CUTTING TECHNIQUE INFLUENCE ON A PROPERTIES OF TOOL STEELS

Martin KRAUS

VSB - Technical University of Ostrava, Faculty of Metallurgy and Material Engineering, RMTVC, Ostrava, Czech Republic, EU; martin.kraus@vsb.cz

Abstract

In general, the surface and subsurface layers of material are affected during cutting and machining. It is mainly due to the heat input of thermal cutting kinds to the cut location. At mechanical methods it is again mechanical deformation. This together with other agents put there major or minor affection of prime surface. These changes consequently can affect properties of the final product negatively. The relevance of these changes is depends naturally on a ratio of a general materials volume and a cutting area size (volume of affected zone). They can suggest results of mechanical properties tests for testing specimens also, which were prepared by some of mentioned method.

This article deals with the cutting method and machining influence on the properties of wide sheets from tool steels. In the concrete the steel 90 MnCrV8+A were chosen. Several cutting methods were compared - thermal, mechanical, electro-erosion. The tests of mechanical properties were made with accent on hardness and tensile tests. The microstructure were evaluated by optical and electron microscopy (SEM). Also the observation of tensile test rods cracking surfaces brought interesting results.

Keywords: Surface, affected zone, machining, cutting, electro-erosion machining

1. INTRODUCTION

Dividing of materials is a wide problem. For a metals, respectively steels several divisive methods are used. The oxygen, plasma and voltaic arc cutting with cutting by laser or electron beam and are ranged in thermal (heat) cutting methods segment [1-4]. Between the mechanical methods is a possible cutting by saw, milling by cutter, quarrying, chipping insert. Specific are next electro-erosive (spark erosion), electrochemical methods, eventually water jet machining (WJM) or abrasive water jet machining (AWJ) [5-10].

For a several steel grades the research was realized about possible effect on cut edges environment owing to different cutting methods. Further is observed possible defects (that were arise by this way) influence on a general state, properties and behaviour of material. For example, at the production of tensile tests rods. The influences of chosen cutting methods are documented on a steel 90MnCrV8+A. There is proving the using of less commonly exploited electro-erosive methods as a perspective. That is electro-thermic process whereat is reach to pass of material by electrical discharge between cathode (tool electrode, cooper wire) and anode (work-piece). This anode is immersed in a liquid dielectric. By high energy concentration (10^5 till 10^7 Wmm^{-2}) material is melting and sublime. By this method it is possible cutting conductive materials only [6,7].

2. MATEIRAL AND EXPERIMENTAL METHODS

For experiment the tool steel 90MnCrV8+A was chosen. It's steel with middle hardenability. Steel is advisable for a quenching in oil. It has good proportion stability during the heat treatment (proportion changings are usually around 0.05 %). Have good abrasion resistance, cutting ability and heat formability. Strength properties required by standards are limited only for hardness values till HB max. 225 [11]. Steel is good for producing gauges, moulds, hand tools and tools for cutting and cold forming. Standardized chemical composition is in the **Table 1**.

Table 1 Standardized chemical composition of a steel 90MnCrV8+A

Element	C	Mn	Si	P	S	Cr	Ni	V
wt.%	0.75 - 0.85	1.85 - 2.15	0.15 - 0.35	max. 0.03	max. 0.035	max. 0.25	max. 0.35	0.1-0.2

Basic semi-product divided by oxygen cutting with plan175 mm x 50 mm was removed from the thick sheet with a thickness 30 mm. For next operation was at first divided by electro-erosion longitudinally upright on origin surface (**Fig. 1**). Two parts arisen. From the bigger two tensile test bars with round cross-section and threaded head were made. Diameter of a reduction section was 10 mm (specimens 9A and 9B).

From the second smaller part the flat bar with reduction section was made (specimen X9). Wider side of it was cutting by oxygen (origin cut of semi-product) and opposite side by electro-erosion (divisive cat). Specimen gets the final form by cutters milling of complete one of narrower side and reduced part of opposite side, which was originally by band saw separate. In this way was possible qualify appropriate effect of those divisive methods at the stress loading along a tensile test. Bar wide was 12 mm; cross section roughly 144 mm^2 (with regard to asperity of side cutting by oxygen). In **Fig. 1** is a cutting scheme of a semi-product and technique of tensile test rods preparing.

