

## THERMAL EFFECTS ON STEELS AT LASER CUTTING

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**Abstract:** The submitted article describes the effects of a thermal separation of material on the properties of the surface layers. The separation of material is an integral part of a preparation of all final products. During cutting the surface layer of the separated material is effected, which then has an influence on the sequence of the following operations. The method of thermal separation of material was selected for the experiment described in the article a method of laser cutting. The material selected for the method was a common steel ČSN 411373, which is industrially produced and processed. The effect on the material was shown by measuring micro-hardness using the micro-hardness tester DM 2D.

**Key words:** micro hardness, laser cutting, vickers micro hardness

### 1. INTRODUCTION

As regards material separation methods, more sophisticated and effective methods are used today beside the classical ones. The new everyday development and changes of modern electronic technology and machine tool engineering brings new generations of many different products. Global development of these methods plays a vital role in the industrial process.

The cutting of material is usually the first operation that has to be done when producing some component. There are different types and methods of steel cutting. The most common methods of material splitting are cutting by water jet, laser, plasma and flame. In some cases, the heat caused by cutting influences the outer layers of the processed material.

Among two other common methods of cutting there are cutting by tools with defined geometry and abrasive processing – such as grinding or sanding. Some progressive methods could be also applied using physical, electrical and chemical processes as well as other sources of energy for removal of the material.

All these methods of material splitting force us to explore their impact to the qualities of cut material, especially to the layer that is in direct contact with the cutting tool. Learning about changes in structure and qualities of processed materials could assist in development of material separation and processing technologies.

#### 1.1 Testing of micro-hardness

Development of hardness measurement methods for individual structural parts – measurement of micro-hardness – was an important requirement for studying the structure of solids. Micro-hardness testing devices are inbuilt in metallographic microscopes or they are used as stand-alone devices.

Measurement of micro-hardness is done by pushing of the diamond body, shaped in Vickers or Knoop pyramid, into the surface of measured body by forces ranged from 1g (0,009807 N) to 1000g (9,807 N). While common testing of (macro) hardness according to Vickers is done by means of load of 10 N

to 1200 N, the forces weaker than 10 N were used first in 1932, when such testing was done at the National Physical Laboratory in UK.

The accuracy of measurement is lower as the applied forces are weaker (smaller size of the dint). Moreover, as the load force weakens and enters the area of micro-hardness, the Vickers hardness is no more depending on the power of applied load (unlike in macro-hardness that is measured according to geometric similarity of individual dints).

#### 1.2 Micro-hardness according to Vickers

Test of hardness according to Vickers is prescribed by European standard ČSN EN ISO 6507-1.

The penetrating body – made of diamond shaped as a regular tetragonal pyramid with the square base and with preset vertex angle ( $136^\circ$ ) between opposite walls – is pushed against the surface of testing body. Then, the diagonal size of the dint left after load removal is measured (Fig. 1).

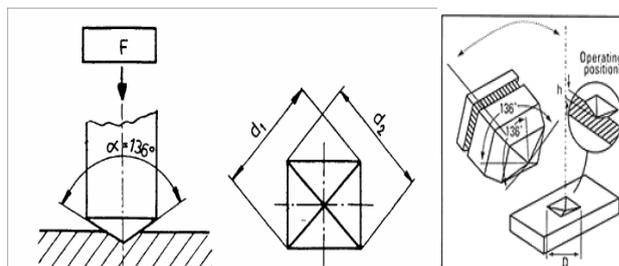


Fig. 1. The basic principle of hardness testing according to Vickers

$$F = 0,1891 \times (F / d^2) \quad (1)$$

Where:

F – Testing load in N

d – Arithmetic average of two diagonals  $d_1$ ,  $d_2$  in mm.

Vickers' hardness is then expressed as the ratio of the testing load applied to dint area in form of regular tetragonal pyramid with square base and the vertex angle equal to the angle of penetrating body ( $136^\circ$ ).

### 2. EXPERIMENTAL PART

There was one methods of material cutting selected in the experimental part. The method has a thermal impact to the outer layer. Steel ČSN 411373 was selected for testing of thermal influence in the cutting area. The testing sample was made by using the technology of cutting by laser. The sample preparation was done in companies specialized to these technologies of material cutting.

