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EXPERIMENTAL RESEARCH REGARDING THE TEMPERATURE ALONG THE CUTTING EDGE OF DRILLS

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ABSTRACT

The energetic charge of cutting edges for drill is variable along them depending, first of all, on the cutting speed – ascending from the axis to the periphery of the drill. In this way, the cutting edge's temperature tends to rise from the axis to the periphery, determining in the same direction the wear of the drill.

For drills with a variable angle of attack, descending from the axis towards the periphery, the thinning of the chip's thickness can compensate the effect of increasing the cutting speed, and as a result, the cutting edge's temperature.

In this paper, we determine, through experiment, the level of temperature along the cutting edge of drills, by comparison, for standard drills and multi-flute drills with variable angles of attack (curved edge drills). The measurements were made using an appropriate cutting chart, transversal turning, using an edge of the drill, with a FLIR Systems ThermoVision A20M thermic vision camera. The loading results for the drill with a Ø20 diameter and two types of processed materials are presented, with variable parameters.

KEYWORDS: twist drill, curved edges, turning, thermic transfer, thermograms, infrared, durability

1. THEORETICAL CONSIDERATIONS REGARDING THERMIC TRANSFER IN THE DRILLING PROCESS

High temperatures that appear in the treating processes involving cutting for drills represent one of the causes of reducing durability, by increasing wearing in twist drills, with limitations and unsatisfactory effects concerning final products. Conventionally, it can be considered that, for a cutting tool, there are three sources of heat - figure 1 [1, 2]:

- shear plane;
- face of the tool;
- flank of the tool.

If we mark Q_ϕ, Q_γ and Q_α the heat quantity coming from these sources, then, the total heat quantity is given by the ratio:

$$Q = Q_\phi + Q_\gamma + Q_\alpha. \quad (1)$$

The generated heat is diffused in the cutting, in the tool, the piece and the environment, so we can write the thermal balance:

$$Q_\phi + Q_\gamma + Q_\alpha = Q_{\phi p} + Q_{\phi a} + Q_{\alpha p} + Q_{\alpha s} + Q_{\gamma s} + Q_{\gamma a} + Q_{ma}, \quad (2)$$

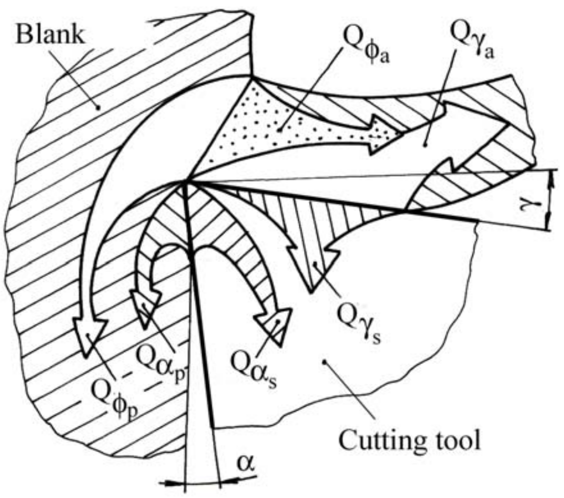


Fig. 1. *Heat source in the process of cutting [11]*

where:

- $Q_{\phi p}$ - the quantity of heat coming from transforming mechanical work of straining in the shear plane and taken over by the piece;
- $Q_{\phi a}$ - the quantity of heat coming from transforming the mechanical work of straining in the shear plane and taken over by the chip;
- $Q_{\alpha p}$ - the quantity of heat coming from transforming the mechanical work of friction on the flank and absorbed by the piece;
- $Q_{\alpha s}$ - the quantity of heat coming from transforming the mechanical work of friction on the flank and taken over by the tool;
- $Q_{\gamma s}$ - the quantity of heat coming from transforming the mechanical work of friction on the face and absorbed by the tool;
- $Q_{\gamma a}$ - the quantity of heat coming from transforming the mechanical work of friction on the face and taken over by the chip;
- Q_{ma} - the quantity of heat absorbed directly by the environment.

In these conditions, in the case of drilling, a part of the mechanical work used for volumetric plastic strain is transmitted in the form of conduction heat in the cutting edge’s area of the drill, at the junction with the cutting material.

If the actual heat in the material of the cutting tool, c_s, and the metal mass associated with it respectively, m_s, are known, then we can define the simplified form of the heat quantity absorbed by the tool:

$$Q_s = c_s \cdot m_s \left(T_s - T_0\right), \tag{3}$$

where T_s is the temperature in the cutting tool, and T_0 is the environment’s temperature ($T_0 = 20\,^{o}\mathrm{C}$).

It is obvious that the high temperature of the tool, determined by a high quantity of energy received in the cutting process, influences in an unwanted way the tool’s wearing intensity, through known wearing mechanisms [1].

