doi: 10.18323/2782-4039-2024-2-68-9

Surface finish and cutting efficiency in gingelly oil during machining: regression analysis

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Received 31.08.2023 *Accepted 19.02.2024*

Abstract: This study evaluates the use of gingelly oil as an eco-friendly cutting fluid for the turning operation. Experiments were conducted to determine the effect of nose radius, and rake angle on tool wear, surface formation, and cutting force. In addition, different lubrication techniques, such as cutting fluids and bio-oils, were investigated to determine their potential for minimising friction, heat generation, and tool wear during machining. In comparison to dry cutting, and conventional petroleum-based lubricants, the results demonstrate that gingelly oil consistently produces smoother surface finishes, and reduces cutting forces. The relationships between cutting parameters, and surface finish were analysed using statistical modelling, with *R*-square and *p*-values used to quantify correlations and predictor significance. The findings highlight the viability of gingelly oil as a cutting fluid and the significance of optimising process parameters for increased machining efficiency.

Keywords: cutting efficiency in gingelly; mechanical processing in gingelly oil; cutting fluid; sustainable machining; surface finish; tool wear; rake angle; nose radius.

For citation: Shailesh Rao A. Surface finish and cutting efficiency in gingelly oil during machining: regression analysis. *Frontier Materials & Technologies*, 2024, no. 2, pp. 101–111. DOI: 10.18323/2782-4039-2024-2-68-9.

INTRODUCTION

The choice of cutting fluid is critical in machining operations, since it directly affects surface quality and cutting efficacy. Generally, the cutting fluid creates a protective barrier between the cutting tool and the workpiece, reducing tool wear and friction. The use of bio-oils in the machining process has recently shown an improvement in the cutting efficiency and surface quality. Here the lubricating characteristics improve the overall surface quality, by allowing for a more seamless interaction between the tool and the workpiece.

In conventional machining processes, the dynamic interplay between the cutting tool, and the workpiece is critical to achieving the desired surface polish and form. This contact, defined by a ploughing motion, results in the removal of metals, shaping the workpiece with the accuracy of sharp tools, and sparking an investigation into cutting mechanisms [1]. The cutting processes have a wide range of performance implications, including surface quality, precision, tool wear, chip formation, burr development, material selection, and more [2]. These characteristics, taken together, define the research focus, with the goal of gaining a full understanding of industrial machining. A key difficulty in this arena is energy efficiency in manufacturing. Inappropriate process parameters can lead to increased energy consumption and production costs [3]. As a result, a thorough examination into the optimal process parameter selection becomes necessary.

In the field of improved machining process, the degradation of the nose radius, and other tool surfaces is a cause for worry. Defining workpiece process parameters is critical to achieving the specified machine surface and other desirable characteristics. The standard turning parameters, if not carefully chosen, might result in suboptimal machine surfaces and unnecessary tool wear. To address this, the vibration and instability of turning tools have been thoroughly investigated [4]. The consequences of tool vibration are poor surface polish, detectable noise, and edge blunting, emphasising the complex interaction of elements in achieving machining precision.

The authors [5] investigated tool wear and longevity in the turning of aluminium alloys. The study incorporates systematic variations in the rake angle and other relevant process variables to determine their impact on tool longevity. The positive rake angle improved the tool life during the machining process. Establishing an appropriate tool configuration improves turning conditions, with machinability gains gained by precisely aligning the tool point, angle, height, and deflection [6]. The nose radius is a critical parameter to consider when evaluating turning processes, as it has a significant impact on the outcome of machining operations. There are detailed studies on heat generation, surface development to the rake angle utility, and tool life for machining hard materials [7]. Further, the cutting forces are determined using a lathe tool dynamometer for the various negative and positive rake angles. Notably, positive rake angles helped in reducing the cutting force [8].