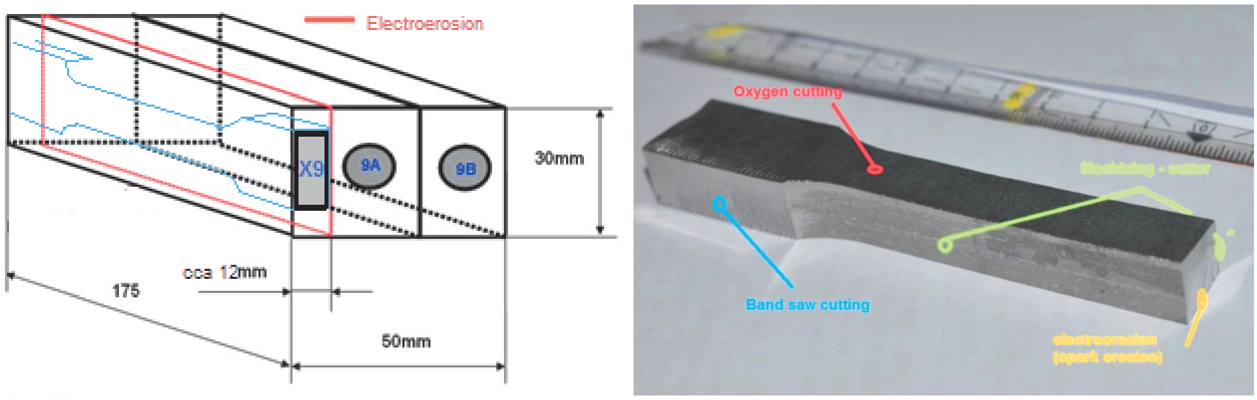

Fig. 1 The cutting scheme of semi-product (X9; 9A; 9B - tensile test bars location) and flat tensile test bar

The semi-product was divided by oxygen CNC machine MG 2. The natural gas was used as a fuel gas. For electro-erosive cutting was used CNC machine EIR 008.

From the end of a rods semi-product were removed specimens for metallographical observation of effected edges. Preparation of surfaces of those specimens was made by standard grinding and polishing. Photographic documentation was then taken with the use of light microscope Olympus IX70 after etching by 4 % of Nital (solution of nitric acid with ethanol).

For check hardness HBW 2.5/187.5 was verified [12]. These values corresponding with values of upper limit by standard required.

Table 2 Hardness verifying

indentation	1	2	3	4	5
HBW 2.5/187.5	232	232	226	233	230

After the metallographical observation were made the microhardness measurement by Vickers HV 0.05 in equidistant lines of indentations, always the surface upright [13]. This measurement was aimed at support facts from metallographical observation. Concretely a hardness measured of surface and subsurface layers, which arisen by thermal cutting or machining methods.

Prepared test bars were tested by standard tensile tests [14] - flat bar because of direct research of effect by cutting method and specimens with round cross section for check on mechanical properties.

After the tensile testing was removed metallographical sample from flat rod 10 mm under fracture surface. Aim has been state appropriate changings after tensile deformation on cutty and machined edges.

Past tensile tests the fracture surface was evaluate also. A tendency was catch up possible initiation of fracture damage and documented appropriate of cutting and machining methods on a rupture start. For this evaluation by scanning electron microscopy the electron microscope JEOL JSM - 6490LV with EDS analyzer Inca x - act was used.

3. RESULTS AND DISCUSSION

In the case of chosen steel 90MnCrV8+A two thermal cutting methods were used - by oxygen and electro-erosion. At oxygen cutting strong affected zone increase. Its thickness is the biggest on upper edge, till 3081 µm. In middle section degrease to average 2550 µm. And near bottom edge is only 1738 µm wide. In **Fig. 2a - g** is microstructure evolution with rich extended structure morphology of quenched structures from surface till prime material.

