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The Cutting Front Side Geometry in The Applications of D3 Cold Work Tool Steel Material Via Abrasive Water Jet

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ABSTRACT

Abrasive water jet cutting that is used as cold cutting technology in industrial applications is preferred as most productive method when especially metallurgic and mechanic specialties of materials are taken into consideration. When the surface quality, speed of processing period and part cost are taken into consideration, which are targeted in D3 cold work tool steel materials used frequently in especially metal industry, it appears that the most appropriate method is abrasive water jet cutting. It is more difficult to obtain sharp corner and straight surfaces on water jet processing by especially like turning, milling, drilling and cutting methods. Aim of this study is to foreknow deviation amount in cutting geometry that is seen as one of the biggest disadvantages in abrasive water jet cutting and to enable to process by knowing whether the targeted surface tolerance is included or not. In addition, with aim of interpreting results and researching characteristic of surface that is obtained on D3 cold work tool steel material processing with abrasive water jet, lateral progressing speed and panel thickness were kept stable.

Key words: Cutting by abrasive water jet, Split of D3 cold work tool steel material by abrasive water jet, cutting front side geometry

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1. INTRODUCTION

In general, processing quality in cutting operation is related to topography of produced surface and kerf geometry. Cutting method with AWJ is intensely used as cutting method in industrial areas in recent years as it doesn't cause any thermal damage that is affected by heat. With this method, materials like set steel can be processed easily. Processing speed with AWJ is approximately ten times faster than traditional sensitive cutting operations [1]. Water jet, which is a product of advanced technology, is one of the most productive cutting methods. It is a cutting method that processes any kind of materials without changing their metallurgical and mechanic specialties, never abraded and its turning is not obvious at all. It doesn't leave any burrs on the angles and it doesn't generate any power to distort the materials during the cutting process. As there is no heat effect to the processing material and also structural corruption, blackening, warping, melting, drop formation and burning problems are out of question, water jet cutting can even cut the most complex geometries with high precision and very clear surface characteristics. [2-3]. Schematic display of abrasive water jet cutting system is shown in Figure 1.

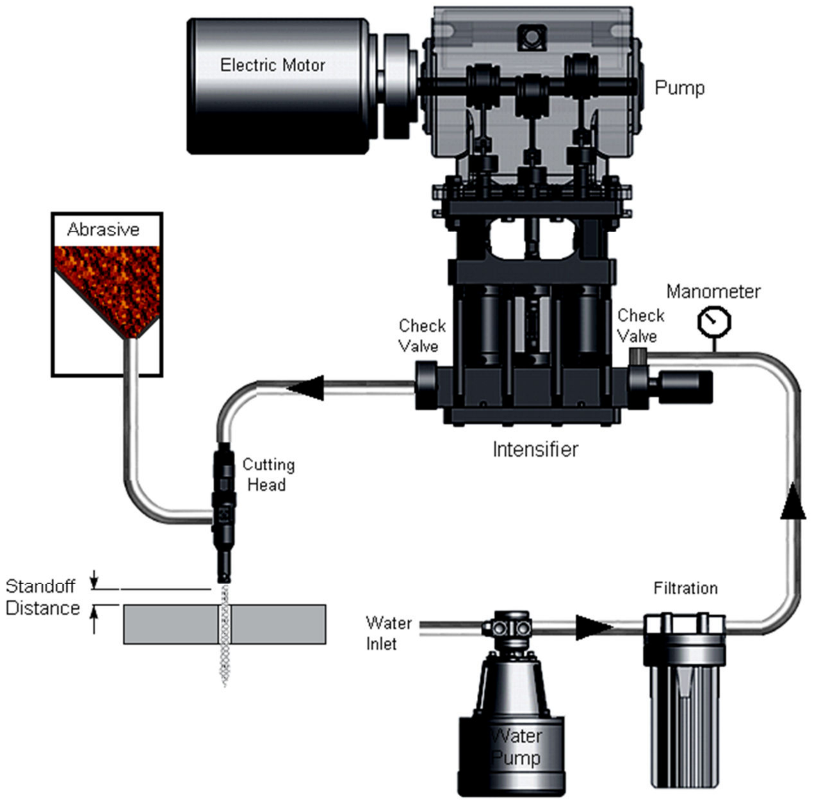


Figure 1. Schematic display of abrasive waterjet cutting system [2, 4]

Production sector always aims to increase production quantity by improving quality while looking for methods of decreasing costs. On the basis of this improvement, demands of clients that dominant powers in the market provoke, is effective beyond self-control of the sector. When we take into consideration all these impacts and investigate production sector in global sense, it is seen clearly that a very big acceleration is in issue "from designing to delivery". Most important reason to prefer abrasive waterjet cutting is that it does not have any metallurgic and thermal impacts. Another important factor is big improvements about new materials like especially plastic and composite materials that come up by space technology. It is very difficult and not possible to process these new materials by traditional methods. Waterjet is preferred as the most ideal cutting method for materials that are in issue. It is too difficult to increase productivity on top level in cutting systems because of being affected by so many variables. How many different materials can be cut? Which speed can cutting operation is made with? How much narrow tolerance you can supply on a surface that is cut? Are the angles that are cut clean enough? And what is cunders quantity size that is in area which is affected from heat? And necessity to answer so many questions like these made it necessary to compare cutting methods with traditional methods in recent years. The best system in some situations may make it necessary to use one combination of these cutting technologies together [1].

Generally, mechanisms in this operation process with abrasive waterjet are related to process parameters and material thickness. In the first stage, abrasive grains that crash to work part in a narrow angle provide to obtain a relatively smooth surface. The mechanism in this stage is called "cutting-abrasion stage". The mechanism that is effective in second area where shows inconsistent processing specialties and causes linear trace is called "deformation-abrasion mechanism". This second penetration process is the main reason for the linear trace in the bottom section of cutting surface. In this area shavings removal process can be checked with erosive abrasion that is related to abrasive grains which are effective in a larger angle (Figure 2.)[2, 5].

