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Pparameters Controlling Abrasive Water Jet Technology: Erosion And Impact Velocity For Both Ductile And Brittle Materials

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Abstract: - This work intends to study and analysis all operations used in water jet technology and their related applications. This work aimed to study the abrasive machining by forcing the abrasive particles, or grains, into the surface of the workpiece. Testing abrasive jet which uses a mixture of water and abrasive to more effectively cut through materials. Studying material response to impact either as ductile or brittle erosion. Ductile erosion is relevant to metals and similar materials that are capable of significant plastic deformation. Brittle erosion applies to ceramics, glasses, and hard metals that crack and fragment under impact. The paper aims to Analyze and study the most important variables in impact erosion, i.e., impact velocity and impact angle affecting material removal the main objectives of the study is to study the abrasive machining by forcing the abrasive particles, or grains, into the surface of the workpiece. Testing abrasive jet which uses a mixture of water and abrasive to more effectively cut through materials. Studying material response to impact either as ductile or brittle erosion. Analyze and study the impact velocity which considered as the most important variable in impact erosion.

Keywords: - *water jet, abrasive materials, ductile, brittle materials, crack, impacts .*

I. INTRODUCTION

Abrasive materials or grains are technically any material can be used to abrade another material. For any industrial application, however, abrasives are minerals from a select group of very hard minerals used to shape, finish, or cut other materials. In processes, abrasive machining works by forcing the abrasive particles, or grains, into the surface of the workpiece so that each particle cuts away a small bit of material. Abrasive machining can be divided into two categories (bonded or loose) based on how the grains area applied to the workpiece. In bonded abrasive processes, the particles are held together within a matrix, and their combined shape determines the geometry of the finished workpiece. In loose abrasive processes, there is no structure connecting the grains.

Loose abrasive is a broad class of abrasive machining processes that include Impact abrasive machining. Impact abrasive machining uses a mixture of fluid and solid particles that is accelerated, and then impacts the surface of a target workpiece; thus, causing permanent deformation or material removal. When material removal is unfavorable, it is called wear, while favorable material removal is called machining. When a jet removes material from a target surface by impacting at near-normal angle, the process is called erosion. When impact is at near tangent angle, it is called abrasion. [1]. Water (H2O) is the most abundant compound on Earth's surface, covering about 70%. In nature, it exists in liquid, solid, and gaseous states. It is in dynamic equilibrium between the liquid and gas states at standard temperature and pressure. At room temperature, it is liquid, nearly colorless with a hint of blue. Water has higher density and is incompressible, compared with air. Water has an important indirect role in impact abrasive machining: Stores and transfers the energy required to accelerate abrasive particles, guides the abrasive particles and focuses impacts within a small spot, flushes debris and abrasive particles away from the working zone, and ensures that fresh surface material is always exposed, Provides some lubrication between the particle and workpiece, reduces frictional heating, and provides an effective convection cooling medium, where heat generated during deformation is immediately extracted from the workpiece. [1].

Jet, fluid jet is a nozzle intended to eject gas or fluid in a coherent stream into a surrounding medium. A nozzle is a relatively simple device, is device whose purpose is to create a high velocity fluid stream at the expense of the fluids pressure. It is contoured in an appropriate manner to expand a flowing fluid smoothly to a lower pressure, thereby increasing its velocity. [2].

There are many researches discussed this issue but little of them investigate and make experimental investigation. Rolla, Missouri (1983) a dimensionless pipe length analysis was developed to summarize the possible responses of a modulator system for any combination of pipe lengths. The parametric summary has as many variables as pipes in the modulator system. The transfer matrix method with pipe friction neglected is used for the response equations. The results are compared to the more exact method of characteristics. Bodnrov