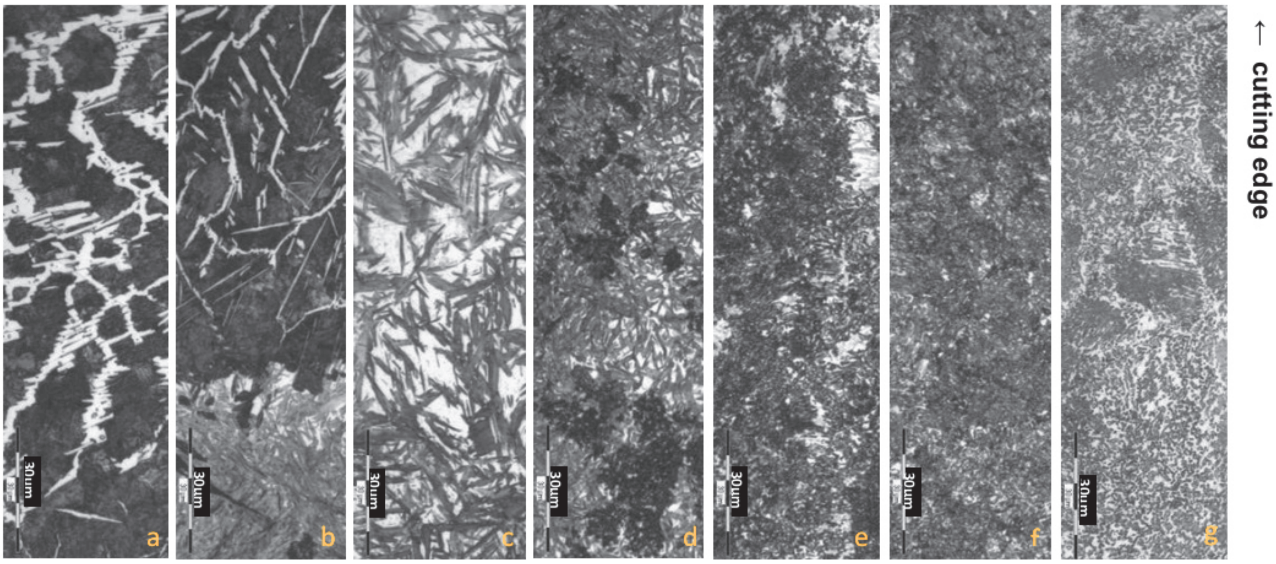

Fig. 2 The microstructure evolution on the side divided by oxygen cutting: a) - thin surface layer; pearlite and ledeburite; b) - pearlite and cementite, as a line network and needles; c) - lathy martensite with residual austenite; d) - lathy martensite with residual austenite (white areas); dark areas with fine lamellar pearlite (troostit); e) - pearlite, martensite and residual austenite; f) - partially spheroidized ferrite a residual austenite; g) - prime material with fine carbides and remains of partially spheroidized lamellas

As another type electro-erosive method was used for steel cutting. **Fig. 3a** shows a cut realized by this method. Is possible observe very thin incoherent layer (odd composition) with numerous noses and impacts. Their size is around 13 µm and their affection is insignificant.

From a group of machining methods were used two. It is milling by cutter (**Fig. 3b**) and cutting by band saw (**Fig. 3c**). On above is visible, that affected materials zone is minor. It makes itself felt as a deformation and elongation of “materials fibres” along the cutting. In the case of milling side (edge) are evident in addition imprints (tooth shape) by used tool.

