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Analysis of Material Deposit on HS6-5-2C Drills Cutting Edges at Processing 42CrMo4 Steel

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Abstract
At reaming processing by drilling, for small and unique series production there are normally used speed steel drills even if the processed material would require metal-carbide drills. This is also the case of 42CrMo4 steel, used also for gear wheels. Being an alloy steel with chromium and molybdenum its processing poses problems. Because the material deposit on the drill's edge has negative consequences, its analysis becomes relevant. The analysis of material deposit is appropriate in order to minimise its negative consequences or to avoid forming it.

Keywords
cutting, drilling, material deposit

1. Introduction

The deposit of the processed material on the cutting edge, according to [5], has been reported since the beginning of the systematic study of the metal cutting process (Haussner 1982). The mechanism of forming the deposit on the cutting edge [2, 3, 4] can be explained on the basis of the existence of the friction between the chip and the face surface of the cutting tool, which determines both temperature in the cutting area and the braking of the chip layer in the immediate vicinity of the face surface. The braked layer has a strongly pressed structure and due to the adhesion forces between the chip and the cutting tool it adheres to the cutting edge. As the hardness of the deposited layer exceeds the hardness of the processed material by 2.5 ÷ 3.5 times [2, 3, 4, 5], the deposit forms a new cutting edge (deposit edge) that cuts instead of the cutting edge of the tool (Figure 1). The cutting edge's height increases "H" (Figure 1) and due to the frictional forces and the reaction of the material on the cutting tool, it is quickly destroyed. The phenomenon occurs cyclically and after some research reported in [2] the cyclicity would be 5 ÷ 50 Hz and according to the bibliographic source [3] the cyclicity would be greater than 100 Hz.

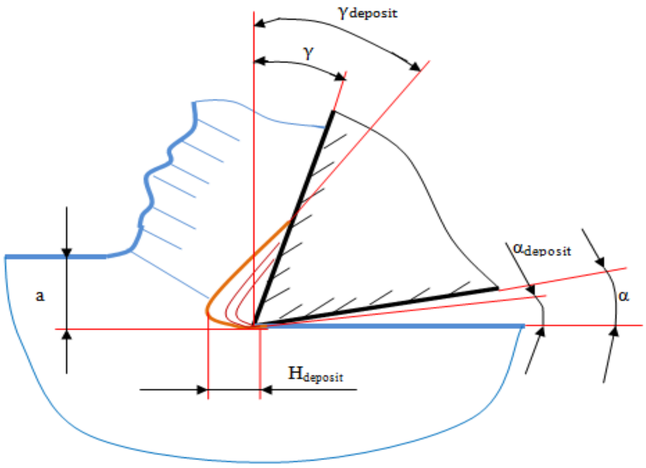

Fig. 1. Material deposit, according to [2, 3, 4]

In Figure 1 there are the next notations: a – thickness of the cutting layer, α – clearance angle, γ – rake angle, H – height of material deposit. Also from Figure 1 it can be observed that the material deposit modifies the cutting angles, it raises the rake angle (which is a positive aspect) but it lowers the clearance angle (which is a negative aspect).

The forming of the material deposit and its dimension depend on:
- the processed material;
- the cutting parameters;
- the cutting tool geometry;
- the used cutting fluid.

The influence of the cutting speed and of the cut layer thickness on the material deposit is shown in Figure 2 (according to [4]).

