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THE IMPACT OF INDEPENDENT VARIABLES SURFACE MACHINING DUPLEX STAINLESS STEEL ON THE FLANK WEAR

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ABSTRACT

Surface engineering is important for carried out to improve the quality of the surface layer of the material. It is important that in special applications of corrosion resistant steel, low surface roughness is obtained. Duplex stainless steel is becoming more widely used for example in the petrochemical industry or shipbuilding. Duplex stainless steel is a material classified as difficult-to-cut. It is therefore important to investigate the impact of machining parameters on the durability and wear of a cutting tool. In the paper has determined the influence of variables machining: feed rate, depth of cut, cutting speed, on the maximum tool flank wear. Surface machining was carry out with carbide tipped inserts. The criterion of the smallest roughness and the highest wear was proposed.

Keywords: duplex stainless steel; machining; flank wear; cutting tool; surface layer

INTRODUCTION

Stainless steels currently enjoy high interest shows that every year takes place a few percent increase in production. Differentiation of properties, depending on the chemical composition, microstructure, quality of the surface layer, constantly expand the application areas of these materials. A special group are ferritic-austenitic steels (duplex steels hereinafter) whose development allows to increase the durability of machine parts exposed to erosion and corrosion wear.

The combination of high mechanical strength, high corrosion resistance and relatively low cost compared to similar materials, contributed to making duplex stainless steels one of the fastest growing groups of stainless steels. The duplex stainless steels are two-phase chromium-nickel-molybdenum-iron alloys in which the proportions of the components allow optimization of the equilibrium of the volume fractions of austenite and ferrite [1-13]. Two-phase stainless steel is considered to be difficult-to-cut materials. It is therefore important to determine the cutting edge wear [4-6, 10, 14]. The wear of the turning tool occurs on all surfaces with direct contact with the workpiece material and is manifested by the loss of the tool material. The most frequently determined are indicators of wear of a turning knife-edge, such as: flank wear (VB) and distance between primary cutting edge and the most distant - crater wear (KB).

EXPERIMENTAL MATERIALS AND METHODS

Two-phase stainless steels known as duplex by treatment have physical properties similar to those of the ferritic steels, while, due to the chemical composition and resistance to corrosion are similar to austenitic steel. The experimental research was carried out in the Laboratory of Department of Marine Maintenance of the Faculty of Marine Engineering of the Gdynia Maritime University. The external cylindrical surfaces were prepared for machining process by universal turning lathe.

Cutting parameters were selected based on own research for longitudinal turning: feed rate $f = 0.1 \div 0.2$ mm/rev, depth of cut $a_p = 0.5$ mm, cutting speed $v_c = 50 \div 100$ m/min, on the maximum tool flank wear VB. Surface machining was carry out with inserts CCMT where all are made of sintered carbides of the 2025 grade. The criterion for selecting the right cutting-tool inserts geometries for very precise machining was the arithmetic mean of the ordinates of the surface roughness profile (Ra= 0.16 ÷ 1.25 µm) and maximum tool flank wear (VB = 200 µm).

Throughout of the longitudinal turning of samples with duplex stainless steel (DIN EN 1.4410, PN-EN X2CrNiMoCuN 25-7-4, AISI 2507) (Table 1.) is usually short durability of the cutting inserts.

It is therefore important to determine the length of spiral cutting. Length of spiral cutting is a constant (L_{SC} = 9.5 m) and useful to the insert, geometry, and grade, depth of cut and material that shall be subject machined and can be calculated from the formula:

$$L_{SC} = \frac{\Pi\, D_m}{1000}\,\frac{l_m}{f} \tag{1}$$

where: D_m [mm] - the diameter of the workpiece in the machined surface,
l_m [mm] - length of the cutting surface,
f [mm/rev] - feed rate.

Surface roughness were measured using a profilometer Hommel Tester T1000. Parameters measurements were performed to the principles contained in ISO standards EN ISO 4287 and EN ISO 13565.