(2011) discusses the background and results of research focused on the action of a high-speed water jet on concrete with different qualities. The sufficient and careful removal of degraded concrete layers is very important for the renovation of concrete structures. High-speed water jet technology is one of the most common methods used for removing degraded concrete layers. Different types of high-speed water jets were tested in the experimental part. The classical technology of a single continuous water jet generated with one nozzle was tested as well as the technology of revolving water jets generated by multiple nozzles (used mainly for the renovation of larger areas). C.D.K. Gauert et al. (2013), proposed an alternative tool for selective underground mining of high-grade ore sections in stratiform ore bodies showing a preferred 'bottom' or 'top' enrichment such as the Witwatersrand reefs and the Bushveld Complex platiniferous reefs. This technique, utilizing known mining technology together with more advanced machinery and additives as used in industrial and cleaning applications, may lead to an increased life-of-mine (LOM) for mining operations. A series of experiments was successfully carried out in a laboratory on Witwatersrand quartzite material, indicating acceptable cutting performance. Mining volumes by selectively cutting of reef portions are considered to be comparable to traditional drilling and blasting. Economic advantages of water jet mining include energy savings due to the lower quantity of gangue rock to be hoisted to surface, as well as savings by a decrease in the usage of blasting materials. Capital expenditure of water jet cutting, if applied on a broad scale, could be lower in the long term than that of conventional drilling and blasting methods. Mining by the application of high-pressure water jet technology could become a competitive 'green technology' improving the economics and safety of labor-intensive mining operations. They also suggested that water jet cutting at an industrial scale can become a routine hard-rock mining technique in the future.[5]. Cristian B. et al., (2012), presented the aspects regarding an innovative nonconventional technology: abrasive water jet cutting. There are presented aspects regarding technique of abrasive water jet cutting (principle, parameters, and theoretical considerations about them), equipment (with emphasis on very high pressure pump) and performance of this technology (materials possible to be cut, cutting parameters for some materials). There are presented also results (theoretical aspects, specific techniques, cutting results) regarding other than cutting technological operations possible to be performed with abrasive water jet: drilling with abrasive water jet.

II. RESULTS AND DISCUSSION

By analyzing the experimental data, it has been found that the effects of the tow basic parameters, water pressure, and nozzle traverse speed on the smooth depth of surface cut. The effect of each of these parameters is studied while keeping the other parameters considered in this study as constant.
For (2.5 cm) thickness D2 work piece, the relationship between nozzle traverses speed and cut quality while water pressure is constant 200Mpa.fig.1.

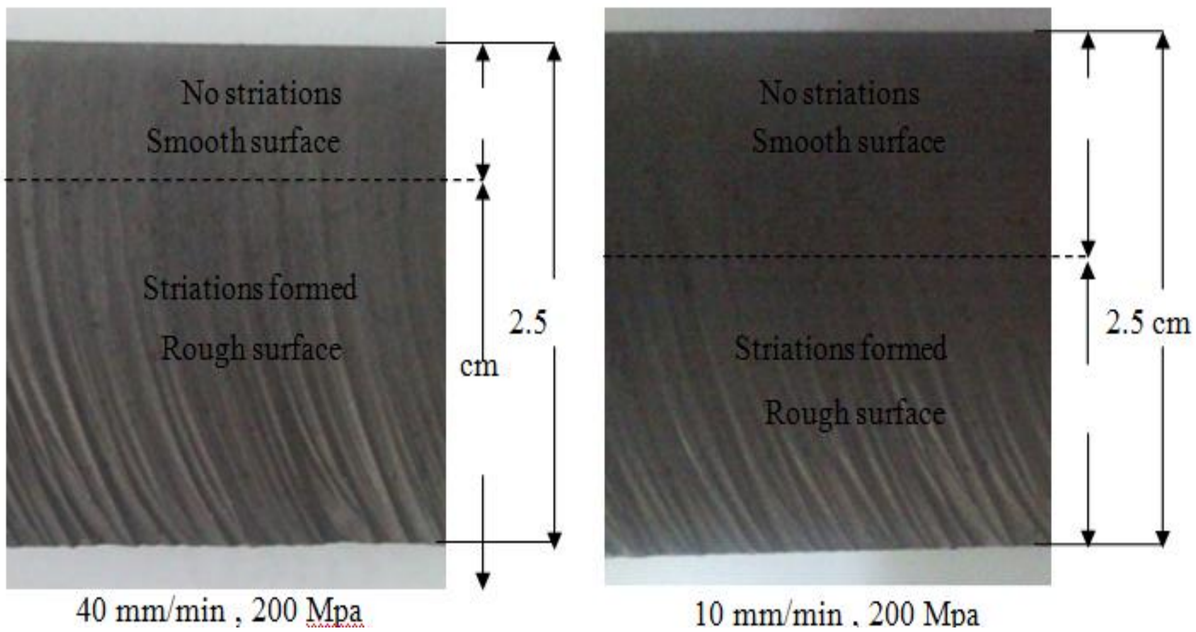

Fig.1 Surface quality

Table 1. First part results

No	1	2	3	4	5	6
Traverse speed (mm/min)	5	10	20	30	40	50
Smooth depth h_s (mm)	13	10	8.7	7.5	6.5	5.8

Fig.2 shows the results of cutting material for trailback and taper cases.

