A Comprehensive Report on Water Jet Cutting

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Abstract— In this paper a comprehensive report has been presented in the light of research work undertaken in the field of abrasive water jet cutting. This machining process is the one of the non-conventional machining processes. Various research has been carried out computationally and experimentally in order to bridge the research gap in metal machining process through non-conventional machining technology.

Key words: AWJ, Metal, Abrasive, Velocity

I. Introduction

For cutting metal with high accuracy and quality abrasive water jets are used with suitable parameters for this process. AWJ can also be applied for milling [1], turning [2–3], grinding [4], polishing [5] and complex machining [6]. However, cutting of shapes from plate-type materials remains the most frequent application up to now. Although this method can achieve very good standards of quality, there is still space for improvement. The study presented in this paper can be used to improve the AWJ cutting quality, thus generating economic benefits.

II. Literature review

Andrey et al. 2019 improve the cutting capacity of water jets without increasing the hydraulic power of equipment, pulsed water jets are basically used to increase the rock cutting efficiency. However, there are no mature recommendations for selection of rational parameters, and the relationship between indicators of rock cutting efficiency and parameters of pulsed water jet is still not established. In this context, we aimed at developing a generalized equation for calculating rock cutting efficiency, in which all the major parameters in consideration of rock cutting process are included. Then, a calibration of the rational parameters of rock cutting by pulsed water jets was conducted. For enhancing the productivity and diminishing the energy consumption the obtained result are quite beneficial.

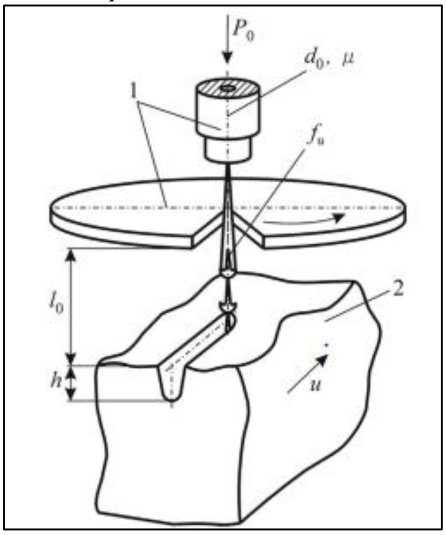

Figure 1: Basic principle and major factors of rock cutting by pulsed water jets [10]

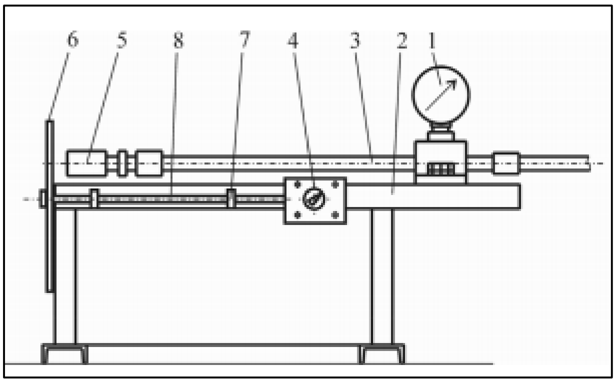

Figure 2: Equipment for forming pulsed water jets. 1 - high-pressure manometer; 2 - frame; 3 - vibration alleviation device; 4 - electric motor with a thyristor speed regulator; 5 - jet-forming device; 6 - disc; 7 - bracket; 8 - disk mounting axis. [10]

Libor et al. 2018 test a theoretical model for calculating abrasive water jet (AWJ) cutting parameters in order to reduce the shape deformation in curved cutting trajectories. Experimental results were produced using commercial AWJ machines. Despite the limitations of these commercial AWJ machines in terms of both software and hardware, the comparison of calculated and experimental results showed a sufficient correspondence between the theoretical and experimental data sets, with the difference lying within the range of measurement uncertainty. The difference between theoretical and experimental results is up to 2.5 %, similarly to the combined measurement uncertainty. The maximum deviations of the measured values from the calculated averages are up to 0.2 mm and the measuring device uncertainty is up to 0.1 mm. A method aimed at reducing the shape distortion caused by AWJ in curved geometric features is suggested and tested. It was unambiguously demonstrated that the jet markedly reduces the shape deformation in curved geometric features when it is tilted according to the proposed method. Such an error compensation procedure can be already applied on commercial machines.