Changes to machining process parameters, such as spindle speed and feed rate, cause the tool profile and nose radius to become blunted. This tendency is most pronounced when the parameters are changed, resulting in higher tool wear and degradation, particularly with deeper cuts [9; 10]. The incorrect parameter selection has significant consequences beyond tool wear, including increased temperatures and a degraded surface finish. The rake angle is an important aspect in determining tool performance, and when maximised, it adds to longer tool life. However, it introduces the trade-off of dulling and creating tool clatter, emphasising the delicate balance required for parameter selection [11–13]. The interplay between the tool's nose radius and rake angle has a substantial impact on the tool profile during machining, altering the smoothness of the machined surface. Hence, maintaining a specified nose radius range, such as 0.4–0.5 mm, has been shown in improving surface quality, especially when cutting high-strength AISI 1040 stainless steel [14]. The deeper incisions, as well as the presence of a nose radius, contribute to crater development and tool flank wear. The inappropriate turning process settings can result in discontinuous chips [15; 16]. An alternate method, magnetic cutting, has shown promise in improving turning machinability, surface characteristics, and tool life [10]. These advanced methods highlight the complex link between machining parameters and their significant influence on tool performance and surface properties in metalworking operations.

The chip-tool interface contact area is determined by the rake angle of a cutting tool. It is difficult to select the rake angle, since any deviation from the optimal value impacts the tool profile and machined surface. An increase in rake angle results in an increase in chip-tool friction. The cutting force, and contact area are both reduced by the rake angle. Many studies are being conducted to determine how process parameters influence rake angle, and machining processes. It is difficult to comprehend its impact on machining parameters. An investigation, of the ways in which rake angle affects machining parameters in ductile and brittle materials, was carried out by the researchers. During the procedure, a comprehensive study was done to identify the machining settings [14]. The rake angle and feed rate both contribute to a reduction in cutting force, when machining steel alloys. Here an in-depth investigation was conducted into the connection that exists between vibration and rake angle. The amplitude of vibration decreased as the rake angle increased [17]. An investigation was conducted on the modifications to the tool life rake angle. By reducing the rake angle, the nose radius was blunted. It was determined that a rake angle of 20° produced the greatest results in terms of tool life and surface finish [18].

Cutting fluids are critical for reducing heat generated at the chip-tool interface because of cutting forces. These fluids have the dual function of cooling and lubricating the cutting operation, resulting in longer tool life. Cutting fluids passing over the chip-tool interface, contribute to lower cutting temperatures [19]. The current research is focused on alternate cooling and lubrication technologies such as bio-oils, cryogenics, and chilled air, to address environmental problems and optimise milling operations [20; 21].

In the continued pursuit of sustainable machining methods, current research efforts are mostly focused on the usage of bio-oils. The researchers are currently investigating the viability of replacing petroleum-based lubricants with bio-oils, which are known for their non-hazardous properties. Some studies on the usefulness of vegetable oils, such as palm and shear butter oils during turning operations are carried out to determine their impact on surface quality and tool performance. They found an improvement in the surface quality and improvement in the tool life during the machining process [22]. The comparative investigation of palm and shear butter oils demonstrated significant improvements in chip thickness, and tool lifespan, with the added benefit of reducing the disagreeable aromas associated with traditional petroleum-based lubricants [23]. Similarly, the extraction of jatropha seed oil during machining resulted in lower surface temperatures, and better surface finishes, demonstrating the potential of bio-oils in improving machined surfaces [24]. Notably, as compared to mineral-based cutting solutions, coconut oil produced better surface quality and related to less tool wear [25].

The comparative examination of diverse bio-oils, as mentioned by researchers [26; 27] has become a focus point in comprehending their individual properties and performance characteristics. Using statistical techniques such as Anova, researchers are improving process parameters in experimental designs, to improve the use of bio-oils in machining operations [28; 29].