2. THEORETICAL MODELS FOR STUDYING THERMIC TRANSFER IN DRILLING

Temperature distributions developed in the cutting process have been investigated both experimentally and analytically for many years. In spite of that, most studies of temperature field have been limited to orthogonal cutting [15], [8], [4], [12], like turning, fewer being the ones dedicated to non-orthogonal cutting, like drilling, milling or polishing [13], [2], [3]. In technical literature, there are numerous methods of studying heat flow and temperature distribution, the methods considered can be both numerical and experimental. Hervey and Cook [6] developed a model to predict medium temperatures along cutting edges of the drill, while DeVries [5] developed a more sophisticated analytical model for defining this distribution of temperature across the cutting edge.

Agapiou and DeVries [1] extended the research and elaborated an analytical model for temperature distribution based on calculating the cutting’s temperature at the interface cutting tool - cutting. This model was later improved by Agapiou and Stephenson [1], who extended the analytical model in order to calculate the transient temperature in a state of balance. Their model analyzed the heat flow and distribution of the temperature inside the cutting tool, by considering it as a semi-finite object.

Models are necessary for mathematically representing the integrant behavior of materials in conformity with different cutting conditions. With the purpose of accelerating numeric calculations, the majority of drilling simulations were made at a certain simplified level like reducing the 3D issue to a 2D statement [2], associating drilling to a diagonal cutting process 14], etc., considering the drill’s cutting edge of a series of elementary cutting tools (ECT) that perform an orthogonal process [3]. The same author analyses the issue of heat transfer obtained through friction, when the cutting tool and the chip interact, using a simplification assumption. Thus, he considers heat flows uniform in the contact zone between the cutting tool-chip for each ECT, so that the heat flux resulted from friction is equal to the sum of thermic heat flows from the chip, and from the cutting tool respectively.

3. EXPERIMENTAL MODELS FOR STUDYING THERMIC TRANSFER IN DRILLS

The majority of previous research studies have taken into account the developing of multiple methods of measurement for boring/holing temperature, the most common being: using thermocouples placed in the twist channel or inside the drill, scanning through electronic microscopy, using thermic sensitive paints, thermography.

Watanabe [16] measured the drilling temperature with a thermocouple encased in the cutting tool, obtaining almost constant temperature values .

Mills and Mottishaw [10] measured the temperature in the drilling process by examining the micro-structural changes in the material of the processed piece and discovered that the highest temperatures were close to the drill-s axis.

Agapiou and DeVries [1], measured the temperature profile close to the drill’s cutting edges with the help of thermocouples integrated in the drill’s twisted channel. They noticed that the temperatures recorded close to the end of the edge were much higher than they predicted. M. Bono [3] imagined a thermocouple-metallic foil system to measure temperature distribution along the main edge. A laser of metallic foil is used, incorporated between two lasers of plastic that are inserted into the piece to be processed – figure 2. When the hot drill touches the metal foil, a thermoelectric junction takes place between the two elements. As the drill goes through the foil, the contact point moves across the main edge, and, thus, there it is possible to emit a continuous thermoelectric signal. As a result, there is an efficient recording of temperature distribution along the length of the edge.

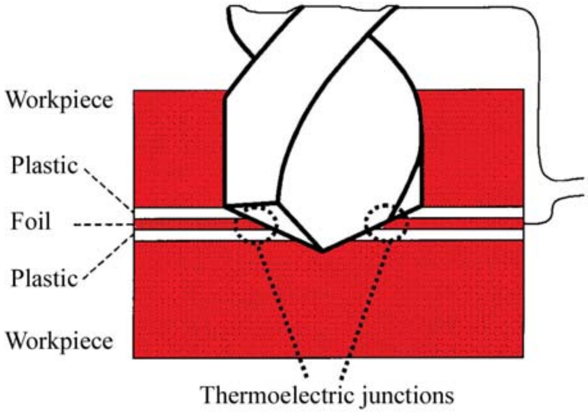


Fig. 2. *Thermocouple-metal foil system [3]*

Mieszczak and Lis [10] measured the temperatures during the cutting process, indirectly, by using an infrared camera and a spotlight. The infrared camera was placed on a tripod at a 1300 mm distance from the soon-to-be processed piece, and the spotlight was placed under that piece. The spotlight was tilted so that angles of incidence and of reflexion are normal at the surface of the spotlight, as much as possible – figure 3.

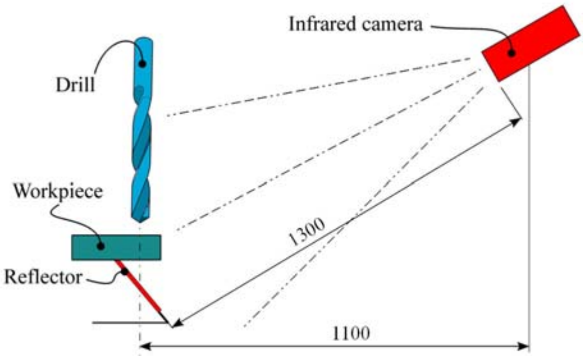


Fig. 3. *System of measuring temperature with infrared camera and spotlight [10]*

4. EQUIPMENT AND METHODOLOGY DESCRIPTION OF EXPERIMENTAL RESEARCH

In this paper, we investigated the temperature of the cutting edge in turning with a twist drill with three curved edges, in comparison to turning with a twist straight two-edged drill, observing the feed effect, the speed of cutting and the geometry of the cutting tool over temperature of the contact zone cutting tool-blank to be processed.

