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The Workability of Melamine Coated Particle Boards

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Abstract A study was conducted to test the wear on a cutting edge when machining melamine coated particle boards. This study utilized particle boards made by 3 different producers. In each of the 3 cases there was a high degree of dissimilarity in the wear of the cutting edge after processing. The following factors were found to have a profound effect on tool wear: sand content, weighted average sand, cutting path, cutting speed and the sharpness angle. No impact on tool wear was found with regard to resin and filler content in melamine film and micro-hardness of melamine film.

Key words: Melimine coated particle board; cemented carbide tool; tool wear; sand content; sand size.

Introduction

Melamine covered particle board is known to be very a difficult material for milling. The short lifetime of the cutting edge increases processing costs which makes the problem very important from a practical point of view. The main reasons for the abnormally rapid tool wear and short lifetime of the cutting edge are: the high concentration of wear accelerating substances, and high hardness and high brittleness of work piece. The present study was undertaken in an attempt to determine the factors influencing the wear of the cutting edge by peripheral milling of different melamine surfaced chip board (CB).

Experimental Procedures

Variables of experiment

Independent variables : speed of the arbor (RPM) (measured under load) : 2937, 4447, 6030, 7852, 10009 min^{-1} ; contour rake angle (gf) [rad] ; contour sharpness angle (bf) [rad] ; feeding length : 36-1390 m ; resin content in melamine film [g/m²] ; content of filler in melamine film [g/m²].

Independent variables with random variation : total sand content (SAC) [mg/kg] ; weighted average sand size (WASS) [μm].

Calculated independent variables : feeding rate per edge (FRPE): 0.35-0.27mm ; cutling depth (CDP): 1-3.6 mm ; cutting speed (CS) [m/s] ; cutting path (CP) [m]. Cutting path was calculated from the formula :

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$$CP = 0.993189 \cdot TM \cdot RPM \cdot (\phi1 + \phi2) \cdot RCE \quad [m] \quad (1)$$

where:

$$\phi1 = \arcsin\ (FRPE/(2 \cdot RCE) \quad [rad] \quad (2)$$

$$\phi2 = \arccos\ (RCE\text{-}CDP)/RCE \quad [rad] \quad (3)$$

$$FRPE = NBR \cdot BDL/(TM \cdot RPM) \quad [m] \quad (4)$$

$$CDP = MBDW/NBR \quad [m] \quad (5)$$

TM-time of processing [s], RPM-rotary speed of the arbor [min^{-1}], RCE-radius of the cutting edge [m], CDP-cutting depth [m], NBR-number of boards, BDL-length of board [m], and MBDW-total width of work piece processed [m].

The main assumption for calculation of CP was that of continuous contact between the work piece and the cutting edge. This assumption was not satisfied completely because of pores in the middle part of the chip boards and also because of cracks that arose in the melamine layer after some period of work. This fact does decrease the real CP in comparison to the calculated one.

Observed parameters of machine, tool and work piece properties: initial sharpness of cutting edge (hs) [μm]; hardness of tungsten carbide [$\mu Hv_{O\text{-}1KG}$]: 17903 MPa; roughness of rake surface Ra: 0.21 μm; roughness of clearance surface Rac: 0.33-1.5 μm; bevel angle: 0 rad; radial play of the arbor: 0.01mm; radial run out of the arbor: 0.013mm; static stiffness of the arbor: 5732 N/mm; moisture content of the CB: 4.3%; total density of CB: 630-765 kg/m^3; forced emission of formaldehyde (FFE) [mg/h/kg]; hardness of melamine film [$\mu Hv_{0.2KG}$].

Dependent variables: recession of cutting edge in plane of bisector of sharpness angle (h) [μm], and edge quality.

Some preliminary tests were done. These results were taken out of an uncompleted multivariable experimental design expanded to 36 tests (Table 4).

Materials and methods

Initial sharpness described by the radius of edge round-off (r) [μm] and recession of real edge and theoretical angle point (hs) [μm] were measured using replica methods and pictures taken with a microscope. The wear of the cutting edge, represented by the recession of the cutting edge in the direction of the bisection of the sharpness angle, was measured using of a Form Talysurf profilograph, equipped with a PCD knife shaped stylus with sharpness angle of 90°, manufactured by Taylor Hobson, England (Fig. 1). The results were input using a serial interface to an IBM PC computer. The wear rate was calculated using a specially developed program. The roughness of the cutting edge surface was measured by a Mitutoyo Surfotester (Table 1).