The investigation and prediction of the performance of various bio-oils as cutting fluids, in machining operations, can be accomplished by implementing advanced data analytics approaches [30]. Here a comprehensive predictive model can be created to systematically evaluate the feasibility and effectiveness of various bio-oils. The researcher created a model that contains complicated factors, such as bio-oil classification, machining parameters (e. g., cutting speed, input rate), material properties, and specific targeted machining outcomes [31]. The prediction model uses advanced statistical approaches, and machine learning algorithms to identify complicated patterns, and relationships in the dataset. This permits the estimate of the impact of using specific bio-oils as cutting fluids based on available data [32]. The model expands its predictive capabilities to measure critical performance indicators, such as surface finish quality, tool wear rate, and chip formation, for each bio-oil under changing machining settings [33]. The use of predictive modelling in the study of bio-oils, as cutting fluids, provides researchers with profound insights into the nuanced benefits and drawbacks of certain bio-oils [34]. This analytical method supports informed decision-making processes, machining operation optimisation, and environmental impact mitigation, by encouraging the use of non-hazardous and sustainable cutting fluids.

According to the available literature, a thorough evaluation of the feasibility, and performance of various bio-oils as cutting fluids in machining processes, involves rigorous experimental investigations as well, as the use of predictive modelling methodologies. The impact of bio-oils on essential metrics such as surface finish, tool wear, chip formation, and environmental consequences should be thoroughly investigated in this research. The bio-oils shows potential as practical and environmentally benign replacements, to petroleum-based lubricants in machining operations, according to the existing literature. However, in-depth experimental research combined with advanced predictive modelling techniques, are required to gain a deeper knowledge of their performance characteristics.

This study is required to perform extensive trials, and build accurate predictive models capable of comprehensively assessing the efficacy of bio-oils as cutting fluids. Furthermore, these initiatives not only encourage sustainable practices and minimise reliance on petroleum-based lubricants, but they also help to expand bio-oil knowledge and its use in the manufacturing sector.

METHODS

This study identified gingelly oil, an edible vegetable oil derived from gingelly grains, as a viable substitute for mineral oils in the machining process. Table 1 compares the characteristics of gingelly oil and petroleum-based oil. In the investigation, a BALAJI Model 215 Super Series medium-duty lathe was utilised. 20 mm in diameter and 100 mm in length AISI 1014 mild steel workpieces were securely held in a three-jaw chuck, and spun at 328 and 750 rpm. The feed rates were held constant at 0.23 mm/rev for both experiments. For the machining process, an INDIAN TOOL manufacturer produced an HSS tool with 10 % cobalt, a 12.7 mm square section, and a 50 mm length. The experimental work was carried out with a variety of tool rake angles (5, 8, and 11°), and tool tip radii (1, 1.5, and 2 mm). The gingelly oil was delivered at a constant rate of 50 ml/min, while the petroleum-based oil (SAE 20W-40) served as a cutting fluid, and lubricant at a rate of 72 ml/min. The experiments were conducted in three distinct ways: without any cutting fluid (dry running), with a cutting fluid derived from petroleum (SAE 20W-40), and with gingelly oil as the cutting fluid. The surface roughness (Ra) of the workpieces was determined using a portable MITUTOYO SJ-210 surface roughness measuring device. This experimental setup enabled a thorough evaluation of gingelly oil's effectiveness as a cutting fluid, comparing its impacts on surface roughness to those of dry running, and standard petroleum-based cutting fluids. The cutting forces were measured using a lathe tool dynamometer. The cutting tool was inserted into the Contact-type Lathe Tool Dynamometer, and secured to the lathe's cross slide. Before starting the lathe machine, both the speed and feed were set to zero, and the feed was automatically applied to the tool. The surface roughness measurements were taken using a talysurf (MITUTOYO brand) under varied cutting conditions.

RESULTS

Fig. 1 demonstrates a notable disparity in surface smoothness, depending on the size of the workpiece, and the type of cutting operations used, especially when utilising a 5° rake angle, and 1 mm nose radius. The employment of the dry cutting technique resulted in a lower level of surface roughness, in comparison to the utilisation of cutting fluids, regardless of whether the cutting fluids were derived from petroleum or gingelly oil. Despite this, the surface roughness values increased with the increase in specimen diameter. Here the amount of sharpness over the cutting tool tip did not have any impact on the quality of the surface finish. Although some of the examples revealed surface qualities that were remarkable, others displayed levels of roughness that were far higher. Considering this, it appears that the surface finish is determined by a greater number of elements than the sharpness of the cutting tool in these conditions.