Daniel 2014 select the best technology for cutting metal. In this article i will briefly discuss the different ways of cutting metal, such as water jet cutting, as well as laser and plasma cutting. These techniques and their comparisons are illustrated in a table to highlight the differences between them. Further comments are then provided on the key aspects of this comparative method, leading to the appropriate conclusions, which responds to the seemingly simple question: Which technology is best suited to cutting metal.

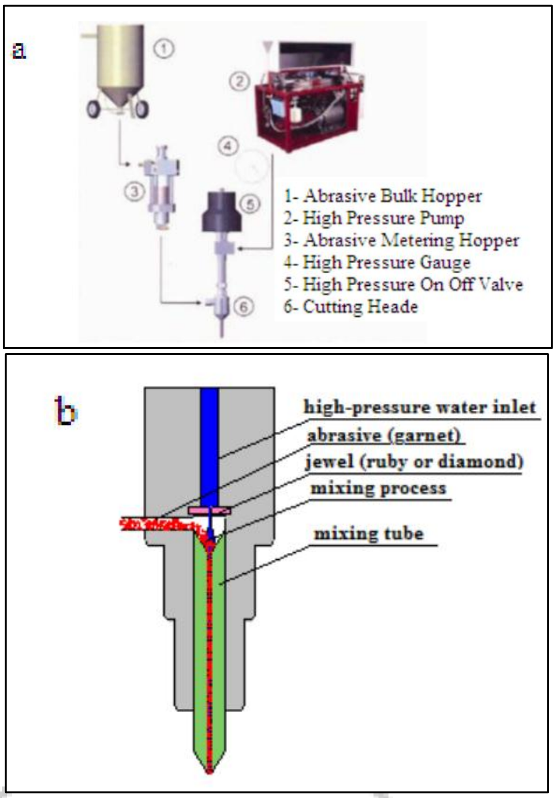

Figure 3: (a) abrasive water jet cutting system [6]; (b) the principle of operation of the abrasive water jet nozzle [12]

Niranjan et al. 2018 studies , the influence of dynamic process parameters such as water pressure, traverse speed and abrasive mass flow rate on depth of penetration and surface topography in high strength AZ91 magnesium alloy were investigated using Abrasive Water Jet (AWJ) cutting technology. Process parameters were varied at 3 levels and influences of each parameter on penetration ability were identified using analysis of variance (ANOVA). Contribution of water pressure and traverse speed on jet penetration found higher compared to abrasive mass flow rate. Profile projector was used to measure depth of penetration. Microstructural features and topography of cut surfaces were examined using Scanning Electron Microscopy (SEM). Micro cutting and ploughing were observed on the top and bottom portion of the cut which were similar to that of modes of deformation in other ductile materials like aluminium and steel. Surface roughness of cut surfaces was measured using Taylor Hobson surface roughness tester. Surface roughness found higher at higher traverse speeds and lower at lower traverse speeds. This study also highlights the suitability of AWJ cutting technology for cutting magnesium and its alloys.

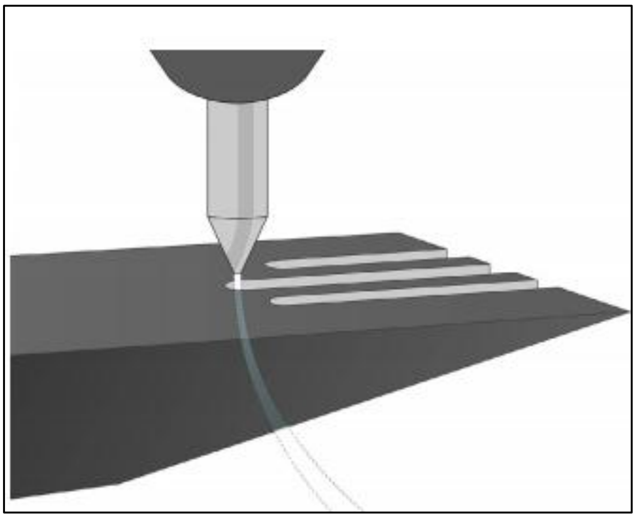

Figure 4: AWJ cutting of trapezoidal Specimen [13]

