12th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

INFLUENCE OF FOCUSING TUBE WEAR ON THE CUT-SURFACE QUALITY

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ABSTRACT
The wear of the focusing tube is a very important feature of the abrasive water jet machining. Of all rejected focusing tubes, 85% are worn. Similary, the age of focusing tube influences the cut geometry and quality of machined surface. With regard to the stated, wearing of the focusing tube is subject of this paper. Focusing tube outlet diameter was measured as well as its influence on the surface quality.
Key words: focusing nozzle, wear, surface quality

1. INTRODUCTION

Continuous development of high pressure water jet machining was initiated in the first decade of the twentieth century. Modern abrasive water jet instalations are water assisted at a pressure exceeding 4000 bar, whereby water jet reaches even up to 900 m/s.
Figure 1. shows the working part of an abrasive water jet installation is most commonly called water jet head or nozzle.

The inlet water entering the water jet head (nozzle), most commonly at 3000÷4000 bar pressure, passes through jewel. The diameter of the orifice (jewel) entry ranges from 0.18÷0.4mm. Extremely small diameter of the nozzle ensures very high water speed, amounting up to 900m/s. The jet subsequently arrives at the mixing chamber the diameter and length of which are usually 6mm and 10mm respectively. Owing to the Venturio effect vacuum occurs, sufficient to absorb a particular amount of abrasive dependent on the abrasive nozzle diameter. Water jet speeds up the abrasive particles accompanying them through a long cylindrical focusing tube.

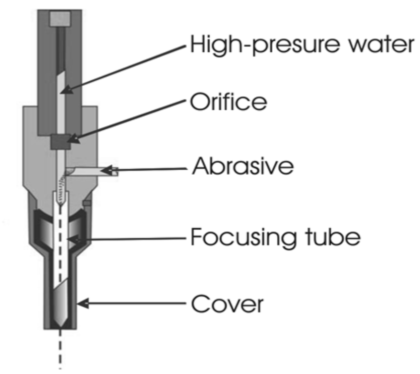

Figure 1. Water jet head (nozzle), scheme

Water and abrasive mix exits the focusing tube in the form of a coherent jet providing the machining. Focusing tube is usually made of tungsten carbide. Its inner diameter and length range from 0.8 to 1.6 mm and 50 to 80 mm respectively. It is tungsten carabide that is used owing to its high resistance to to abrasive wear.

2. FOCUSING TUBE WEAR

The term ‘wear’ is used to manifest a number of issues, such as:

- Tube weight loss
- The incidence of wear patterns along the inner surface
- Change of the outlet geometry

- Exit diameter increase

The initial wear of the focusing tube is easiest identified by monitoring of the tube weight loss. The tube is measured before the beginning of the process as well as over the period of machining. Weight loss is induced by the erosion of the inner wall of the focusing tube which also brings about the incidence of wear patterns along the inner surface of the tube. Excessive usage of the focusing tube causes changes in the exit geometry, i.e. the occurence of the opening exccentricity. The exccentricity is defined by the ratio between the smallest and the biggest size at the exit.
The most common method for monitoring of the state of the focusing tube is monitoring of the exit diameter. A number of authors have found linear relationship between exit diameter and time.
Different parameters of the machining , i.e. size of abrasive particles, focusing tube length govern the increase in the exit diamter.

3. PROPERTIES OF SURFACES MACHINED BY ABRASIVE WATER JET

Major properties of surfaces machined by abrasive water jet are as follows:

- cutting width
- cone cutting
- roughness of the machined surface.

All these properties are indicators of quality of the machined surface. In this paper, roughness of the machined surface, i.e. the influence of the state of the focusing tube, has particularly been addressed.

4. EXPERIMENTAL INVESTIGATIONS

In this paper, the focusing tube wear was investigated by the half of the exploitation life of the tube. The ROCTEC©100 focusing tube has been investigated. The data provided by the producer suggest 120 hours of exploitation life of the tubes. The followoing parameter values at which the focusing tube was being exposed over the study were constant, i.e.

- working pressure p = 3500bar
- abrasive flow Qa = 306 g/min
- abrasive type – garnet, MASH#80

The diameter of the focusing tube outlet was measured at the beginning of the process using a new tube. It was subsequently checked over 10- to 15-hour interval.
Measuring of the diameter of the tube outlet was concurrent with cutting of samples made of different materials so as to monitor the effect of the focusing tube wear on roughness of the machined surface.
These sample materials were used:

1. Č 4580: Rm=630 MPa; $R_{p0.2}$=205Mpa
2. marble, dry state compressing solidity β_{max}=109Mpa, density 2.71 g/cm^3
3. clyrate, PMMA, density 1.150 to 1.190 kg/m^3

All samples were treated at idential cutting speed (V=120mm/min). Ra was used as major roughness parameter.
Ra parameter was checked at five and three spots along the sample length and heights respectively, as shown in Fig. 2.