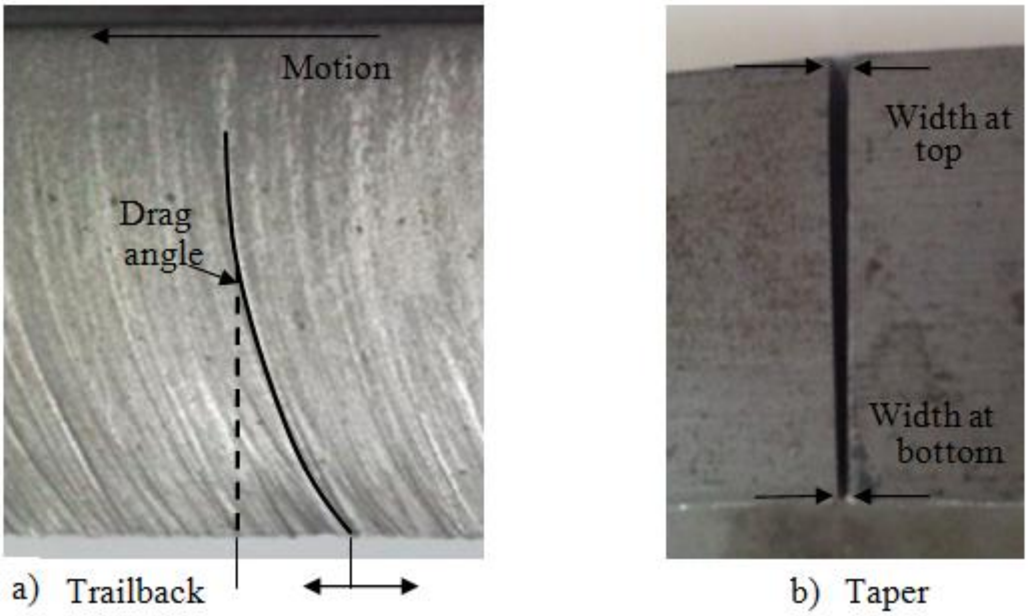

Fig.2 Cut quality: a) Trailback (surface quality), b) Taper (geometric of cut).

Table 2 shows the results of cutting case.

Table 2. Trailback and taper results

No	Traverse speed (mm/min)	Trail back (mm)	Taper = Width at top – width at bottom (mm)		
			Top	Bottom	Taper
1	5	1.2	0.9	0.8	0.1
2	10	2.6	0.9	0.75	0.15
3	20	3	0.9	0.72	0.18
4	30	3.4	0.9	0.64	0.26
5	40	3.9	0.9	0.5	0.4
6	50	4.5	0.9	0.47	0.43

Fig.3 shows the relation between cut quality and traverse speed of water jet.

