Abrasive water jet cutting report engineering essay

Profession

Up until about the mid twentieth Century the bulk of production relied on `` two traditional procedures of forming and machining (Tlusty, 2000) . Forming is the procedure of altering the form of the whole work piece, whereas machining removes merely certain, and desired countries. Whilst these cardinal procedures still form the really anchor of contemporary production, there has besides been the demand for new procedures to be developed.

The traditional procedures, as highlighted above, have a figure of built-in restrictions which limit their application to industry. In the instance of conventional machining procedures, a crisp film editing tool is used to organize a bit from the work by shear distortion. This consequences in the formation of high forces together with the corresponding mechanical energies. Together with this are a figure of extra jobs that can originate. Due to sum of energy required to transport out the operation, a physique up of unwanted heat can happen, which frequently leads to deformation of the work piece and surface snap. In certain instances, the forces introduced by the procedure are highly high and in order to procure the work piece considerable clamping forces are required ; this excessively can take to deformation.

Together with these restrictions, the development of stuffs with belongingss of high strength, high hardness and high stamina has driven the debut of untraditional machining methods. Nontraditional machining (NTM) methods have been developed since World War II in an effort to turn to machining demands which can non be carried out by conventional methods entirely

(DeGarmo, Black & A ; Kohser, 2003) . NTM methods provide the ability to machine:

Complex geometries ;

Components with an first-class surface coating ;

Delicate constituents, which otherwise would non defy the clamping forces ; and

Brittle stuffs or stuffs with really high hardness.

There are four types of untraditional procedures ; classified harmonizing to the principle signifier of energy used to consequence stuff remotion. These include: mechanical, electrical, thermic and chemical. One procedure which falls into the mechanical class is scratchy H2O jet (AWJ) film editing, and will be the focal point of this study. First, and prior to discoursing AWJ, the procedure of H2O jet (WJ) film editing will be introduced.

Water Jet Cutting (WJC)

Water jet film editing, which is besides known as waterjet machining and hydrodynamic machining, was foremost developed in 1968, followed by the first commercial system in 1971 (Zhong & A ; Han, 2003) . Through the usage of a all right, hard-hitting, high-speed watercourse of H2O directed at the work piece (surface) , a cut is created, as illustrated in figure 1 below. In order to bring forth the all right watercourse of H2O, a nose with an gap (opening) typically in the order of 0. 1 - 0. 4mm is used (Groover, 1996) . Together with this, runing force per unit areas of around 400MPa and above are used to supply sufficient energy for cutting to be carried out. Furthermore, the fluid of the jet can frequently make 900m/s and the cardinal procedure parametric quantities include: H2O force per unit area, opening diameter, H2O flow rate and the working or 'standoff ' distance between the nose and the work piece.

Figure 1 - Schematic of WJC Process (Groover, 1996)

As the typical film editing force per unit areas as mentioned are required, a hydraulic pump is used to supercharge the fluid. The fluid is so passed through a valve, which regulates the flow rate in order to accomplish the optimal cut. The concluding phase of the fluid is to go through through the nozzle opening and impact the work piece surface from a controlled tallness.

Procedure Parameters

The stuff from which the nose is made is doubtless the most of import parametric quantity in footings of procedure control (as this greatly determines the opening diameter) . The nozzle unit comprises of a unstained steel holder, together with a gem ; normally sapphire, ruby or diamond. Of these stuffs, diamond lasts the longest but is the most expensive. Recent progresss in the production of man-made sapphire offer this stuff as non merely the most cost effectual solution, but besides due to other advantages excessively.

Man-made sapphire can be machined moderately accurately and besides has a high opposition to have on. The most common causes of nozzlefailureare due to sedimentations come ining the fluid watercourse, therefore underscoring the demand for high degrees of filtration of the fluid prior to pressurisation, to cut down nozzle wear. With proper nozzle design a tight, coherent waterjet can be produced and maintained really accurately.

When transporting out the cutting procedure, both the opening diameter and the 'standoff ' distance must be closely monitored to keep a changeless deepness of cut. As the nozzle wears, compensatory alterations in the draw tallness must be made. Although existent draw distances vary from beginning to beginning, distances in the order of millimeters are normal ; normally around 0. 25 - 3. 5mm.

