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Effect of Some Cutting Parameters on Surface Finish of Bright Mild Steel

EBOJOH, E; FRANCIS-AKILAKI, TI

Department of Production Engineering, University of Benin, Benin City, Edo State, Nigeria

**Corresponding Author Email: voke.ebojoh@uniben.edu*
**ORCID: https://orcid.org/0000-0001-5432-6020*
**Tel: +234(0)7065474779*

Co-Author email: tina.odibi@uniben.edu

ABSTRACT: The objective of this paper was to evaluate the effect of some cutting parameters on surface finish of bright mild steel (BMS). Samples were cut into the required piece with dimension 50mm x 200mm and the turning operation done using a tungsten carbide tip tool. The cutting variables include speed of the spindle, feed rate and depth of cut. The result obtained shows that a feed rate of 0.75mm/rev affects the surface finish the most with a roughness value of 3µm, while the combination of a depth of cut of 0.2mm and maximum speed 700rpm have the minimum effect on the surface finish (Ra value of 1.1µm) of low carbon steel.

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Keywords: Roughness value; Spindle speed; Feed rate; Depth of cut; Surface finish

Steel multifunctional, adaptable and one of the most important material compared to other materials and it is environment friendly because it is recyclable. The processing and production is 20 times more compared to all non-ferrous metals and is widely used in the manufacturing process to produce various products. Metal cutting on the other hand is an industrial process meant to remove excess materials. The output quality is of great importance in cutting processes of metal; hence improvement is required in the output quality which can be obtained significantly by optimizing the cutting variables.

Optimization of some of these parameters does not only improve output quality but also ensures manufacturing cost is low. Supriya and George (2014) establish three surface finish parameters on cutting characteristics of a standard work material under dry and wet conditions of machining like Low Carbon steel. Cutting force data was used, and a model for the cutting force component was developed empirically which include the power factor. The goodness of fit was tested on the model with the data that was gotten from the experimental procedure. A surface finish Ra with small magnitude and increased value of cutting speed was established. Furthermore the application of cutting fluid tends to improve the surface finish of the work piece. It was also observed that the power consumption decreases when the feed rate increase and rises when the cutting speed increase, indicating the ineffectiveness of cutting fluid at high speeds on the workpiece.

Yousefi and Zohoor (2019) carried out turning in a lathe using a nitride tool on hardened steel. It was observed that the hard condition of the steel made for the variations of surface finish and dimensional accuracy which vary differently from the turning operation done traditionally. Vibration and tool wear analysis was performed which showed that flank wear

**Corresponding Author Email: voke.ebojoh@uniben.edu*
**ORCID: https://orcid.org/0000-0001-5432-6020*
**Tel: +234(0)7065474779*

has an insignificant influence on the dimensional accuracy and that the vibrational effect was much. From the experiment carried out, it was noticed that feed rate increased from 0.08 to 0.32 mm/rev steadily and there was a decrease in the feed unexpectedly to a least value 0.16 mm/rev, also increasing the feed rate from 0.16 to 0.32 mm/rev, increases the dimensional deviation significantly.

Further the best dimensional accuracy resulted in the lowest level of the cutting depth of 0.5 mm depth, the medium level of the feed rate of 0.08 mm/rev, and the spindle speed 200rpm. The roughness value Ra of 0.312 μm was obtained at these parameters. To reduce surface roughness and increase material removal rate (MMR) Nadafa and Shinde (2019) tried to reduce the consumption of energy while machining by optimizing the parameters during face milling of mild steel. Using Taguchi method, 27 experimental runs was performed. The process parameters of spindle speed, feed rate, and depth of cut were optimized. The output performance characteristics which include surface roughness (Ra), Material Removal Rate (MRR), and power consumption were determined. Looking at the three cutting parameters described above, Saraswat *et al* (2014) tend to do an optimization on them by developing a model. The combination of the optimal levels of the factors of the three parameters was obtained to get the least roughness value Ra. Performance characterization of the turning operation using ANOVA and Signal-to-Noise ratio was utilized. The analyses showed a close relationship of the predicted values and calculated values. They found that the developed model can be used to predict the surface roughness in the turning of mild steel. Using the genetic algorithm technique, Ganesh *et al* (2014) did an optimization of cutting parameters on the CNC. The Cemented Carbide tool was employed and the three parameters were varied. A linear second order PDE model using the Response Surface Method (CCD) was designed experimentally. The formulation was done by collecting all responses of the Machining time and Ra with the Spindle Speed, Feed rate, and Depth of cut in the development of the model.