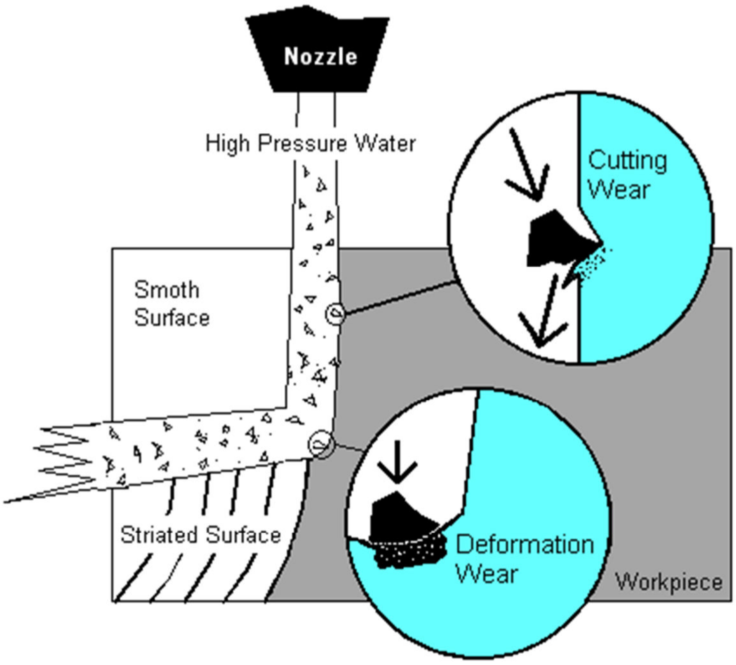


Figure 2. Kerf surface formation processes with abrasive waterjet cutting [5].

When surfaces achieved by abrasive waterjet are investigated the increase of surface roughness is indispensable related to cutting depth (Figure3). And, this appears and changes as a function of cutting depth on work part. Such as any cutting operation process that high energy beam is used, this type of change on surface roughness during cutting with abrasive waterjet makes it necessary to research shaving removing mechanism [6].

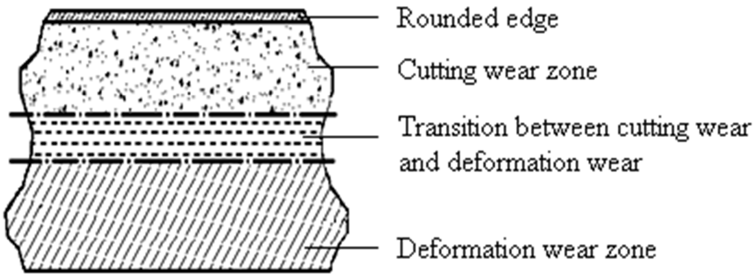


Figure 3. Surface quality that is cut with abrasive waterjet [6].

During the process with cutting abrasive waterjet, a strached surface appears as an indispensable result because of sharpness of abrasive grain, loss of speed and pressure in the jet. Because of these linear surfaces it is not possible to have an ideal cutting operation and it causes to level formation that is described as cutting front geometry in Figure 4.

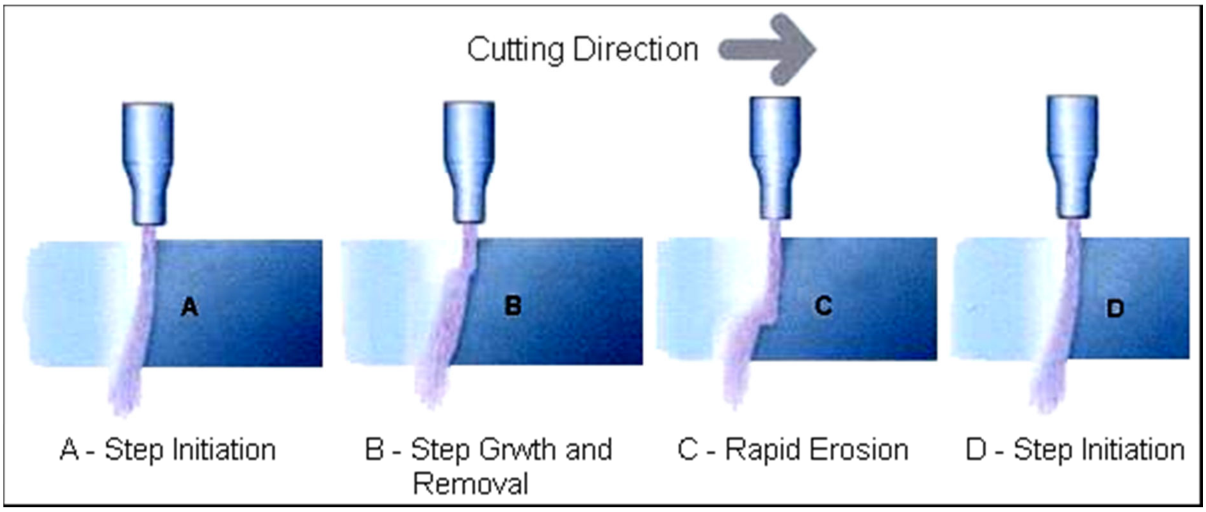


Figure 4. Formation processes of cutting front geometry [7].

Power that affects material during cutting with abrasive waterjet has an impact on the cutting direction as much as on the vertical direction. Size of power that effects both directions is specified with real cutting front geometry, not specialties of work part material. Geometry front cutting; has two components and one of them is slant with smaller angle according to abrasive waterjet and the other one is with small angle and affects highly as corrosion areas [7].

2. EXPERIMENTAL STUDY

2.1. Material

In this study, panels that are prepared from D3 cold work tool steel in 5, 10, 15 and 20 mm thickness are used. Reason for selecting thickness of panels like this is to assist for finding values in middle thickness with mathematical model and equation. Chemical composition of the material is shown on Table 1. and cutting system and cutting parameters that are used in the study is shown on Table 2.

Table 1. Chemical composition of the material.

C	Si	Mn	P	S	Cr	Mo	Ni
1. 93	0. 213	0. 231	0. 0220	<0. 001	11. 31	0. 101	0. 175
Al	**Co**	**Cu**	**Ti**	**V**	**W**	**Fe**	
0. 0163	0. 0177	0. 118	0. 00467	0. 109	0. 0831	<85. 66	

Table 2. Technical data on the abrasive water jet system and the pressure unit.