WJC: Advantages and Disadvantages

WJC offers many advantages over conventional machining methods. This machining procedure provides the ability to cut stuffs without firing or oppressing the work piece. Furthermore, no important heat is generated, therefore, deformation is minimised and in some instances, eliminated. Unlike machining or grinding, no dust is produced ensuing in small environmentalpollution. Other advantages include minimum material loss and easiness of mechanization when used with numerical control and industrial automatons. Whilst such advantages exist, one of the chief disadvantages to H2O jet film editing is that there are merely a limited figure of stuffs that can be cut economically (MTU, 2009) . Although it is possible to cut tool steels utilizing this procedure, the provender rates have to be greatly reduced and therefore the edged clip increased. This, in kernel, consequences in a high cost procedure. Such stuffs that can be cut utilizing the H2O jet procedure include: plastics, fabrics, complexs, floor tiles, rug, leather and composition board.

Abrasive Water Jet Cutting (AWJC)

To allow the film editing of difficult stuffs such as ceramics, metals and glass, together with those softer stuffs, for illustration froth and gum elastic, the WJC procedure requires the add-on of scratchy atoms, therefore organizing the scratchy H2O jet (AWJ) cutting technique. In a similar mode to WJC, the procedure is carried out utilizing a high-pressure, high-speed watercourse of H2O ; nevertheless, the discrepancy being that an scratchy stuff is drawn in by a vacuity, which is created by jet watercourse.

Figure 2 - Schematic of AWJC Process (Meier, Louis & A ; Pilot, 1995)

Figure 2 illustrates a typical apparatus for transporting out scratchy H2O jet film editing. It can be seen that this follows closely the agreement of WJC equipment, nevertheless, with the add-on of a twosome of cardinal characteristics ; viz. the scratchy eating system and a 'catcher ' , which is required to protect theenvironmentfrom the high energy jet.

Procedure Parameters

As antecedently highlighted, the WJC procedure depends on a figure of parametric quantities. Whilst many of these are movable to the AWJC procedure, there are besides add-ons to reflect the alteration in cutting method. Momber & A ; Kovacevic (1998) present a list of such parametric quantities, which can be seen in figure 3 below.

Figure 3 - AWJC procedure parametric quantities (Momber & A ; Kovacevic, 1998)

Although it is by and large accepted by many writers including JankoviA‡ (2008) that the nose or opening diameter is the cardinal film editing parametric quantity, in the instance of AWJC, the abradant besides has considerable influences on the quality of the cut achieved. A choice of the parametric quantities as listed above has been explored in the subsequent subdivision, followed by an overview of the entire system control in the subdivision thenceforth.

Procedure Parameters: Overview of Observed Influences

The most of import parametric quantity, by far, is the orifice diameter. The deepness of cut is straight relative to the opening diameter ; nevertheless, making an optimal point at big diameters. Although related to pump force per unit area, figure 4 below clearly illustrates this point, demoing how the deepness of cut varies with opening diameter.

Figure 4 - Influence of opening diameter on the deepness of cut (HeI? ling, 1988)

Another parametric quantity that is closely linked to the opening diameter is the focal point diameter. This component of the cutting equipment determines the strength of the watercourse, therefore holding a direct consequence on the material remotion rate as shown by figure 5 below.

Figure 5 - Influence of focal point diameter on the volume remotion rate

(Blickwedel, 1990)

The focal point diameter is of import non merely in footings of the volume remotion rate but besides the deepness of cut. Figure 6 below shows how the deepness of cut is besides determined by this parametric quantity ; diminishing as the focal point diameter additions. The lessening in deepness of cut following an optimal point is realised by Himmelreich (1992) and has been attributed to high grades of turbulency. On the other manus, a peculiarly little focal point diameter gives rise to particle hit and clash, giving an inefficient procedure.

Figure 6 - Influence of focal point diameter on the deepness of cut (HeI? ling, 1988)

Of the cutting parametric quantities listed, the crossbeam rate can be said to hold the greatest influence on the film editing procedure, followed closely by the draw distance. Both of these parametric quantities are controlled by machine design and therefore are bound by the makers ' specification.