Recording the thermic field is presented in the form of a thermogram in which the domain of recorded temperatures is defined for a certain time interval of processing, the method used being that of thermography, which allows to precisely establish the extension of the thermomechanic influence zone, of temperature variation and of maximum temperature values for a number of points localized in different work zones.

4.1. Experimental equipment

The experiments were performed on a SN400 lathe, without cooling agent, at room temperature, in the engine room of the Department of Manufacturing, Robotics and Welding Equipment from the Faculty of Mechanical Engineering, equipment necessary to determine recorded measurements - figure 4:

- infrared thermovision camera FLIR Systems ThermoVision A20M (1);
- specimens from OL37, 18MnCr11 (2) respectively;
- twist drills with two straight edges, and three curved edges respectively, diameter - Ø20 mm (3);
- the specialized software to obtain and process ThermaCAM Researcher Professional thermograms (4);
- contact thermometer TOHO TTM 004 (5);
- SN400 normal lathe – blank fastening system (6).

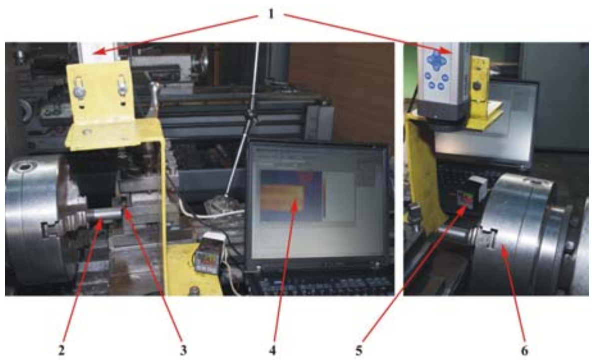


Fig. 4. *Experimental stand for investigating thermic transfer phenomena in turning with drills FLIR Systems ThermoVision A20M Infrared Thermovision Camera*

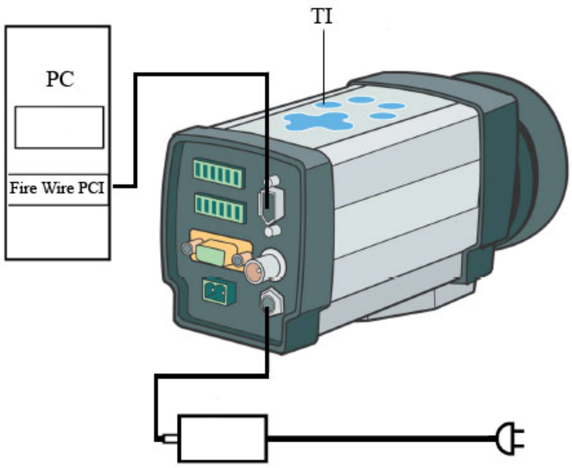


Fig. 5. *ThermoVision A20M thermovision camera (TI – intergated keyboard)*

The ThermoVision A20M infrared thermovision camera from Flir Systems is connected to a portable calculus terminal, with the possibility to command it from both the computer and through an intergated keyboard – keys placed on the upper side of the camera for ease of access – figure 5.

The most important characteristics of the thermographic camera were set up: measuring field: 20÷900 °C, image frequency: 50 Hz, image resolution: 160x120 pixels, thermic sensitivity < 0,1 °C, digital video interface: FireWire, band spectrum: 7,5÷13 µm.

With the purpose of obtaining the best infrared image, we have to take into account the parameters that describe the physical properties of the processed material (emittance, reflected temperature), environment temperature, relative humidity in the air, the distance from the camera lens to the contact zone between the cutting tool and the processed material. Other set parameters (fig. 6): value of emittance factor, established based on the nature of the material - 0,76 (OL37), 0,69 (18MnCr11) respectively; the distance from the piece: 0,2 m; relative humidity in the air: 50%; room temperature: 20°C.

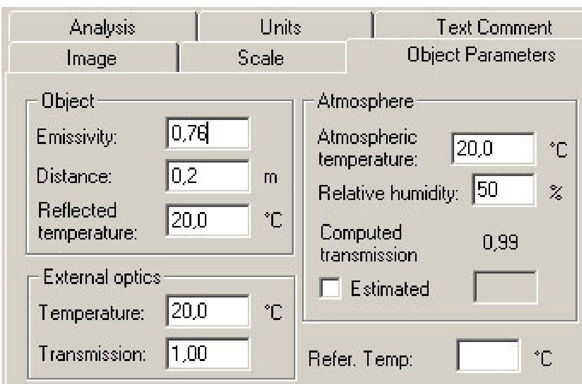


Fig. 6. *Parameters that describe the physical properties of the processed material samples*