Cutting frame with the abrasive water jet and the pressure unit			
Orifice diameter	0. 25 mm	Energy consumption	58 kwh
Pump capacity	3 l/dak	The booster working pressure	Min 35 – Max 200
Water consumption	≈ 3. 5 l/min	The pump piston diameter	20 mm
The temperature of the water used by	48 °C	The inlet pressure of water into the pressure	6 bar

the system		booster	
The working pressure of the booster	200 bar	The inlet diameter of water into the nozzle	0. 25 mm
The outlet pressure of water from the pressure booster	20 bar	The inlet diameter into the abrasive nozzle	0. 75 mm
Water flow rate	3 l/dak	Stand - off distance	4 mm
The outlet velocity of water from the nozzle	800 m/s	Water pressure at the instance of discharge	400 MPa
Temperature at the instance of cutting	≈ 55 °C	Jet angle	90°
Current consumption during work	380 V	Electric engine capacity and consumption	22 kw, 58 kwh
The amount of abrader consumed	250 g/dak	The material used in the nozzle head	Sapphire
The abrader used	GMA Garnet	Chemical Composition	$Fe_2O_3Al_2\ (SIO_4)_3$
Abrasive hardness	7. 5 - 8 Mohs	Abrasive particle size	300 µm
The pressure boost capacity	At a rate of 1/20	Nozzle length	76. 2 mm
Abrasive water outlet diameter from the nozzle	1mm	The inlet pressure of water into the pressure booster	6 bar
Slurry concent	% 18	Mixing tube lenght	88.9 mm
Mixing tube diameter	1.27 mm	Orifice Life	40-50 saat

2.2. Method

Test Samples in each thickness is cut four times on lateral progression speed that is advised by producer firm of pressure unit (Ingersoll Rand) and cutting surfaces have had eight different surfaces. In addition, each panel is cut four more times with 20mm/minute lateral progression speed that determined by us and 8 surfaces are gained (Figure 5).

Gained cutting surface is measured on five different depths periodically related to thickness of panel. 20 measurements are made from each of eight surfaces related to panel thickness and it is calculated by finding roughness values arithmetic averages related to panel thickness of cutting depth.

This operation is also applied to find hardness values. A roughness measurement is measured by Mitutoyo Surf test Analyzer 402, hardness measurements are measured by INSTRON WOLPERT TESTOR and HV30 value is measured by hardness measurements device.

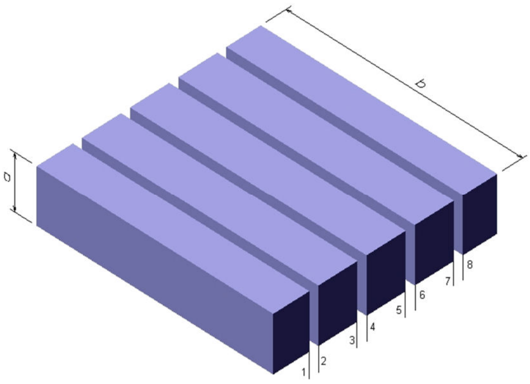


Figure 5. Samples that are gained after cutting operation and cutting surface qualities

Table 3. Lateral Speeds that is applied on cutting materials.

Materials	5 mm		10 mm		15 mm		20 mm	
	Recommended and identified fixed feed rates (mm/min)							
D3 cold work tool steel	R	I	R	I	R	I	R	I
	120	20	53.9	20	33.82	20	24.5	20

3. RESULTS AND DISCUSSION

3.1. Evaluation of Samples

3.1.1. Obtained Surface Specialties

To evaluate cutting with AWJ of D3 cold work tool steel material which is usually used in production sector and to research mechanic and micro structure specialties, samples that are prepared 5, 10, 15, 20 mm of thickness are cut 20 mm/min lateral speed advised by bench software. Surface roughness values obtained from different quality parts of cutting surfaces are adapted to graphics (Table 4. and Figure 6.). According to the evaluations, average surface roughness (Ra) values obtained from the 5 mm thickness of D3 cold work tool steel steel material's cutting process with ASJ are measured as 6.35 µm under advised speed and 2,55 µm under 20 mm/min common lateral progress speed. It is also measured as 5.55 µm for the 5 mm thickness of D3 cold work tool steel under the advised speed and 2,65 µm under 20 mm/min common lateral progress speed.

Researches that are made in the literature stick to curvilinear-linear traces that appear as a characteristic of cutting surfaces with AWJ majored on characterizing according to the depth of cutting and also on the energy loss stemming from cutting process with AWJ related to the geometry of these traces. In this study, experimental indications also show that it can be described with energy loss related to cutting material thickness that occurs by deviation from ideal cutting geometry. Obtained results shows parallelism with the literature.

The most conspicuous results that are seen on graphics; Beginning from the surface that jet beam touches, there is a corruption on the surface specialties as it gets deeper and roughness values in bottom side of cutting surfaces are much higher than the upside. If you make an evaluation except from the 5 mm thickness samples, as related to increase of material thickness, a corruption is seen on surface quality even though advised lateral speeds are decreased.

This situation is described as an important parameter on surface roughness of material thickness on cutting operation with AWJ. It is observed that surface roughness values on 5mm thickness samples are higher than other thickness samples. This situation, when high resistance specialty of material and deformation effect of high pressure influential during AWJ process are taken into consideration, it is connected to negative effects of incremental high cutting power under a certain thickness of products. By this way in literature cutting with AWJ, it is verified that advised as 10 mm bottom limit is valid for D3 cold work tool steel materials. One of most impressive results that is seen on the graphics about material, surface roughness values obtained from 5mm thickness samples are higher than other thickness samples. This situation is in accordance with literature studies that emphasize corruption of surface specialties together with incease of thickness and shows that two different erosion mechanisms are occurred [8-11].

Table 4. Over the surfaces obtained through cutting the D3 Cold Work Tool Steel material in different lateral feed rates subject to measurement distance variation of surface roughness values[1, 27].