Kumar *et al* (2014), did an experimental study that looked at the “effects of three parameters which includes speed, feed, cutting depth, and the addition of nanomaterial as the coolant on the surface finish on EN-8 by the HSS M2 tool. A statistical relationship between speed, feed, cutting depth in conjunction with the coolant type to optimize the turning conditions based on surface roughness was the reason of the research study. The study was carried out using the Response Surface Method software. However, the study focused on varying the aforementioned parameters under different spindle speeds to establish the parameters with the most and least effect on the surface finishes on mild steel. In estimating the surface roughness of components that are machined under various turning parameters Osarenmwinda (2012) develop an empirical models using regression analysis software. The lathe was used for the turning operation at varied cutting speed range of between 76 rev/min to 600 rev/ min with a constant depth of cut of 1 mm/pass and a feed rate of 0.5 mm/rev. The center line average method using a digital Ra tester was used to measure surface roughness. Both the experimental and model values where compared and where found to be close. The Mean Absolute Percent Deviation (MAPD) which measures absolute error as a percentage was measured with their various percentages to be 1.46% 4.55 % and 4.76% of stainless steel, mild steel and aluminum cast respectively. The model performance was therefore found to be adequate for prediction. By taking cutting speed, feed rate and depth of cut as process parameters and getting the optimized value of Surface Roughness and Cutting temperature Experiments were conducted by Ososomi and Ekhayeme (2022). They used some tools such as the L9 orthogonal array, the signal-to-noise (S/N) ratio, and the analysis of variance (ANOVA) to study the performance characteristics in the turning on CNC with respect to surface roughness

The analyzed results shows the combine process parameters for minimum surface roughness is obtained at 75m/min cutting speed, 0.2 mm/rev feed, and 1.0 mm depth of cut for minimum surface roughness. It was noticed too that feed rate and spindle speed plays important role in minimizing surface roughness.

For surface roughness and cutting temperature, the values of 2.313μm and 65.390C was obtained using their respective objective functions with their optimum values. In calculating the theoretical arithmetic mean surface roughness, Ra, Ståhla *et al* (2012), presented “an analytical equation using a tool with a circular nose radius. The variance between the expected and the obtained surface roughness was investigated. The results show that the surface roughness could be considered as being inside an interval of two analytically determined Ra-values. Yung-Chih *et al* (2020) did an analysis on the influence of the cutting parameters on the surface roughness of machined parts with focus on the machining stability of the cutter. The chattering effect on the machining stabilities was calculated and a series of machining tests carried out on aluminum pieces under different cutting parameters and then the surface roughness prediction models in the form of nonlinear quadratic and power-law functions was established based on the multivariable regression method.

Palanikumar *et al* (2008) did an experiment that focused on some cutting parameters which include spindle speed, feed rate and cutting depth on a lathe and the response thereof which is the surface roughness. A model was developed for the prediction of the response on the material under investigation. In determining the effect of the machining parameters ANOVA and RSM was used.

The effect of machining parameters using other machining methods which include milling and cooling strategies was also introduced by Okafor (2020) which may lead to sustainable manufacturing through cost effectiveness and environmental friendly technique for those working in the high-speed machining area.

Using the Taguchi method, Vikram *et al* (2014) also delve into the effect of some machining parameters as it relate to surface roughness of materials under study. The work focused on surface roughness produced in speed machining on a lathe. Machining was carried out on steel material using coated carbide inserts and HSS tools. Spindle speed and feed rate was chosen as one of the control parameter and adopted for the analyses. ANOVA was then utilized to know the contribution of the machining parameters on the roughness.

The result of the ANOVA test showed that spindle speed contribute high in producing the surface roughness while machining with both using coated carbide inserts and HSS tools respectively. Also, Bala Raju *et al* (2013) investigated the “effect of cutting speed, depth of cut and feed rater in turning operations of mild steel and aluminum to know their surface finish value in conjunction to the power requirement of the entire system. Design of experiment based on the 2^k factorial method and the ANOVA was carried to identify which parameter has more effect on the roughness of the material. Model was developed and tested for its adequacy by using a 95% confidence level.