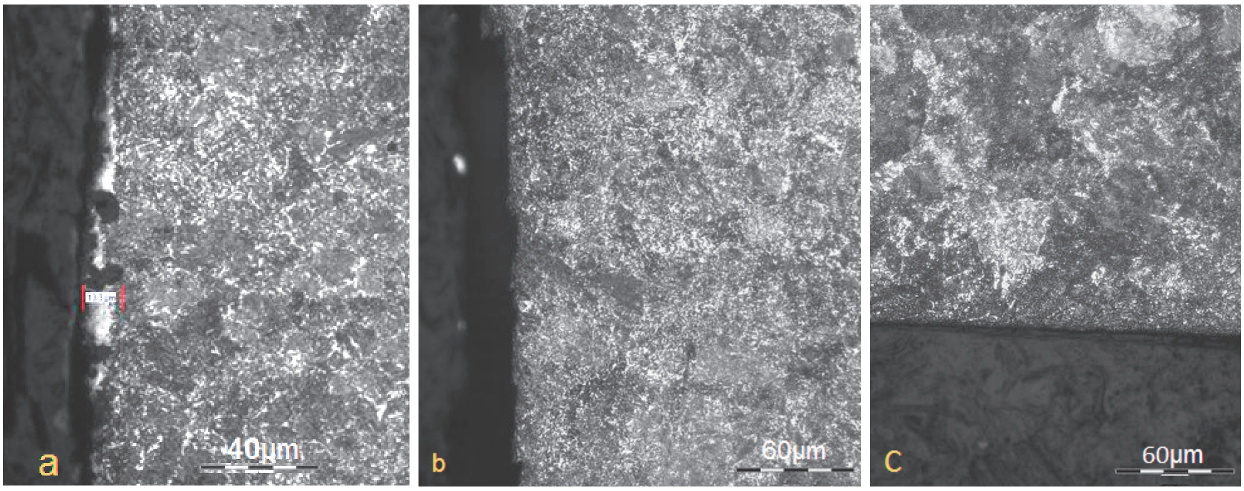

Fig. 3 Cutting edges before tensile test: a) - electro-erosion; b) - cutter; c) - band saw

The progression of microhardness measurement by Vickers HV 0.05 is state in **Fig. 4** and **5**. Into both of graphs was a converted hardness value (for prime material) add for better measured values documentation and comparison. This value was get from tensile strength at performed tensile tests. Tensile strength value was converted on HV value by ČSN EN ISO 18265 standard [15]. This hardness value is only informatively, but it is in good agreement with standards requirements. Results of measurement are corresponding excellently with metallographical ascertained thickness of affected layers. Strong hardening after oxygen cutting is a dominant. While minimally is after electro-erosion. Mechanical machining methods are strengthening a surface of divide edge around 1 mm thickness.