## 2.1 Micro-hardness testing according to Vickers

A device used for micro-hardness testing is called micro-hardness tester.

Micro-hardness testing of structural components and phases is one of the most important tools used in metallographic industry. By means of micro-hardness testing, individual structural components could be identified relatively exactly, such as lower and upper bainit, lowly and highly carbonated martenzit etc.

The measurement is done by means of digital micro-hardness tester DM 2D from AFFRI. Measurement conditions are stated in the Tab. III above. The tester is able to measure the hardness according to Vickers as well as according to Knoop. An inbuilt 16bit monolithic high-power microprocessor equipped by photomechanical software was used. Its power can be fully adjusted according to the needs of micro-hardness testing in new century.

Steel label	Chemical composure (%)		
	C	P	S
ČSN 11373	0,17	0,045	0,045

Tab. 1. Chemical composure of steel 11373

Load	200g (HV 0,2 F=1,961N)
Load time	10s

Tab. 2. Measurement conditions

## 2.2 Sample preparation

As the sample surface must have a metallic shine and the surface roughness must not excess Ra 0.2, the sample preparation is very important step. In general, the sample could be fixed in a gripping or set into spaces and after grinding by soft grindstone, the sample has to be sanded by metallographic sand papers of different numbers so that the dint could be clearly seen.

## 2.3 Laser

Testing samples were made by means of TRUMPF laser. The power used for preparation of the testing sample was 2400 W and pressure 0,6 bar. The temperature in controlled cutting process reaches up to 106 °C, (cutting speed was 2,7 m/min). Maximum power of respective laser is 5 kW with accuracy of 0,1 mm. The original structure of measured sample was a pearlitic one, respectively ferrite-pearlitic, with hardness ranging from 170 HV to 180 HV. Cutting by laser has a thermal impact on the original pearlitic structure and changes it to bainitic structure. The change is caused by great difference in temperature between the cutting area and the surrounding environment. The temperature in the cutting area is approximately 106 °C. The standard temperature of the surrounding environment is 22 °C, which causes very quick cooling creating the non-equilibrium state (hardening) in the cutting area and thus creating the structure of bainit. The measured hardness value in the cutting area was approximately 340 HV (Fig. 2) that corresponds to structure of upper bainit. Due to the characteristics of the tested material (11373), especially due to its low contain of carbon (0,17 %), lower values of hardness can be expected. The measured values show that the depth of the influenced layer is up to 1 – 2 mm. The changes of hardness are insignificant in greater distance from the cutting line (Fig. 2).

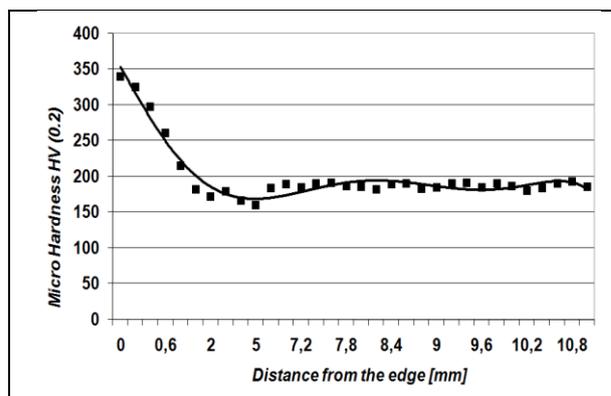


Fig. 2. Change of micro-hardness (cutting by laser)

## 3. CONCLUSION

The submitted article deals with the impact of laser cutting on the surface layer of material. The material used for experimental part was steel (ČSN - Czech state Norm) ČSN 411373. The specimen thus made were ground (polished) and in this way prepared for the microhardness test. Microhardness was measured on the microhardness tester DM – 2D. The results of the measurement were put in the graph.

The results show that testing bodies cut by laser shown the hardness of 340 HV. Maximum thickness of the layer influenced by cutting was 1 - 2 mm.

## 4. ACKNOWLEDGEMENTS

This article is financially supported by the internal grant of TBU in Zlín No. IGA/10/FT/11/D funded from the resources of specific university research and by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

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