Fig. 2 depicts the effect of a higher cutting speed (750 rpm) on surface irregularity for various diameters of workpieces based on experimental data. When the cutting speed was increased to 750 rpm with a 5° rake angle, a remarkable increase in surface irregularity from 5.4 to 8.7 µm was observed. The increased rake angle and a 2 mm nose radius resulted in smoother surface finishes, and decreased cutting forces, as surface roughness improved. Notably, lower nose radii exhibited insufficient tool-to-workpiece adhesion, resulting in dispersed cutting force values for dry and petroleum-based cutting fluids. With its triglyceride content, gingelly oil displayed superior lubrication properties, generating a robust lubricant film that reduced friction and tool wear during machining. Consequently, this contributed to the finer formation of the machined workpiece's surfaces.

DISCUSSION

Effect of surface finish on different lubrication conditions

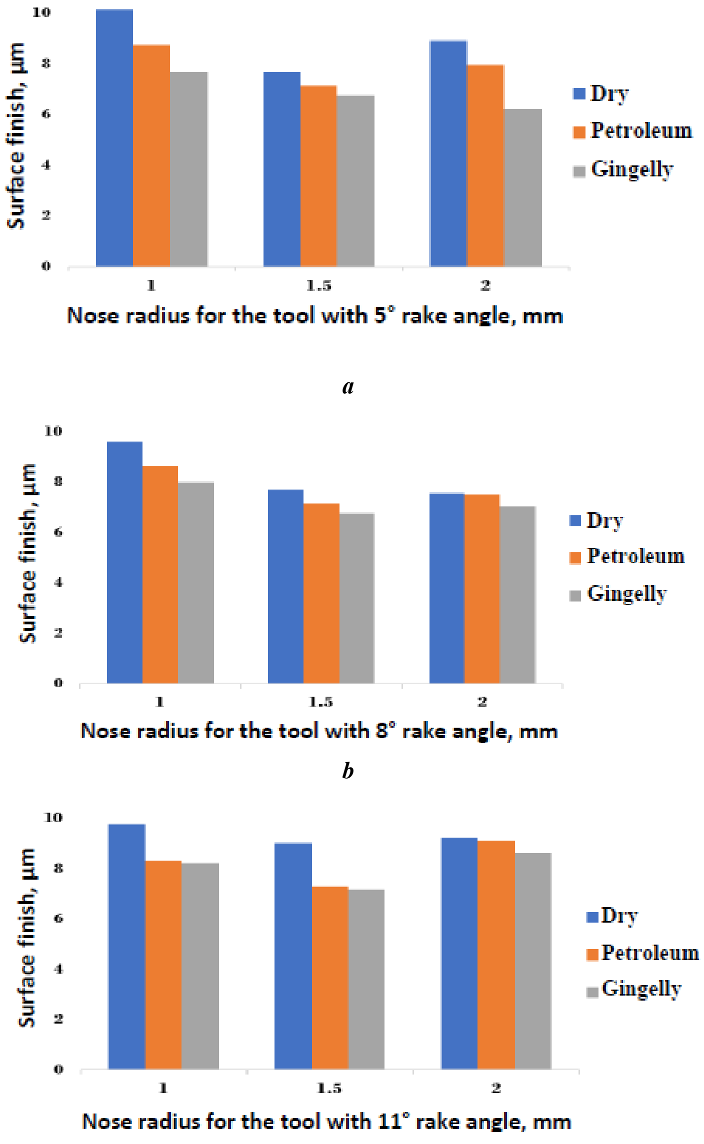
Further investigation indicated that raising the cutting tool's nose radius, resulted in increased adhesiveness between the tool and the workpiece, resulting in better and

***Table 1.** Characteristics of petroleum based oil and gingelly oil*
***Таблица 1.** Характеристики смазочно-охлаждающей жидкости на нефтяной основе и кунжутного масла*