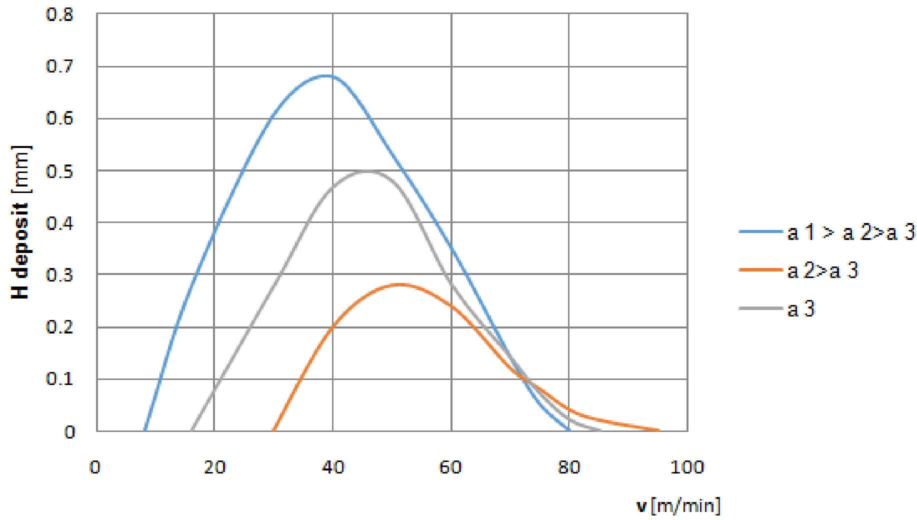

Fig. 2. The influence of the cutting speed and of the cut layer thickness on the material deposit

The consequences of the material deposit are more negative than positive. If in the first phase it protects the cutting edge, the breakage of the deposit leads to the wear of the cutting edge by removing material from it. The cyclical formation of the deposit on the edge determines inconsistency in the roughness of the processed surface and due to the variation of the cutting force, it appear vibrations with negative consequence on the stability of the cutting process.

As can be seen from figure 2, the cutting speed strongly influences the formation of the deposit edge. When cutting ordinary steels (with low carbon content) (Figure 2) the interval of formation of the deposit edge is 10 ÷ 80 m / min. The maximum height of the deposit on the edge is about 0.7 mm and after some sources [2, 4] even 0.8 mm.

The processed material influences the deposit on the edge by the degree of plasticity. The higher this is, the higher the deposit height is. The geometry of the cutting tool influences the deposit on the cutting edge especially through the rake angle "γ". After [4], at very large rake angles ($\gamma > 40^0$) the deposition on the edge is not formed. But there are very few materials at which the rake angle of the cutting tool is greater than 40^0.

The use of cutting fluids is beneficial due to the reduction of the friction between the chip and the rake surface of the cutting tool. The specialty literature offers information about material deposit on the cutting edge, especially for turning and less for other cutting processes (for example drilling, widening). At the same time, there is little information on the formation of the material deposit on the alloy steels that are difficult to process.

Many times, in the production of small and unique series, but also in repairs, we have to process holes in alloyed steel using speed steel drills. Between the processed materials there is also 42CrMo4 steel.

2. Experimental Data about Material Deposit at Drilling 42CrMo4 Steel

To find out to what extent a deposit is formed on the drill cutting edge when processing 42CrMo4 alloy steel, a batch of 27 HS6-5-2C speed steel drills was taken, each having a diameter of 8 mm. The processed material has the next chemical composition: C = 0.38÷0.45%, Si = 0.4% (maximum), Mn = 0.6÷0.9%, P = 0.035% (maximum), S = 0.030, Cr = 0.9÷1.2, Mo = 0.15÷0.3. The tensile strength of 42CrMo4 steel is 950 MPa (N/mm^2) and the hardness is 230 HB.

To determinate the optimum cutting parameters it was used the source [6], resulting: s = 14 m/min, f = 0.25 mm/rev. The cutting time was five seconds to see whether the formation of the deposit on the edge has a frequency greater than or less than 1/5 Hz. The measurement of the deposit was done with Mitutoyo microscope presented in Figure 3, with precision of 1μm and the obtained data are centralized in Table 1.

