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Research Article

SURFACE ROUGHNESS AND DEVIATION FROM CIRCULARITY IN WATER JET CUTTING OF AL 7075 T651 SERIES ALUMINUM ALLOY MATERIALS

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Abstract – Today, there are many different methods for cutting hard and difficult to machine materials such as stone, composites, ceramics, metals and alloys. In most of these methods, it is very difficult to achieve the desired surface quality and tolerance range. The abrasive water jet can cut smoothly and within the desired tolerance range with water and abrasive grit without any chemical material. In this study, AL7075 T651 aluminum alloy material was cut on an abrasive water jet machine by changing the cutting pressure, abrasive flow rate and feed rate values at 3 different levels and keeping the other parameters constant, and the surface roughness and deviation of the holes from the circularity values were examined after cutting. According to the data obtained after the experiments, the increase in cutting pressure and abrasive flow rate decreased the surface roughness, while the feed rate increased. Increasing the cutting pressure decreased the deviation from circularity, while the feed rate and abrasive flow rate increased the deviation from circularity.

Keywords – Abrasive Waterjet Cutting, Deviation From Circularity, Surface Roughness, Waterjet, Waterjet Cutting.

I. INTRODUCTION

A. AL7075 T651

The main alloy element is zinc. It is widely used in structural components in the aviation and medical sectors. It can be strengthened by increasing its durability with tempering processes. As can be seen in Table 2, the alloy has been subjected to a series of processes and finalized and made ready for manufacturing. The main purpose of these processes is to eliminate the physical deterioration of the material during processing and to achieve the desired mechanical properties [1].

Table 1 AL 7075 T651 Alloy Content

Cr	0.18-0.28 %	Fe	< 0.5 %	Al	Remaining
Cu	1.2-2 %	Si	< 0.4 %		
Mg	2.1-2.9 %	Mn	< 0.3 %		
Zn	5.1-6.1 %	Ti	< 0.2 %		

Table 2 Temper Code Definition [2]

T	6	5	1
Heat treatment process	artificially aged	Stress relieved	planarity obtained after stress reduction

B. *Abrasive Water Jet Cutting Method*

Figure 1 Water jet cutting machine

It is a system consisting of abrasive water jet, cutting head, pump, cutting table, computerised control unit and abrasive feeding units. These machines can cut in 2500 - 4500 bar ranges. Water is transmitted from the tank to the pump. It is conveyed to the head by gaining high pressure by means of powerful pumps. In the head, the pressure is increased by passing through a smaller diameter orifice. Then, in the mixing chamber, it combines with the abrasive coming from the sand feeding unit and starts to remove chips from the material surface. Since there is no thermal density in the cut area, the desired surface is obtained without the need for retouching. In some systems, water is filtered to be reused [3].

It is suitable for use in the manufacture of low tolerance parts. There is no heat deformed area on the workpiece after cutting. Stable and clean cutting is provided. Suitable for cutting materials of different structures. Wide material cutting range. Initial installation is costly. It cuts slower than laser and plasma cutting machine. Due to its complex structure, the failure rate is high. This increases maintenance costs [4].

In the cutting stage, cutting is affected by multiple parameters and the best cutting condition is achieved with the appropriate combinations of these parameters. Since cutting is a costly process that requires a quality surface, it is vital to determine the optimum cutting parameters. Cutting pressure, nozzle diameter, feed rate, abrasive flow rate, abrasive grit type and cutting height are the basic parameters [5].

The feed rate is the parameter that determines the progress made per minute (mm). Increasing the feed rate causes the material removal at the desired level and the formation of a rough surface. A smooth surface can be obtained by supporting with other parameters [6].

The abrasive flow rate determines how many grains of grit are transferred to the cutting zone per minute. Generally, increasing the flow rate increases the surface roughness value. The variation of the Ra value depends on the optimum cutting parameter. If less material is removed than desired, the surface starts to deteriorate. Nozzle diameter, nozzle diameter is very small in abrasive water jet. In this way, minimum kerfing is required [7].