Characteristics	Petroleum based oil (SAE 20W-40)	Gingelly oil
Flash point	210 °C	255 °C
Fire point	215 °C	280 °C
Density at 50 °C	774 kg/m^3	780 kg/m^3
Kinematic viscosity at 50 °C	2.39×10^{-5} m^2/s	3.72×10^{-5} m^2/s
Dynamic viscosity at 50 °C	1.86×10^{-3} N-s/m^2	2.67×10^{-3} N-s/m^2
Colour	Red	Clear yellow

more consistent surface finish values. The smoother surface finishes of 4.9 to 6 µm were attained with a tool nose radius of 1.5 mm, when gingelly oil was utilised as the cutting fluid. Furthermore, using a larger tool nose radius of 2 mm resulted in a 20 % reduction in surface roughness measurements, demonstrating the beneficial effect of increased nose radius on surface quality. Moving to an 8° rake angle, a limited variation range of cutting forces resulted in a significant difference in surface finish between the dry cutting procedure and the usage of petroleum-based cutting fluid. This is due to probable flaws in the machining process during turning operations. When gingelly oil was used as the cutting fluid, however, there was a considerable improvement in contact between the cutting tool and the workpiece, resulting in smoother surface finish values. Notably, increasing the tool nose radius improved the surface polish even more, due to increased ploughing area, and longer contact time between the tool and workpiece.

Further, the increase in the rake angle effectively reduced burr formation at the tool-workpiece interface, allowing the tool to glide through the material with greater ease. However, dynamic forces must be considered in a balanced manner, as exceedingly steep rake angles may not guarantee smoother operation. An optimal rake angle of 8°, appeared to accomplish favorable dynamic force balancing, reducing tangential force, while increasing thrust force at the interface of the tool tip. During this procedure, slight increases in surface roughness were observed. As a cutting fluid, gingelly oil demonstrated superior lubrication and cooling properties compared to cryogenic fluids, allowing for improved tool-to-workpiece slippage and thereby enhancing machinability. In addition, the use of higher cutting