Table 1 The chemical composition and mechanical properties for samples of duplex steel DIN EN 1.4410, PN-EN X2CrNiMoCuN 25-7-4, AISI 2507

C [%]	**Cr** [%]	**Ni** [%]	**Mo** [%]	**Mn** [%]	**Si** [%]	**N** [%]	**S** [%]	**P** [%]
0.03	25.0	7.0	4.0	2.0	1.0	0.35	0.015	0.035
$R_{p0.2}$ [MPa]	**R_m** [MPa]	**R_m** [MPa]	**A_5** [%]	**HV**	**E** [GPa]	**ρ** [kg/dm^3]	**λ** [J/m·s·K]	**c_w** [J/kg·K]
550	750	1000	15	310	200	7.8	15	500

Observation and measurement of the tool wear after turning of duplex stainless steel samples was carried out using Scanning Electron Microscopy EVO MA 15 (Fig. 1). The Scanning Electron Microscope Zeiss EVO MA 15 is a device designed for examining the microstructure of solids. The device allows the imaging electron samples with a resolution of 3 nm at 30 kV. The range of possible magnification range from 5 to 1 000 000 times. The microscope enables the observation of samples with a mass up to 500 grams (at full mobility of the microscope table in XYZ directions) or up to 5 kilograms (then the table motion is limited to the XY axis directions). The microscope enables observation of samples as well as measurements of geometric quantities. The microscope is additionally equipped with an EDS analyzer. Energy Dispersive Spectrometer (EDS) XFlash 6/30 by Bruker extends the research possibilities of scanning electron microscopy with accurate and fast chemical analysis (qualitative and quantitative) of the observed surface of metallographic specimens.

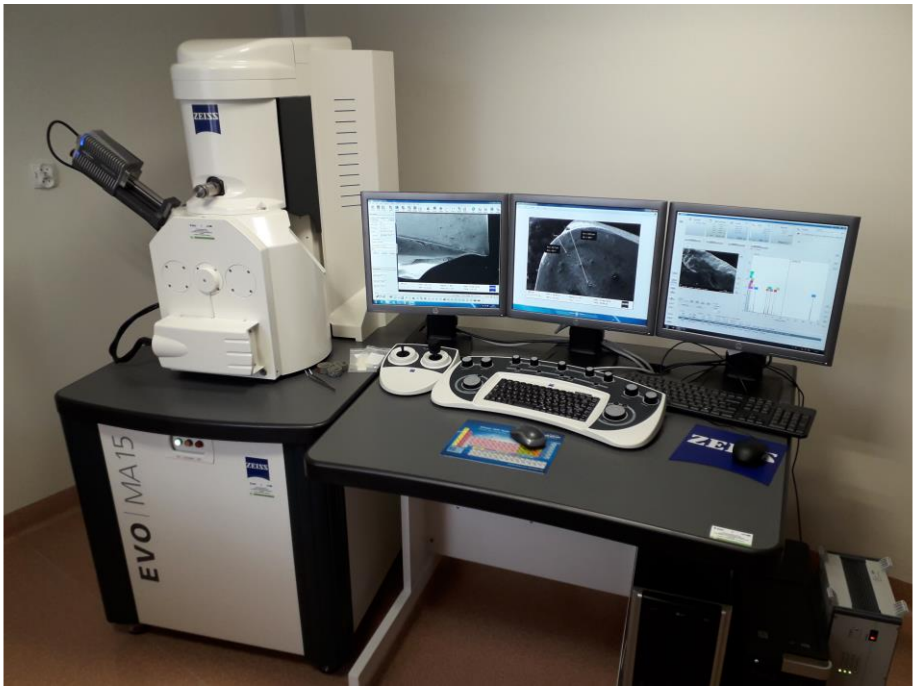

Fig. 1 Scanning Electron Microscopy EVO MA 15

RESULTS OF RESEARCH

After turning finishing duplex stainless steel, it was determined that the machining parameters affect the surface quality and knife wear. A number of roughness parameters have been defined. The smallest values of the parameter arithmetical mean deviation of the roughness profile Ra = 1.55 μm were determined after turning with the cutting insert CCMT 09T308-UM 2025 for the cutting parameters: v_c=70 m/min, *f*=0.2 mm/rev, a_p=0.5 mm.