Surface Characteristics of D3 Cold Work Tool Steel Material Obtained after AWJ Cutting Process													
Lateral feed rate		120 mm/min						20 mm/min					
Measurement Depth (mm)		1		2	3	4	5	1		2	3	4	5
5 mm	Ra (µm)	21		23	25.1	28.3	30	14.25		16.12	18	19.54	21.07
	Rz (µm)	15.5		17.25	19	20.3	22	12.25		13.12	14.1	15.67	17.35
	Rmax (µm)	3.15		3.81	3.9	4.6	4.67	3.05		3.3	3.55	3.75	3.95
Lateral feed rate		53.9 mm/min						20 mm/min					
Measurement Depth (mm)		1	2	4	6	8	10	1	2	4	6	8	10
10 mm	Ra (µm)	17.1	17.87	19.62	21.2	22.6	24	15.25	15.75	16.75	17.9	19.2	20.5
	Rz (µm)	13.5	13.62	14	14.36	15.05	15.75	12	11.94	11.81	12.25	13.25	14.25
	Rmax (µm)	2.56	2.581	2.63	2.66	2.7	2.81	2.15	2.159	2.198	2.255	2.325	2.525
Lateral feed rate		33.82 mm/min						20 mm/min					
Measurement Depth (mm)		1	3	6	9	12	15	1	3	6	9	12	15
15 mm	Ra (µm)	16	16.44	17.3	18.6	20.3	24.3	15.75	16.37	17.62	19.15	20.95	22.75

	Rz (µm)	12.1	12.4	12.8	13.3	14.9	15.9	12.5	12.75	13.25	13.8	14.4	15.1
	Rmax (µm)	2.57	2.585	2.6	2.615	2.735	2.96	2.225	2.31	2.47	2.59	2.67	2.75
Lateral feed rate		24.5 mm/min						20 mm/min					
Measurement Depth (mm)		1	4	8	12	16	20	1	4	8	12	16	20
20 mm	Ra (µm)	17.25	17.81	18.94	20.45	22.35	24.25	12.05	12.87	14.125	15.25	16.25	17.25
	Rz (µm)	13.5	13.75	14.25	14.5	14.95	15.25	10.45	10.8	11.44	12.17	13.08	14.22
	Rmax (µm)	3.32	3.36	3.47	3.56	3.665	3.743	3.17	3.24	3.33	3.45	3.58	3.66

Comparatively higher level roughness values of 5 mm thickness samples according to 10, 15 and 20 mm thickness samples brings the studies that do not advise cutting with AWJ in foreground [12-14]. This situation that is not effective on materials of aluminum group can be attributed to process these materials that have lower resistance comparatively more easily [15]. But, the results that are obtained in terms of surface specialties are quite negative for D3 cold work tool steel material 5 mm thickness as related to increase of materials. This situation can be tied up to intension of deformation causing from the high pressure forms on low thickness materials.

It is known that pulling resistance is high on steel materials. Because of being higher of cutting powers that is formed during processing of high resistance materials, deformation effect on the surface will be much more with becoming smaller of section. As a result of this, an increase of surface roughness can be expected. To be able to eliminate this negative effect seen on 5 mm thickness samples is related to decrease on intesion of deformation. With this purpose, the first thing to interfere between parameters is to decrease pressure and lateral forwardness speed. In this study, because of the pressure being selected as a fixed parameter, it is necessary to evaluate the effects of lateral speed selected as a variable parameter. Thus, by decreasing speed significantly (to 20 mm/min), obtained roughness values approach to values that are obtained for other thicknesses. Considering common lateral forwardness speed for 20 mm/min, an expected decrease has been seen. The average surface roughness value (Ra) changes related to thickness. This situation shows that lateral forwardness speed is an effective parameter on surface specialties (Table 4).

The surface specialties that belong to the materials of D3 cold work tool steel from the surface that jet beam touched first in an effort to be modeled related to measurement distance and change on average surface roughness values (Ra) that are commonly used in an industrial sense, the process of curved assimilation is applied to the graphics that shows these changes and is ascertained that these changes can be expressed with a collateral polinom (parabol) observed the highest indication factor (R^2). It is shown on Figure 6. a,b,c,d,e,f,g,h, for D3 cold work tool steel on different thickness (5, 10, 15 and 20 mm)