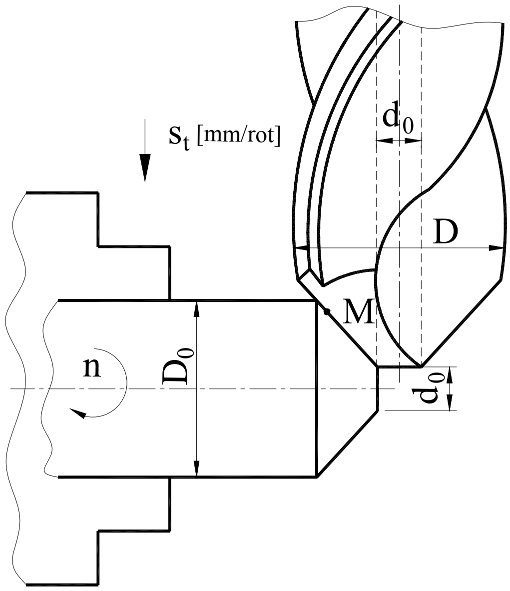


Fig. 7. *Cutting layout*

The cutting layout in the turning process, figure 7 and the samples-sizes were chosen so that, for short periods of time, they re-enact the actual cutting state of a twist drill's edge:

- cutting speed in point *M*,

$$v_M = \frac{\pi \cdot D \cdot n}{1000} \; [m/min]. \tag{4}$$

For D = 20mm, cutting speed is equal to the peripheric speed of the drill;

- The size of the transversal feed, s_t. This is equal to the axial feed of the drill on the spur:

$$s_t = s_d \; [mm/rot.] \tag{5}$$

It is obvious that the situations described are fulfilled for a short period of time, because reducing the speed of the *M* point of contact drill-blank, along the direction of the transversal feed (s_t) has the effect of reducing the cutting speed, while the rotations of the drill's main shaft are constant.

The samples were made of OL37 and 18MnCr11, respectively, turned, in advanced, to a diameter of Ø20 mm. Before the actual processing, with the help of similar drills used in the experiment, samples were roughed, so that when the temperature is recorded while processing, the edges of the two cutting tools be in contact with the blank along their entire length – figure 8. In figure 9, the samples are rendered during processing preceding recording of temperatures, performed with the straight edge drill (fig. 9a), and with a curved edge, respectively (fig. 9b).

a. b.

Fig. 8. *Blank obtained with a curved edge drill (a), and a straight edge drill (b)*

a. b.

Fig. 9. *Primary processing of samples by turning with a straight edge drill (a), and a curved edge drill (b)*

ThermaCAM Researcher Professional Specialized Software

ThermaCAM Researcher Professional is the specific software for the thermographic camera ThermoVision A20M – capable to measure and capture images of objects that emit infrared radiations. Because radiation is a function dependent on the temperature of an object's surface, the software allows the camera to record temperature in real time, but can also be used to capture and process thermograms that cover the temperature field recorded at the interface cutting tool-processed material. The captured images show the thermic cicles at a certain point during the cutting process. Afterwards, the recorded phenomena can be analysed with the thermographic camera, after it is disconnected, as well as the type of information transfer like text or images, towards a variety of other programs, such as MS Excel or MS Word.

The TOHO TTM 004 contact thermometer

With multiple functions, an easy access and selectable entries, the TOHO TTM 004 thermometer has thermocouples that allow measurements of temperature for some reference elements that calibrated the thermography room, so that the measured temperature is equal to the temperature read by the contact thermometer.

At the same time, the contact thermometer was used to maintain a constant initial temperature of the cutting tool and of the blank material for each determination, thus:

$$T_{cutting\ tool} = 20^o C\ ;\ T_{sample} = 25^o C\ .$$

4.2. Research methodology

In order to study some aspects regarding the temperature of the edge in the process of turning with a twist drill with three curved edges, we considered the comparison with the similar phenomenology of processing with a straight edged drill, a case very often studied in technical literature. The novelty lies in the fact that there is no actual turning, it is a closed cutting, thus the possibilities to measure the temperature with a thermovision camera would have practically been cancelled.

Therefore, we opted for a transversal turning, using blanks whose external line is in contact with the whole edge length of the two twist drills (figure 9) and have identical diameters with those of the cutting tools from the experiment - Ø20 mm.

Samples from two different materials were used - OL37 and 18MnCr11, varying in saturation and work speed.

In table 1, process parameters of the experiment are presented.

Table 1. *Characteristics of process parameters*

Parameters	***Two straight edged drill / Three curve edge drill***			
s_t [mm/rot]	0,1 0,14	0,1 0,14	0,1 0,14	0,1 0,14
n [rot/min]	31,5	63	80	125
v [m/min]	1,98	3,96	5,03	7,85

The camera was set in a real thermography situation, seeking specific parameters – figure 6.

Through the software ThermaCAM Researcher Professional, the camera's recordings are taken over, which can be numerically or graphically expressed, as images, profiles, histograms, etc. All results are based on an infrared image, with a temperature scale on the right – figure 10, the program being able to show a single image at time interval selected in advance – we chose a frame per second.

