Mem. Fac. Sci. Eng. Shimane Univ.
Series A
35, pp. 139-147 (2001)

Workpiece Edge Quality after Milling Melamine-Coated Particleboard

Bolesław PORANKIEWICZ* and Chiaki TANAKA**

**Agricultural University of Poznań, Department of Woodworking Machinery and Machine Construction Base, Wojska Polskiego 38/42, 60 627 Poznań, Poland*
***Department of Natural Resources Process Engineering*

Abstract

This study examines the edge quality of a workpiece of melamine-coated particleboard after peripheral milling. Novel multivariable relations were developed to relate material machined properties, cutting edge stereometrical parameters and machining parameters to the resulting machining quality.

Keywords: Coated Particle Board, Material Machined Properties, Cutting Edge, Stereometrical Parameters, Edge Quality

INTRODUCTION

It is known from the literature that machining quality deteriorates with increased feed rates per tooth (f_{RPT}) and cutting edge wear (h) [6]. Similar effects were observed for cutting speed (C_S) and large cutting edge wear (h) [6]. Deterioration of the machining quality with increasing vibrations of the tool support of the machine was also observed [6]. The most important criterion of machining quality during peripheral milling of coated particleboard appears to be the state of the workpiece edge since a skin easily gets chipped. This criterion is a basis for defining the acceptable wear of the cutting edge [4]. In the literature, a rank-weighted, unsymmetrical, quantifier (S_A) of the edge quality after coated particleboard machining was established for evaluation and verified as optimal [1, 6]. For some coated particleboards, produced by different manufacturers, large variations in machining quality after peripheral milling in constant cutting conditions has been reported (Fig. 1.) [3, 5]. Large workpiece edge damage (chipping) can be observed.

The damage affects a large width of the wide surface of the workpiece, and a much lesser depth measured at an angle of 45° to wide surface of the workpiece. Because the (S_A) is evaluated based on the depth of the damages, the use of the (S_A) quantifier in case of large damage was ineffective. The low tear off strength (T_{OS}) of the skin of some particle boards was evidenced as a major factor impacting abnormal poor edge quality [3, 4]. In practical work, the edge quality for different coated particleboards after peripheral milling has been studied.

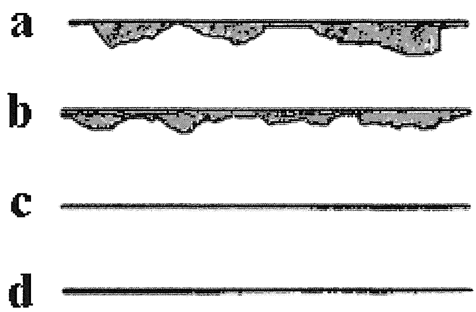

Fig. 1. The edge state of coated particle boards by different tear-off strength (T_{OS}), after similar cutting path length (L_S)); a)–T_{OS}=0.9 MPa; b)–T_{OS}=1.1 MPa; c)–T_{OS}=2.11 MPa; d)–T_{OS}=1.53 MPa (from [4])

MATERIALS AND METHODS

Experiments were performed on three-layer melamine coated particleboards, designed for furniture industry, and manufactured industrially in different factories. The average density of the particle boards was 630 ÷ 770 kg/m^3, moisture content 4 ÷ 6%, and thickness 12 ÷ 18.5 mm. Peripheral milling was conducted on a SCM milling machine with arbor rotation speeds of 2930, 4447, 6030, 7853, 10008 rpm. The machine was equipped with a Festo feeding device with rubber wheels. This allowed control of the feed speed in the range of 0.5 ÷ 22 m/min. The cutting depth was 3.4 mm. The feed rate per tooth (f_{RPT}) was calculated according to the milling time, the feeding length (L_F) and RPM. One cutting edge was employed. The skin tear off strength was evaluated on a strength machine using a shaft glued to the surface. Before gluing, a ring indentation of depth 0.3 mm was made (Fig. 2). The particle boards were milled with different cutting edge wear (h), cutting speeds (C_S), sharpness (β_F) and rake angles (γ_F). The particleboards with high (T_{OS}) were machined in the first part of experiment. In this case, the (S_A) quantifier was employed for evaluation of edge quality. The measurements were performed with a knife type stylus and an inductive transducer. In the second experiment, the particleboards with low and high (T_{OS}) were machined. In this case, the quantifier evaluated from maximum with of workpiece edge damage (M_{SU}) was employed. A tool microscope was used for measurements of the width of damage. Table 1 and Table 2 present the experimental matrices.