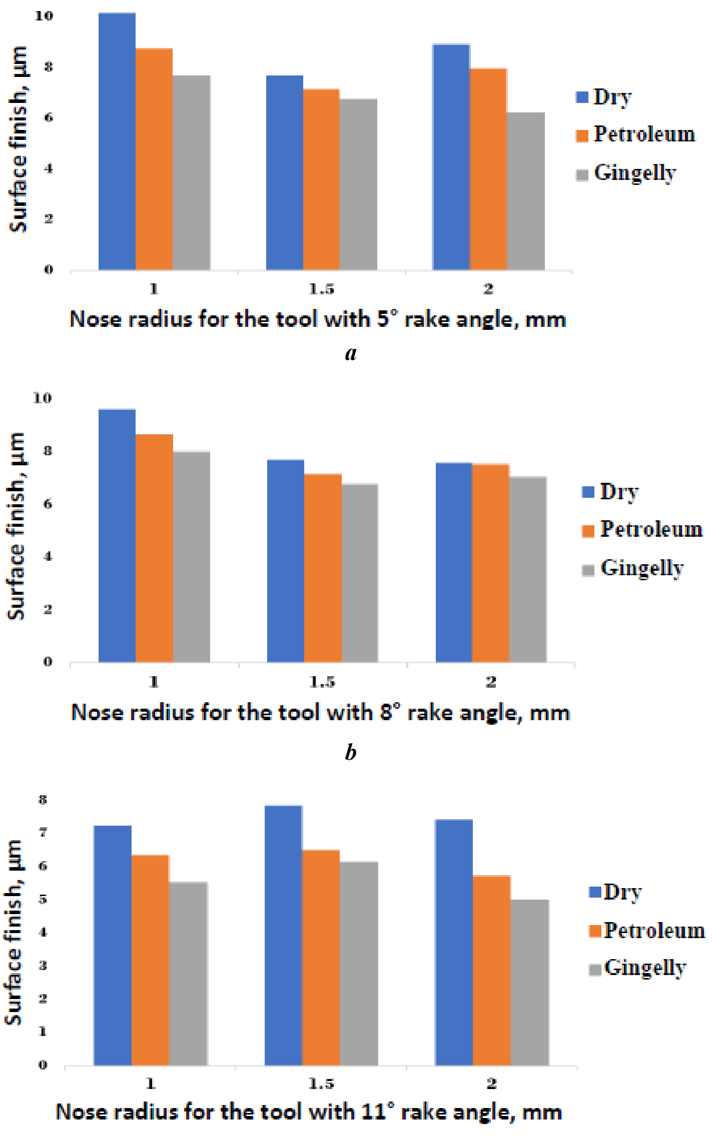


a

b

c

Fig. 1. *Effect of the surface finish over nose radius*
*for the varying rake angles 5° (**a**), 8° (**b**), 11° (**c**), and cutting speed 328 rpm*
Рис. 1. *Влияние на качество поверхности радиуса закругления вершины*
*при передних углах инструмента 5° (**a**), 8° (**b**), 11° (**c**) и скорости резания 328 об/мин*



a

b

c

Fig. 2. *Effect of the surface finish over nose radius*
*for the varying rake angles 5° (**a**), 8° (**b**), 11° (**c**), and cutting speed 720 rpm*
Рис. 2. *Влияние на качество поверхности радиуса закругления вершины*
*при передних углах инструмента 5° (**a**), 8° (**b**), 11° (**c**) и скорости резания 720 об/мин*

speeds (750 rpm) with gingelly oil, led to significant advances in cutting processes, resulting in superior surface finishes, when compared to lower cutting speeds. Combining a higher cutting speed (750 rpm), a rake angle of 8°, and a nose radius of 2 mm with gingelly oil as the cutting fluid, resulted in significant improvements in machining performance. Compared to other process parameters, these enhancements included reduced cutting forces (approximately 5 to 25 % reduction), and enhanced surface roughness (approximately 2 to 15 % improvement).

Statistical model

The objective of the statistical model proposed in this research is to examine the impact of process factors on the quality of the output in the machining process. Here the cutting force, and roughness data from the experimental work is tabulated in Excel sheet and R software was used to determine the correlation and regression studies. Table 2 presents the dataset for 20 mm diameter specimen, encompassing factors such as nose radius, rake angle, cutting force, and surface finish.

The experimental study showed a statistically significant inverse link between surface finish, and various lubrication conditions, particularly in relation to nose radius and rake angle. The rake angle correlation coefficients ranged from −0.2 to −0.4, whereas the nose radius correlation coefficients ranged from −0.3 to −0.6. The discovered negative relationships, suggest that increasing the rake angle and nose radius improves the surface quality. A regression model was created to improve understanding of the relationship between different machining parameters and surface finish. This study focused on the interaction between several independent variables, such as cutting speed, cutting force, rake angle, and nose radius, and the dependent variable, surface finish. However, the built multiple regression model was ineffective, as demonstrated by R-square values, ranging from −0.1 to −0.3. The more independent process parameters were added to the model, its overall stability and accuracy decreased. On the other side, investigating the effect of rake angle and cutting force while maintaining constant cutting speed surfaced as a potentially valuable route for enhancing the model. This phenomenon is most likely due to the increased complexity and interdependence brought about by the integration of several variables.

Furthermore, the p-values produced from the multiple regression model were found to be greater than the 0.05 significance level. This shows that the predictors utility in clarifying surface finish variability, did not approach statistical significance, possibly due to intricate interactions among variables that were not fully accounted for by the model.

This research aims to understand the intricate correlation between surface finish and critical cutting factors in machining processes. It utilises regression methods to address the shortcomings of conventional methodologies. Conventional approaches have faced difficulties in accurately capturing the complex non-linear relationships and interactions between important factors such as cutting speed, cutting force, rake angle, and nose radius. To overcome this deficiency, we have implemented divided strategies, which are effective in handling complex interconnections, and assessing the combined effect of these dividing elements on the evenness of the surface. To cover a wider range of cutting circumstances, trials were carried out with several diameters (8, 12, and 15 mm). The experimental data was then organised and analysed for various nose radius, and rake angle settings.