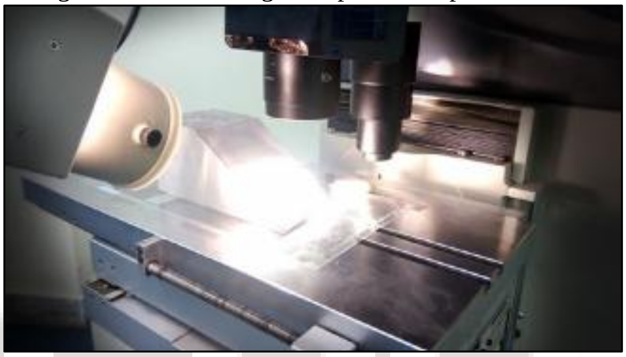

Figure 5: Specimen placed on glass base of profile projector [13]

Andrzej 2016 Existing models of predict the abrasive water jet cutting effects, does not give satisfactory results in a wide area of parameter changes, in particular for different, unusual materials. This implies the need to carry out extensive research in order to expand the empirical database. To optimize the process can be used modern methods referred to as Design of Experiment (DoE). One of the methods to determine the effect of parameters on the controlled different technological processes is orthogonal array design, also called the Taguchi approach. This method allows to limit the amount of research needed to achieve the desired test results, reducing the time required course for their performance and at the same time their costs. Characterized by Taguchi ratio signal / noise (S / N) enables the assessment of the significance of the impact of various parameters on the process, which is still not well enough understood. The article discusses one method for cutting optimization of aluminum alloy by high pressure abrasive water jet.

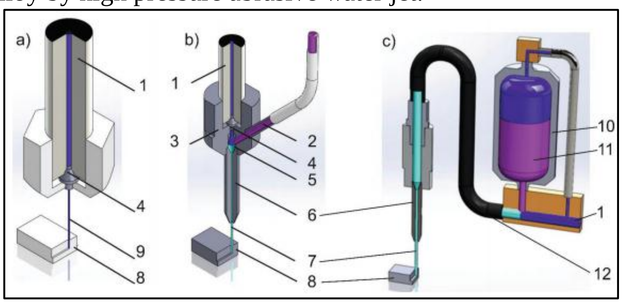

Figure 6: Schematic diagram of: a) Water Jet cutting and b) Abrasive Water Jet cutting, c)Abrasive Suspension Water

Jet:1. High pressure water inlet, 2. Abrasive inlet, 3. Cutting head, 4. Water nozzle, 5. Mixing chamber, 6. Focusing tube, 7. High Speed Abrasive Water Jet, 8. Sample, 9. High Speed Water Jet, 10. Pressure vessel, 11. Wet abrasive (slurry), 12. High pressure flexible hose. [14]

Derziia 2015 presents the effects of material thickness, traverse speed and abrasive mass flow rate during abrasive water jet cutting of aluminum on surface roughness were investigated. GMT garnet was used as abrasive material with 80 mesh. Surface roughness was measured across of depth of cut. The experimental results show that traverse speed has great effect on the surface roughness at the bottom of the cut. It was also discussed the correlation between the surface roughness and other abrasive water jet cutting variables. Based on the experiments, the optimal process parameters for each material thickness were defined.

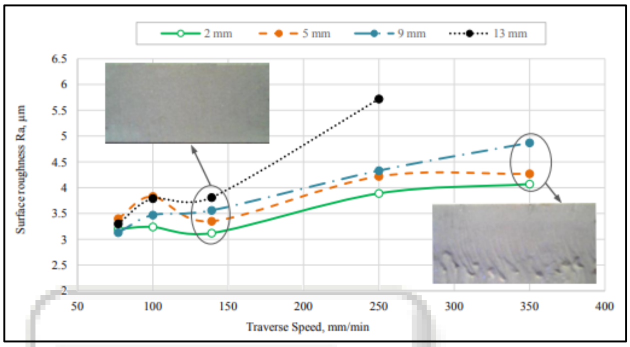

Figure 7: The effect of traverse speed on the surface roughness on different zones of the cut surface – 15 mm thickness. [15]

Yuxing et al. 2019 Water jet guided laser machining is a new processing technology using water beam fiber to guide laser to machining work-piece surface, which has the advantages of parallel cutting, ideal ratio of depth to width, small heat affected zone, less micro-cracks, less recast layer, no pollution, etc. However, it is easy to make the nozzle burn and the laser deviate from the processing area when the laser beam is coupled to the water beam through a coupling cavity with a nozzle with large aspect ratio due to the shrinkage of water beam in the nozzle and the pulling water beam deviation by aggregated water droplets. In view of the above defects, this paper presents a deflected water beam guided laser method based on non-uniform electric field. The related technical principles are analyzed, and the simulation of non-uniform electric field deflection water beam is also carried out. Theoretical analyses and simulation results provide theoretical support for water jet guided laser technology based on non-uniform electric field deflection water beam.

