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Influence of Cutting Conditions on Surface Roughness During Milling of AISI 1060 Steel

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Abstract:
Chip-forming operations are referred to as "machining" in the engineering community, and this word is found in several dictionaries. The machining of metals and alloys is essential to many industrial processes, including the ultra-precision machining of incredibly delicate components. Metal cutting is typically connected with large enterprises that produce large items. The process of milling involves passing a workpiece through a rotating multiple teeth cutter to remove material. Due to the high tolerances and surface finishes that milling can offer, it is ideal for adding precision features to a part whose basic shape has already been formed. In this study AISI 1060 steel was used as workpiece material. Three cutting parameters were chosen namely; cutting speed, depth of cut and cutting feed. The cutting tests take place using a traditional milling machine of trade mark Frezarka FWD 32 to apply suitable speeds used normally in real machining processes. Based on the design of experiments using Taguchi method, a matrix of twelve tests is implemented. Based on the results of this work, it can be concluded that there is a good relationship between the cutting conditions and the average surface roughness, Ra. Thus, the roughness of the surface during milling can be optimized by the choose of the suitable cutting values of speed, feed and depth of cut.

Keywords: Milling process, ANOVA, Surface roughness, AISI 1060 Steel, Taguchi method.

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تأثير ظروف القطع على خشونة السطح أثناء تفريز الفولاذ *AISI 1060*

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الملخص
يشار إلى عمليات تشكل الرائش باسم "التشغيل" في الأوساط الهندسية، وتوجد هذه الكلمة في عدّة معاجم. إن تشغيل المعادن وسبائكها ضروري للعديد من العمليات الصناعية، بما في ذلك الماكينات الفائقة الدقة لمكونات حساسة. وعادة ما يكون قطع المعادن مرتبطاً بصناعات كبيرة تنتج أصنافاً كثيرة. تنجز عملية التفريز لقطع المعادن بتمرير قطعة عمل من خلال قطّاع متعدد الأسنان بالتناوب لإزالة رائش مادة المشغولة. ونظراً لما يمكن أن تقدمه عملية التفريز من تسامحات عالية ومن نهاية سطحية عالية، فإن من المثالي

إضافة هذه السمات الدقيقة إلى مشغولات انتجت بطرق تصنيع أخرى. في هذه الدراسة، استُخدم الصلب *AISI 1060* كمادة عمل. واختيرت ثلاثة عوامل للقطع هي: سرعة القطع، وعمق القطع، والتغذية. وتجري اختبارات القطع باستخدام آلة تفريز تقليدية تحمل علامة تجارية هي Frezarka FDD 32 لتطبيق السرعة المناسبة المستخدمة عادة في عمليات التشغيل الحقيقية. واستناداً إلى تصميم التجارب التي تستخدم طريقة تاقوشي، يجري تنفيذ مصفوفة من 12 اختباراً. بناءاً على نتائج هذا العمل، يمكن الخلوص إلى أن هناك علاقة جيدة بين ظروف القطع ومتوسط خشونة السطح، *Ra.* وبالتالي يمكن تحسين خشونة السطح أثناء عملية التفريز إلى أقصى حد باختيار قيم التشغيل المناسبة من السرعة والتغذية وعمق القطع.

الكلمات المفتاحية: التفريز، انوفا، خشونة السطح، الفولاذ 1060، طريقة تاقوتشي.