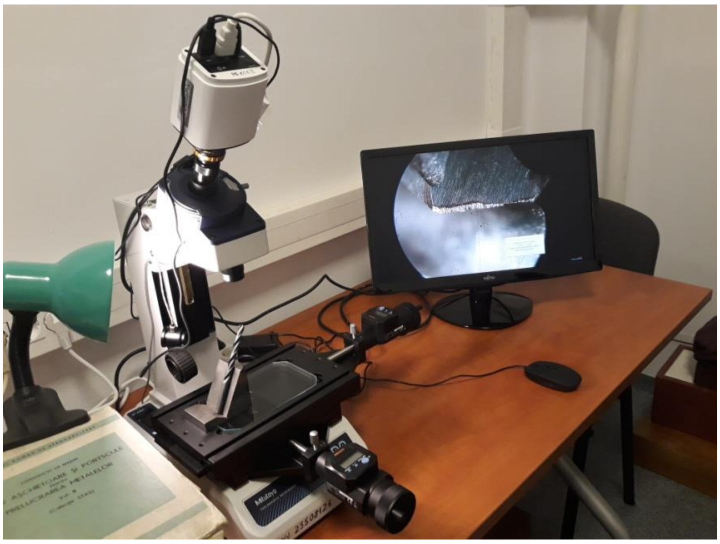

Fig. 3. Microscope for measuring the deposit on edge

The Figure 4 presents the material deposit on the main cutting edge of the drill. It can be observed that it is modifying the rake angle (it is increasing it) and lowers the clearance angle.

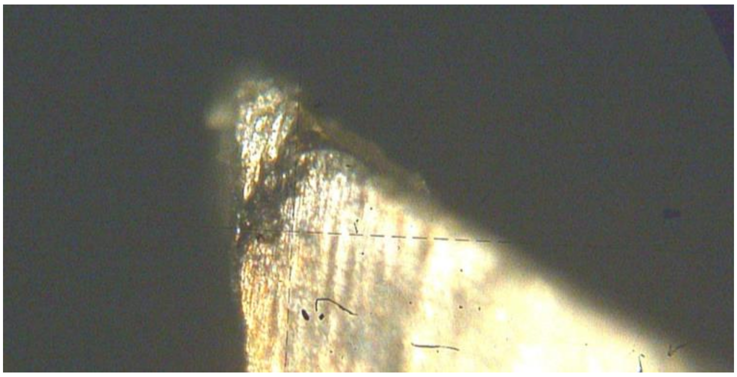

Fig. 4. The material deposit on the drill cutting edge

Analysing data from Table 1 it can be observed:

- all the drills had deposit of material;
- at 12 drills the deposit was formed only on a single edge;
- at 15 drills the deposit was formed on both edges;
- excepting two edges, the deposit was not formed on the entire edge length (Figure 5);
- the minimum diameter for which de deposit was formed is 5,66 mm that corresponds to a cutting speed of 4.68 m/min (Figure 6);
- the maximum height of the deposit is H_{max} = 0.419 mm (Figure 7);
- the height of the cutting deposit decreases along the main cutting edge to the minimum diameter which confirms the dependence of the deposit on the cutting speed (Figures 6 and 7).

Table 1. Data about deposits on drills edges

No. of drill	Diameter "D" of drill [mm]	Placement of deposit on edge 1(D_1) [mm]	Length of deposit [mm]	Maximum height "H_1" of deposit [mm]	Placement of deposit on edge 2 (D_2) [mm]	Length of deposit [mm]	Maximum height "H_2" of deposit [mm]
1	8	0	0	0	8	2.452	0.271
2	8	8	2.193	0.252	0	0	0
3	8	8	0.286	0.188	8	2.491	0.308
4	8	8 2.904	0.567 0.8	0.219	7.415	1.983	0.223
5	8	6.135	0.742	0.198	8	1.049	0.353
6	8	7.105 4.278	0.385 0.476	0.109	8	2.457	0.228
7	8	0	0	0	8	1.445	0.264
8	8	6.730	2.709	0.253	8	1.441	0.257
9	8	0	0	0	8	2.793	0.267
10	8	8	1.602	0.211	5.173	0.409	0.206
11	8	6.620	1.474	0.216	8	2.648	0.311
12	8	0	0	0	8	1.372	0.296
13	8	8	0.567	0.154	8	2.670	0.251
14	8	0	0	0	8	0.883	0.233
15	8	8	2.185	0.191	0	0	0
16	8	8	1.986	0.346	0	0	0
17	8	8	1.572	0.184	0	0	0
18	8	8	2.289	0.233	8 7.191	0.230 0.221	0.161
19	8	7.541	0.790	0.117	8	0.097	0.112
20	8	8	1.659	0.268	8	On entire edge	0.176
21	8	6,258	0.573	0.204	8	2.823	0.383
22	8	8	1.815	0.419	0	0	0
23	8	8	3.083	0.245	8	On entire edge	0.24
24	8	0	0	0	8	2.590	0.296
25	8	8	1.983	0.309	5.298	1.896	0.231
26	8	6.749	0.955	0.240	8	1.763	0.321
27	8	8	1.294	0.253	0	0	0