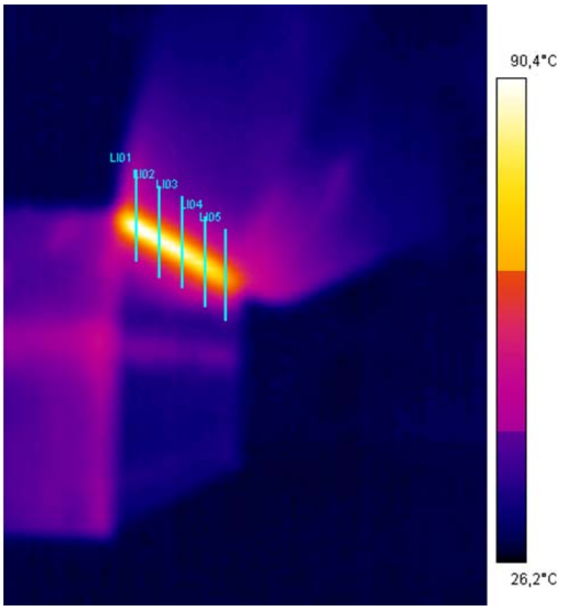
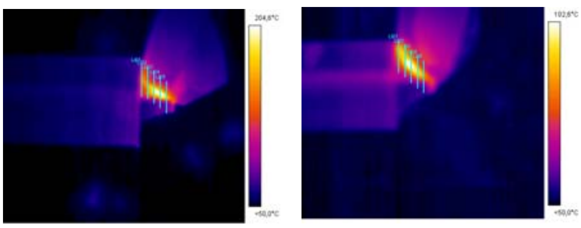


Fig. 10. *Frame-image at one second of processing*

In order to numerically analyse the temperatures and the statistical information from the images resulted from absolute or relative measurements, measurements lines were used – markers on the infrared image – that highlight the areas where the radiations of the objects are equal. This is true only in case the object’s emittance is the same in the entire image, the measurement limit line not being able to exist outside the mximum or minimum temperatures of the initial range (-20 ^{o}C ÷ 250 ^{o}C). Markers can be punctual - they measure temperature in a single place on the image; areal – they measure temperature, the maximum, minimum, medium and standard deviation in a chosen perimeter in the image; liniar – they measure the minimum, maximum temperature, mean and standard deviation along a straight or flexible line in the image.

In the present study we opted for drawing a measurement line (L01, L02, …, L05), the recorded value being the maximum temperature. This choice was made because we do not know exactly where the maximum temperature is recorded, on the drill’s edge or on the sample, but we can consider the maximum value of temperature, predicted to be in the contact point between the tool and the sample’s material, can be found on this measuring line – figure 11.



a. *b.*

Fig. 11. *Measurement lines for recording the temperature for the straight edged drill (a), and the curve edged drill (b)*

ThermaCAM Researcher Professional allows to see the temperature variation in real time, for each frame-second of processing - figure 12, or the data can be stocked and analyzed afterwards.

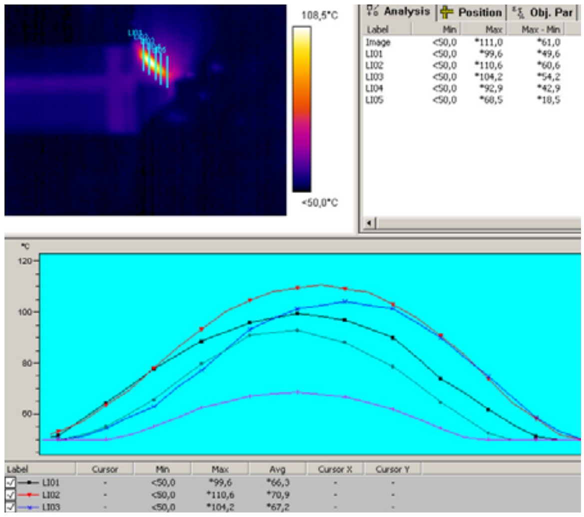


Fig. 12. *Temperature variation on the 5 measurement lines at a given time*

Current images can be saved in different formats: .BMP – used only to see the images, .CSV – the temperatures from the whole image are stocked in a text format that can be read with MS Excel, FLIR, MatLab etc. In this case, the data were saved in a .IRP text file format, that can be transferred in MS Excel and which contains the maximum value temperatures recorded in Kelvin degree.

4.3. Measurement conditions

In the evolution of the experiments, we started with the premise of a comparison with the similar phenomenology from processing with a straight edged drill, while some measurement conditions must be mentioned:

- there is no actual turning, this being a closed cutting, in which case the possibilities to measure temperature with a thermovision camera would have been minimum;
- the processing is a transversal turning, using blanks whose exterior is in contact with the whole length of the drills edges;
- the blank diameters are identical with the drill’s diameters - Ø20 mm;
- the cutting was made outside, the duration of each experiment being of 10 seconds;
- the initial temperature of the twist drill and of the blank was maintained relatively constant at 25÷27 ^{o}C for the cutting tool and 28÷30 ^{o}C for the blank, through cooling applied after each experiment;
- visualizing the contact area with the termography camera was made from the placing surface of the drill’s spur, with the purpose of avoiding interference with the measurements because of the generated cutting, by adequately placing the

camera and the drill in relation to the turning machine’s sense of rotation.