By using the mathematical model the main and interaction effects of various process parameters on turning were studied. The prediction of surface roughness using RSM was analysed by Yahya *et al* (2015) on some machining parameters.

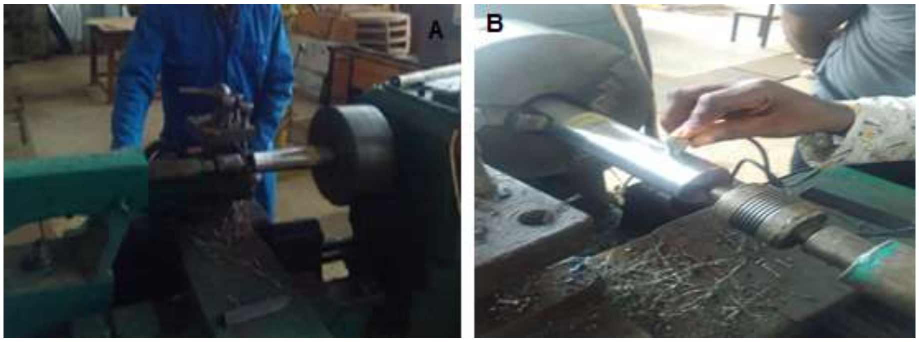
The study looked at cutter flutes in conjunction to cutting speed, feed rate, and cutting depth. Using Minitab16 software a model relationship between the surface roughness and the machining parameters was developed. The sensitivities of the roughness values to the machining parameters were analyzed using on analysis of variance. The result shows that cutter flutes have significantly high influence on surface roughness followed by the two other factors while cutting speed has the least influence on the roughness. Tulasiramarao *et al* (2013) further looked at the effect of some cutting parameters on the surface finish of stainless steel and aluminum. The study was to find the optimal control parameters that give the minimum surface roughness. In their work, the effects of process parameters were considered and a graphical method was used to determine the parameters with the least effect on the surface finish of the specimen.

The effect of working fluid (coolant) on surface roughness was investigated by Bikash *et al* (2022). Since metal working fluid selection depends upon the machining condition as well as the tool combination it is necessary to know that these MWFs are prepared from unsustainable crude oil extracts which may pose some teething challenge. Hence lubricoolant techniques such as high-pressure jet minimum quantity lubrication (MQL), nanoparticles-based MQL”, and cryogenic cooling techniques was investigated. The results show that the cryogenic and nanoparticles-based MQL is the most promising cooling and lubrication technique.

From the foregoing this research is set out to look at the effect of these parameters, cutting speed or spindle speed, depth of cut and feed rate on Bright mild steel as we vary the parameter settings on the lathe experimentally.

MATERIALS AND METHODS

The specimens (bright mild steel rods) were cut into the required dimensions and mounted on the lathe chuck and the turning operation carried out with a carbide tip tool for 30 runs in the following three cases; keeping the depth of cut and feed rate constant and spindle speed was varied; keeping spindle speed and depth of cut constant while feed was varied, and keeping feed and cutting speed constant while the depth of cut was varied. Table 1 to table 9 shows the settings and the variations of the three parameters to be investigated while the properties of the mild steel are presented in Jewo and Ebojoh (2021). Using TM-8810 Coupling Ultrasonic Thickness Meter the roughness value from the turning process was measured and recorded.



Plates 1a and b: Workpiece on the lathe during and Surface tester on the surface of the workpiece

Table 1: Constant Speed and Feed with varied Depth of cut

S/N	Spindle speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)
1	400	0.20	0.75
2	400	0.20	0.50
3	400	0.20	0.25

Table 2: Constant Spindle speed and Depth of cut with a varied Feed rate

S/N	Spindle Speed (rpm)	Feed rate (mm/min)	Depth of Cut mm
1	400	0.20	0.75
2	400	0.22	0.75
3	400	0.24	0.75

Table 3: Constant Feed and Depth of cut with varied Speed

S/N	Spindle Speed (rpm)	Feed rate mm/min	Depth Of Cut mm
1	400	0.20	0.75
2	450	0.20	0.75
3	700	0.20	0.75