Increasing abrasive grain size increases surface roughness. When a larger grain comes into contact with the abraded area, it can start to degrade the surface. The hardness of the grains also affects the surface quality. Commonly used grits are garnet, olivine and silicon carbide [8].

Cutting pressure is one of the most important parameters affecting cutting. Increasing the pressure increases the surface wear rate as it creates kinetic mobility locally. Surface quality is also generally improved. However, if the pressure range is not determined correctly, the surface quality may deteriorate. In addition to pressure variation, the relationship with other parameters is also very important in terms of surface roughness [9].

II. MATERIALS AND METHOD

A. *Preparation of Test Samples*

During the cutting preparation stage, 7075 T651 alloy material was obtained from Seykoç Aluminum Company in accordance with the standards. Table 3 shows the alloy contents and test results.

Table 3 AL7075 T651 Alloy Content and Test Results

Değerler	(%) (Elements)										
Standart	Fe	Si	Mn	Cr	Ti	Cu	Mg	Zn	Each	Total	Al
Min.				0,18		1,2	2,1	5,1			
Max.	0,5	0,4	0,3	0,28	0,2	2	2,9	6,1	0,05	0,15	Kalan
(%) (Test Results)											
	0,34	0,15	0,16	0,22	0,03	1,5	2,6	5,5			

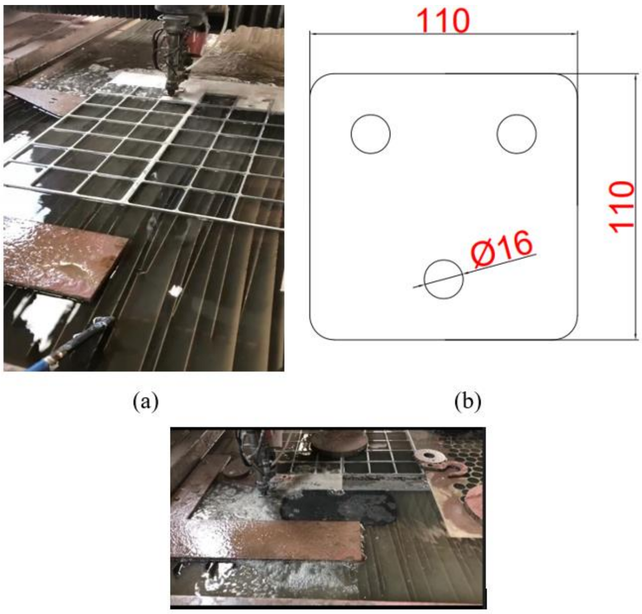
Table 4 AL7075 T651 Mechanical Properties and Test

	Minimum	Maximum	Test Results
Tensile Strength (Mpa)	540		570
Yield Strength (Mpa)	470		498
Elongation %	8		13,5
Hardness(HB)	x		168-170

Table 5 Variable Parameters and Levels

Feed Rate	Abrasive Flow Rate	Cutting Pressure
400 mm / min	250 gr / min	3000 bar
430 mm / min	300 gr / min	3400 bar
460 mm / mni	350 gr / min	3800 bar

The parameters shown in Table 5 were varied within the specified level ranges and the other parameters were kept constant. Nozzle diameter was kept constant. Garnet 80 was used as abrasive grain. A full factorial experimental design was created with these variables. The cutting process was carried out on the Resato ACM 2040 model abrasive water jet machine in Bronz Automotive company.