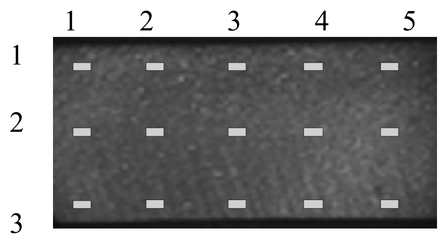

Figure 2. Checking spots along the machined sample surface

The table below presents values of the diameter of focusing tube outlet in the function of the cutting time
According to the study results presented in Table 1. a diagram has been created showing to what extent focusing tube wear depends on cutting time. As shown in the figure 3, the longer duration of cutting the wider diameter of the focusing tube outlet. As previously noted, a number of authors

firmly suggest linear correlation between these parameters, therefore the broken line in the figure stands for linear function which, by the smallest quadrate method, best provides approximate values of the correlation obtained by the study.

Table 1. Values of the diameter of focusing tube outlet, d_f being in the function of the cutting time

t[min]	0	855	1545	2345	3195
d_f[mm]	1.02	1.055	1.109	1.152	1.318

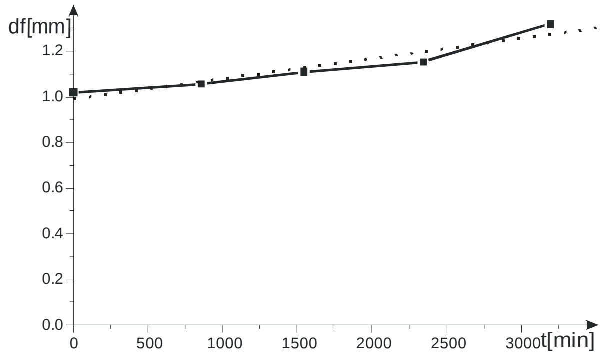

Figure 3. Change of the diameter of the tube outlet, df being in the function of cutting time

Tables 2, 3 and 4 shows the Ra values for iron Č4580, marble and clyrate in the function of cutting time.

Table 2. The Ra values functioning as cutting time for ***Č4580***

t[min]		1	2	3	4	5	Ra_{sr}
0	1	2.59	3.17	2.99	2.49	2.71	2.79
	2	2.27	2.76	2.97	2.38	2.70	2.616
	3	2.99	2.84	2.36	2.95	3.18	2.864
855	1	3.31	2.95	3.47	2.99	3.19	3.182
	2	3.25	3.32	2.98	3.07	3.06	3.136
	3	3.11	2.29	3.45	2.51	2.91	2.854
1545	1	2.83	3.23	3.94	2.53	3.28	3.162
	2	3.14	3.61	2.98	3.57	3.34	3.328
	3	2.58	3.62	2.67	2.98	3.18	3.006
2345	1	2.90	3.57	3.52	4.19	3.21	3.478
	2	3.08	3.24	2.56	3.47	3.20	3.11
	3	2.94	3.04	2.49	2.65	4.7	3.164
3195	1	4.59	5.29	2.98	3.09	3.02	3.794
	2	2.68	2.89	3.68	3.12	2.76	3.026
	3	3.40	3.17	4.59	4.19	3.69	3.808

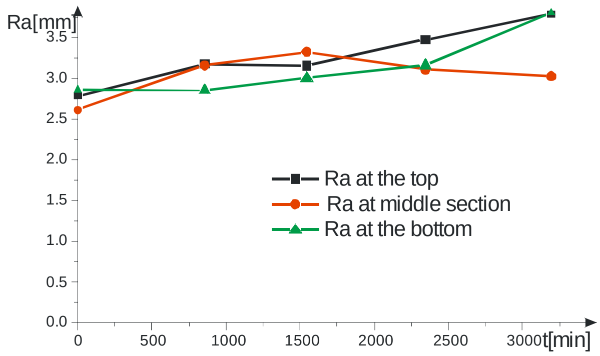

Figure 4. Change in Ra function of cutting time for ***Č4580***

Table 3. The Ra values functioning as cutting time for ***marble***

t[min]		1	2	3	4	5	Ra_{sr}
0	1	3.18	2.73	3.54	3.27	2.67	3.078
	2	3.36	3.27	2.62	3.52	3.29	3.212
	3	3.58	4.65	3.99	4.68	4.57	4.294
855	1	3.20	4.31	3.29	3.32	2.93	3.41
	2	2.76	3.82	2.77	4.15	3.53	3.406
	3	4.20	3.11	2.99	3.48	3.63	3.482
1545	1	4.56	3.98	4.83	4.23	4.70	4.46
	2	3.54	3.24	3.60	2.51	2.74	3.126
	3	3.82	3.98	2.54	3.36	2.71	3.282
2345	1	5.57	4.15	4.23	4.41	4.24	4.52
	2	3.41	4.07	2.92	3.80	3.19	3.478
	3	3.76	4.56	3.72	3.37	4.19	3.92
3195	1	4.24	4.63	4.78	3.56	5.19	4.48
	2	4.41	3.23	3.01	3.26	3.51	3.484
	3	3.76	3.24	3.23	3.49	3.57	3.458