Table 4: Constant Spindle speed and Feed rate with varied Cutting Depth

S/N	Spindle Speed (rpm)	Feed rate mm/min	Depth of Cut mm
1	450	0.20	0.75
2	450	0.20	0.50
3	450	0.20	0.25

Table 5: Constant Speed and Cutting Depth with a varied Feed rate

S/N	Spindle Speed (rpm)	Feed rate (mm/min)	Depth of Cut (mm)
1	450	0.20	0.75
2	450	0.22	0.75
3	450	0.24	0.75

Table 6: Constant Feed and Depth of cut with varied Speed

S/N	Spindle Speed (rpm)	Feed rate mm/min	Depth of Cut (mm)
1	400	0.20	0.50
2	450	0.20	0.50
3	700	0.20	0.50

Table 7: Constant Spindle speed and Feed with varied Cutting Depth

S/N	Spindle Speed (rpm)	Feed rate (mm/min)	Depth of Cut (mm)
1	700	0.20	0.75
2	700	0.20	0.50
3	700	0.20	0.25

Table 8: Constant Spindle speed and Cutting Depth with a varied Feed rate

S/N	Spindle Speed (rpm)	Feed rate (mm/min)	Depth of Cut (mm)
1	700	0.20	0.75
2	700	0.22	0.75
3	700	0.24	0.75

Table 9: Constant Feed and Depth of cut with varied Spindle speed

S/N	Spindle speed (rpm)	Feed rate (mm/min)	Depth of Cut (mm)
1	400	0.22	0.50
2	450	0.22	0.50
3	700	0.22	0.50

RESULTS AND DISCUSSION

The graphs present experimental results obtained for BMS. In Figure 1 to Figure 3, the plot train shows the influence of the variation of depth of cut on the surface roughness of bright mild steel when the spindle speed and feed rate are held constant. There is a steady increase in the Ra value as the depth of cut increases and then peaks before a decline again. Figure 1 shows that at a depth of cut of 0.5mm the Ra value is at 1.7µm and then decreases to about 1.1 µm at a depth of 0.75mm when the spindle speed is 400rpm and feed rate of 0.2mm/min. Also in Figure 2, with a constant spindle speed of 450rpm and feed rate of 0.2mm/min, a roughness value of 2.9 µm was achieved as shown.

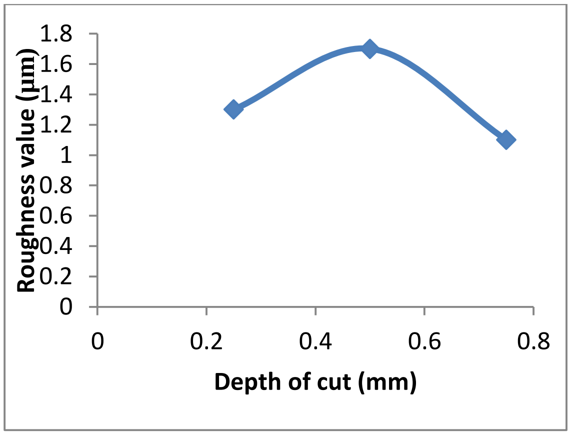


Fig 1: Relationship of surface roughness with a depth of cut

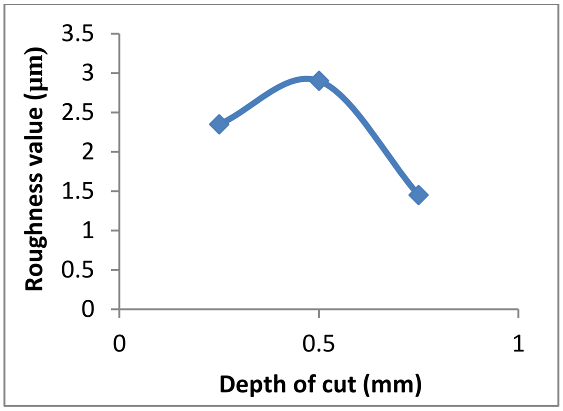


Fig 2: Relationship of surface roughness with a depth of cut

Further, in Figure 3, with a constant spindle speed of 700rpm and feed rate of 0.2mm/min, a roughness value of 1.4µm was achieved as shown while as the depth increases from 0.5mm to 0.75mm the Ra value was 1.1µm. Figure 4 to Figure 6 shows the influence of the variation of feed rate on BMS, while the spindle speed and depth of cut are held constant. Figure 4 is the graph showing a constant spindle speed of 400rpm the Ra value is at 2.2 µm at a feed rate of 0.22mm/min. As the feed rate increases the Ra value increases and then starts to drop as shown in the graph.