The influence of cutting force, diameter, and rake angle on surface polish while keeping a consistent nose

Table 2. *Cutting force and surface roughness values for the different process parameters*
Таблица 2. *Значения силы резания и шероховатости поверхности при разных параметрах процесса обработки*

Rake angle	**Nose radius**	**Cutting force (N)**			**Cutting speed (rpm)**	**Surface roughness (µm)**		
		dry turning	**petroleum based lubrication**	**gingelly oil lubrication**		**dry turning**	**petroleum based lubrication**	**gingelly oil lubrication**
5	1	459	451	448	328	9.350	7.388	7.455
5	1.5	466	441	438	328	9.350	7.388	7.455
5	2	452	444	319	328	8.948	7.021	5.331
8	1	444	432	420	328	6.967	6.521	5.335
8	1.5	458	451	450	328	7.161	6.661	6.117
8	2	430	437	318	328	5.636	7.963	6.548
11	1	466	458	447	328	9.788	8.327	8.221
11	1.5	473	469	446	328	9.017	7.287	7.171
11	2	441	438	318	328	9.248	9.132	8.626
5	1	470	462	444	750	10.152	8.758	7.682
5	1.5	477	461	448	750	7.682	7.152	6.758
5	2	382	343	327	750	8.920	7.980	6.230
8	1	469	450	444	750	9.596	8.651	7.989
8	1.5	476	460	454	750	7.682	7.152	6.758
8	2	360	323	310	750	7.560	7.510	7.030
11	1	472	461	457	750	7.249	6.351	5.532
11	1.5	483	462	434	750	7.847	6.490	6.143
11	2	356	317	311	750	7.420	5.730	5.020

radius was successfully investigated. The results of these analyses were evaluated using statistical metrics, notably *R*-square values, and *p*-values, which reveal the strength of the correlations and the importance of the predictors. The *R*-square and *p*-values for the various rake angle and nose radius are shown in Tables 3 and 4.

It was found that a rake angle of 8°, and a nose radius of 2 mm, resulted in higher surface finish performance in their testing. Among all the trial settings investigated, these exact combinations of cutting parameters produced the greatest results. It is understood that chatter (vibrations during cutting), climatic conditions, machine parameters, and other unknown variables, all influence the variation in cutting force and surface finish. These variables can cause variability in the machining process, resulting in variations in cutting force, and surface finish quality. Despite the influence of these and other elements, it is found that the rake angle, nose radius, cutting speed, and diameter all played important roles in enhancing surface polish, and cutting force. These critical cutting parameters were found to have a major impact on final surface smoothness, and guaranteeing adequate cutting force levels during the machining process.

Statistical metrics, such as *R*-square and *p*-values are used to quantify the associations, and assess the relevance of the identified predictors. The *R*-square value quantifies the amount of variance in the dependent variable (surface finish), explained by the independent variables (rake angle, nose radius, cutting speed, and diameter). The *p*-value, on the other hand, reveals the statistical significance of the predictors' effects. Based on the *R*-square and *p*-value data, the greatest values were associated with an 8° rake angle, and a 2 mm nose radius. This understands that these precise rake angle and nose radius combinations, have a significant and favourable impact on surface finish quality. Working under these optimised conditions resulted in significantly improved surface finish, when compared to other experimental settings, according to the data. In contrast, weak *R*-square and *p*-values were obtained for other working circumstances. This implies that the machining process operated poorly under these conditions, resulting in worse surface finish quality, and possibly larger cutting pressures. Finally, the experimental work demonstrated the significance of optimising the rake angle, and nose radius to create a superior surface quality and regulate cutting forces throughout the machining process.

CONCLUSIONS

In conclusion, this study examined gingelly oil as a cutting fluid in machining, and its effects on surface finish and cutting forces. Gingelly oil outperformed petroleum-based lubricants in machining, providing better lubrication and cooling. Gingelly oil consistently produced smoother surfaces and lower cutting forces, than dry cutting and petroleum-based lubrication.