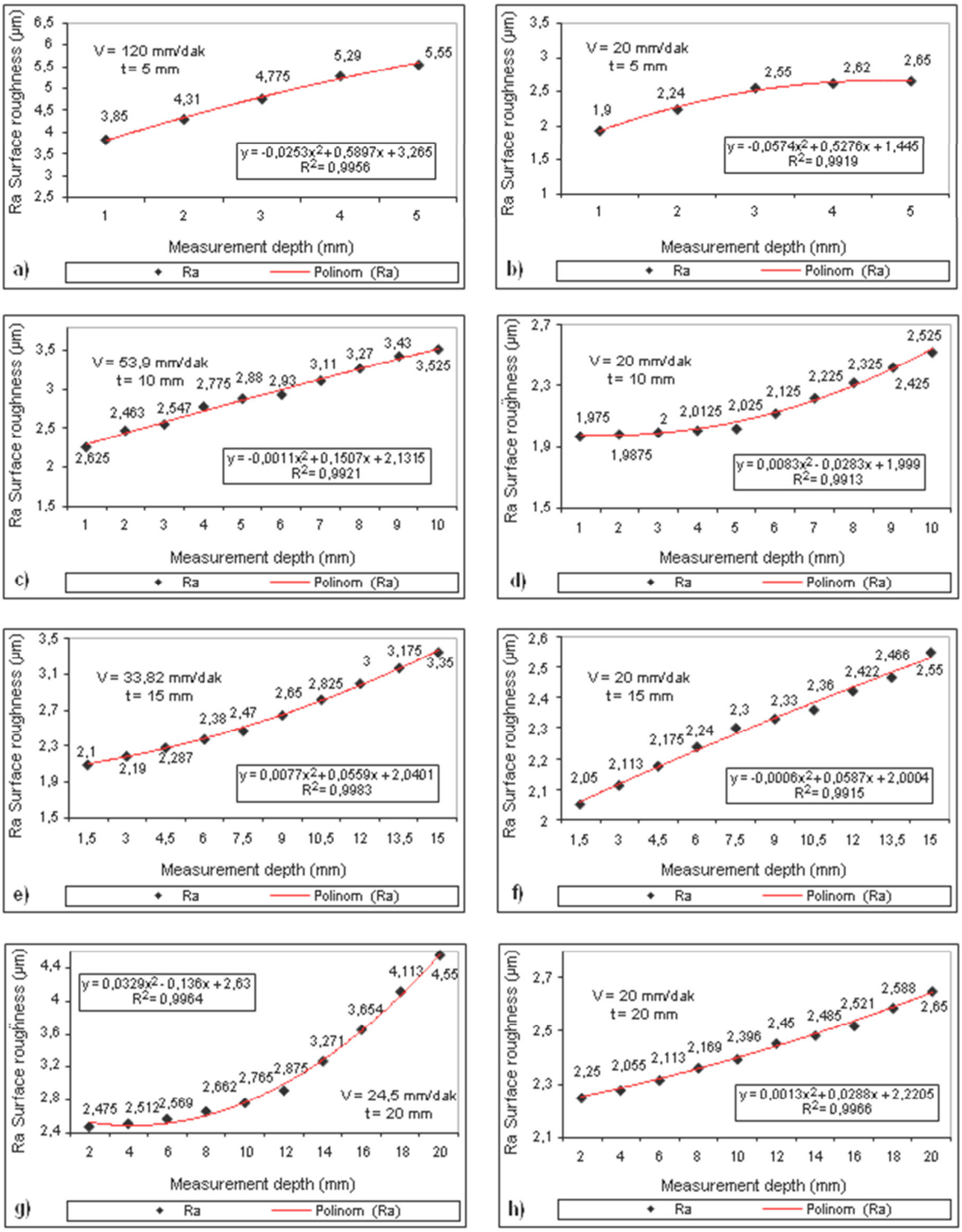


Figure 6. Parabolic (collateral polinom) models of average surface roughness values related to measurement distance that is obtained with cutting different lateral speeds of D3 cold work tool steel material in different thicknesses.

3.2. The Modeling of Average Surface Roughness Values of Surfaces which is cut with AWJ;

With findings that are obtained by these graphics, for different thicknesses, it is seen that surface roughness can be modeled with a collateral polinom with approximately R^2=0.99 accuracy. As “y” indicates the average surface roughness value and “x” indicates the cutting depth (it is expressed as the cutting depth on graphics) from the surface jet beam touches, the polynomial equations that indicate surface specialties on different thicknesses and the indication factors that belong to these equalities are summarized on Table 3.

These equalities that represent the change of average roughness (Ra) values determined as experimental related to cutting depth approximately in accuracy of $R^2 = 0.99$ has prepared a foundation that can be used in this kind of simulation studies and numeric modeling that can be made for similar materials and thicknesses. The similarity of these equalities that charactarise average surface roughness as parabolic and the curve equations that charactarise the cutting front geometry shows that the surface roughness specialties can charactarise it as a function of energy losses that play role in determination of cutting front geometry [16 - 22].

Table 5. Equalities and indication factors that characterize average surface rough nesses that are obtained in different thicknesses for D3 cold work tool steel.

Material	Thickness (mm)	Lateral feed rate (mm/min)	Equation*	Coefficient of determination (R^2)
D3 cold work tool steel	5	120	$y = -0.0253x^2 + 0.5897x + 3.265$	0.9956
		20	$y = -0.0574x^2 + 0.5276x + 1.445$	0.9919
	10	53.9	$y = 0.0098x^2 - 0.0086x + 2.6737$	0.9904
		20	$y = 0.0083x^2 - 0.0283x + 1.999$	0.9913
	15	33.82	$y = 0.0077x^2 + 0.0559x + 2.0401$	0.9983
		20	$y = -0.0006x^2 + 0.0587x + 2.0004$	0.9915
	20	24.5	$y = 0.0329x^2 - 0.136x + 2.63$	0.9964
		20	$y = 0.0013x^2 + 0.0288x + 2.2205$	0.9966

Evaluation of D3 cold work tool steel material and Aluminum group materials on average surface roughness that is had on common lateral speed 20 mm/min. The most striking result when we compare D3 cold work tool steel material with aluminum materials, roughness values of aluminum materials are much higher for these two materials. This can be explained as related to mechanical specialties of these materials. Pulling resistance, flow resistance, elasticity module and hardness values of aluminum materials are much lower than steel materials.

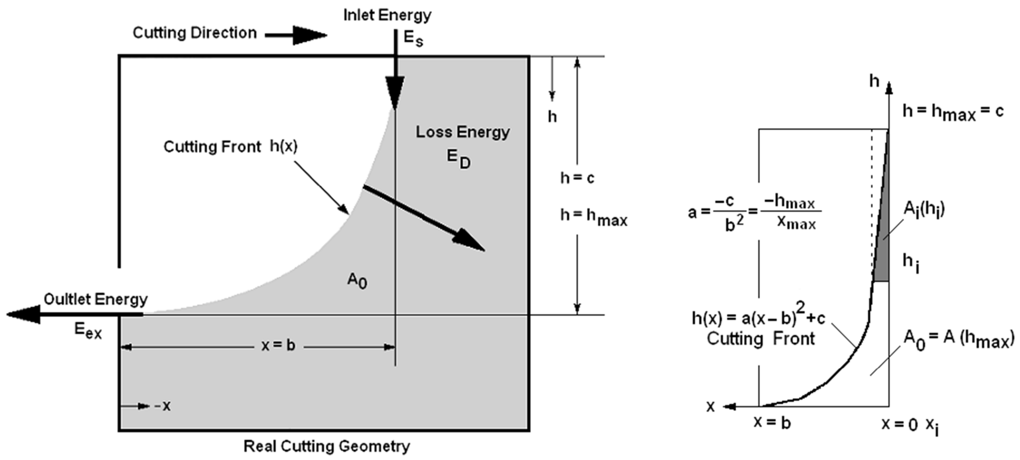
High deformation effect that is formed by high pressure on operation with AWJ corrupts the surface specialties of these materials that have lower resistance and hardness qualities, because of deformation [15]. These findings show that it is necessary to make optimization of cutting parameters much more carefully during especially ductile materials operation with AWJ if high quality surface specialties are aimed. For ductile materials, instead of cutting operation shavings to be separate from main material, sticking by plastering to the main material and cutting set through the effect of applied power is an important problem that is exposed also in classic cutting methods and is required for cutting set to have a much sharper mouth to inhibit this.