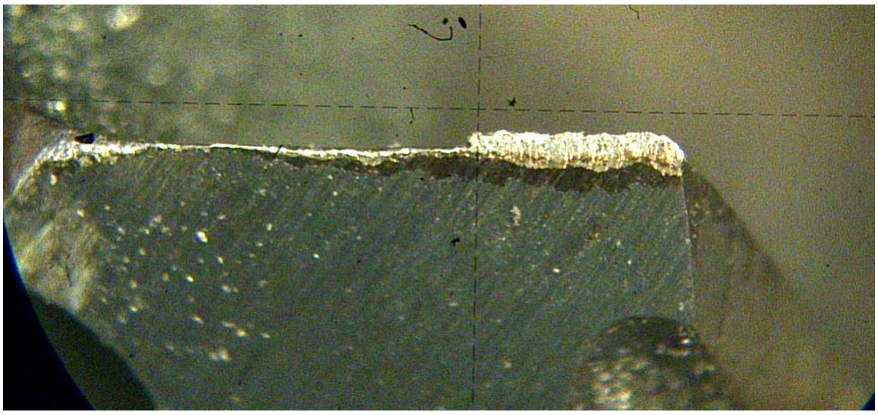

Fig. 5. Material deposit at drill no. 7

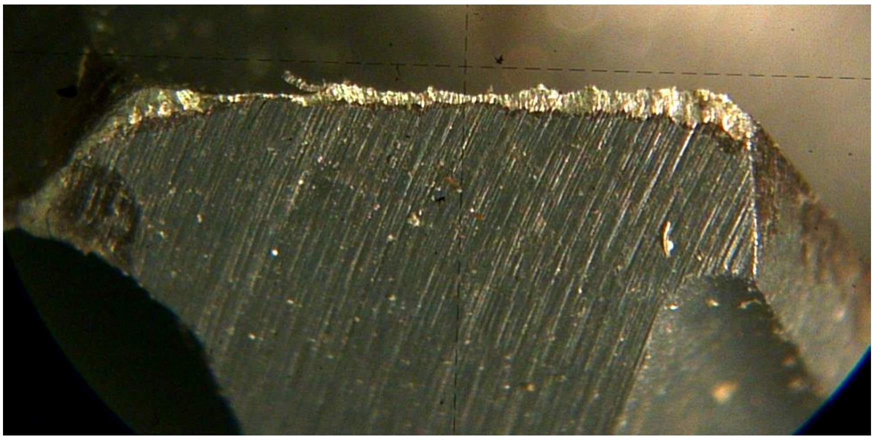

Fig. 6. Minimum diameter where the deposit was formed (at drill no. 23)