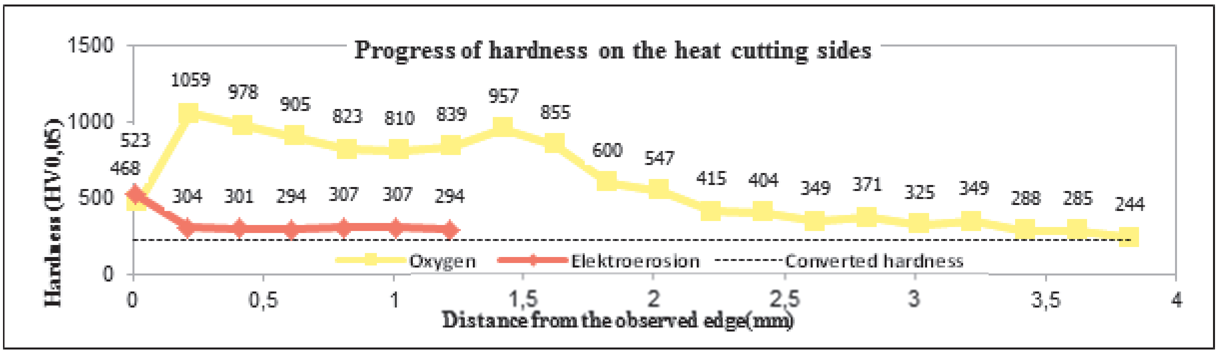

Fig. 4 Progress of hardness on the heat cutting sides

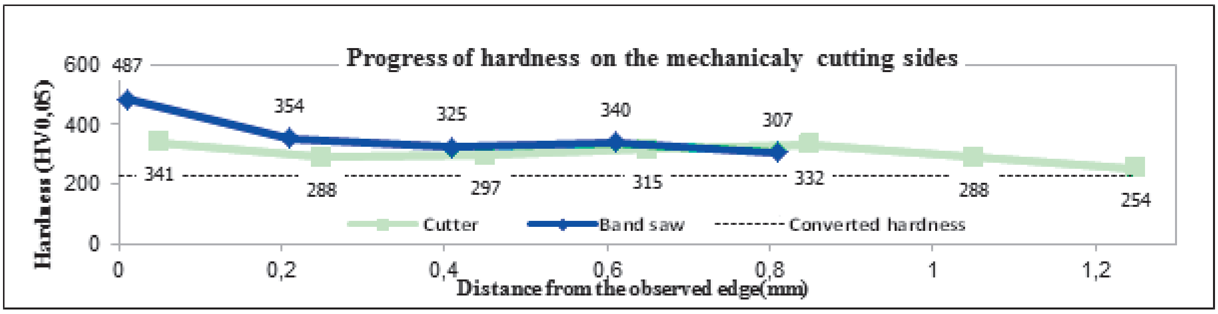

Fig. 5 Progress of hardness on the mechanically cutting sides

Tensile tests showed mostly the same character of the course of deformation curve. Round test bar reached tensile strength 796 MPa. In the event of flat bar X9 rupture of reduced body before yield point (in elastic part of tensile curve) was happened. Tensile tests results are in **Table 3**.

Table 3 Results of tensile tests

specimen	Max. force	Yield point R_{eH}	Strength R_m	Elong. A_5	Contr. Z	Shape of test rod
	[kN]	[MPa]		[%]		
9a	62,5	423	796	20,6	36	round
9b	62,5	425	796	21,4	36	
X9	46,6	Max. strength 346		Early fracture (rupture)		flat

After tensile test were metallographically observed every cutting edges several millimetres under fracture surface perhaps in case of the flat bar X9 was not evident plastic deformation. In **Fig. 6a** - side after oxygen cutting - is not visible any damage. Also on other sides cutting by electro-erosion (**Fig. 6b**) and cutter (**Fig. 6c**) are not marks of damages.

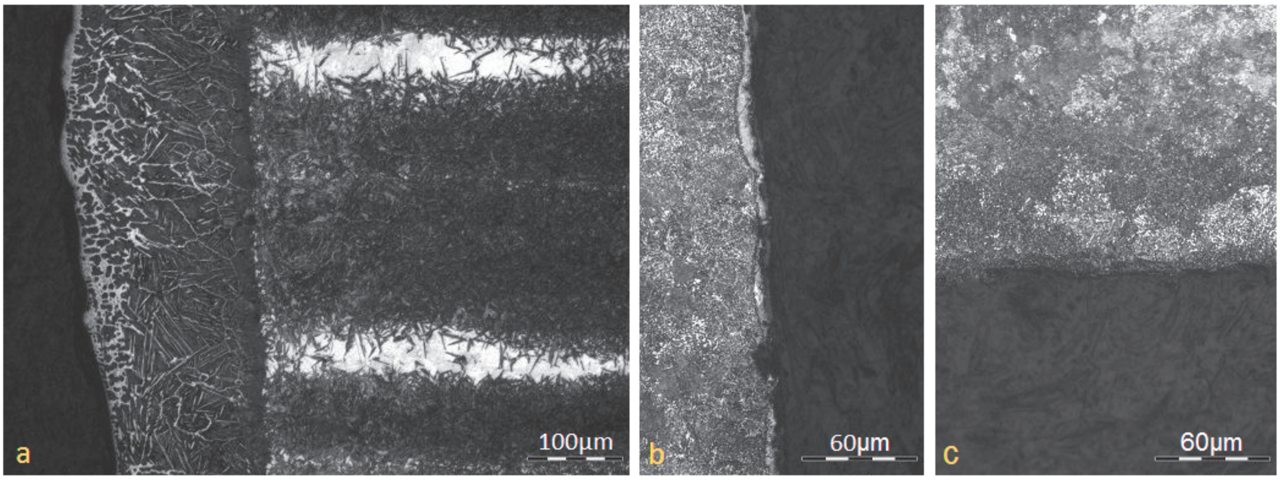

Fig. 6 Cutting edges after tensile test: a) - oxygen cutting; b) - electro-erosion; c) - cutter