Statistical analysis showed that optimising process parameters, especially rake angle and nose radius, improves surface finish quality. Surface finish and cutting forces were improved with an 8° rake angle and 2 mm nose radius. These optimised cutting conditions, outperformed other experimental settings, demonstrating the importance of cutting parameter selection and control in machining operations. Predictive modelling can evaluate bio-oils as cutting fluids, according to the study. Predictive models can estimate bio-oil effects on surface finish quality, tool wear rate, chip formation, and other performance indicators using historical data and experimental results. This method optimises machining, guides decision-making, and promotes sustainable cutting fluids.

Table 3. *R-square and p-values for different values of nose radius*
Таблица 3. *R-квадрат и p-значения при разных значениях радиуса закругления вершины*

Nose radius	*R*-square	*p*-value	Lubrication method
1	0.014	0.36	Dry
1	0.01	0.03	Petroleum
1	0.3	0.015	Gingelly
1.5	0.1579	0.09447	Dry
1.5	0.3	0.1243	Petroleum
1.5	0.5	0.0005	Gingelly
2	0.3	0.04	Dry
2	0.5	0.003	Petroleum
2	0.66	0.019	Gingelly

Table 4. *R-square and p-values for different values of rake angle*
Таблица 4. *R-квадрат и p-значения для разных значений переднего угла инструмента*

Rake angle	*R*-square	*p*-value	Lubrication method
5	0.17	0.05	Dry
5	0.3046	0.008478	Petroleum
5	0.3351	0.005295	Gingelly
8	0.3394	0.002	Dry
8	0.3409	0.009779	Petroleum
8	0.5878	0.0004	Gingelly
11	0.32	0.04	Dry
11	−0.115	0.08926	Petroleum
11	0.44	0.008	Gingelly

Gingelly oil and other bio-oils appear to be viable and environmentally being replacements to petroleum-based lubricants in manufacturing. However, more research is needed to understand the complicated connections between cutting parameters, and surface polish and cutting forces. Predictive modelling can help the industry implement sustainable practices by revealing bio-oil performance in certain machining settings.

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Качество обработки поверхности и эффективность резания в кунжутном масле во время механической обработки: регрессионный анализ

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Поступила в редакцию 31.08.2023
Принята к публикации 19.02.2024

Аннотация: В исследовании оценивается возможность использования кунжутного масла в качестве экологически чистой смазочно-охлаждающей жидкости при токарной обработке. Проведены эксперименты для определения влияния радиуса закругления вершины и переднего угла инструмента на износ инструмента, формирование поверхности и силу резания. Кроме того, были исследованы различные смазочные материалы, такие как смазочно-охлаждающие жидкости на нефтяной основе и биомасла, с целью определения их потенциала для минимизации трения, выделения тепла и износа инструмента во время обработки. Установлено, что по сравнению с сухим резанием и обычными смазками на нефтяной основе кунжутное масло обеспечивает более гладкую поверхность и снижает силу резания. Взаимосвязь между параметрами резания и качеством обработки поверхности анализировалась с использованием статистического моделирования. Для количественной оценки корреляций и значимости предиктора использовались коэффициент детерминации (R-квадрат) и p-значения. Результаты подчеркивают эффективность использования кунжутного масла в качестве смазочно-охлаждающей жидкости и важность оптимизации параметров процесса для повышения эффективности обработки.

Ключевые слова: эффективность резания в кунжутном масле; механическая обработка в кунжутном масле; смазывающе-охлаждающая жидкость; надежная обработка; качество обработки поверхности; износ инструмента; передний угол; радиус закругления вершины.

Для цитирования: Шайлеш Рао А. Качество обработки поверхности и эффективность резания в кунжутном масле во время механической обработки: регрессионный анализ // Frontier Materials & Technologies. 2024. № 2. С. 101–111. DOI: 10.18323/2782-4039-2024-2-68-9.