5. RESULTS AND THE INTERPRETATION OF RESULTS

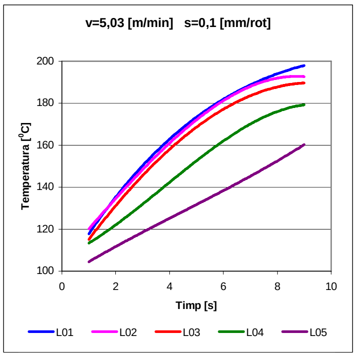
By processing samples from the two materials - OL37 and 18MnCr11, using as cutting tools a twist drill with two straight edges and a twist drill with three curved edges and varying the parameters of the cutting status according to table 1, after data processing, the most important values were obtained and grouped, in tables and graphically, depending on the influences generated by work conditions and cutting parameters, highlighting the following:

- feed;
- cutting speed;
- the geometry of cutting tools;
- the processed material.

1. The influence of the cutting speed. Material: OL 37

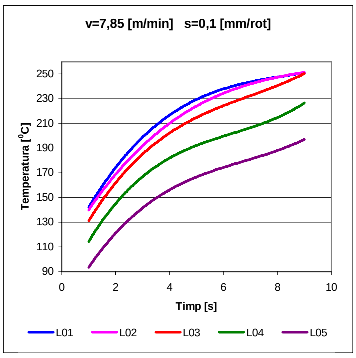
Burghiu cu tăiş rectiliniu, n=80 rot/min, v=5,03 m/min, s=0,1 mm/rot

L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
390,326	117,176	391,639	118,489	385,315	112,165	384,837	111,687	382,954	109,804
409,569	136,419	410,709	137,559	410,043	136,893	396,819	123,669	374,899	101,749
423,907	150,757	422,76	149,610	418,9	145,750	408,191	135,041	389,446	116,296
435,323	162,173	429,679	156,529	426,889	153,739	412,024	138,874	405,372	132,222
442,402	169,252	445,447	172,297	441,001	167,851	428,456	155,306	410,31	137,160
459,211	186,061	456,318	183,168	452,091	178,941	428,681	155,531	409,861	136,711
464,867	191,717	460,648	187,498	455,208	182,058	444,178	171,028	411,072	137,922
462,027	188,877	465,469	192,319	464,234	191,084	455,524	182,374	427,747	154,597
472,832	199,682	465,469	192,319	461,018	187,868	449,106	175,956	434,457	161,307
	199,682		**192,319**		**191,084**		**182,374**		**161,307**



Burghiu cu tăiş rectiliniu, n=125 rot/min, v=7,85 m/min, s=0,1 mm/rot

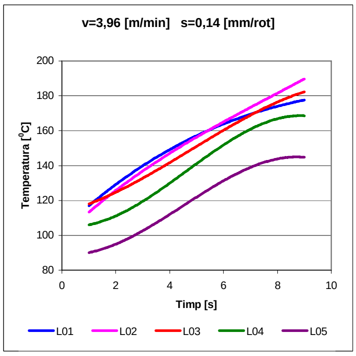
L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
411,494	138,344	412,625	139,475	403,493	130,343	388,468	115,318	368,828	95,678
453,551	180,401	441,697	168,547	435,356	162,206	413,044	139,894	386,023	112,873
473,612	200,462	468,786	195,636	459,985	186,835	446,353	173,203	421,688	148,538
488,669	215,519	480,192	207,042	477,541	204,391	456,481	183,331	431,718	158,568
495,135	221,985	495,821	222,671	481,82	208,670	463,926	190,776	442,711	169,561
511,816	238,666	507,475	234,325	500,028	226,878	467,083	193,933	436,089	162,939
521,873	248,723	518,602	245,452	504,145	230,995	480,371	207,221	453,695	180,545
521,586	248,436	518,738	245,588	517,537	244,387	494,293	221,143	471,498	198,348
522,303	249,153	524,682	251,532	521,83	248,680	496,65	223,500	465,814	192,664
	249,153		**251,532**		**248,68**		**223,5**		**198,348**



2. The influence of the processed material
Material: OL37

Burghiu cu tăiş rectiliniu, n=63 rot/min, v=3,96 m/min, s=0,14 mm/rot

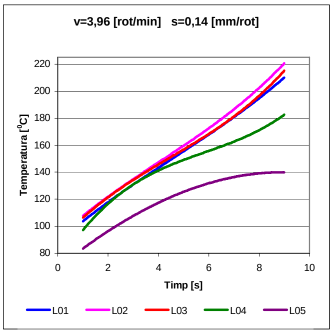
L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
389,646	116,496	385,138	111,988	388,978	115,828	377,831	104,681	363,556	90,406
399,751	126,601	399,407	126,257	403,031	129,881	391,414	118,264	369,528	96,378
421,075	147,925	412,937	139,787	402,755	129,605	381,401	108,251	372,358	99,208
420,007	146,857	420,739	147,589	416,929	143,779	407,762	134,612	382,387	109,237
422,599	149,449	427,454	154,304	416,952	143,802	414,751	141,601	402,165	129,015
443,36	170,21	434,852	161,702	442,626	169,476	425,038	151,888	400,803	127,653
437,515	164,365	443,594	170,444	434,797	161,647	439,377	166,227	418,256	145,106
453,541	180,391	464,778	191,628	454,432	181,282	431,563	158,413	408,215	135,065
448,041	174,891	458,354	185,204	453,9	180,750	445,003	171,853	421,353	148,203
	180,391		**191,628**		**181,282**		**171,853**		**148,203**