Metal spinning inclination of this kind of materials is a fact that effects surface roughness from machinability critters as negative. Same circumstance is exist also during cutting ductile materials with AWJ and it is underlined in the literature that sharp angled abrasive grain type is more effective on process of ductile materials[23]. When abrasive parameters are kept fixed in cutting of analyzed materials with AWJ, it is an inevitable result for the particle type effective on other materials to show negative results for pure commercial aluminum and A1 6061 aluminum compound [1, 15].

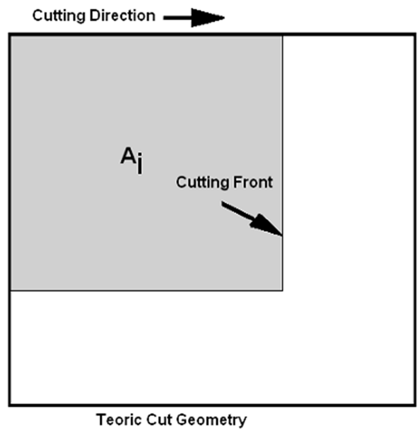
3.3. Characterazation of Cutting Front Geometry

In process with AWJ, linear marks are seen in opposite direction to lateral proceeding as related to decrease of cutting productivity. It is considerable that the similarities of these marks that appear as independent from different process parameters on process of different materials. Various analysts introduce on studies that are on crunchy and ductile materials the presence of similar marks in order to correct this observation. Researches that are made are aimed to characterize the form of these marks via the cutting depth and to explain energy losses that cause decreasing of cutting efficiency in process with AWJ related to the geometry of these marks [24-27]. During cutting with AWJ, these energy losses that appear with different reasons causes the decreasing of efficiency and departing of the jet beam from the cutting direction and following a geometry called “Cutting Front Geometry”. Researches in the literature emphasize that the curvial-linear marks that specify the surface specialties cut with AWJ appear as paralled to cutting front geometry [28-32].

At the same time, experimental studies that is made to find energy losses show that relativity in proratable cutting depth ($\phi(h) = h / h_{max}$) and the parameter of energy loss (X) can be stated with an collateral polynom. It has been ascertained that regression parameters of these polynoms are independent from not only processing conditions but also sample material. In the study, factors that can be used for energy loss from relations made up with parabolic models and the equalities that can be used for prediction of energy loss are modelled as mathematical. Demonstrating in Figure 7.a, starting point of mathematical model that Momber developes bases on the parabolic model in Figure 7.b that is constituted by comparing the ideal cutting front geometry without any energy loss and the cutting front geometry constituted during the real operation [22, 33, 34].



a. Formation of Cutting Front Geometry and Parabolyc Model



b. İdeal Cutting

Figure 7. Energy loss comparison between ideal cutting and actual cutting [23, 33].

Starting the way from information in the light of literature, it is aimed to charactarise, similarly, the cutting front geometry on the samples that are at 10 and 20 mm thickness and are made from materials analysed in this study. With this purpose, cutting front geometry is released by separating the samples which are not cut for the whole length into two parts from the cutting area and deviation amounts of cutting front geometry from ideal geometry related to cutting depth are ascertained as proportional by growing the photo of this surface (Figure 8).

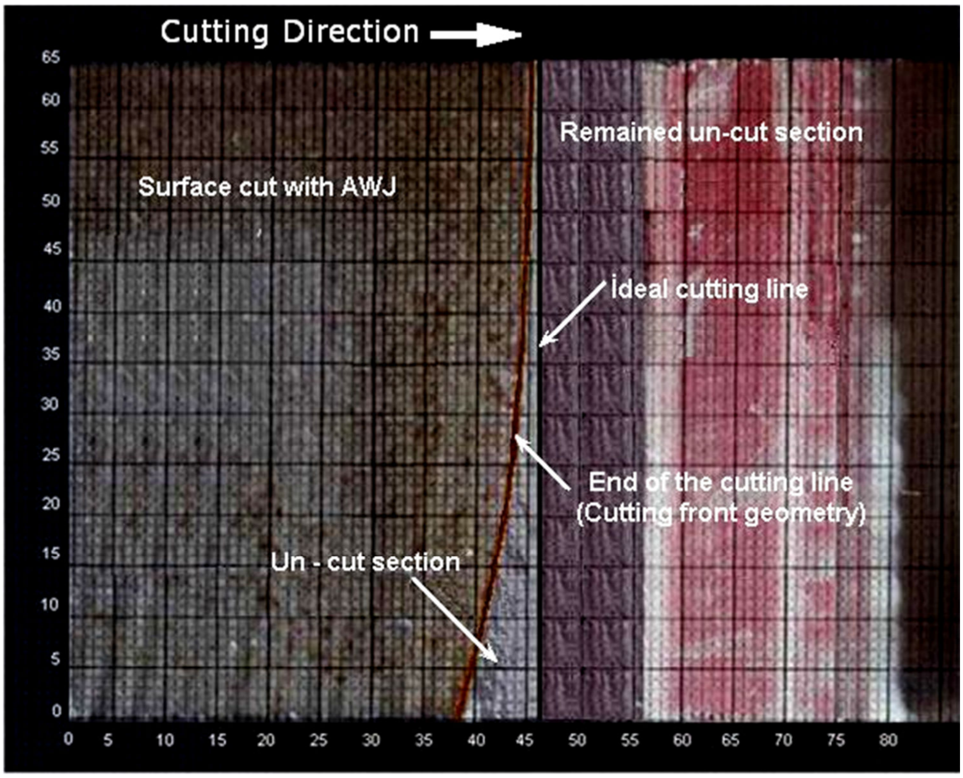


Figure 8. Determination of cutting front side geometry deviation from the ideal geometry [1, 4].