Introduction

Many dictionaries define machining as the process of creating chips, and this is how the term is used in the engineering industry. Large companies that produce large products are typically linked with metal cutting. Metal and alloy machining is essential to many production processes, including the ultra-precision machining of highly delicate components. Feeding a workpiece past a spinning multiple teeth cutter removes material is the description of the process of milling [1]. The milling machine is the device that holds the workpiece, turns the cutter, and feeds it. A quick way to machine is through the cutting action of the many teeth surrounding the milling cutter. The machined surface could have a curvature, an angle, or be flat. Any combination of shapes can also be achieved by milling the surface. Usually, it is employed to create parts with several characteristics, including slots, pockets, holes, and even three-dimensional surface shapes, that are not axially symmetric [2]. Additionally, milling is frequently employed as a secondary process to enhance or improve features on components made with a primary process. Milling is the best method for adding precision features to an item whose basic shape has already been produced since it can achieve high tolerances and surface finishes [3]. Every cutting edge on the milling cutter's perimeter functions as a separate cutter during the rotational cycle. The workpiece is resting on a table that regulates the feed in opposition to the cutter. There are three conceivable table movements in most machines: vertical, transverse, and longitudinal. However, in others, the table may additionally have a swivel or rotational movement. The milling machine can execute most tasks that are performed on shapers, drill presses, gear-cutting machines, and broaching machines [4]. Compared to a shaper, it creates holes to precise limits more easily and with a better finish. It is possible to take large cuts without significantly sacrificing accuracy or finish. Cutters function effectively and require little maintenance before needing to be re-sharpened. The milling machine is an essential instrument in the shop and tool room since it can usually finish the job in a single pass of the cutters. A milling operation's efficiency, quality, and overall success are all influenced by the cutting conditions of the machining process [5]. Among these parameters is the cutting feed, which is the distance the cutting tool or workpiece progresses in a single spindle and tool revolution, the depth of the tool in the workpiece along its axis as it performs a cut is known as the axial depth of cut. Low feed rates are necessary for significant axial depths of cut because they place a heavy stress on the tool and shorten its life. The depth of the tool along its radius in the workpiece as it makes a cut is known as the radial depth of cut.

The wide range of cutters that are available makes the milling machine quite adaptable. These cutters are often categorized as follows based on their overall shape: the most basic kind of milling machine is the hand mill, which is operated by hand. Either, the table installed on a permanent bed or the column and knee structure may be used. With the exception of its stronger build and power-feeding system, which regulates the table movements, the plain milling machine is comparable to the hand machine. There are three motions in plain milling machines of the column and knee types: longitudinal, transverse, and vertical [6]. In essence, the universal machine is a tool room machine designed to perform extremely precise tasks. It resembles a basic milling machine in appearance, but it is different because the worktable has a fourth movement that allows it to swivel horizontally, and it has an index or division head at the end of the table. In order to increase their usefulness as tool room machines, universal machines can also be fitted with a vertical milling attachment, rotary-table attachment, vise, slotting attachment, and other accessories. For universal machines, automatic cycle solutions are available that manage the table traverse and feed entirely from beginning to end [7]. Because the cutter spindle is positioned vertically, the machine is known as a vertical milling machine. The table moves similarly to that of simple machines. However, the spindle head can be turned, allowing the spindle to be positioned at any angle between vertical and horizontal in a vertical plane. The name of milling machine of the planer type comes from how much it resembles a planer. The work is fed against the spinning cutter at the appropriate speed on a long table that only moves longitudinally. The cutting spindle can move both vertically and transversely. These machines are intended for precise contour and profile duplicating as well as large-scale milling tasks involving the removal of substantial stock [8]. Fixed-Bed types of milling machines are robust manufacturing machinery that the worktable is supported by a hefty, hard casting called the bed, which only moves longitudinally. These machines often have an automatically regulated machining cycle and can handle heavy milling cuts on long-run manufacturing tasks. Numerical control (NC) equipment intended for small- to medium-lot production is called machining centers [9]. In a single configuration, the machining center can mill, drill, bore, ream, tap, and contour. Machine centers can be used to start and stop machines, change or select tools, perform two- or three-dimensional contouring using linear or other interpolation techniques, feed in one or more of the two or three axes, start or stop the spindle at a predetermined speed and rotational direction, index the table to a predetermined position, and turn on and off coolant, depending on the specific machine [10]. Off-machine loading and unloading of a pallet containing one or more parts is done by a computer NC profiler machine. Short threads and surfaces can be milled on the inside as well as the outside using planetary milling machines. Machines for engraving, profiling, and die and mold cutting have been developed, along with pantograph [11].

One element of surface finish is surface roughness. It is measured by the direction deviations of a real surface's normal vector from its ideal form. The surface is smooth if these variances are minimal, and rough if they are considerable [12]. Roughness is commonly understood in surface metrology to be the short-wavelength, high-frequency component of a measured surface. But in reality, to make sure a surface is appropriate for a certain task, it's frequently required to know both the amplitude and frequency. An actual object's interaction with its surroundings is significantly influenced by its surface roughness [13]. Roughness has an impact on a number of functional characteristics of parts, including coating, friction, wear and tear, light reflection, heat transmission, and the capacity to distribute and retain lubrication [14]. As a result, in order to maintain quality, the intended surface finish is typically specified and the necessary procedures are needed. Therefore, it is crucial to check the workpiece's surface roughness in order to evaluate the component's quality [15].