Material: 18MnCr11

Burghiu cu tăiş rectiliniu, n=63 rot/min, v=3,96 m/min, s=0,14 mm/rot

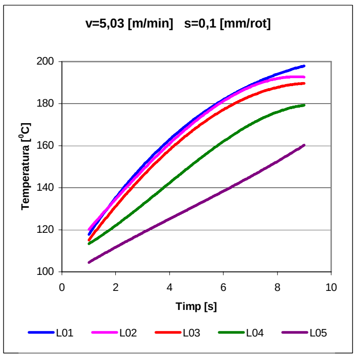
L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
376,306	103,156	384,44	111,290	382,816	109,666	370,136	96,986	355,501	82,351
395,189	122,039	386,037	112,887	386,498	113,348	390,91	117,760	370,963	97,813
395,876	122,726	416,728	143,578	414,215	141,065	402,742	129,592	379,667	106,517
423,609	150,459	410,479	137,329	411,048	137,898	412,649	139,499	396,536	123,386
422,23	149,08	442,317	169,167	440,947	167,797	428,467	155,317	394,134	120,984
444,548	171,398	447,529	174,379	440,26	167,110	422,126	148,976	400,677	127,527
461,438	188,288	454,78	181,630	447,434	174,284	439,808	166,658	409,046	135,896
456,867	183,717	473,727	200,577	472,668	199,518	442,796	169,646	420,367	147,217
487,156	214,006	495,821	222,671	488,577	215,427	456,023	182,873	409,228	136,078
	214,006		**222,671**		**215,427**		**182,873**		**147,217**



3. The influence of the feed. Material: OL 37

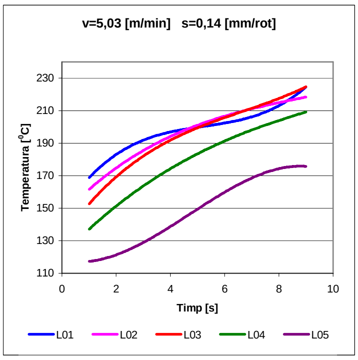
Burghiu cu tăiş rectiliniu, n=80 rot/min, v=5,03 m/min, s=0,1 mm/rot

L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
390,326	117,176	391,639	118,489	385,315	112,165	384,837	111,687	382,954	109,804
409,569	136,419	410,709	137,559	410,043	136,893	396,819	123,669	374,899	101,749
423,907	150,757	422,76	149,610	418,9	145,750	408,191	135,041	389,446	116,296
435,323	162,173	429,679	156,529	426,889	153,739	412,024	138,874	405,372	132,222
442,402	169,252	445,447	172,297	441,001	167,851	428,456	155,306	410,31	137,160
459,211	186,061	456,318	183,168	452,091	178,941	428,681	155,531	409,861	136,711
464,867	191,717	460,648	187,498	455,208	182,058	444,178	171,028	411,072	137,922
462,027	188,877	465,469	192,319	464,234	191,084	455,524	182,374	427,747	154,597
472,832	199,682	465,469	192,319	461,018	187,868	449,106	175,956	434,457	161,307
	199,682		**192,319**		**191,084**		**182,374**		**161,307**



Burghiu cu tăiş rectiliniu, n=80 rot/min, v=5,03 m/min, s=0,14 mm/rot

L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
443,966	170,816	434,863	161,713	422,057	148,907	410,963	137,813	391,81	118,660
450,104	176,954	448,198	175,048	452,781	179,631	426,594	153,444	392,785	119,635
468,239	195,089	458,122	184,972	450,623	177,473	434,435	161,285	401,132	127,982
471,605	198,455	464,916	191,766	458,486	185,336	436,917	163,767	410,516	137,366
473,919	200,769	473,256	200,106	470,451	197,301	465,775	192,625	429,085	155,935
484,391	211,241	497,271	224,121	491,017	217,867	464,461	191,311	421,433	148,283
450,198	177,048	457,414	184,264	481,782	208,632	491,647	218,497	461,708	188,558
511,989	238,839	504,409	231,259	485,674	212,524	445,711	172,561	429,119	155,969
490,294	217,144	487,932	214,782	499,975	226,825	494,184	221,034	454,831	181,681
	238,839		**231,259**		**226,825**		**221,034**		**188,558**