(a) (b)

(c)

Figure 2 a: Cutting sample 1, b: Sample drawing, c: Cutting sample 2

Table 6 AL7075 T651 Experiment Design

NO.	Cutting Pressure (bar)	Abrasive Flow Rate (g/min)	Feed Rate (mm/min)
1	3000	250	400
2	3000	250	430
3	3000	250	460
4	3000	300	400
5	3000	300	430
6	3000	300	460
7	3000	350	400
8	3000	350	430
9	3000	350	460
10	3400	250	400
11	3400	250	430
12	3400	250	460
13	3400	300	400
14	3400	300	430
15	3400	300	460
16	3400	350	400
17	3400	350	430
18	3400	350	460
19	3800	250	400
20	3800	250	430
21	3800	250	460
22	3800	300	400
23	3800	300	430
24	3800	300	460
25	3800	350	400
26	3800	350	430
27	3800	350	460

B. *Experiment Process*

1. *Deviation from Circularity Measurement with CMM*

The deviations from the circularity in the holes were measured with the FARO brand CMM in Bronz Automotive Company. The measurement results of 27 specimens are shown in Table 7. Data were recorded from 10 different points in each hole.

Table 7 AL 7075 T651 CMM Measurement Results

	Cutting Pressure (bar)	Abrasive flow rate (g/min)	Feed Rate (mm/min)	Deviation from Circularity
1	3000	250	400	0,0837
2	3000	250	430	0,0893
3	3000	250	460	0,0946
4	3000	300	400	0,0892
5	3000	300	430	0,0905
6	3000	300	460	0,0915
7	3000	350	400	0,0956
8	3000	350	430	0,0968
9	3000	350	460	0,0998
10	3400	250	400	0,0545
11	3400	250	430	0,0596
12	3400	250	460	0,0652
13	3400	300	400	0,0629
14	3400	300	430	0,0725
15	3400	300	460	0,0822
16	3400	350	400	0,0745
17	3400	350	430	0,0798
18	3400	350	460	0,0875
19	3800	250	400	0,0305
20	3800	250	430	0,0355
21	3800	250	460	0,0375
22	3800	300	400	0,0345
23	3800	300	430	0,0365
24	3800	300	460	0,0404
25	3800	350	400	0,0528
26	3800	350	430	0,0598
27	3800	350	460	0,0624

- Effect of Feed Rate on Deviation from Circularity

As seen in the results, deviation from circularity increased as the feed rate increased. With the increase in the speed, the surface abrasion time will decrease and the deviation from the circularity will increase since sufficient abrasion will not be achieved.