A multivariable non-linear, regression analysis of the experimental matrices was performed using a computer optimization program based on the gradient-random method. This program was developed in previous work [2] with further changes [4]. Calculations were performed at Poznań Supercomputing and Networking Center (PCSS) on an IBM PS–2 computer. The approximation quality was checked using summation of residuals square (SK), average deviation from regression curve (SR), and variation (V).

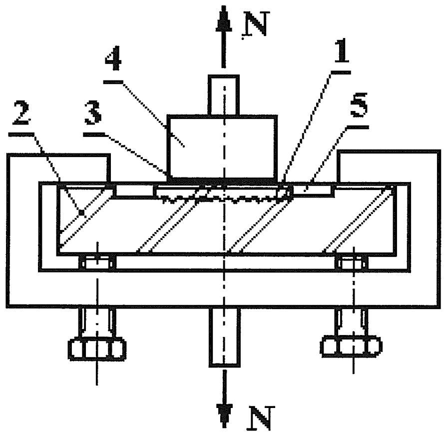

Fig. 2. The method of evaluation of tear-off strength of skin (T_{OS}); 1– tear-off section; 2–specimen tested; 3–glue film; 4–shaft; 5–ring shaped indentation

Table 1 The experimental matrix No. 1

h μm	T_{OS} Mpa	CS m/s	M_{SU} mm
26	1.53	65.0	0.105
26	2.11	65.0	0.120
26	1.13	65.0	0.710
26	1.10	65.0	1.135
26	0.90	65.0	2.090
4	2.11	65.0	0.050
4	1.13	65.0	0.045
4	1.10	65.0	0.070
40	1.28	65.5	1.840
22	1.92	65.5	0.240
33	1.92	73.5	0.070
71	1.28	29.1	2.480
120	0.90	65.4	2.960

RESULTS AND DISCUSSION

The model (1) is a generalization of the relationship between work piece maximum damage (M_{SU}^{P}), tear off strength (T_{OS}), cutting edge wear (h) and cutting speed (C_S)

$$M_{SU}^{P}=8.818\cdot 10^{-3}\cdot 0.112^{TOS}\cdot h^{2.134}\cdot C_S^{.129}-1.726\cdot 10^{-14}\cdot C_S^{.943}-2.497\cdot 10^{-3}\cdot T_{OS}^{-1.603}\cdot h^{3.496}+0.06403[\mathrm{mm}];\ M_{SU}^{0} \quad (1)$$

Table 2 The experimental matrix No. 2

γ_F 0	α_F 0	CS m/s	f_{PT} mm	h μm	S_AO mm/m
−0.35	24.5	65.35	0.3	23	8.0
−0.35	24.5	65.35	0.8	23	18.5
−0.35	24.5	65.35	1.8	23	91.6
9.50	25.0	19.22	1.0	19	11.1
9.50	25.0	19.22	1.0	120	30.8
17.48	24.5	19.18	0.9	24	17.9
17.48	24.5	19.18	1.6	24	42.7
17.48	24.5	19.18	0.9	113	43.7
29.77	24.0	65.24	0.3	54	5.0
29.77	24.0	65.24	0.8	54	6.7
29.77	24.0	65.24	1.6	54	11.5
29.77	24.0	65.24	2.2	54	56.4
29.77	24.0	65.24	1.6	133	18.3
29.77	24.0	65.24	2.2	133	64.0
−0.35	15.0	65.14	0.3	5	9.6
−0.35	15.0	65.14	0.8	5	22.5
17.48	15.0	19.25	1.3	17	11.3
17.48	15.0	19.25	2.6	17	78.6
17.48	15.0	19.24	1.3	95	49.1
17.48	24.5	65.12	0.3	21	7.3
17.48	24.5	65.12	0.8	21	8.3
17.48	24.5	65.12	1.6	21	12.6
17.48	24.5	65.12	2.2	21	46.3
−0.35	5.0	65.03	0.3	3	6.9
−0.35	5.0	65.03	0.8	3	50.0
−0.35	5.0	65.03	1.2	3	70.7
29.77	25.5	19.24	0.9	34	10.2
29.77	25.5	65.27	0.3	25	5.2
29.77	25.5	65.27	0.8	25	7.2
29.77	25.5	65.27	1.2	25	17.3
29.77	25.5	65.27	2.2	25	17.3
−0.35	25.5	19.16	1.0	17	21.1
9.50	25.0	19.17	1.4	12	22.6
9.50	25.0	19.17	1.4	92	44.9
−0.35	34.2	29.12	0.9	44	12.9
29.77	5.5	19.22	1.4	35	1.8
9.50	25.9	19.22	1.3	29	15.8
29.77	5.61	39.46	0.7	37	3.1
20.22	15.3	73.36	0.4	31	1.3
9.50	25.1	39.46	0.7	36	2.1