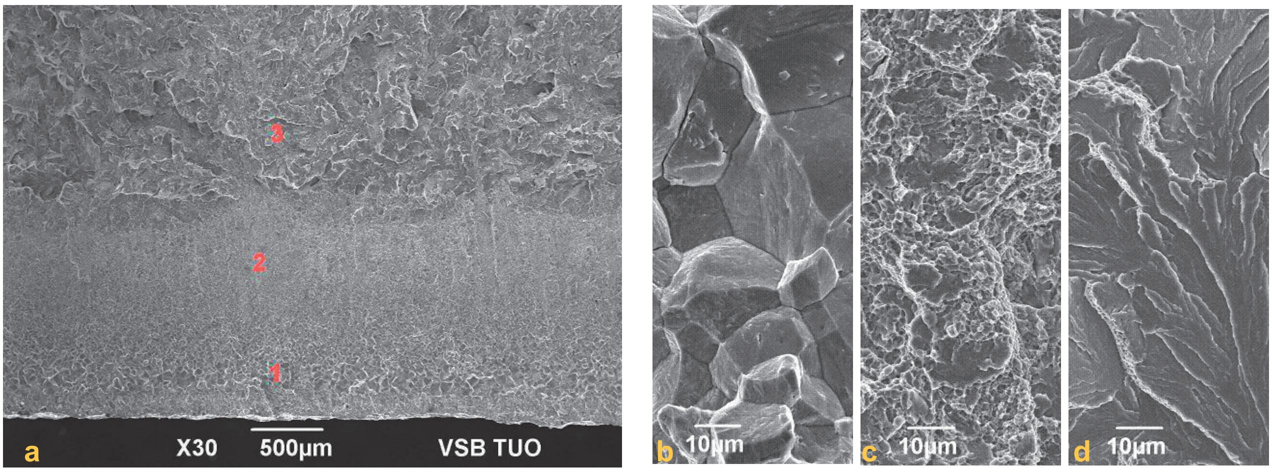

Fig. 7 Microstructure of fracture surface of test bar X9 by SEM: a) - general view with three areas; b) - area 1 is intercrystalline brittle fracture; c) - area 2 is intercrystalline fracture with little voids; d) area 3 brittle fissure of a lamellar pearlite

SEM observation revealed interesting facts. **Fig. 7a** is showing general view on a side after oxygen cutting (bar X9). There possible observing three zones. **Fig 7a - 7c** present these areas in detail. The edge after oxygen cutting is proving as the initiatory point of early fracture of the flat test bar. On bars with round cross-section was plastic deformation (and contraction) relatively small, the fractures had a brittle character rather.

CONCLUSIONS

This article was focused on evaluation of materials dividing methods influence on materials properties. Big part is dedicated also to preparing of test specimens by these methods. By metallographical observation, electron microscopy and changes of mechanical properties (strength, hardness, microhardness) were described those effects on chosen material. At specific material - steel 90MnCrV8+A were four dividing methods evaluated. Oxygen cutting, electro-erosion, milling by cutter and band saw separation. The situation was observed after pure cutting and after tensile tests on the test specimen.

Great heat affection showed itself at the oxygen cutting edges. Microstructure changes in thickness till 3 mm had arisen. This affection is markedly bigger than indicated literature values for plasma cutting (around 0.5 mm according to material grade) [1, 3, 16] A sample divided by plasma cutting was not available for observed steel. In all heat affected zone hardness considerably increased. Which one numbering values about 1000 HV till to thickness 2 mm.

At mechanical cutting methods is looming minor plastic deformation in tenths of millimetres. And hardness values elevation in those zones approximately till 1 mm distance from the edge.

By electro-erosive method has been obtained absolutely least affection. This method gave only minimally specimens edge affect, approximately 0.3 mm. There rising only very thin (some oxide) layer. Its ambient is harder than prime material. Along in course to specimens middle the material is visual and by mechanical properties view-point homogenous. As a very perspective was confirmed using of electro-erosive methods. It is applies e.g. for test specimens preparing also. For dividing of bigger material pieces may be this method arguable, by reasons of time and economical severity.

On tensile test indeed take place early brittle fracture of the flat bar prepared by describe techniques in elastic area still. The running of test till to rupture again was copying test running of other round test bars. The analysis of fracture surface showed appropriate initiation of brittle fracture just at side (edge) after oxygen cutting, which is formed by quenched microstructures.

Cutting technique can markedly affects final products properties, was verify. Especially in case smaller material volumes, for example tensile test bar, etc.

Describing experiences are corresponding with results at other steel grades from this research frame. These results are not included on this article.

The obtained results that will be in future enriched by results of chemical composition changes in affected zone and also complete and compare with matters related with water jet machining etc.

ACKNOWLEDGEMENTS

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