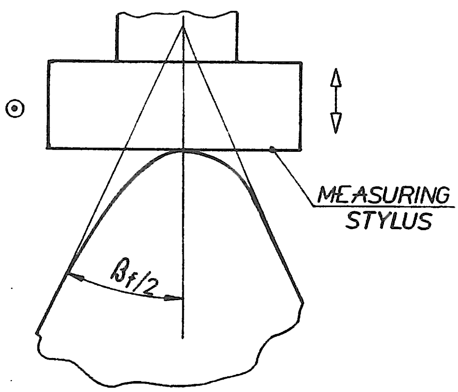

Fig. 1. The idea of wear measurement.

For processing, a milling machine type SCM, manufactured in Italy was used. The machine was equipped with a FESTO 0.75 kW engine and an automatic feeding system. Sandvik Sweden cutter heads with diameters of 123 and 140 mm with two turn-over inserts were used. In the experiment only 1 cutting edge was utilized, of which material was a cemented carbide type K05 (WC-Co6%) manufactured by Leuco, Germany.

For the experiment the CB types A, B, and C, manufactured by three different producers with dimensions 1800 × 400 and 12-20mm thick, were used. Sand content and filler content tests were conducted using the burning method (Table 2 and 3). Sand content and filler content in relation to absolute dry mass was also calculated. The SAC, in a 0-1 mm skin layer of CB, was more than twice as much as the total SAC for the entire CB. The figures for CB types A, B and C were 492, 344, and

Table 1. Sharpness angle, roughness of clearance surface and initial sharpness (hs and r) of cutting edge used.

Test number	bf	Rac	hs	r	Test number	bf	Rac	hs	r
	[rad]	[μm]	[μm]	[μm]		[rad]	[μm]	[μm]	[μm]
6	0.9529	0.53	8	3	22	0.9748	0.57	8	3
7	0.9533	0.37	5	2	24	0.9512	0.52	5	2
8	0.9774	0.50	5	2	25	0.9456	0.62	6	2
9	0.9552	0.42	5	2	35	0.9599	0.42	5	2
10	0.9674	0.55	4	1	36	0.9599	0.52	4	1
11	0.9681	0.41	3	1	39	0.9639	0.52	5	2
12	0.9681	0.58	6	2	40	0.9762	0.50	4	1
13	0.9673	0.35	2	1	41	0.9643	0.78	6	2
14	0.9599	0.69	4	1	42	0.9730	0.45	5	2
15	0.9701	0.51	6	2	43	0.9599	0.41	5	2
18	0.9742	0.52	4	1	44	0.9629	0.48	4	1
19	0.9643	0.45	9	3	78	1.1287	1.50	28	13
20	0.9465	0.39	6	2	143	0.7810	0.52	34	39
21	0.9648	0.33	7	2					

Table 2. The properties of melamine films used.

Type of melamine film	Specific gravity		Resin content	Filler content	Micro hardness
	Rough	Impregnated			
	[g/m²]	[g/m²]	[g/m²]	[g/m²]	[μHv$_{O0.2KG}$]
13	37.8	124.9	87.0	0	—
12	70.3	152.1	81.8	27.9*	49
11	104.0	232.5	128.5	39.6*	—
2	82.3	169.7	78.3	39.5*	—
3	76.1	162.2	86.1	23.2*	48
41	101.3	231.9	130.6	20.2**	—
42	115.4	228.9	113.5	27.0*	54
43	114.9	—	—	18.8***	—

Filler in melamine film : *—white, **—brown, ***—red,

Table 3. The properties of chip boards used.

Type	Density ADS	Moisture content	Total sand content very big	big	small	dust	Sand size very big	big	small	dust	Forced formaldehyde emission
	kg/m³	%	[mg/kg]				[μm]				[mg/kg/h]
A	630	5.5	1.4	5.0	0.7	218	1641	938	410	73	0.26
B	635	4.5	2.0	18.9	133.8	0.9	1710	876	268	73	3.14
C1	765	5.4		17.1	83.9	308		962	619	73	1.90
C2	680	4.3	26.4	142.2	317.9	592	2098	1108	714	73	1.90
C3	690	5.5		65.0	267.5	944		1042	510	73	1.90

Table 4. The parameters and results of the experiment.