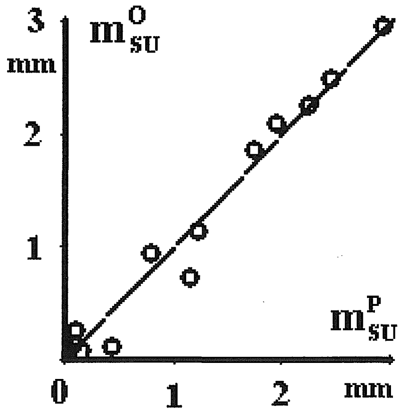

Fig. 3. The plot of the damages width (mP_{SU}) predicted from formula (1), versus (mD_{SU}) values observed

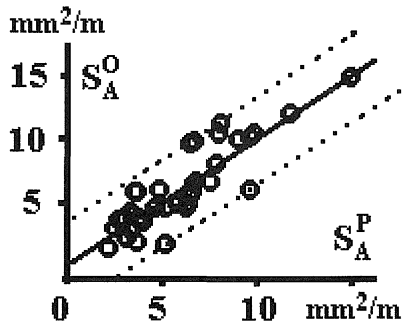

Fig. 4. The plot of predicted from formula (2) quantifier SP_A, versus SD_A values observed

The model (1) is a generalization of the relationship between edge quality described by the $(S_A{}^P)$ quantifier, feed rate per tooth (f_{RPT}), rake angle (γ_F), clearance angle (α_F) and the cutting edge wear (h))

$$S_AP = 13.062\cdot 0.0375^{\gamma F}\cdot \alpha_F^{-0.206}\cdot f_{RPT}^{1.787}\cdot h^{-0.430} + 0.348\cdot h^{0.618}\cdot f_{RPT}^{0.477} + 4.84\cdot 10^{-5}\cdot 0.327^{\gamma F} \times f_{RPT}^{-8.823}[\mathrm{mm}^2/\mathrm{m}] \quad (2)$$

The tear off strength (T_{OS}) and the cutting edge wear (h) are the major influences on edge quality, as defined by the maximum width of the workpiece's edge damage $(M_{SU}{}^P)$ and their interaction term. The reason for workpiece edge damage is side compression stress generated by the cutting edge.

The impact of cutting edge wear (h) decreases with increase of (T_{OS}). As (T_{OS}) decreases, acceptable machining quality can allow the use of lower acceptable cutting edge wear (Fig. 5).

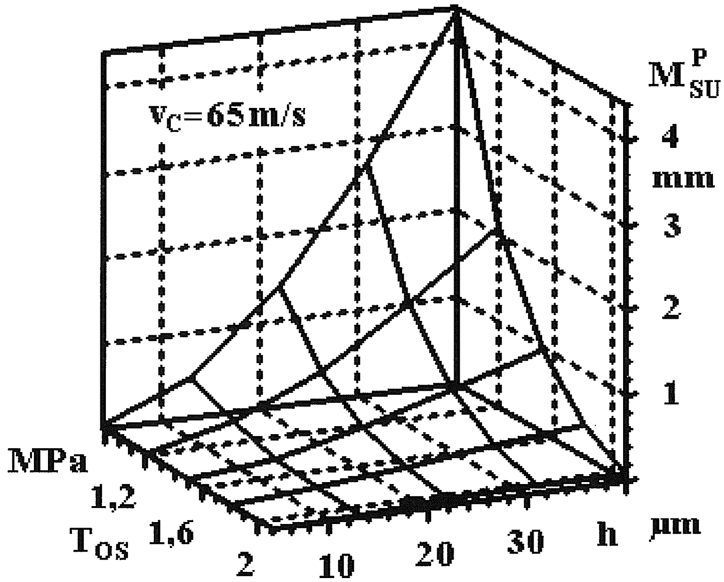

Fig. 5. The plot of the maximal width of edge chipping (m_{SU}), predicted from model (1), versus the tear off strength (T_{OS}) and the cutting edge wear (h)