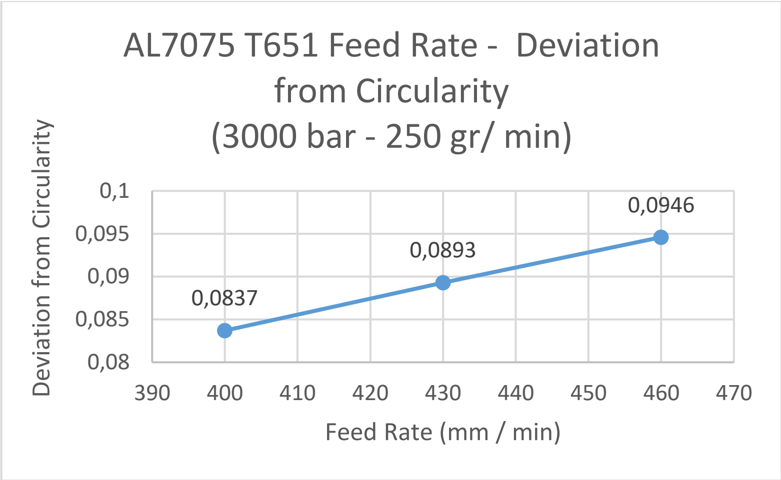


Figure 3 Deviation from circularity – Feed Rate

- Effect of Cutting Pressure on Deviation from Circularity

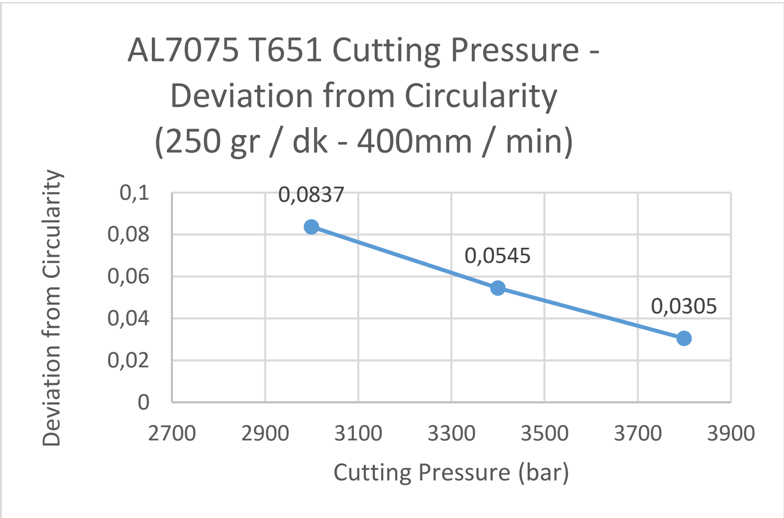


Figure 4 Deviation from Circularity – Cutting Pressure (situation 1)

When the experimental results are analysed, in the first case, the increase in cutting pressure in Figure 4 causes a decrease in the deviation from circularity. More stable energy density provides a cleaner surface. The increase in feed rate and flow rate with the increase in pressure continued the increasing trend in the deviation from the circularity as shown in Figure 5.

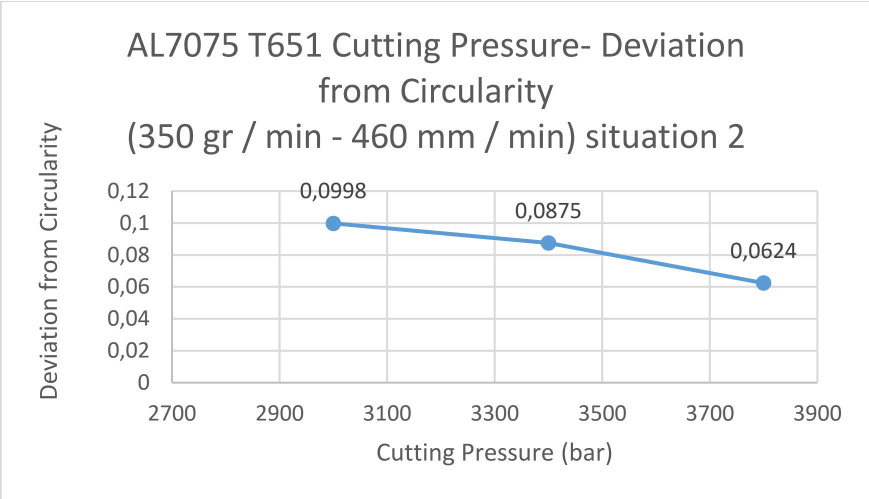


Figure 5 Deviation from circularity – Cutting Pressure (situation 2)

- Effect of Abrasive Flow Rate on Deviation from Circularity

An increase in deviation from circularity was observed with increasing abrasive flow rate. The higher the flow rate, the more material is removed and as a result the deviation tends to increase.