Figures 7 and 8 overleaf illustrate the influence of both the crossbeam rate and draw distance. It can be clearly seen that the deepness of cut lessenings as the crossbeam rate additions, following closely that of a squared map. However, on the other manus, the relationship between the draw distance and the deepness of cut is moderately additive ; with the deepness of cut decreasing as the draw distance additions.

A big figure of scratchy stuffs are available for usage in AWJC. Typically these are loosely categorised as either oxides or silicates and there are, in a similar manner to the whole procedure, many parametric quantities that determine the features of an abradant.

Figure 7 - Influence of crossbeam rate (left) and standoff distance (right) on the deepness of cut (Blickwedel, 1990)

Whilst it is hard to state precisely which parametric quantity has the greatest influence on the procedure, it is clear that both the hardness of the stuff together with the atom form and size, need consideration. Typical hardness values vary from 30 HV for Cd up to 200 HV for B carbide (Kriegel & A ; Palmour, 1961) .

Figure 8 shows the influence of both the atom form and size, whereas figure 9 overleaf high spots the significance of the mass flow rate of abradant on the deepness of cut achieved.

Figure 8 - Influence of abradant (atom) diameter and size on the deepness of cut

(Ohlsen, 1997 ; Oweinah, 1989)

Figure 9 - Influence of scratchy mass flow on the deepness of cut

(Oweinah, 1989)

Abrasive Water Jet Cutting: Associated Problems

It is clear from the old subdivision that there are many parametric quantities that have an consequence on the AWJC procedure. If such parametric quantities are non carefully controlled, so the efficiency of the procedure decreases along with the quality of the machined portion. Some of the associated jobs are presented in table 1.

Problem and definition

Parameter (s) affected by

Consequence on constituent

Taper. This characteristic arises due to a difference in the breadth of the cut at the top surface and the bottom surface and is given as a ratio (besides flank angle) .

Abrasive mass flow rate

Focus diameter

Standoff distance

Trave rate

This characteristic determines the dimensional truth of the portion.

Initial Damage Zone. Abrasive atoms impact the surface at normal angles doing craters and abrasive-wear paths.

Standoff distance

Focus diameter

(Abrasive atom size - composite stuffs)

Some fictile distortion can happen.

Change (debasement) in surface roughness/waviness.

Trave rate

Focus diameter/length

Abrasive mass flow rate

Abrasive atom size/type

Surface belongingss of stuff are non as desired.

Decrease in fatigue life of cut stuff due to check formation.

Abrasive atom size

Fatigue life reduced. Onset ofstress-corrosion snap.

Surface indurating due to procedure.

Abrasive stuff

Variation of hardness at distance from cut.

Micro-structural alterations:

Surface checking

Phase alterations

Abrasive-particle fragment implanting

Delamination in composite stuffs

Burr formation

Assorted

Assorted

Table 1 - Problems that can originate when transporting out AWJC

Abrasive Water Jet Cutting: Control Methods

To guarantee such issues as those mentioned in table 1 do non happen, accurate control mechanisms must be in topographic point. There are many supervising mechanisms in topographic point today, some of which have been briefly described below. These methods lead to the control of the cutting procedure ; nevertheless, this is non automated in these instances.

Jet-Structure Monitoring - used to command focal point diameter. Diameter of entry to concentrate point monitored to reflect alterations of focal point diameter. Wear rate can be monitored utilizing this method.

Acoustic Sensing - used to supervise overall focal point conditions. System based on the fact that a alteration in the focal point conditions (orifice diameter and concentrate diameter) affects the sound generated by the system. Figure 10 (overleaf) illustrates the difference between the acoustic form of a new and worn nose.

Inductive Measurement - used to supervise scratchy H2O jet speed. Method requires magnetic scratchy atoms. Abrasive jet is encircled by two little spirals, which is connected to a detection system. When the atom passes through the spiral, a little electric signal is created and the velocity determined. Figure 11 shows the typical apparatus of equipment, in this instance. Besides, laser systems similar to the above, nevertheless utilizing light pulsations alternatively.

Material-Removal Visualisation - used to supervise material remotion rate. In a similar mode to Acoustic Sensing, noise of cut is monitored. Frequency of signal indicates type of cut (inter-granular/trans-granular failure) and therefore determines the efficiency of the cut.