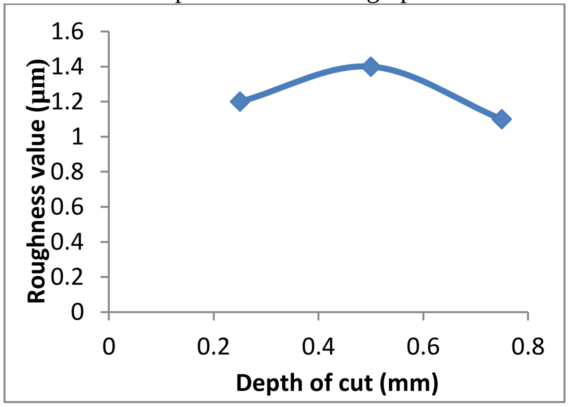


Fig 3: Relationship of surface roughness with a depth of cut

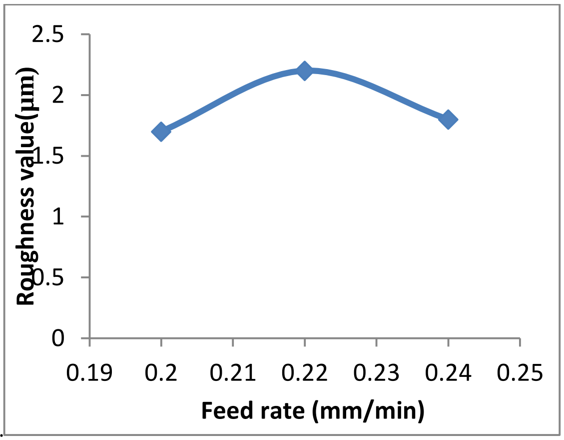


Fig 4: Relationship of surface roughness with a feed rate

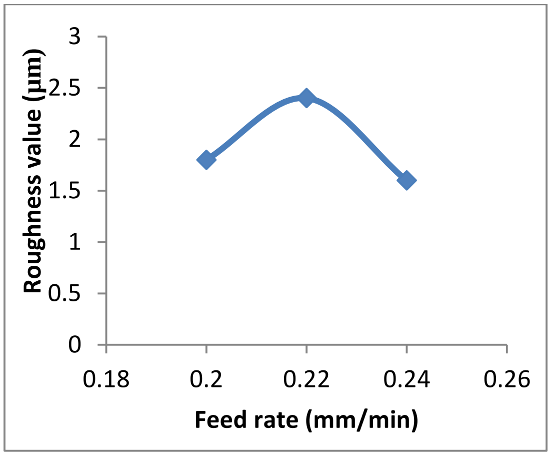


Fig 5: Relationship of surface roughness with a feed rate

As the feed rate increases from 0.2mm/min to 0.22mm/min the Ra value increases and then starts to drop as shown in Figure 5 to a Ra value of 1.6 µm. At a Spindle speed of 450rpm, the Ra is at its peak of 2.4µm. Also at a Spindle speed of 700rpm, the Ra value is at 3.0µm. Following the same turning process and using the same turning parameters as used in Figure 4 and Figure 5, as the feed rate increases the Ra value increases. However, as the speed is increased and kept constant the Ra values increases as shown in Figure 6.