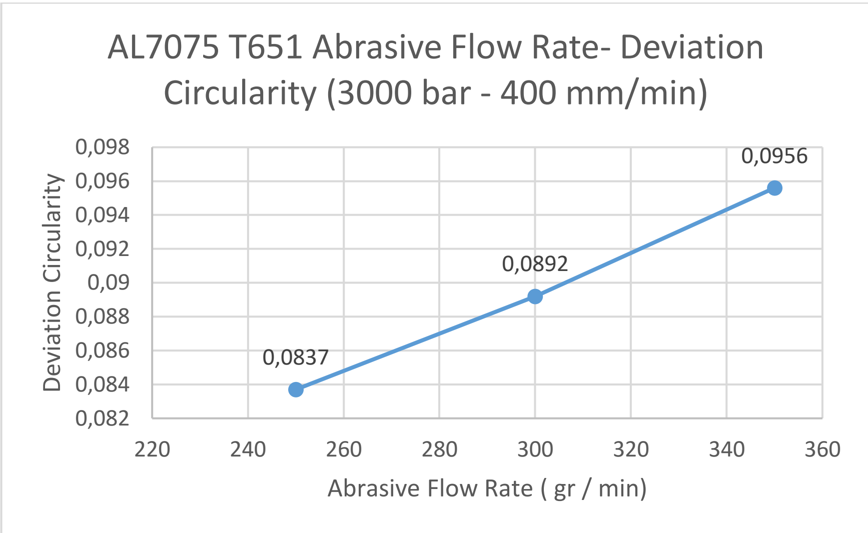


Figure 6 Abrasive Flow Rate- Deviation Circularity

2. *Surface Roughness Measurement*

Surface roughness (Ra) measurements were carried out at Selçuk University, Faculty of Technology Laboratory using a Mahr surface roughness measuring machine. The probe travel was kept constant at 1,750 mm. Data were taken from 3 points in each hole. The measurement results are listed in table 9.

Table 8 AL 7075 T651 Surface Roughness Measurement Results

	Cutting Pressure (bar)	Abrasive Flow Rate (g/min)	Feed Rate(mm/min)	Surface Roughness (Ra)
1	3000	250	400	1,778
2	3000	250	430	1,876
3	3000	250	460	1,895
4	3000	300	400	1,762
5	3000	300	430	1,816
6	3000	300	460	1,835
7	3000	350	400	1,643
8	3000	350	430	1,665
9	3000	350	460	1,736
10	3400	250	400	1,695
11	3400	250	430	1,752
12	3400	250	460	1,789
13	3400	300	400	1,65
14	3400	300	430	1,755
15	3400	300	460	1,752
16	3400	350	400	1,602
17	3400	350	430	1,65
18	3400	350	460	1,656
19	3800	250	400	1,635
20	3800	250	430	1,735
21	3800	250	460	1,736
22	3800	300	400	1,612
23	3800	300	430	1,659
24	3800	300	460	1,702
25	3800	350	400	1,472
26	3800	350	430	1,489
27	3800	350	460	1,512

Figure 7 A: Test specimen Ra measurement, B: Surface roughness measurement device

- Effect of Cutting Pressure on Surface Roughness

When the graph is analysed, when the cutting pressure increased, the surface roughness value. decreased. Since more consistent energy density is transmitted to the surface with increasing pressure, the surface quality has improved. Depending on other parameters, this ratio may vary. Increasing the pressure too uncontrolled may cause an increase in the Ra value as it will cause inconsistent wear.