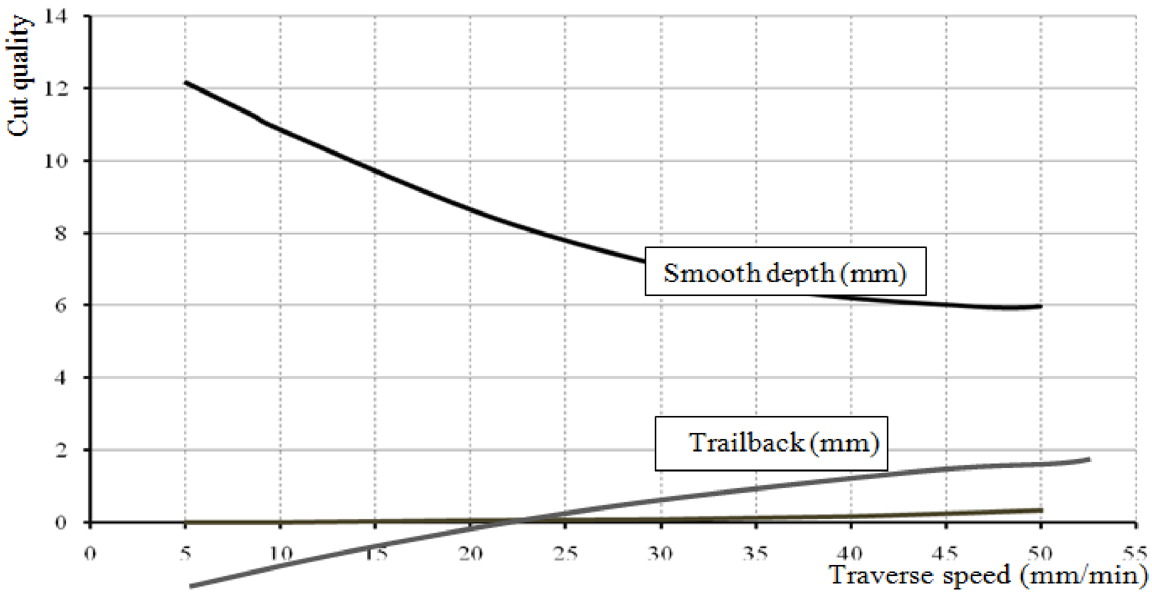

Fig.3 Effect of variable traverse speed (mm/min) on cut quality

Fig.4 shows the relation between smooth depth and traverse speed.

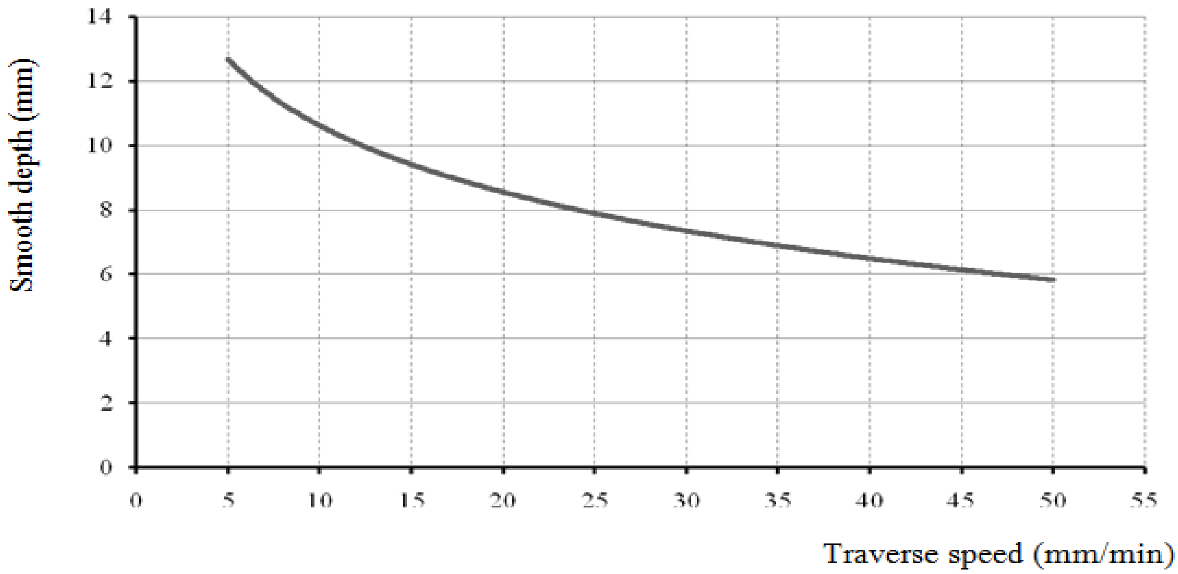

Fig.4 effect of variable traverse speed (mm/min) on smooth depth (mm)

The relationship between variable water pressure and smooth depth of surface cut while nozzle traverse speed is constant 10 mm/min. Table 3 shows the second part results of this study.

Table 3 second part results

No	1	2	3	4	5
Water pressure P_i (Mpa)	200	250	300	350	400
Smooth depth h_s (mm)	10	13.6	16	18.5	22

Fig. 5 shows the relation between the smooth depth and water pressure.