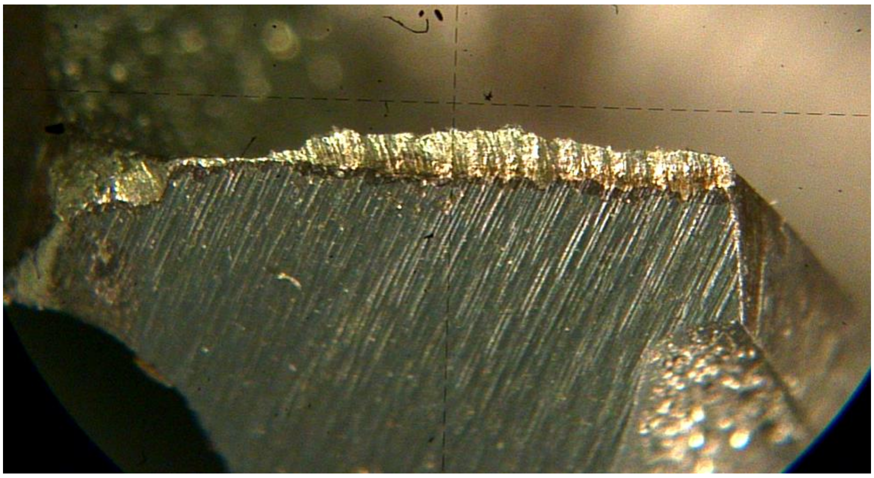

Fig. 7. Maximum height of deposit (at drill no. 22)

In Figure 8 you can see the moment of detachment of the deposit from the edge of the drill. It is noted that this detachment occurred at a maximum deposit height of 0.257 mm.

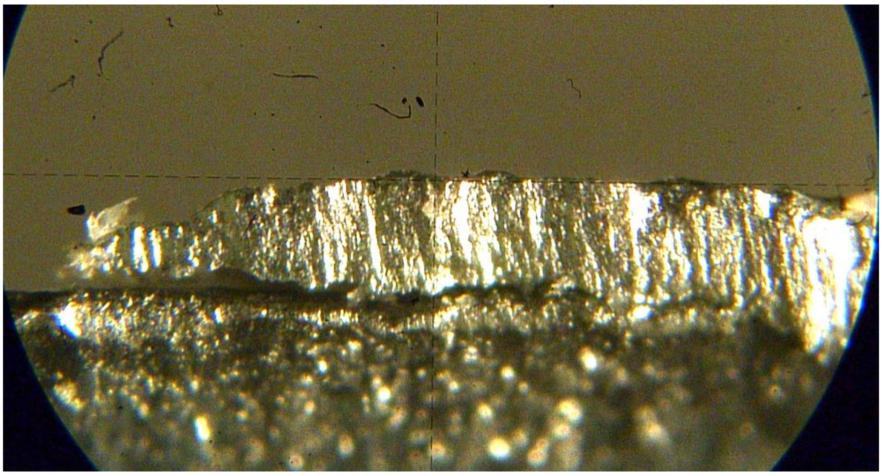

Fig. 8. Detachment of the deposit from the edge (at drill no. 8)

Table 2 shows the maximum height of the material deposit for a drill, regardless of what edge.

Analysing the values from Table 2 it can be observed that the drills can be divided in discrete values of the deposition height (example H = 0.221÷0.280) and in this way, it results data from Table 3.

Table 2. Maximum height of material deposit for a drill

No. of drill	Placement of deposit on edge 1 or 2 [mm]	Deposit length [mm]	Maximum height ”H” of deposit [mm]	No. of drill	Placement of deposit on edge 1 or 2 [mm]	Deposit length [mm]	Maximum height ”H” of deposit [mm]
1	8	2.452	0.271	15	8	2.185	0.191
2	8	2.193	0.252	16	8	1.986	0.346
3	8	2.491	0.308	17	8	1.572	0.184
4	7.415	1.983	0.223	18	8	2.289	0.233
5	8	1.049	0.353	19	7.541	0.790	0.117
6	8	2.457	0.228	20	8	1.659	0.268
7	8	1.445	0.264	21	8	2.823	0.383
8	8	1.441	0.257	22	8	1.815	0.419
9	8	2.793	0.267	23	8	3.083	0.245
10	8	1.602	0.211	24	8	2.590	0.296
11	8	2.648	0.311	25	8	1.983	0.309
12	8	1.372	0.296	26	8	1.763	0.321
13	8	2.670	0.251	27	8	1.294	0.253
14	8	0.883	0.233				

Table 3. Number of drills for each deposition height category

Deposition height category	Interval of deposition height [mm]	Interval size [mm]	No. of drills from each category
1	0.111÷0.220	0.11	4
2	0.221÷0.290	0.07	13
3	0.291÷0.360	0.07	8
4	0.361÷0.420	0.06	2

In Figure 9 is the graphical representation of data from Table 3.