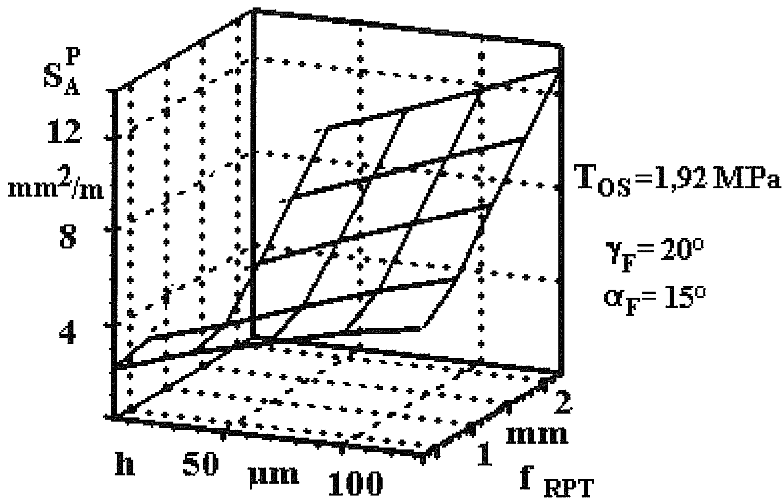

Fig. 6. The plot of the edge quality expressed by (S_A), predicted from model (2), versus the feeding rate per tooth (f_{RPT}) and the cutting edge wear (h)

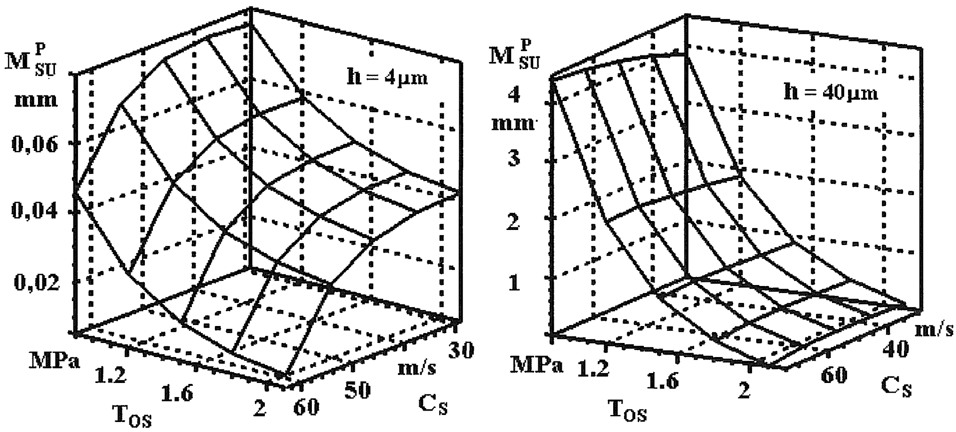

Fig. 7. The plot of the maximal width of edge chipping (m_{SU}), predicted from model, versus the tear off strength (T_{OS}) and cutting speed, a) for $h=4\,\mu$m a); b) for $h=40\,\mu$m

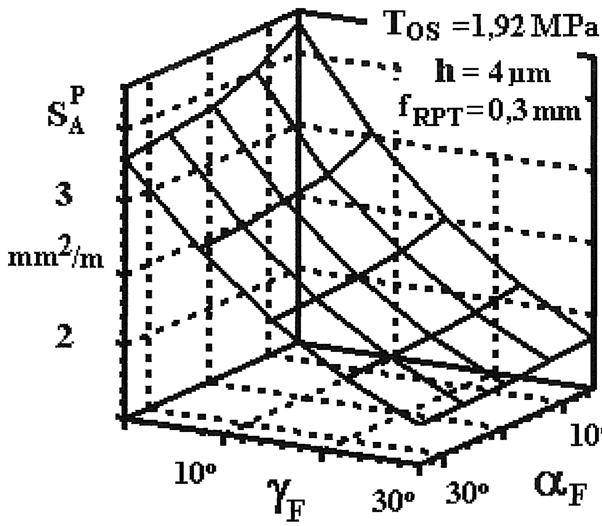

Fig. 8. The plot of the edge quality expressed by descriptor (S_A), predicted from model (2), versus the rake (γ_F) and clearance angle (α_F)

The reason is the interaction term $T_{OS} \cdot h$ in the model (1). For some particleboards with very low $T_{OS} < 0.9$ MPa, acceptable machining quality is not possible even with sharp tools.