Even smaller values of the Ra = 1.05 μm parameter were determined for the cutting parameters: feed rate of *f* = 0.1 mm/rev, with a constant cutting speed v_c = 70 m/min and depth of cut a_p=0.5mm, using a CCMT 09T304-UM cutting insert carbides of the 2025 grade with a CVD Ti(C,N)/Al_2O_3/TiN (2μm/1.5μm/2μm) [14].

The cutting inserts were characterized by the following features: cutting edge angle κ_r= 90°, tool included angle ε_r = 80°, rake angle γ= 6° and γ= 7°, flank angle α= 7°, nose radius r_ε= 0.4 mm and r_ε= 0.8 mm. For this turning tool, the smallest flank wear VB = 36 μm and crater wear KB = 18 μm was obtained (Fig.2). The surface roughness reduction ratio was equal to K_{Ra} = 3.21, which is the highest value among the presented scope of research.

The wear of cutting edge shown a view from the scanning electron microscope of the cutting inserts. The condition of used tool point surfaces was assessed using the corresponding SEM images shown in Figures 2 to 4. You can see the effects of wear on the rake face and flank. For cutting inserts with nose radius 0.8 mm the built-up edge with the clash of the major flank can be observed. However, on the cutting insert with a radius of 0.4 mm there is slight wear in the form of abrasive wear.

a)

b)

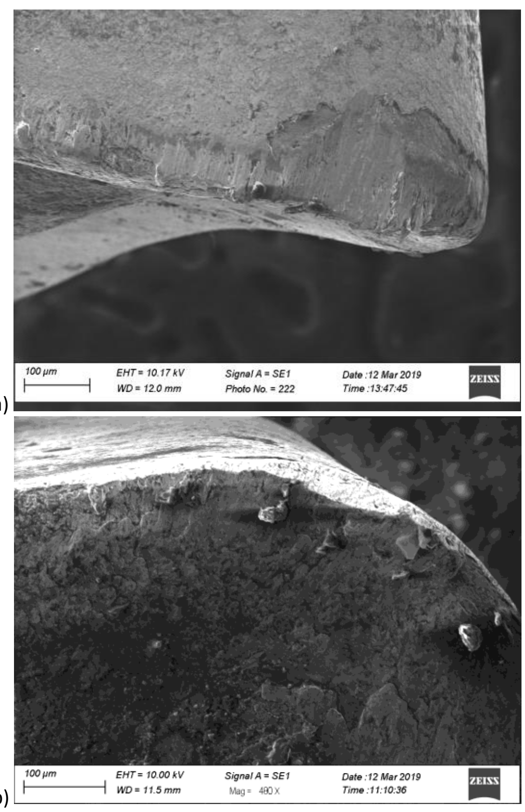

Fig. 2 The microscopic view of flank (a) and rake face (b) wear for CCMT 09T304-UM 2025 cutting insert

a)
b)

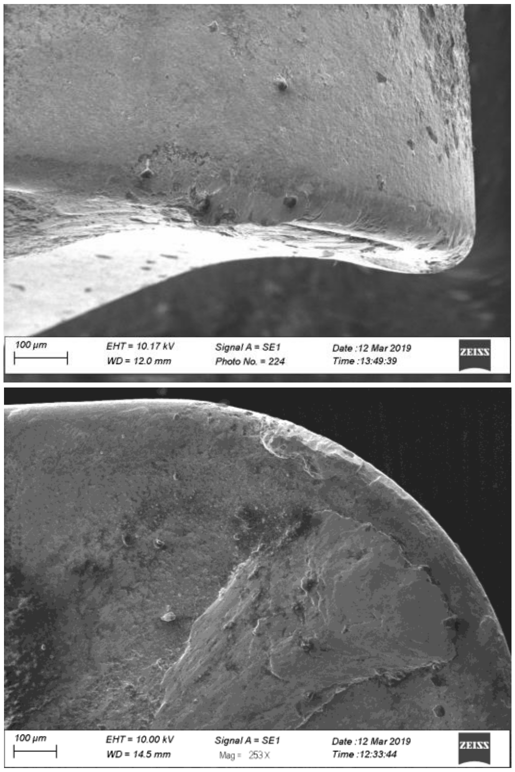

Fig. 3 The microscopic view of flank (a) and rake face (b) wear for CCMT 09T308-UM 2025 cutting insert

a)
b)