Material and methods

AISI 1060 Steel was the workpiece material employed in this investigation. Because of its high carbon content, 1060 steel is appropriate for uses requiring a high degree of hardness and wear resistance. High-carbon steel 1060 is a versatile material that may be used in a range of demanding applications due to its hardness and wear resistance [16]. The chemical composition, in weight percent of this material is shown in Table 1.

Table 1: Chemical composition of the workpiece material [17]

Material	AISI 1060 Steel								
Element	C	Al	Si	S	Cr	Mn	Ni	Cu	Fe
Weight %	0.76	0.02	0.31	0.03	0.05	0.74	0.07	0.06	97.97

The material was received in the form of blocks that were machined to parallel rectangles-shape having the dimensions shown in Figure 1.

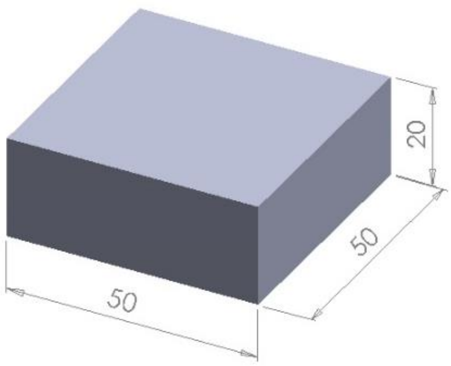

Figure 1: Workpiece geometry.

In this work, outer milling tests were performed. All of the cutting tests were performed under dry conditions on JAFO milling machine (Model, Frezarka FWD 32 Jafa FWS). In order for the effect of each parameter on the surface characteristics of the workpiece can be thoroughly investigated, three cutting parameters were chosen namely; cutting speed, cutting feed and depth of cut. The first independent parameter chosen was the cutting speed. In industry, the cost of machining depends strongly on the speed; the cost can be reduced by increasing the speed. In this study four cutting speeds in the range of 1120 r/min to 2400 r/min. Because of its great effect on the produced surface characteristics, the cutting feed was the second independent parameter used in this work, the range of feed is from 100 to 500 mm/min. The third parameter chosen was the depth of cut which can significantly affect the produced surface characteristics depending on the workpiece material. Four depths were used in this study ranging from 0.1 to 0.5 mm. The conditions are summarized in Table 2. The milling cutter that is used in this work is an indexable milling cutter with carbide inserts of Spkn 1203 EDR-EE model.

Table 2: Summary of cutting conditions.

Parameter	Level 1	Level 2	Level 3	Level 4
Cutting speed (rpm)	1120	1400	1800	2400
Cutting feed (mm/min)	100	250	355	500
Depth of cut (mm)	0.1	0.2	0.3	0.5

Traditional experimentation involves considerable effort and time. They are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only [18]. The Taguchi technique was created by Taguchi. He proposed that the three steps of system design, parameter design, and tolerance design should be followed while building an optimized process or product. [19]. When designing a system, an engineer uses their understanding of science and engineering to create a basic functioning prototype that includes both the process and product design stages. The selection of components, materials, approximate values for product parameters, etc., is done during the product design stage. Optimizing process parameter values is the aim of parameter design in order to enhance quality attributes. Lastly, tolerances around the ideal configurations suggested by the parameter design are found and examined using tolerance design. To obtain high cutting performance in milling, the parameter design proposed by the Taguchi method is adopted in this paper. Basically, experimental design methods were developed originally by Fisher [20]. After then, the experimental findings are converted into a signal-to-noise (S/N) ratio. In order to quantify the quality attributes that deviate from the desired values, Taguchi suggests using the S/N ratio. When analyzing the S/N ratio, three quality characteristic categories are typically identified: the lower the better, the higher the better, and the nominal the better. In order to determine whether process parameters are statistically significant, an ANOVA is also carried out. It is possible to predict the ideal set of process parameters using the S/N and ANOVA studies.

The examined workpiece material, which is the steel, mentioned above, is fixed directly on the milling table where it is fed against the cutter. The milling cutter rotated according to the spindle speeds of the machine. The direction of workpiece movement is perpendicular to the face of the cutter. This movement is controlled automatically according to the movement of the milling machine mechanism. During this movement of the table, the machining of the workpiece's face takes place. The cutting tests take place using a traditional milling machine of trade mark Frezarka FWD 32 mentioned above to apply suitable speeds used normally in real machining processes. Based on the design of experiments using Taguchi method a matrix of nine tests is implemented. The matrix of conditions of experiments using the technique mentioned above is shown in Table 3. Twelve machining tests have been made with different conditions based on the design of experiments listed in Table 3.