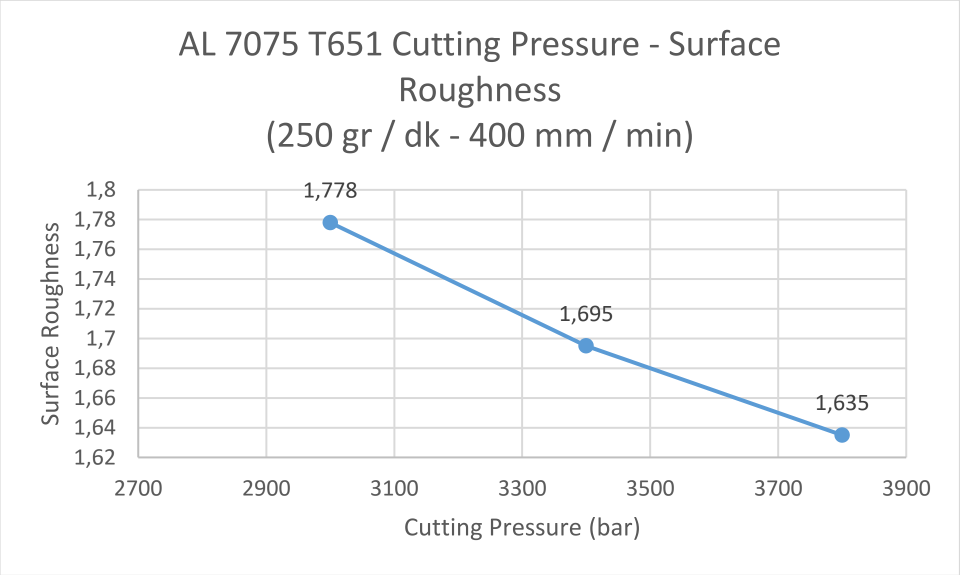


Figure 8 Cutting Pressure – Surface Roughness

- Effect of Abrasive Flow Rate on Surface Roughness

As seen in fig 9. the surface roughness value decreased with the increase in abrasive flow rate. The reason for this is that the increased flow rate causes improvement on the surface as it removes stable chips from the material. The decrease in Ra value continued to decrease with the increase in pressure as shown in Figure 10. It decreased to a lower level.

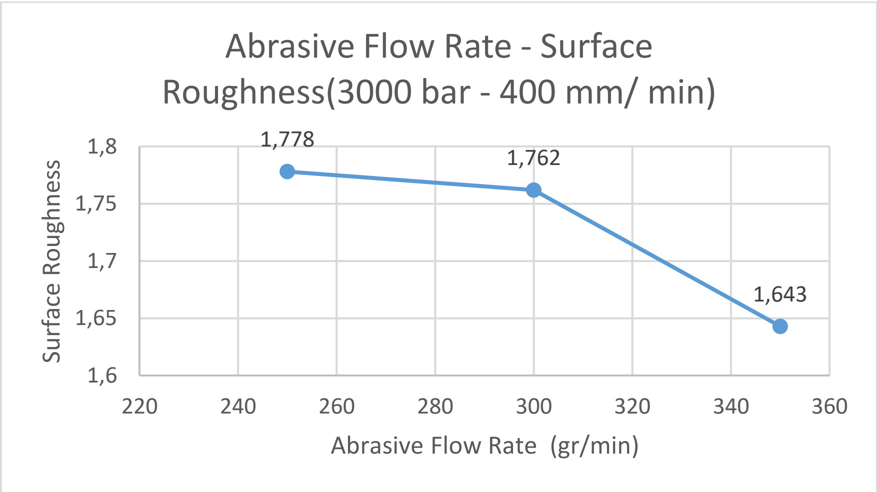


Figure 9 Abrasive Flow Rate – Cutting Pressure (Situation 1)

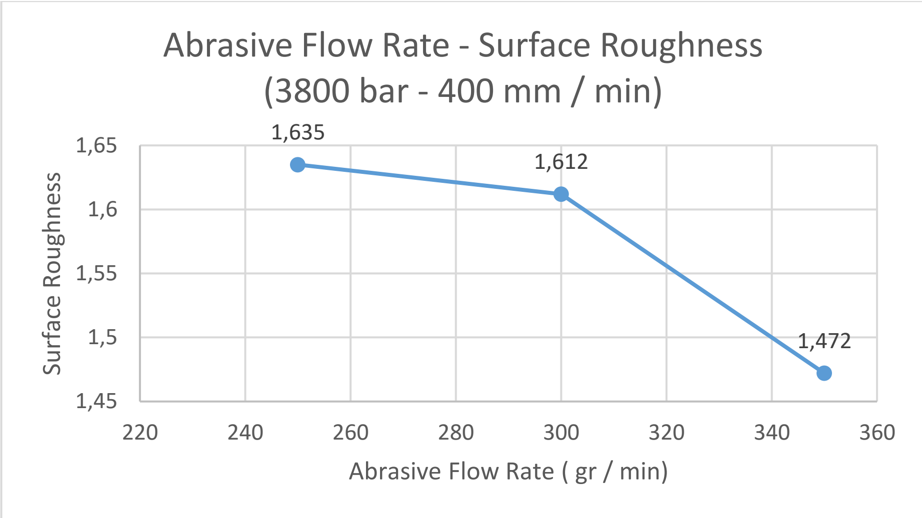


Figure 10Abrasive Flow Rate – Surface Roughness (Situation 2)