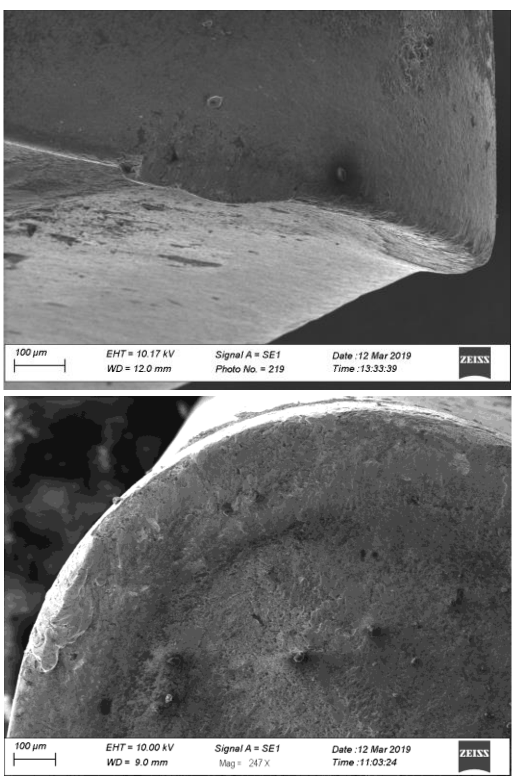

Fig. 4 The microscopic view of flank (a) and rake face (b) wear for CCMT 09T308-MM 2025 cutting insert

The wear was measured using software dedicated to microscopy and the results are shown in the Table 2. The arithmetical mean deviation of the roughness profile of the surface and maximum height of profile average value of the five measurement was shown in Table 2 and Figures 5.

Table 2 The measurements of the parameter of surface roughness for inserts used for turning cylindrical samples and example indicators of wear of a cutting edge

No samples	*Insert Shape*	*f [mm/rev]*	v_c *[m/min]*	*Rz [μm]*	*Ra [μm]*	K_{Ra} *[-]*	*VB [μm]*	*KB [μm]*
08-MM-100	CCMT 09T308-MM	0.2	100	9.19	1.93	1.71	241.7	120.9
08-MM-70		0.2	70	8.41	1.64	2.14	194.1	97.1
08-MM-50		0.2	50	11.97	2.31	1.43	292.2	146.1
08-UM-100	CCMT 09T308-UM	0.2	100	7.55	1.53	2.16	111.4	55.7
08-UM-70		0.2	70	7.44	1.55	2.13	96.4	48.2
08-UM-50		0.2	50	7.95	1.63	2.02	141.2	70.6
04-UM-70-2	CCMT 09T304-UM	0.2	70	13.85	3.03	1.09	64.7	32.3
04-UM-70-1		0.1	70	5.33	1.05	3.21	35.9	17.9

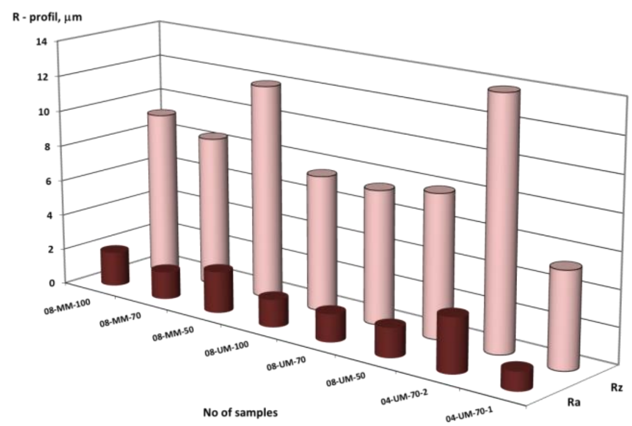

Fig. 5 The arithmetical mean deviation (Ra) and the maximum height of profile (Rz)

The criterion of the smallest roughness and the highest wear was proposed. The criterion for selecting the right cutting inserts geometries for finishing was the arithmetical mean deviation of the ordinates of the surface roughness profile, which should be within the range from 0.16 μm to 1.25 μm and the second criterion is of the maximum tool flank wear 200 μm. It can therefore be concluded that the tools used for testing meet the wear criterion. The cutting tools meet the criterion with the exception of insert shape CCMT 09T308-MM (Fig. 6).