Test number	gf [rad]	bf [rad]	CS [m/s]	CP [m]	SAC [mg/kg]	WASS [μm]	FFE $\times 10^{-3}$ [mg/kg/h]	h [μm]
A 6	0.1658	0.9529	19.22	6153	223.5	93.4	0.26	21
A 7	0.5196	0.9633	39.46	8096	223.5	93.4	0.26	32
A39	0.1658	0.9639	19.24	3425	223.5	93.4	0.26	16
A40	0.3051	0.9762	39.49	6942	223.5	93.4	0.26	29
A41	0.3051	0.9643	65.55	2192	223.5	93.4	0.26	15
A44	0.3051	0.9681	39.50	965	223.5	93.4	0.26	11
A143	0.3051	0.7810	19.14	3142	223.5	93.4	0.26	22
A11	0.5196	0.9681	65.50	3385	223.5	93.4	0.26	21
A13a	0.1658	0.9673	39.46	9114	223.5	93.4	0.26	30
A13b	−0.0061	1.1184	65.34	4437	223.5	93.4	0.26	13
A37	0.5196	0.9639	65.50	3389	223.5	93.4	0.26	22
A24	0.3529	0.9512	73.36	3901	223.5	93.4	0.26	26
A25a	0.3529	0.9456	73.36	3834	223.5	93.4	0.26	24
A15a	0.5196	0.9760	65.50	3924	223.5	93.4	0.26	23
A43a	0.3051	0.9599	29.13	2465	223.5	93.4	0.26	17
A42a	0.3051	0.9556	51.43	2447	223.5	93.4	0.26	23
A78a	0.1658	1.1287	19.16	2898	223.5	93.4	0.26	8
A 9a	0.5196	0.9552	19.22	12683	223.5	93.4	0.26	30
A10a	0.1658	0.9674	29.10	6577	223.5	93.4	0.26	25
A12a	−0.0061	0.9683	29.12	18624	223.5	93.4	0.26	38
A20b	0.3529	0.9465	73.35	4020	223.5	93.4	0.26	31
B15b	0.5196	0.9701	29.09	11544	155.6	341.7	3.14	67
B16b	−0.0061	0.9730	51.36	9186	155.6	341.7	3.14	58
B21b	0.3529	0.9648	73.35	3146	155.6	341.7	3.14	33
B21b	0.3529	0.9648	57.55	2591	155.6	341.7	3.14	30
B22b	0.3529	0.9748	73.35	3802	155.6	341.7	3.14	36
B36a	0.5196	0.9599	65.49	3480	155.6	341.7	3.14	38
B36b	0.5196	0.9599	65.49	4572	155.6	341.7	3.14	40
C18a	0.3529	0.9742	73.29	3303	1078.7	406.0	1.90	157
C18b	0.3529	0.9742	57.50	3599	1078.7	406.0	1.90	139
C35	0.5196	0.9599	65.44	4094	1078.7	406.0	1.90	120
C19a	0.3529	0.9643	73.32	3641	409.0	222.3	1.90	101
C 8	0.5196	0.9774	65.47	3964	409.0	222.3	1.90	77
C19b	0.3529	0.9643	44.16	2312	1078.7	214.0	1.90	129
C20b	0.3529	0.9465	73.30	4485	1276.5	214.0	1.90	122
C14	0.5196	0.9599	65.37	4059	1276.5	214.0	1.90	95

3211 mg/kg respectively. The SAC for a 1-2 mm layer of CB type C was greater by almost 3500 mg/kg. The sand size analysis was done using photographs in intervals of [μm]: very big >1500, big <1500, 400>, small <100, 400>, dust <100 (Table 3). The weighted average sand size was also calculated. A free formaldehyde emission test was done using DRAGER AB, Germany test pipes (type FORMALDEHYDE 0.2/A 6733081). The conditions for this test were such that, 20-300g of CB at a temperature of 50 ℃ for 10-20 hrs was tested (Table 3). The results were processed using a Monte Carlo simulation program developed by the author [1]. For calculation of the quality of the approximation, two dimensional linear regression coefficients for observed and predicted values and standard deviation of residuals (SD) were employed.

Results and Discussion

The lowest wear of the cutting edge for the skin layer of CB was type A. The relationship among h, CP, CS, bf and gf in this case, can be described by the following formula:

$$h = 0.052 \cdot CP^{0.51} \cdot CS^{0.382} \cdot bf^{-2.733} \cdot 1.558^{gf} \qquad [\mu m] \quad (6)$$

A correlation coefficient of $r = 0.95$ and a standard deviation of SD = 2.2 μm were observed.

For CB type B, higher values were observed in comparison to case A. The relationship among h, CP, CS and gf can be described by the following formula:

$$h = 0.287 \cdot CP^{0.571} \cdot CS^{0.049} \cdot 0.79^{gf} \qquad [\mu m] \quad (7)$$

A correlation coefficient of $r=0.99$ and a standard deviation of SD =2.1 μm were observed.