- Effect of Feed Rate on Surface Roughness

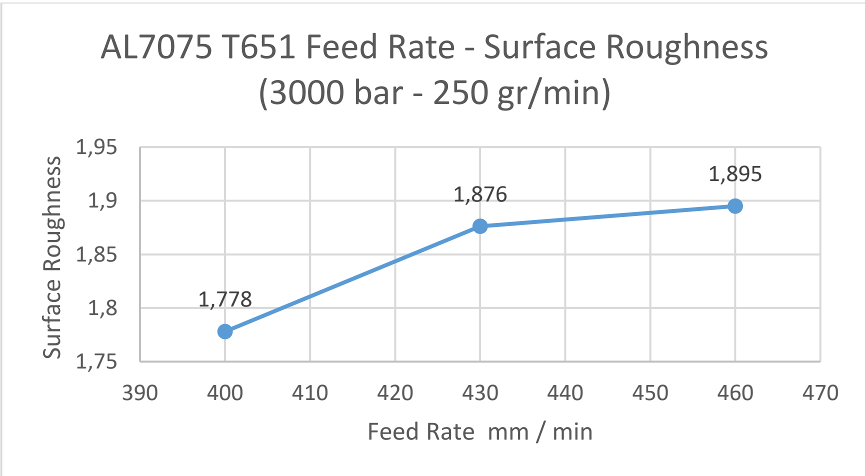


Figure 11 Feed Rate – Surface Roughness (Situation 1)

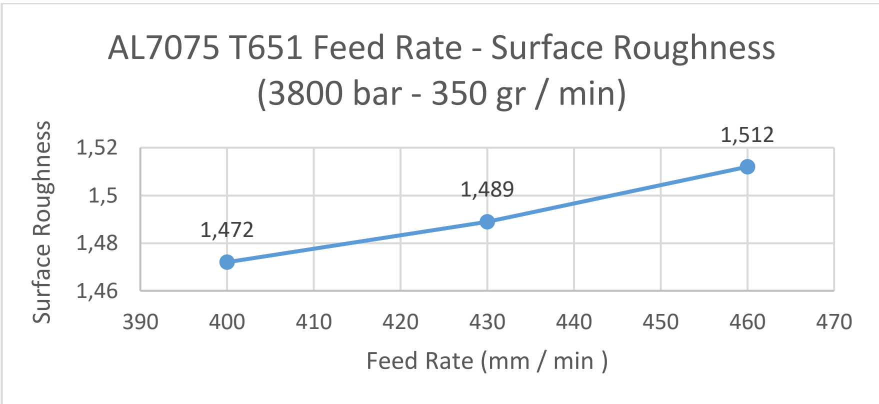


Figure 12 Feed Rate – Surface Roughness (Situation 2)

When the feed rate increases, an increase in the surface roughness value is also observed in Figure 11 Increasing feed rate causes a rough structure in places that cannot be penetrated sufficiently. If the feed rate is too small, it can also cause localised energy density. In this way, the Ra value is increased again.

When the abrasive flow rate was increased to 350 g/min and the pressure was increased to 3800 bar, the surface roughness value decreased compared to the initial situation. However, the increase in feed rate increased the Ra value again. This situation is shown in figure 12.