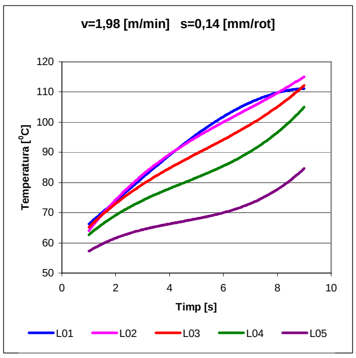


4. The influence of the cutting tool's geometry

Material: 18MnCr11

Burghiu cu tăiş rectiliniu, n=31,5 rot/min, v=1,98 m/min, s=0,14 mm/rot

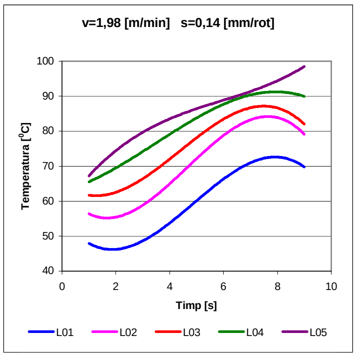
L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
340,109	66,959	337,379	64,229	337,944	64,794	335,021	61,871	329,66	56,510
346,467	73,317	347,254	74,104	345,797	72,647	342,471	69,321	335,596	62,446
353,517	80,367	354,772	81,622	353,386	80,236	349,505	76,355	338,597	65,447
362,29	89,14	364,798	91,648	361,264	88,114	351,921	78,771	338,85	65,700
369,081	95,931	366,046	92,896	359,318	86,168	352,317	79,167	340,324	67,174
379,597	106,447	374,365	101,215	365,225	92,075	355,356	82,206	341,906	68,756
376,235	103,085	377,533	104,383	371,625	98,475	365,773	92,623	347,271	74,121
381,582	108,432	382,816	109,666	383,602	110,452	372,708	99,558	352,169	79,019
385,547	112,397	388,321	115,171	382,816	109,666	376,221	103,071	356,885	83,735
	112,397		**115,171**		**110,452**		**103,071**		**83,735**



Material: 18MnCr11

Burghiu cu tăiş curbiliniu, n=31,5 rot/min, v=1,98 m/min, s=0,14 mm/rot

L01 T_{max} [K]	L01 T_{max} [°C]	L02 T_{max} [K]	L02 T_{max} [°C]	L03 T_{max} [K]	L03 T_{max} [°C]	L04 T_{max} [K]	L04 T_{max} [°C]	L05 T_{max} [K]	L05 T_{max} [°C]
319,919	46,769	328,18	55,030	334,089	60,939	338,382	65,232	340,596	67,446
320,92	47,77	330,689	57,539	336,695	63,545	342,727	69,577	347,103	73,953
323,161	50,011	332,802	59,652	340,315	67,165	348,063	74,913	352,973	79,823
325,64	52,49	336,746	63,596	344,49	71,340	352,227	79,077	356,088	82,938
332,994	59,844	345,547	72,397	351,6	78,450	357,483	84,333	361,855	88,705
336,491	63,341	348,377	75,227	353,731	80,581	357,453	84,303	358,763	85,613
346,422	73,272	359,421	86,271	361,654	88,504	365,792	92,642	367,22	94,070
347,45	74,3	358,19	85,040	361,149	87,999	365,159	92,009	366,087	92,937
341,583	68,433	351,047	77,897	354,124	80,974	362,358	89,208	372,002	98,852
	74,3		**86,271**		**88,504**		**92,642**		**98,852**



The unit energetic charge (for a unit segment of the curved edge) can be expressed as follows:

$$q(r)=C\cdot r\cdot[\sin \kappa_r]^{1-\mu} \qquad (6)$$

where:

- r is the radius of the point considered on the cutting edge of the drill;
- κ_r – angle of attack of the cutting edge, in the radius point „r” of the drill’s edge;
- μ – constant of material;
- C – constant of transformation.

It is obvious that the quantity of unit heat is diminished (that goes for the length unit of the edge) at the same time with the decrease of the angle of attack.

4. CONCLUSIONS

Measuring temperature through termography can be the most eloquent estimation of the thermic phenomenon along the cutting edge of the drill, if there can be conjured a work experiment in which the variation law of cutting speed along the cutting edge of the drill is similar with the actual, real turning process.

The process of measuring temperatures through termography in points along the cutting edge of the drill is accompanied by phenomena specific to the formation of the cutting in the processing of materials with high plasticity, such as: the formation of deposits on the edge, wearing in the form of a jagged blade on the main cutting edge, the formation of shiny scales on the cutting surface, etc. Also, emittance of the cutting material cannot be uniform during the cutting process.

The experiment performed for the two drills with different geometries (with two straight edges and three curved edges), for a wide range of feeds (st = 0,1 mm/rot and st = 0,14 mm/rot), for two types of materials (OL37 and 18MnCr11) in delivery state and four cutting speed levels (1,98 m/min, 3,96 m/min, 5,03 m/min 7,85 m/min), allowed us to distinguish the following conclusions:

1. it is possible to highlight the temperature variation along the cutting edge;
2. for straight edged drill, the temperatures rise gradually from the middle of the drill towards the periphery, because the thickness of the cutting is constant, and also because the cutting speed is variable;
3. the increasing thickness of the cutting (increasing of speed) has as an effect the rising of the temperature in all points on the cutting edge;
4. increasing the cutting speed at the periphery of the drill by increasing the rotations of the blank shows that the cutting temperature is rising;
5. the influence of the material on the temperature is certified by the recording of values higher than the temperatures during the sample processing made of 18MnCr11, compared to those made of OL37;
6. for the curve edged drills there is a decrease in temperature in the external area of the cutting edge, because of the substantial reduction in cutting thickness in this area;
7. it is possible to show a narrowing in the variation interval of temperature growth in the case of curved edge drills.

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