Table 3: Experimental design matrix.

Test No.	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)	Ra (µm)
1	1120	100	0.1	0.2
2	1120	200	0.2	0.34
3	1120	250	0.3	0.52
4	1120	355	0.5	1.1
5	1400	100	0.2	0.22
6	1400	200	0.1	0.28
7	1400	250	0.5	0.62
8	1400	355	0.3	0.95
9	1800	100	0.3	0.26
10	1800	200	0.5	0.56

11	1800	250	0.1	0.36
12	1800	355	0.2	0.85

In this work, the produced surface roughness was carefully measured using standard techniques, and the ALPA-SM RT-20 instrument which is simple and easy to use is used for roughness measurements. This instrument is ideal for measurements directly on workstations or production machines. The ease of use makes it suitable to characterize the roughness of the test piece numerically

Results and discussion

For simplicity, in this investigation, average roughness Ra was measured using the mentioned instrument, as the main parameter on the surface profile, even though the average roughness does not tell the whole information about a surface. The results of this work are presented here, based on the experimental work mentioned above in the methodology. The measured values of average surface roughness, Ra are presented in Table 3.

The graph shown in Figure 2 which has been made based on the analysis of the measured values of the experimental tests shows the relationship between the different factors used in this study and response, Ra, and since smaller values of roughness is the better, and then smaller signal-to-noise is better. The smallest values can be obtained when the speed is 1400 r/m, the feed is 100 mm/min and the depth of cut is 0.1 mm.

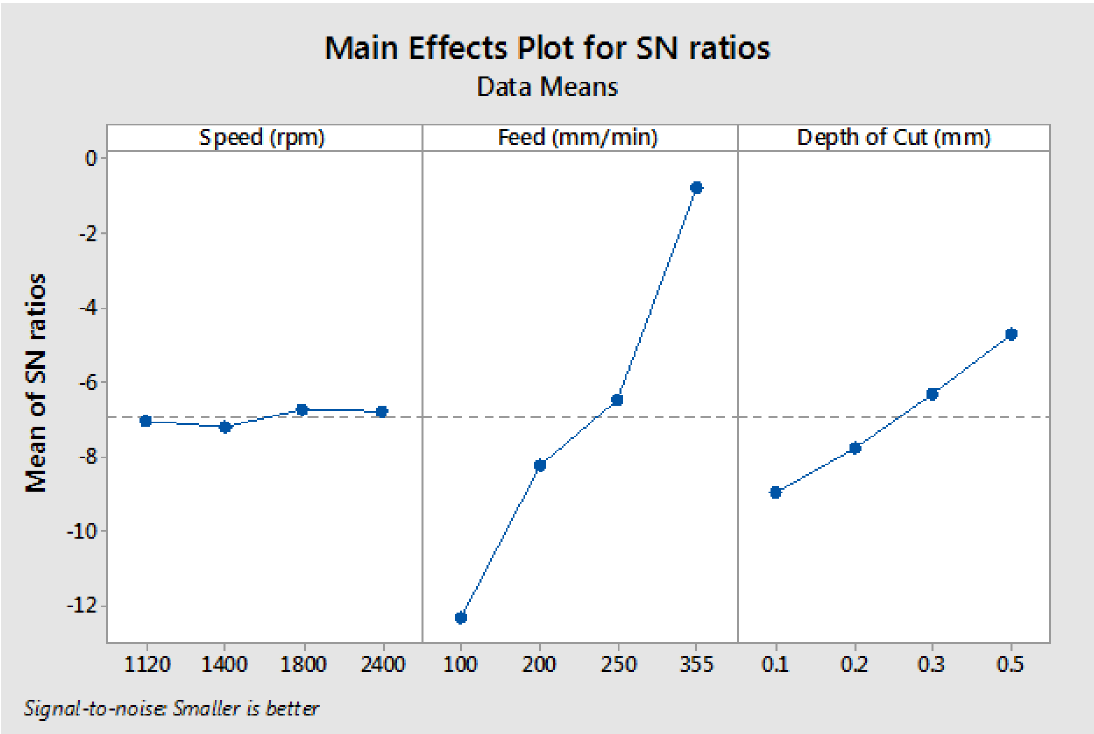

Figure 2: Signal-to-noise graph for speed, feed and depth of cut.