Increase in feed rate per tooth (f_{RPT}) increases machining quality, as indicated by the (S_A) quantifier (Fig. 6). A similar effect is known from the literature [6]. However, two interaction

Table 3 The Correlation coefficient (R), the mean deviation from regression curve (SR), the summation of residuals square (SK), the variance (V) for models (1), (2)

R	SR mm	SK model (1)	V mm^2/m	R	SR mm	SK model (2)	V mm^2/m
0.99	0.16	0.4	0.03	0.87	1.59	93.5	2.8

terms $f_{RPT} \cdot h$ and $f_{RPT} \cdot \gamma_F$ in the model (2) play an important role here, making the problem very complex.

Increase of cutting speed (C_S) for a sharp tool improves the machining quality (Fig. 7). This effect can be explained by the decrease in time available for edge swelling of the work piece material. The impact of (C_S) diminishes with increase of the cutting edge wear (h). For $h > 40$ μm, it cannot be observed.

A rake angle (γ_F) increase enables better machining quality (decrease in (S_A) quantifier) (Fig. 8). The impact of clearance angle (α_F) on machining quality is much lower and can only be seen for the lowest (γ_F) and (α_F) (Fig. 8). For these values of (γ_F) and (α_F), the increase in (α_F) decreases the (S_A) quantifier.

The models (1) and (2) describe novel relationships between the machining quality and some of the mechanical properties of coated particle boards, the stereometrical parameters of the cutting edge and the cutting parameters. Models (1) and (2) allow for prediction of the acceptable cutting edge wear for expected edge quality, in terms of the major cutting conditions.

CONCLUSIONS

1. The tear off strength of skin coated particle board (T_{OS}) in the range of ⟨0.9; 2.11 MPa⟩ affects the edge quality by peripheral milling. Increase of (T_{OS}) increases the edge quality.
2. Feed rate per tooth (f_{RPT}) in the range of ⟨0.3; 2.2 mm⟩ affects the edge milling quality. Decrease of (f_{RPT}) increases milling quality.
3. Cutting edge wear (h) in the range of ⟨5; 133 μm⟩ affects the edge milling quality significantly. Increase of (h) decreases the milling quality.
4. For a sharp tool, cutting speed (C_S) increases in the range of ⟨19.18; 73.36 m/s⟩ cause an increase in milling quality. This effect disappears for cutting edge wear $h > 40$ μm.
5. Rake angle (γ_F) increase in the range of ⟨−0.35; 29.770⟩ results in an increase in milling quality.
6. For low rake angles, clearance angle (α_F) increase in the range ⟨5; 34.2 0⟩ causes only a slight increase in milling quality.

ACKNOWLEDGEMENTS

The authors acknowledge the grant at the Pozna Supercomputing and Networking Center (PCSS), Pozna, Poland.

LITERATURE CITED

1. Drückhammer J. (1983): Qualitätskontrolle bei der Kantenbearbeitung. Holztechnisches Kollogium, TU Braunschweig, Germany.
2. Porankiewicz B. (1988): Mathematical Model of Edge Dullness for Prediction of Wear of Wood Cutting Tools. Proc. 9 th IWMS, UC, Berkeley CA, USA: 169–170.
3. Porankiewicz B. (1993): The Relation Between Some Mechanical Properties and Edge Quality when Milling Melamine Coated Particle Board. Proc. of 11 IWMS, Oslo, Norway: 515–519.
4. Porankiewicz B. (2000): Zużycie ostrzy narzędzi przy frezowaniu płyt wiórowych. Wydawnictwo Poznań skiego Towarzystwa Przyjaciół Nauk, Poznań, Poland, pp: 113.
5. Porankiewicz B., Grönlund A. (1991): Tool Wear-Influencing Factors. Proc. of 10 th IWMS, UC Berkeley, CA, USA: 220–229.
6. Stühmeier W (1989) Fräsen von Spanplatten mit hochharten Schneidstoffen. no. 181, pp. 191. TU Braunschweig: F–B VDI R.2