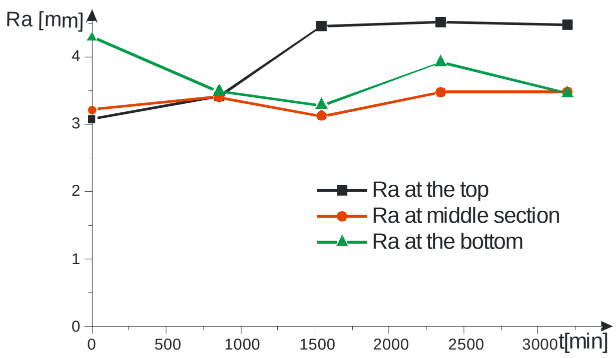

Figure 5. Change in Ra function of cutting time for ***marble***

*Table 4. The Ra values functioning as cutting time for **clyrate***

t[min]		1	2	3	4	5	Ra_{sr}
0	1	2.89	2.49	3.09	3.37	2.76	2.92
	2	3.12	3.74	4.15	4.32	3.44	3.754
	3	3.41	3.46	3.83	3.80	3.32	3.564
855	1	3.73	3.69	3.96	4.29	3.91	3.916
	2	3.29	2.40	3.18	4.44	4.54	3.57
	3	3.63	3.78	4.03	5.47	3.81	4.144
1545	1	3.22	5.04	3.85	4.05	3.70	3.972
	2	3.36	3.65	4.81	3.95	3.79	3.912
	3	4.18	4.15	3.24	4.56	3.91	4.008
2345	1	4.32	3.67	4.31	3.56	4.76	4.124
	2	4.54	3.76	3.97	3.84	3.72	3.966
	3	4.64	4.54	3.98	3.94	4.38	4.296
3195	1	3.55	4.39	3.84	3.78	3.82	3.876
	2	3.85	3.49	4.39	5.00	3.71	4.008
	3	3.97	3.47	3.30	4.34	5.83	4.182

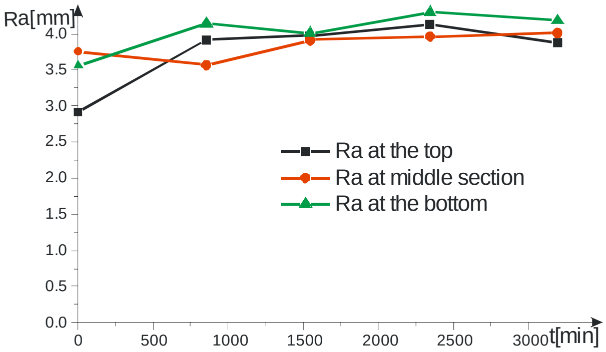

*Figure 6. Change in Ra function of cutting time for **clyrate***

Roughness was checked at PERTHOMETER S5P.
Figure 4 presents roughness change, i.e change in Ra function of cutting time for Č4580 which has been monitored at three different heights of the machined sample.

1. **at the top**
2. **at middle section**
3. **at the bottom**

Figures 5 and 6 show changes in Ra roughness parameter functioning as cutting time at three heights of the sample, for marble and clyrate.
All diagrams infer rise in the Ra roughness parameter with cutting time. This clearly suggests firm correlation between roughness of the machined surface and focusing tube wearing.

5. CONCLUSION

This paper presents the results of the investigation of the correlation between cutting time, change in the diameter of the focusing tube outlet and quality of the machined surface.
It has been suggested that longer duration of cutting induces the increase in the diameter of the focusing tube outlet, this correlation being almost linear. Further experiments are required in order to obtain more accurate correlation of the stated parameters.
Similarly, close relationship between quality of the machined surface and cutting time is also obvious. The longer the working time of the tube the more pronounced roughness of the machined surface for the stated working parameters. This correlation is quite obvious in iron and clyrate, whereas serious irregularities have been evidenced in marble. Roughness at the bottom of the sample occurred regularly as compared to the one at the top of the sample.
In brittle materials, such as marble, pronounced wavering has been evidenced, which may further explain why the results of marble investigation show irregularities. Further investigations are required so as to check and explain this claim.

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