Graphics and equalities that characterize cutting front geometry shows that cutting front geometry constituted from the deviation from ideal geometry during the cutting process with AWJ can be characterized as a parabolic function by a collateral polynom. The graphics of cutting front geometries that are formed with the cuttings of D3 cold work tool steel materials are given in Figure 9. and Figure 10. Indication factor is $R^2 \cong \mathbf{0.99}$ for all samples that are analysed. This situation has a big harmony with studies that charactarize the cutting front geometry in the literature and it is seen that the parabolic curves of cutting front geometry clashes with indication factors [4, 8, 10, 12, and 28]. Thanks to this, it is seen that these marks that the curve assimilation factors and indication factors are determined can be characterized as a simple function type. Cutting front geometry can be modelled by a parabolic function as mathematical by the help of data obtained. A mathematical model is created in order to ascertain this parameter related to the form of cutting front geometry constituted at the hull of cut operation. Results show that there is a nonlinear relationship between cutting depth and energy loss.

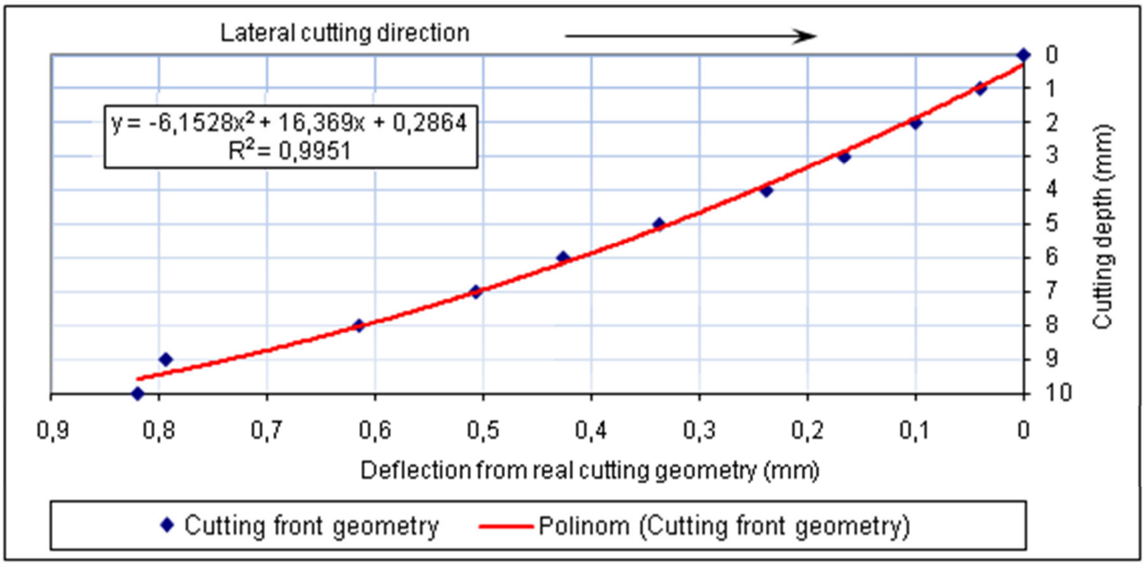


Figure 9. Characterization of cutting front geometry in the samples at 10 mm thickness.

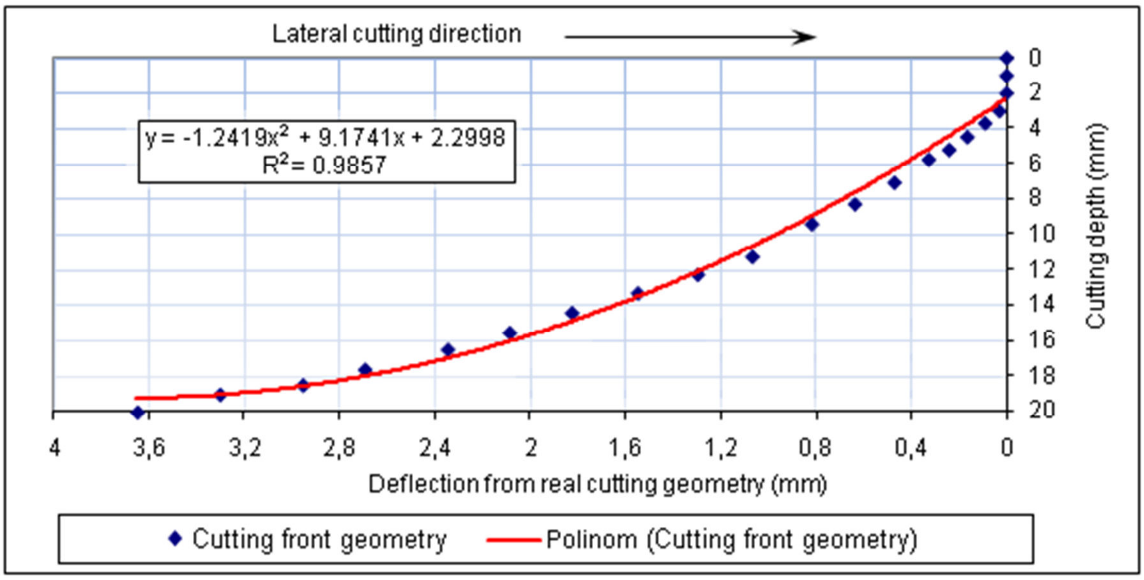


Figure 10. Characterization of cutting front geometry in the samples at 20 mm thickness.

In this study, curve assimilation factors belongs to these functions that are ascertained are the specialties that can be used in determining in areal cutting effiency that are modelled related to shaving removal rate "m" and lateral speed "v". Cutting effiency with operation by AWJ, when we consider the currency of model that connects to curve angle of linear traces$\left(Cos\ \alpha = \frac{m}{v}\right)$ that is made up while water jet leaves from the work material, it will be possible to set up the parameters sensitivitely that will provide required surface quality related to cutting depth in case of watching the angle of departure and using it as a feedback signal for the system [26]. In the litarature, Zeng and his friends [25] and Momber and Kovaçeviç [23] have modelled the shapes of linear traces as a parabolic function. They used this angle as a process control parameter by aiming the angle between the work part and AWJ exit.