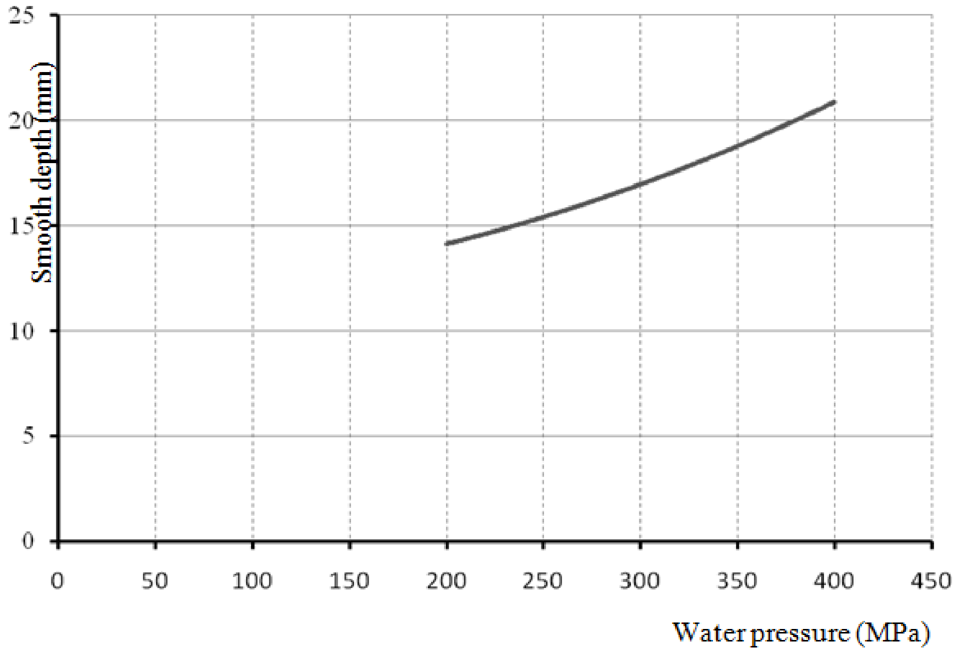

Fig.5 Effect of variable water pressure (MPa) on smooth depth (mm)

Effect of AWJ cutting on different samples by comparison between samples properties and smooth depth (hs) while water pressure (200MPa) and nozzle traverse speed (10 mm/min) are constant. See fig.6, 7and table 4.

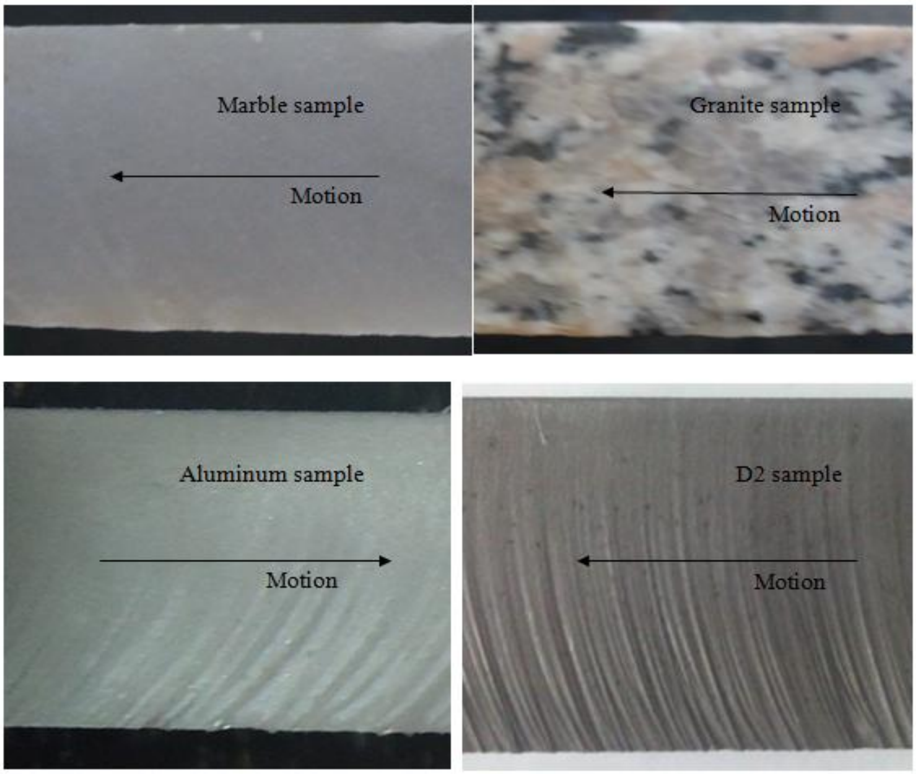

Fig.6 metals cut surface

Table 4

Materials	Metals (ductile)		Nonmetals (brittle)	
	Aluminum	D2	Granite	Marble
Hardness BHN	75	280	650	810
Smooth depth (mm)	13	10	18	22