After the analysis experimental research can be defined that to achieve a reduction in surface roughness after the longitudinal turning finishing of the samples of the duplex stainless steel, should be use with a constant cutting speed v_c = 70 m/min and depth of cut a_p = 0.5 mm for feed rate f = 0.1 mm/rev for cutting insert CCMT 09T304-UM 2025 where is the smallest flank wear VB = 36 μm.

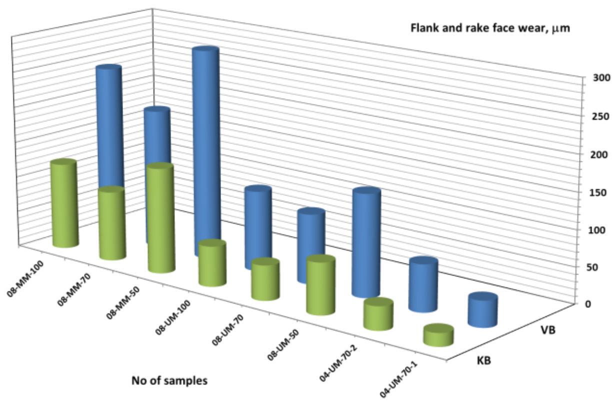

Fig. 6 The flank wear (VB, mm) and rake face wear (KB, mm) for different inserts

Figure 7 shows the EDS analysis showed that this is a build-up of duplex steel. It can be seen that determined by EDS analysis of the presence of alloying elements typical of two-phase stainless steel.

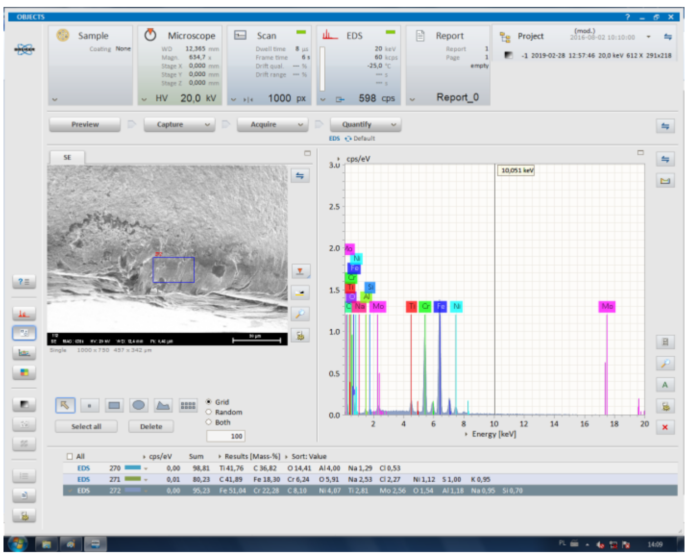

Fig. 7 The flank wear for CCMT 09T308-UM 2025 cutting insert with an EDS analyzer

CONCLUSION

In the paper were presented the influence of the geometry of the cutting edge and machining parameters of duplex stainless steel after finishing turning on the surface roughness reduction ratio and flank wear.

The turning of external cylindrical surfaces of duplex stainless steel in was carried out by inserts shape CC09T3 of the grade 2025 with applied coating by CVD method.

Turning the duplex steel to obtain a smooth surface should be carried out using the cutting insert for the nose radius r_ε= 0.4 mm with cutting parameters: feed rate f = 0.1 mm/rev, cutting speed v_c = 70 m/min, depth of cut a_p = 0.5 mm.

There arithmetical mean deviation of the roughness profile of the surface after turning is equal Ra = 1.05 µm. Therefore, for the finishing of duplex steel, it can be proposed insert type CCMT 09T304-UM 2025, where is the smallest flank wear VB = 36 µm and crater wear KB = 18 µm and surface roughness reduction ratio K_{Ra} = 3.21 was equal.

Only one insert CCMT 09T304-UM 2025 meet the quality criterion, where Ra parameter is less than the value of 1.25 µm and the wear criterion of the maximum tool flank wear VB = 200 µm.

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