The wear observed for CB type C was higher than that in cases A and B. The relationship among h, CP, CS, gf, SAC and WASS for CB type C can be described by the following formula:

$$h = 1.581 \cdot CP^{0.224} \cdot 0.252^{gf} \cdot SAC^{0.26} \cdot WASS^{0.219} \qquad [\mu m] \quad (8)$$

A correlation coefficient of $r=0.97$ and a standard deviation of SD =11.6 μm were observed.

In the case of CB type C the maximum wear of the cutting edge could not be observed from the very beginning of the wear profile of the cutting edge, but about 1 mm from the edge (Fig. 2). This phenomenon is caused by a higher sand content in the 1-2 mm layer. The highest wear, observed for type C particle board, may be explained by the fact that it has the highest content of all sand fractions. The lowest total SAC (154mg/kg) was in the case of CB type B; however, the cutting edge wear for B was not the lowest. This phenomenon may imply that SAC is not the only factor which caused different wear of the cutting edge with regard to the analyzed types of CB. In this case the SAC of the third fraction, <100, 400> μm is higher (133mg/kg) in comparison to the content of the same fraction in CB type A

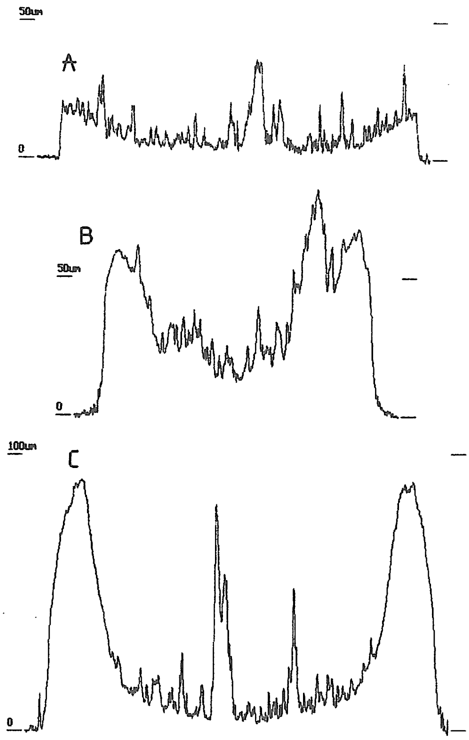

Fig. 2. The profile of worn cutting edge after processing CB board type A, B and C.

(0.7mg/kg). The size of sand seems to affect the wearing process of the cutting edge as much as the sand content, which has not yet been mentioned in any literature.

The increase of CP increases the wear rate in all models. The increase of CS increases the wear rate in model (6) and (7). The impact of CS is lower in formula (7). The increase of bf decreases the wear rate in formula (6). The increase of gf increases the wear in formula (6), but decreases the wear in formula (7) and (8). This is probably due to the different content and size of the mineral contaminates. The presence of additional random variables in model (8), expressed by SD equal to 11.6 μm is probably another reason for differentiation of estimators in this study.

The wear rate caused by the skin layer of CB types A, B and C for a cutting path equal to 5000m, is 1 : 1.7 : 3.8 respectively. The wear observed for skin layer of type A particle board in this study is 5.3 times less than that reported by Salje *et. al.* (1985, 1988) and 3.7 times less than the one given by Sparks *et. al.* (1981). The areas of highest wear can be observed for some tests randomly distributed along the cutting edge. The mechanism for evaluation of the highest areas is a crashing of cutting edge and very big particles of sand contained in the CB. Maximum size of a sand particle found in this study was 4870 μm. The presence of such a large sand particles inside the CB has not been reported in any literature. The biggest size of particle was discovered after burning more than 2 kg of CB, which is 10 times more than the SS 270231 recommendation (Swedish Standards). The 0.05% acceptable level of total sand content in CB presented in some works (Sparks *et al.* 1981) seems not to be sufficient. In many standards the information about acceptable sand size is missing.

The forced emission of formaldehyde was the lowest for CB type A (0.26×10^{-3}mg/kg/h). The highest value of FFE was observed for CB type B chip board (3.1×10^{-3}mg/kg/h); but was not in case C (1.9×10^{-3}mg/kg/h) with the greatest wear. No impact on tool wear was found with regard to resin and filler content in melamine film and micro-hardness of melamine film.

Conclusions

1. The sand content and sand particle size affects the tool wear very much. An increase in sand content and sand size increases tool wear.
2. The cutting path affects tool wear. An increase in the cutting path increases tool wear.
3. The sharpness angle affects tool wear. An increased sharpness angle decreases tool wear.
4. The ratio between the wear rate observed after processing skin layers of CB type A, B and C, by CP=5000m, and with average value of other parameters (CS=65m/s, bf=550, gf=200, SAC=265mg/kg and WASS=255 μm), can be expressed by numbers 1: 1.7: 3.8 respectively.

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