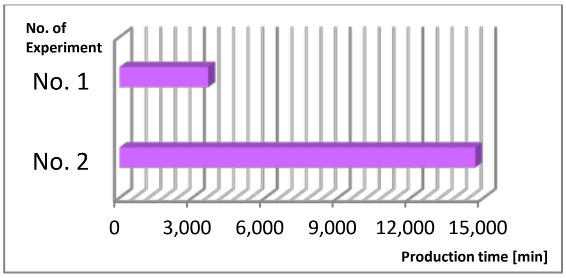

Figure 10. Diagram of total production time – production batch

On the basis of the above mentioned table it can be stated that even at a total production rate of 1200 pieces, it is more efficient to produce the component by progressive high feed milling technology.

The final evaluation of results is realised by determination of the difference between progressive milling technology (Experiment No. 1) and conventional milling technology (Experiment No.2) as well as the percentage expression in one piece production.

Table 6. Comparison of time efficiency in the realised experiments

Parameter (one product)	Value
total production time – high feed milling [min]	3.04
total production time – conventional milling [min]	12.21
Time difference [min]	9.17
Percentage [%]	**75.102**

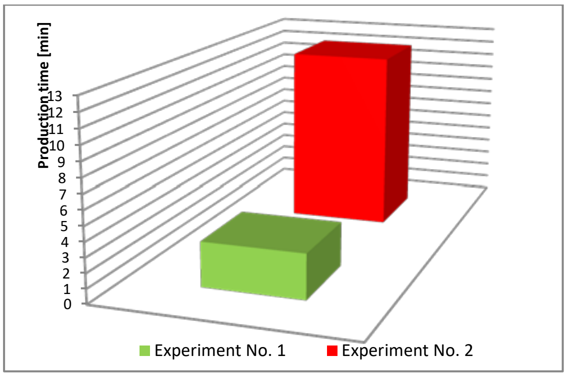

Figure 11. Diagram of time efficiency of realised experiments

As stated above (Table 6. and Figure 11.), it is possible to provide a higher time efficiency of production (more than 75%) by use of the high feed milling for a given material than with conventional milling.

5. Conclusion

Progressive technologies have become part and parcel of every engineering manufacturing plant. Whether it is turning, milling, or cutting-edge technology, innovation has an irreplaceable place in every field. [8],[9],[10] The presented article was focused on presentation of high feed milling technology and its application in the practice in the machining of aluminium alloy. This progressive method was evaluated from the point of view of time efficiency of production. Then, it was compared with time efficiency of conventional milling. From the results it can be stated – during the machining of the aluminium alloy from the point of view of time it is more suitable to apply the high feed milling before conventional milling. The subject of the further research is to determine the economic efficiency of the production process when applying a progressive machining method – high feed milling.

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