Assumption about constution of linear traces is associated with areal kinetic energy of AWJ that enables modelling the energy loss on the material by using the cutting front geometry. Momber described the effect of cutting depth in a mathematical way and created a simple mathematical model by using this relationship to determine the energy loss in quantity. Model has been set on energy balance concept in the work part. When equalities that belong to 10 mm and 20 mm samples are taken into consideration (Table 5), it can be said that curve simulation changes according to increase of thickness and so jet exit angle will also change. Jet exit angle that can be determined by taking advantage of these models can especially be used to maximize the lateral speed. Similarly, curves that are charactarised from a simple function type will enable to determine the non-cut variegated "A_0" appeard by deviation from ideal cutting geometry and thereby to explain the energy loss related to cutting depth .

Table 6. Collateral polynomial equations and indication factors that characterize the cutting front .

Material	Thickness (mm)	Lateral feed rate (mm/min)	Equation*	Corelation Coefficient (R^2)
D3 cold work tool steel	10	53.9	$y = -6.1528x^2 + 16.369x + 0.2864$	0.9951
	20	24.5	$y = -1.2419x^2 + 9.1741x + 2.2998$	0.9857
x= cutting depth (measured distance)			y= deflection from ideal cutting geometry	

As a result of curve assimilation operation which was applied to graphics formed with experimental indications, it was seen that a parabolic function can be charactarised with a quadratic polynomial as a parabolic function with an indication factor (R^2) over 0.99 of cutting geometry appearing with devation from ideal geometry. Researchs carried out in the literature are concentrated on energy loss that causes cutting efficieny to be lower during processes with AWJ related to this geometry. In this study, experimental indication explains with energy losses that appear related to thickness of material on cutting material. Results achieved are paralel with literature. One of the biggest advantages of Cutting systems with abrasive water jet to other systems is its being very close to real hardness of material. (Table 5).

Table 5. Hardness changes of brass material after and before cut with AWJ.

Hardness	**D3 cold work tool steel**
Base material	227.5 HV_{30}
Cut surface	228.33 HV_{30}

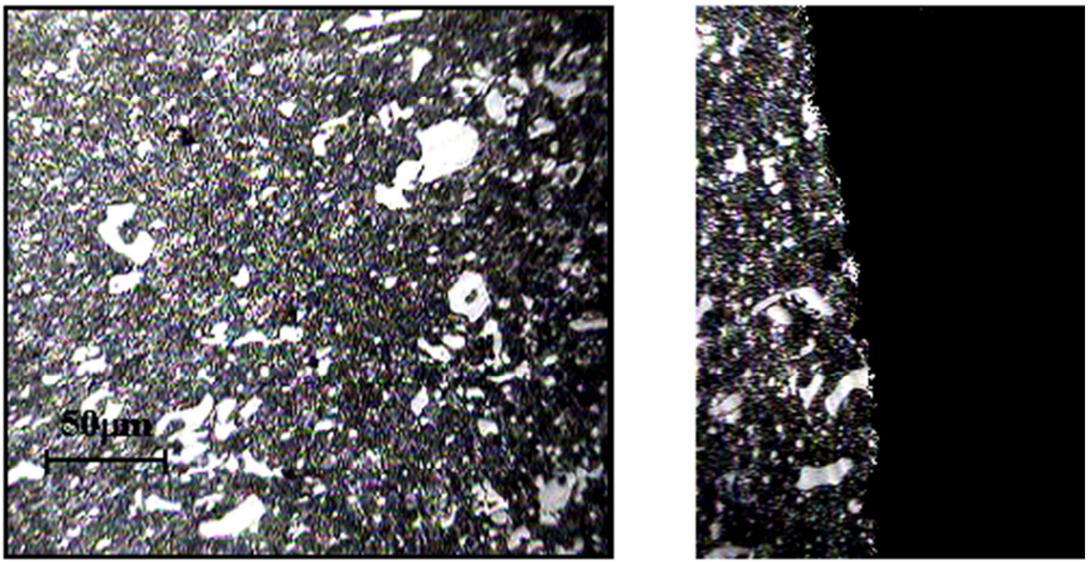


Figure 11. Micro structure of cut angle and D3 cold work tool steel material.

When micro structure photo of material is investigated, it is seen that cut surface structure is not changed. Since

When micro structure of material and cut angle micro structure are compared it is seen limited almost none existing.

After the cutting process hardness of the material showed little variance and this value can be counted as

the producers consider this feature as significant, this application has become to be the most preferred one.

almost none when compared to other cutting methods in the literature [1].

4. RESULT AND SUGGESTIONS

In this study concerning with a compherensive evaluation of cutting method with AWJ, experimental results that are made on different thicknesses of D3 cold work tool steel material from industrial engineering materials are summarized below.

On surfaces that is cut, on up area that is close to first surface that touches jet beam as related to increase in cutting depth, surface specialities are deteriorated. Quality of surface with AWJ that shows these specialities, it must appoint according to surface specialities. Surface specialities that are achieved on 5mm samples show bad surface characteristics when compared with samples on other thicknesses. Negative effects which occur at the process of this material, of which processed cut surface is minimum, can be connected to high deformation rate due to high pressure during AWJ cutting operations.

Related to material and thickness,when the graphics that show results of cutting operations that is done by considering lateral speeds that is offered by bench software are analysed, consistency on the parameters of surface roughness that are obtained for increasing thickness parameters shows the validity of speeds that are chosen. This situation shows that the studies, on cutting with AWJ that can be told as new technology product, evaluating the effects of process parameters on the surface roughness are taken into consideration by producers that make this kind of bench production.

Having an acceptable surface quality on processing with AWJ is related to controlling of AWJ process. Curvilinear and linear lines on cutting surface are associated with energy losses that is directly from jet beam energy. Surface facilities that are achieved when increasing changes of cutting depth of surface roughness is taken into consideration, $R^2 = 0.99$ with a factor, is in specialilty to model an adjunct polynomial. For different material and different thicknesses, this adjunct polynomial equation that is acquired with an indication factor over $R^2 = 0.99$ it is identitied a database that is supported with experimental studies to compose mathematical models of energy loses that cause cutting front geometry for this kind of materials.

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