III. RESULTS

- When the test results of AL7075 T651 were analysed, a decrease in Ra value occurred with the increase in pressure. Pressure is one of the main parameters affecting the surface roughness.
- In AL7075 T651 cutting process, an increase in surface roughness value was observed with the increase in abrasive flow rate.
- The increase in abrasive flow rate deteriorated the surface quality. However, the parallel increase in the pressure value as well as the flow rate decreased the Ra value. It improved the surface quality.
- At the end of AL7075 T651 cutting, Ra value also increases when the feed rate increases.
- In AL7075 T651 cutting process, increasing the pressure showed an increase in the first trials. In addition to the pressure, when the feed rate and flow rate values were increased separately, a significant decrease in the deviation from circularity value was observed.
- In AL7075 T651 machining, an increase in the amount of deviation from circularity was detected when the abrasive flow rate increased. In addition, a decrease in deviation from circularity was observed with increasing pressure.
- In the cutting process of AL7075 T651 material, an increase in deviation from circularity was observed when the feed rate increased.
- The lowest deviation value in the machining of AL 7075 T651 material with abrasive water jet was determined at 3800 bar pressure, 350 g/min abrasive flow rate and 460 mm/min feed rate.
- The best surface in the cutting of AL7075 T651 material was obtained at 3800 bar pressure, 350 g/min abrasive flow rate and 430 mm/min.

IV. DISCUSSION

When the AL7075 T651 material cut is examined in detail, mostly good surface and minimum deviation are observed at high pressure values. In addition, the common combination with other parameters provided better results. As can be seen from the experimental results, optimum parameter selection and determination is extremely vital. Surface quality and deflection values play an important role in precision manufacturing industries.

V. CONCLUSION

When finding the optimum parameter, starting from a high-pressure value can be effective in reaching the targeted values. Although the most effective parameter is the cutting pressure, its compatibility with other parameters is very effective.

ACKNOWLEDGMENT

The heading of the Acknowledgment section and the References section must not be numbered.

REFERENCES

[1] E. Ghali, "Chapter 4 Properties, Use, and Performance of Aluminum and Its Alloys."

[2] R. J. Dashwood and R. Grimes, "Structural Materials: Aluminum and Its Alloys – Properties," in *Encyclopedia of Aerospace Engineering*, Wiley, 2010. doi: 10.1002/9780470686652.eae195.

[3] J. Kapil Gupta, "SPRINGER BRIEFS IN APPLIED SCIENCES AND TECHNOLOGY MANUFACTURING AND SURFACE ENGINEERING Abrasive Water Jet Machining of Engineering Materials." [Online]. Available: http://www.springer.com/series/10623

[4] G. E. . Totten and D. Scott. MacKenzie, *Handbook of aluminum*. M. Dekker, 2003.

[5] J. Nyaboro, M. Ahmed, H. El-Hofy, and M. El-Hofy, "Experimental and numerical investigation of the abrasive waterjet machining of aluminum-7075-T6 for aerospace applications," *Adv Manuf*, vol. 9, no. 2, pp. 286–303, Jun. 2021, doi: 10.1007/s40436-020-00338-7.

[6] N. Tosun, I. Dagtekin, L. Ozler, and A. Deniz, "Abrasive waterjet cutting of aluminum alloys: Workpiece surface roughness," in *Applied Mechanics and Materials*, 2013, pp. 3–9. doi: 10.4028/www.scientific.net/AMM.404.3.

[7] A. ALTINSOY and Y. ARSLAN, "Polioksimetilen Kopolimerinin Su Jeti Tezgâhlarında İşlenebilirliğinin Taguchi Metodu Kullanılarak Optimizasyonu," *Uluslararası Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi*, vol. 3, no. 1, pp. 333–349, Jul. 2021, doi: 10.47898/ijeased.842732.

[8] T. M. Oh, G. W. Joo, Y. Cha, and G. C. Cho, "Effect of garnet characteristics on abrasive waterjet cutting of hard granite rock," *Advances in Civil Engineering*, vol. 2019, 2019, doi: 10.1155/2019/5732649.

[9] N. N. Babu, A. G. Fernando, and A. Muthukrishnan, "Analysis on surface roughness in abrasive water jet machining of aluminium," 2015.