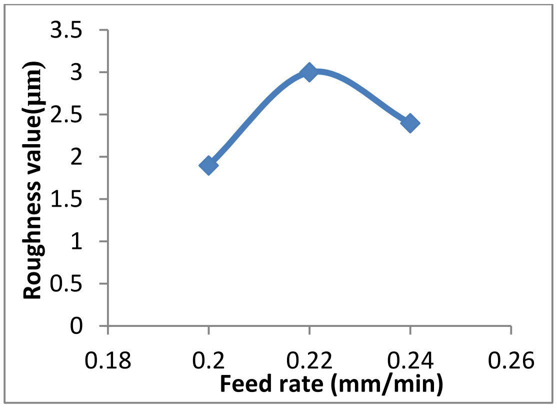


Fig 6: Relationship of surface roughness with a feed rate

In Figure 7 to Figure 9 the influence of the variation of spindle speed on bright mild steel with a depth of cut and feed rate held constant was presented. From figure 7 at a speed of 400rpm, a roughness value of 1.8µm was attained. But as the speed increases the Ra value decreases too. This decrease is also due to the depth of cut and feed rate as presented by Jewo and Ebojoh (2021). Conversely, as the feed rate was kept constant at 0.22mm/min, and an initial speed of 400rpm the Ra value was 1.1µm and increased to 1.4 µm as the spindle speed was increased as shown in Figure 8. After this increase, there occurs a linear decrease of the roughness value to 1.2 µm as the spindle speed reached 700rpm. Again at a constant feed rate of 0.24mm/min, as shown in Figure 9, with a spindle speed of 400rpm, the Ra value was 1.8 µm; and as the speed increases, it was observed that there is a linear decrease to 1.2 µm at 700rpm.

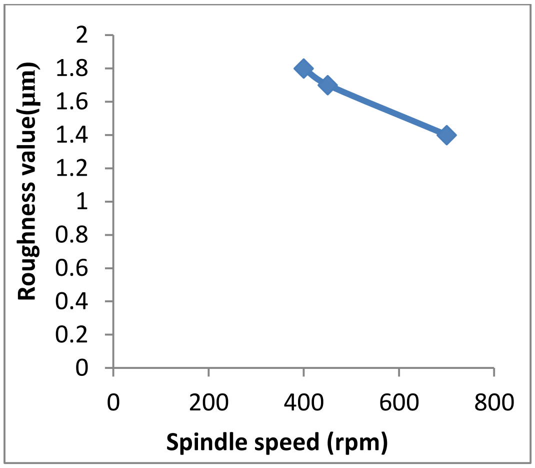


Fig 7: Relationship of surface roughness with spindle speed

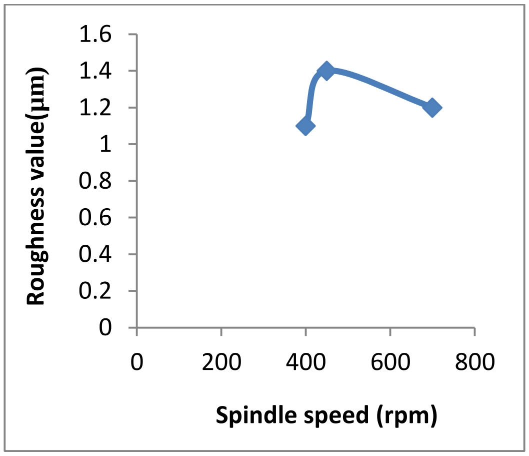


Fig 8: Relationship of surface roughness with spindle speed

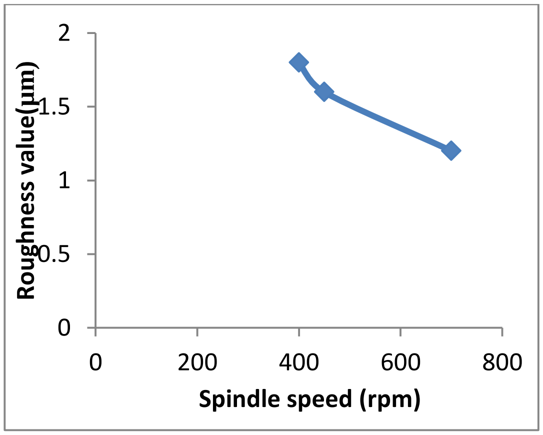


Fig. 9: Relationship of surface roughness with spindle speed

Conclusion: It is observed from the above graphs that an increase in feed rate increases the roughness value, a higher spindle speed on the other hand with a minimum depth of cut results in a minimum roughness value. The result obtained shows that a feed rate of 0.75mm/rev has the most effect on the surface finish with a roughness value (3µm), while the combination of a minimum depth of cut (0.2mm) and maximum spindle speed (700rpm) have the minimum effect on the surface finish (Ra value of 1.1µm) of low carbon steel.

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