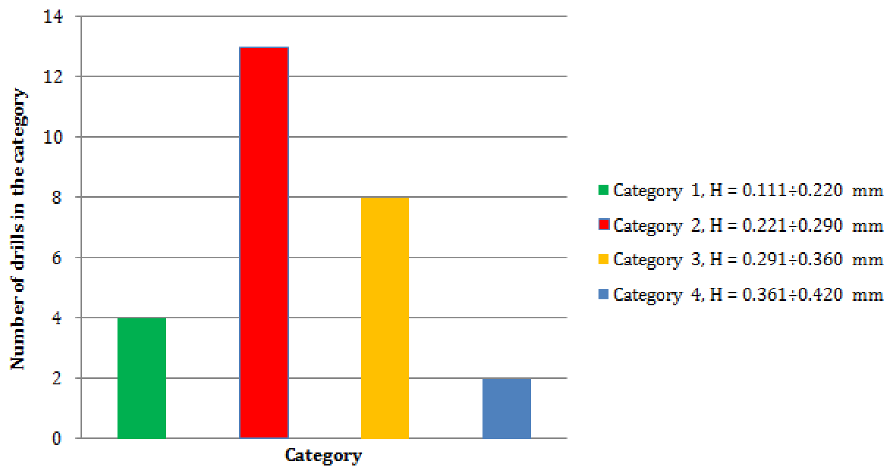

Fig. 9. The graphic of drills division on categories

From Figure 9 it can be seen that 21 drills (most of them) are in categories 2 and 3. The average of the height deposit of the two categories is $H_{2,3\ average}$ = 0.264 mm.

Also, in Figure 10, is captured the inconsistency of the deposit height on the main cutting edge of drill.

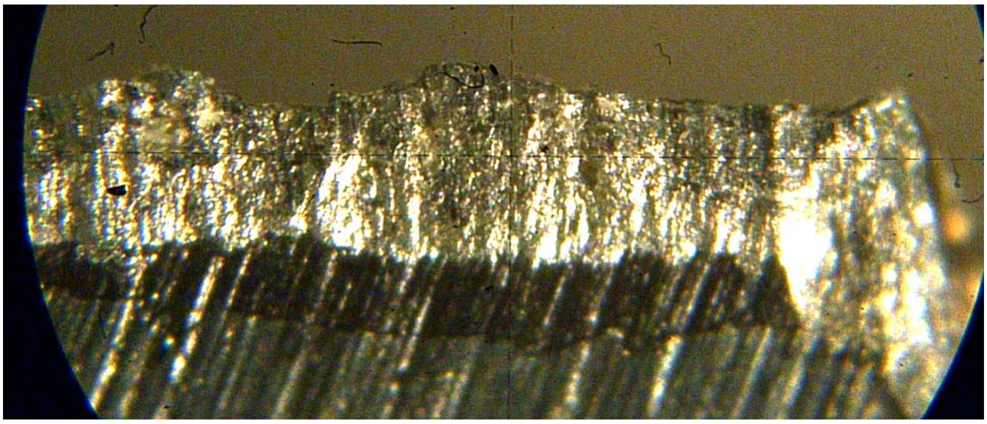

Fig. 10. Irregular material deposit on the cutting edge

3. Conclusions

From the followed experiments, the next conclusions can be drawn:

- the material deposit at processing 42CrMo4 steel with a speed steel drill having the diameter of 8 mm, with optimum cutting parameters, was formed for all the drills used for processing;
- the deposit is inconsistent along the cutting edge;
- the minimum diameter for which the deposit was formed is 5.66 mm that corresponds to a cutting speed of 4.68 m/min;
- in a proportion of 78%, the deposit was detached at an average height of 0.264 mm;
- in order to avoid material deposit on the edge, in the analysed case, the cutting speed must be lower than 5 m/min;
- for drilling 42CrMo4 steel, it would be recommended a metal-carbide drill but also in this case it must be studied if the deposit is formed and which are the optimum cutting parameters.

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