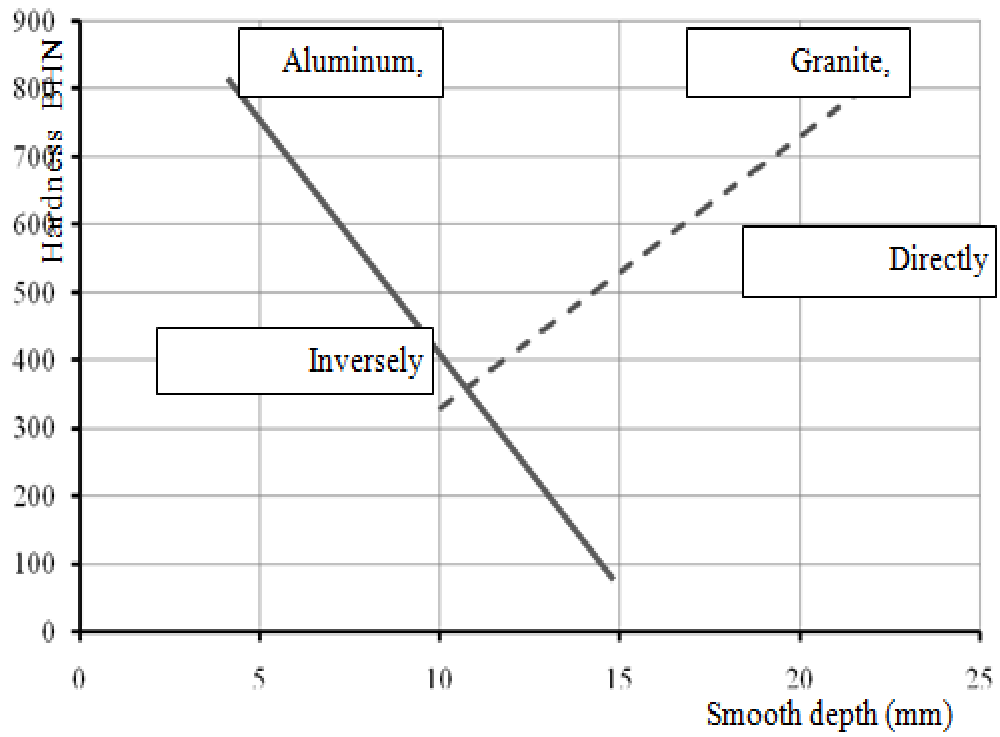

Fig. 7 the relationship between hardness (BHN) and smooth depth (mm)

Due to the random nature of particles impact and collisions, it is practically impossible to estimate the exact shape of the cut groove from process parameters alone. There is currently no satisfactory model for estimating the exact geometry of the kerf, taper angle, or smooth depth of cut.

III. CONCLUSION

When material removal is unfavorable, it is called wear, while favorable material removal is called machining. When a jet removes material from a target surface by impacting at near-normal angle, the process is called erosion. When impact is at near tangent angle, it is called abrasion. The mechanism of abrasive water jet cutting (AWJ) is erosion. Abrasive technically any material can be used to abrade another material. Abrasive machining works by forcing the abrasive particles, or grains, into the surface of the workpiece. An abrasive jet uses a mixture of water and abrasive to more effectively cut through materials. A pure water jet (one without abrasives) is effectively only for very soft materials, such as rubber or food products. Abrasive minerals typically rely on a difference between the hardness of the abrasive and the material being worked upon, with the abrasive being the harder substance. Material response to impact is described either as ductile or brittle erosion. Ductile erosion is relevant to metals and similar materials that are capable of significant plastic deformation. Brittle erosion applies to ceramics, glasses, and hard metals that crack and fragment under impact. Impact velocity is the most important variable in impact erosion, also impact angle is the second most important factor affecting material removal. Maximum erosion occurs at an impact angle near 90 degrees for brittle materials but the peak erosion angle is 20 to 30 degrees for ductile materials.

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