Conclusion

The overall aim of this work was to investigate the effect of cutting conditions on the average surface roughness of AISI 1060 steel during the milling process. Some conclusions can be drawn here:

1. The use of the design of the experiment by Taguchi technique saves time and effort without the lack of accuracy.
2. The analysis by the use of Minitab package gives clear idea about the relationship between parameter and response.
3. The average surface roughness can be improved by controlling the level of the cutting factors.

The better value of roughness can be obtained for example when speed is the medium, feed is the minimum and depth of cut is the minimum

References

1. Wright, E.T.P., *Metal cutting*. fourth ed. 2000.
2. *Milling*. 2018 [cited 2018 29 June]; Available from: http://www.custompartnet.com/wu/milling.
3. Gowd, G.H., et al., *Optimal Selection Of Machining Parameters In CNC Turning Process Of EN-31 Using Intelligent Hybrid Decision Making Tools.* Procedia Engineering, 2014. **97**: p. 125-133.
4. Groover, M.P., *Fundamentals of modern manufacturing: Part 2*. 2010, John Wiley & Sons, Inc.
5. Zain, A.M., H. Haron, and S. Sharif, *Application of GA to optimize cutting conditions for minimizing surface roughness in end milling machining process.* Expert Systems with Applications, 2010. **37**(6): p. 4650-4659.
6. Martellotti, M., *An analysis of the milling process, part II—down milling.* Transactions of the American Society of Mechanical Engineers, 1945. **67**(4): p. 233-251.
7. Machine, R.-T.U., *Column~ Overarm m [~'"~~ Column Overar! C utter~ Wrkpiece I~'~ Spindle LL~~ Cutter.* 1989.
8. Miller, R. and M.R. Miller, *Audel Machine Shop Tools and Operations*. Vol. 9. 2004: John Wiley & Sons.
9. Vafaeesefat, A., *Automatic generation of NC tool path programs for multi-axis mould manufacturing*. 1995: Ecole polytechnique de Montreal.
10. Krar, S. and A. Gill, *Computer Numerical Control Programmig Basics.* 1999.
11. Parraman, C. and M.V.O. Segovia, *2.5 D printing: bridging the gap between 2D and 3D applications*. 2018: John Wiley & Sons.
12. Gold, G. and K. Helmreich, *A physical surface roughness model and its applications.* IEEE Transactions on Microwave Theory and Techniques, 2017. **65**(10): p. 3720-3732.
13. SUHAIMI, H., *DESIGN AND DEVELOPMENT OF SURFACE ROUGHNESS TESTER.*
14. Singh, S., et al., *A STUDY OF THE EFFECTS OF MACHINING PARAMETERS ON SURFACE ROUGHNESS USING RESPONSE SURFACE METHOD ON EN11 ALLOY STEEL IN THE END-MILLING PROCESS.* INTERNATIONAL JOURNAL OF MECHANICAL ENGINEERING AND TECHNOLOGY (IJMET) 2014. **5**(11): p. 47-58.
15. Kamguem, R., S.A. Tahan, and V. Songmene, *Evaluation of machined part surface roughness using image texture gradient factor.* International Journal of Precision Engineering and Manufacturing, 2013. **14**: p. 183-190.
16. Mia, M. and N.R. Dhar, *Prediction and optimization by using SVR, RSM and GA in hard turning of tempered AISI 1060 steel under effective cooling condition.* Neural Computing and Applications, 2019. **31**: p. 2349-2370.
17. Abrão, A., et al., *The influence of heat treatment and deep rolling on the mechanical properties and integrity of AISI 1060 steel.* Journal of Materials Processing Technology, 2014. **214**(12): p. 3020-3030.
18. Oktem, H., T. Erzurumlu, and I. Uzman, *Application of Taguchi optimization technique in determining plastic injection molding process parameters for a thin-shell part.* Materials & Design, 2007. **28**(4): p. 1271-1278.
19. Yang, W.p. and Y. Tarng, *Design optimization of cutting parameters for turning operations based on the Taguchi method.* Journal of Materials Processing Technology, 1998. **84**(1-3): p. 122-129.
20. Rao, C.R., *RA Fisher: The founder of modern statistics.* Statistical science, 1992: p. 34-48.