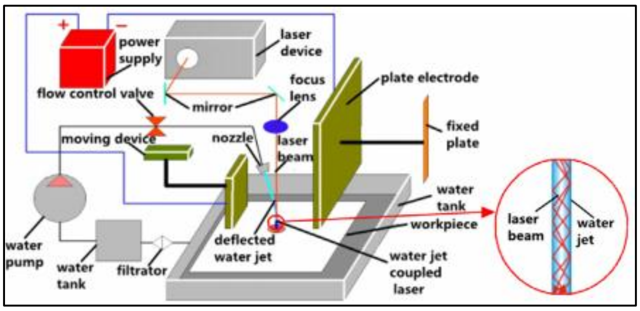

Figure 8: Schematic diagram of deflection water jet guided laser machining principle by non-uniform electric field. [16]

Hongxiang 2017 Dust suppression is an urgent issue for coal mines because the problem of dust has not been solved effectively, harms the health of miners and is a potentially serious threat to the mine environment and safety. Therefore, an effective method for dust suppression is highly desired. In this work, the formation and suppression of cutting dust are analyzed, and a method for suppressing the cutting dust during the formation process in the crushing zone is discussed. Internal and external water jets are used for dust suppression based on the cutting dust formation mechanism and are examined in rock cutting experiments using a newly developed test-bed. The use of internal water jets reduces the cutting dust concentration by over 90% on average, with no obvious relationship between the dust concentration and the water pressure. The use of external water jets reduces the cutting dust by over 65% on average, with an increasing reduction in dust concentration with increasing water pressure from 5 MPa to 20 MPa.

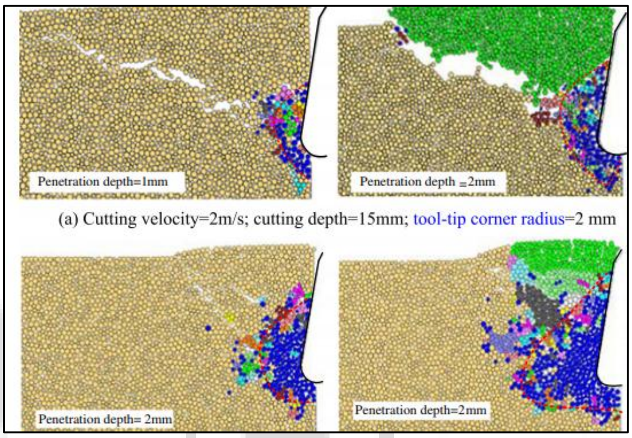

Figure 9: Rock cutting dust formation with different cutting speed. [17]

Piotr Löschner et al. 2016 presents the effect of cutting speed on surface roughness in abrasive water jet cutting of 10mm thick stainless steel samples. Photographs of cut surfaces were taken and roughness parameters were measured in different locations across depth of cut. Differences between obtained surface geometric structures and measured roughness parameter values were presented and discussed. The research has shown a considerable effect of cutting speed on surface roughness, surface quality and presence of machining marks. This effect was especially noticeable in lower parts of examined cut surfaces.

Figure 10: Abrasive water jet cutting process with experimental sample mounted in the holder.[18]

Figure 11: Measurement procedure. [18]

III. CONCLUSION

Water jet cutting is the most versatile method for the separation of materials, and that this technique can cut through almost any material such as steel, stone, ceramics, aluminium, glass, wood, plastics, laminates, etc.

This cutting process is an environmentally friendly process that does not produce any harmful fumes

Increasing the cutting tool height decrease the cutting accuracy.

For better cutting speed, high velocity is required where nozzle places a crucial role.

The cutting efficiency significantly affected as the nozzle angle changes.

Increase in abrasive volume fraction the material removal rate increases.

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