Experimental study on the depth of cut of granite in pulsating water-jet

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Abstract. The ecological, economical and industrial benefits of pulsating water-jet it faces a new challenge in research era. Pulsating water-jet is an evaluation of water-jet technology. In pulsating water-jet technology researchers have done substantial work in a various field such mining, civil, mechanical, ornamentals, geology field. The main purpose of this research is to check the performance of black granite by pulsating and non-pulsating water-jet technology. The disintegrated grooves were analyzed by the Optical Profilometer MicroProf FRT. The topography of the surface was exported to the spip6.0.6 program. From the results, it was observed that higher depth of cut obtained in pulsating water-jet.

Symbols

- d - nozzle diameter [mm]
- A - amplitude [mm]
- f - frequency [kHz]
- z - stand of distance [mm]
- P - pressure [MPa]
- v - traverse speed [mm/s]

1. Introduction

Since 1960’s water jet with high-pressure has been used for rock breakage. This technology has been very popular for scientific research and industrial application by using high-pressure and low volume jet. Although it has been developed for cutting and machining of hard high-temperature ceramics without any significant thermal effect. But
several modifications have been done in this technology. A continuous water jet is a basic type to which several modifications have been done. Today clean water-jet (WJ) and abrasive water-jet (AWJ) (Nag et al., 2017), (Srivastava et al., 2017), (Nag et al., 2018) is usually used in industry. However, these two have technological and economical limits at high pressure. The current trend of erosion of material at low pressure by means of pulsating water-jet (Lehocka et al., 2016). This pulsating water-jet technology of cutting and disintegrating the various material belongs peculiar technology of material disintegration (Tripathi et al., 2016), (Tripathi et al., 2017) and surface treatment (Srivastava et al., 2016), (Srivastava et al., 2017) unheed the fact that the technology attains considerable growth during last decades, number of researchers throughout the world still paying momentous attention to further improvement of its performance and its adaptability to the environmental requirement to make it more economical and comfortable (Foldyna et al., 2004). The pulsed water-jet can be applied in several forms like compressed, interrupted and excited. Among these the interrupted water-jet device controls the diameter, frequency and interval length of pulsed jet by adjusting jet pressure, rotational speed of rotary disc and the size of the nozzle through which we can generate completely interrupted pulses which makes the full utilization of water pressure by eliminating the cushion effect of water (Yong Liu et al., 2015). In this technology, high energy liquid jet uses an extremely narrow free stream of a liquid flowing out of a sapphire or diamond nozzle. Its medium cutting speed varies from values approx. 600m/s to a commercial maximum value approximately 1000m/s, used in devices in Flow international company (Dehkhoda et al., 2014). The advantages of such pulsating jet over continuous jet is that initial impact of pulses of the pulsating jet on our target surface generates the impact pressure that is much more than the stagnation pressure generated by continuous jet under the same working conditions. And pulsating jet also induces the fatigue stress due to the cyclic loading of the target surface. This research focuses on the disintegration of granite by pulsating jet because the use of granite as a building material is dramatically increasing all over the world. This is mainly due to properties of granite such as resistance to environmental influences, hardness, less porous and aesthetic properties (Karakurt et al., 2012).

Figure 1. Evaluation of water-jet [Sitek et al., 2011]

(Lehocka et al., 2016) The erosion effect of water on various materials of various types is known from history cook. Many researchers have given their ideas and experimental results. (Hennery et al., 1972) Experimented the impingement of high-pressure water-jet on rocks. He found that water pressure has more effect on depth of penetration than standoff distance. Time has a great effect on the rate of penetration, most of the rocks cutting being done in the first tenth second of a second. Traverse speed has an inverse effect on depth of penetration. As the number of passes increases the rate of penetration decreases. Pressure has a small effect on specific energy while relative effect has more. Penetration increases with increases in nozzle diameter. It should be optimum when
specific energy is our criteria. Richard Dvořský et al. after an experiment he found that erosive effect of the pure water jet in continuous mode is not sufficient enough for cutting of majority of the hard material. Therefore its erosive effect is often multiplied by inserting of soft abrasive material into the water stream. There is quite promising option to replace the erosive effect of solid abrasive by the implosion of cavitation bubbles at the interface of the liquid and solid surface. The third prospective option to increase the erosive effect of the water jet is the pulsed mode of outflow of a liquid jet in a form of relatively compact macroscopic drops. (Yong Liu et al., 2016) Its impact force is 1.5-2.5 times higher than stagnation pressure of continuous jet. (Foldyna et al., 2012) An understanding of effect associated with liquid impact erosion or water droplet impingement on the solid is needed in a number of technological situations. (Jerome Fortin et al.) The generation of ultrasound vibrations using a device - acoustic converter - is the method of modification of water continuous jet. This method allows the change of frequency and deviation amplitude of the actuator. Magnetostriction and piezoelectric actuators are used for the generation of vibrations. This research article focused on the experimental study of the depth of cut of granite by pulsating water jet.

2. Experimental analysis

The target material is black granite was used. It has having resistance to environment, and aesthetic properties. It has been widely used in outdoor and sculpture, Stone Quarrying Ornamental Decorative Purpose, Artistic & architectural application. The experiments were carried out in an institute of genetics Ostrava, poruba. The technological assembly consists of a Hammelmann HDP which is operating pressure is 160 MPa, maximum flow rate of 67 l min⁻¹ and ABB robot IRB 6640 180/2.55 using as a driving cutting head. Pulsation effect monitored by an Ecoson WJ-UJ 630-40 ultrasound device. Experiments were conducted by pulsating water-jet with frequency 20.2kHz and MVT circular nozzle with 0.9 diameters. The black granite material disintegration parameter is shown in table 1. Fig 2(a) shows the experimental setup and (b) treated surface of the granite. The formed disintegrated grooves were evaluated by MICRO PRO FRT optical profilometer.

| S. No | Type of Nozzle | d(mm) | Power[W] | A(mm) | f(kHz) | z(mm) | P(MPa) |
|-------|----------------|-------|----------|-------|--------|-------|--------|
| 1.    | Circular       | 0.9   | 380      | 6     | 20.2   | 30    | 60     | 14     |
| 2.    | Circular       | 0.9   | 380      | 6     | 20.2   | 30    | 60     | 16     |
3. Result and Discussion

Figure 3(a) shows the disintegrated grooves with pulsating and without pulsating water-jet at 14 mm/sec and 16 mm/sec. 2-D images of the cutting grooves through pulsating and non-pulsating technology in black granite disintegration is shown in Figure 3(b)(d). The figure was observed that the grooves generated by pulsating water jet were more regular as compared to the grooves generated by the continuous water jet as depicted in figure 3(c)(e). The reason behind this behavior is that the continuous water jet does not develop sufficient stagnation pressure to cause the disintegration of the granite sample. Due to more impact energy in pulsating water, therefore, it creates a high depth of the grooves in comparison to continuous jet. It was also observed that at lower traverse speed deeper grooves were generated because at lower traverse speed the jet gets more exposure time for interacting with the black granite material. However, the deeper grooves were formed in the samples treated with pulsating water jet.
4. Conclusion
Test of rock cutting by pulsating and without pulsating water-jet proved the improved performance of pulsating water-jet during the disintegration of rock notwithstanding pulsating water-jet widely used in dimensional stone and ornamental industry (Foldyna et al., 2004). It shows the higher performance at low pressure and achieving higher
cutting performance due to the impact of shock waves on the rock surface. Accordingly, this technology has potential to create viable, no heat affected zone and environment-friendly technology.

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