Workpiece Reaction Force - used to supervise deepness of incursion and surface topography. Empirical expression that takes into history all input parametric quantities excepting the crossbeam rate. Can go a force-feedback system ; leting parametric quantities to be modified to cut down the force.

Figure 10 - Acoustic form for new and worn nose (Kovacevic & A ; Evizi, 1990)

Figure 11 - Initiation monitoring system (Swanson, Kilman & A ; Cerwin, 1987)

The above systems offer a chiefly generic attack to system patterning and supply small or no feedback. Modern control of AWJC makes usage of an intelligent monitoring and control system, which has full feedback capablenesss. Such an illustration by Srinivasu & A ; Babu (2008) utilises two systems: machine-vision based monitoring and intelligent control. The vision based portion monitors the size of the concentrating nose and the control system, which uses unreal nervous webs, continually modifies each parametric quantity to accomplish the best cut. A full analysis of this system is nevertheless beyond the range of this study.

Abrasive Water Jet Cutting: Overview of Applications

The applications of AWJC are huge, covering industries such as aerospace, automotive and electronics. It is beyond the range of this study to cover any peculiar country in important item ; nevertheless a few illustrations have been given below. Traditional and perchance even simple procedures have been ignored, and alternatively this study concentrates on a few non-standard applications.

Meat Cuting

One application of AWJ cutting is in the meat processing industry. Harmonizing to Wang & A ; Shanmugam (2008) , meat film editing is an of import activity and factors such as the cost, the presentation and sliting all need consideration. In this instance, salt is used as an scratchy and really good quality cuts, when compared to conventional film editing and even plain H2O jet film editing, can be achieved.

Crunching Wheel Production

This illustration is slightly different to all other applications of AWJC as in most instances a through cut is desired. Axinte et Al. (2009) present an turning application, whereby crunching wheels are shaped harmonizing to their specification. Whilst this is considered a niche market, the writers conclude that AWJC has non merely the economical but besides proficient advantage for fabrication of this constituent. Assorted determining operations can be carried out, ensuing in such merchandises as figure 12 below.

Figure 12 - Examples of crunching wheels manufactured utilizing AWJC (Axinte et al. , 2009)

Polishing of Steel

Another application of AWJC is smoothing, and in peculiar steel. Yan et Al. (2008) describe this application, foregrounding that electrical-discharge machining (EDM) is normally used for mold production. The writers province that EDM typically leaves a brickle recast bed ; taking to the application of this smoothing method. When compared to traditional methods, AWJC has a lower scratchy ingestion and recycling is improved. In this illustration the abradant is SiC and to help the procedure is covered in wax. This consequences in a much finer surface coating.

Complexs Processing

There are many applications of AWJC in relation to complexs treating as in some instances traditional single-point film editing procedures can non be used. For illustration, Komanduri (1997) describes that it is non possible to machine SiC whisker-reinforced aluminum oxide with a single-point film editing tool ; nevertheless, that it may be possible to determine by crunching. Whilst some complexs can be approached in this manner, rapid tool wear is experienced and therefore the debut of AWJC is a much better method.

Decision

The old subdivision provides a figure of non-standard illustrations where AWJC is being used. Although these give a general overview, AWJC can besides be used for alternate machining procedures, such as: milling, turning, piercing, boring (although non level bottomed holes) and thread film editing (Momber & A ; Kovacevic, 1998) .

Although such procedures as above can be achieved, in a similar instance to before there are many parametric quantities that need to be monitored. This is possibly a downside to this untraditional method unless modern control methods are introduced. Further disadvantages of the procedure include the fact that degradable stuffs can non be cut and the surface coating of machined constituents relies to a great extent on the procedure. Possibly the most important consideration of using this procedure is the apparatus cost ; which can be highly high in certain instances. One other disadvantage is the noise created by this fabrication procedure.

Although, as highlighted above, there are many factors that control the procedure its application to modern industry has grown significantly since its debut in the 1970 's. This has been driven chiefly by technological promotions, therefore leting this procedure to be developed, but besides due to of all time germinating stuffs that servetechnologyapplications of today.