Advanced tool materials and their influence on the parameters of CNC machining of wood-based materials (PART III)

Rokoský Petr, Hanincová Luďka, Procházka Jiří

GOAL OF THE PROJECT

The goal of the project is to quantify machining parameters of tools designed for CNC machining of commonly used wood-based materials. In particular, to analyze the machining process focusing on the cutting forces and energy consumption during machining and to create a methodology for choosing the appropriate tool coating and cutting conditions depending on the machined material.

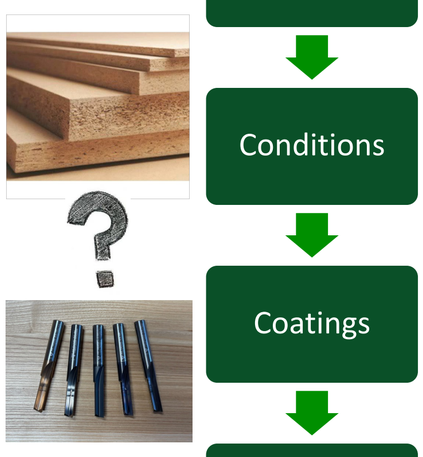

Fig. 1 Goal and methodology

THEORETICAL BACKGROUND

Key parameters such as cutting speed and feed rate are particularly influential, as they significantly affect cutting forces. High cutting forces can lead to excessive tool wear, increasing costs and reducing tool life, as well as negatively impacting surface quality and dimensional accuracy of the workpiece due to machine vibrations. Consequently, controlling cutting forces is essential not only for tool longevity and surface quality but also for lowering energy consumption, thereby making the process more cost-effective and environmentally friendlytings, including DLC, TripleSi, and Hyperlox, can potentially reduce friction, improve tool life, and lower cutting forces. However, past studies have presented inconsistent findings on the impact of cutting speed on cutting forces. Some research suggests minimal influence, while others show a linear increase or decrease in forces with changing speeds, possibly due to differences in materials, speed ranges, and methods used in the studies. This study aims to clarify these uncertainties by exploring how various coatings, cutting speeds, and feed per tooth settings interact to influence CNC milling of MDF .

MATERIAL AND METHODS

Experiments were conducted using a CNC milling machine (SCM Morbidelli m100). Medium Density Fiberboard with a thickness of 18 mm was chosen for its homogeneity.
Five tools, each with a 10 mm diameter and single edge, were tested with different coatings, including a reference (no coating), TripleSi, Hyperlox, DLC, and a simple lapped surface. Cutting conditions involved three cutting speeds (8, 10, 12 m/s) and three feed per tooth values (0.1, 0.2, and 0.3 mm) with a 1 mm depth of cut. Cutting forces were recorded using a Kistler 9257B dynamometer. Both conventional and climb milling were applied. The data were statistically analyzed using ANOVA and the Scheffé test.

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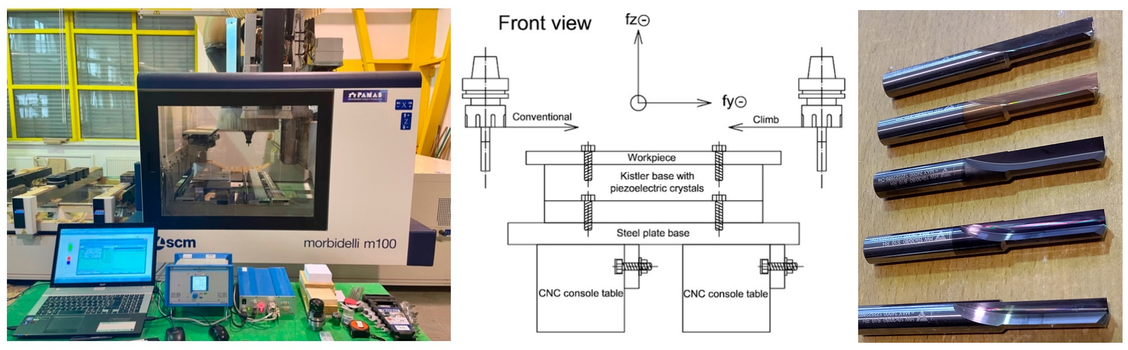

Fig. 2 CNC milling machine and measuring chain; measuring set-up; cutting tools

RESULT AND DISCUSSION

The findings revealed that feed per tooth significantly affects cutting forces, with higher feed rates leading to greater forces. Among coatings, the lapped and TripleSi coatings showed the lowest cutting forces, while DLC consistently had the highest.

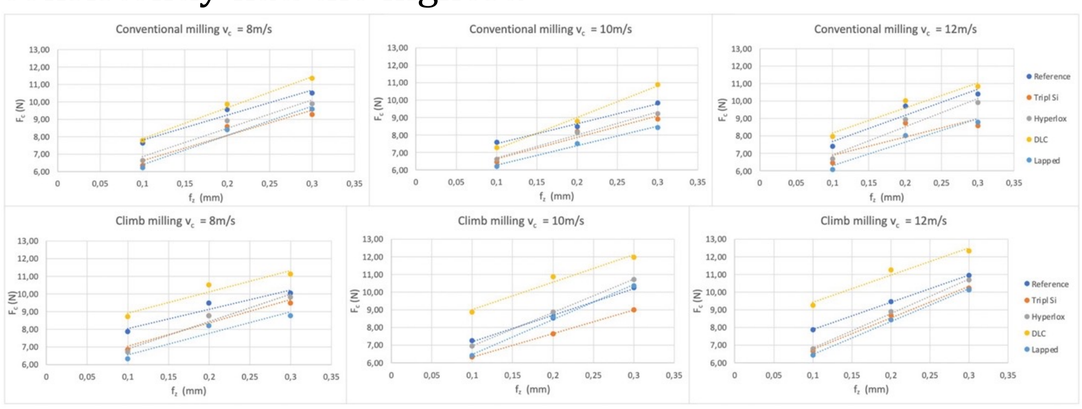

Fig. 3 Average values of cutting forces as a function of feed per tooth.

The relationship between cutting speed and cutting forces varied; however, the impact was minimal compared to feed per tooth. The optimal cutting speed was observed at 10 m/s, where certain coatings demonstrated a reduction in cutting forces. The DLC coating's higher friction coefficient caused increased forces, suggesting it may be less suitable for MDF milling under the conditions tested.

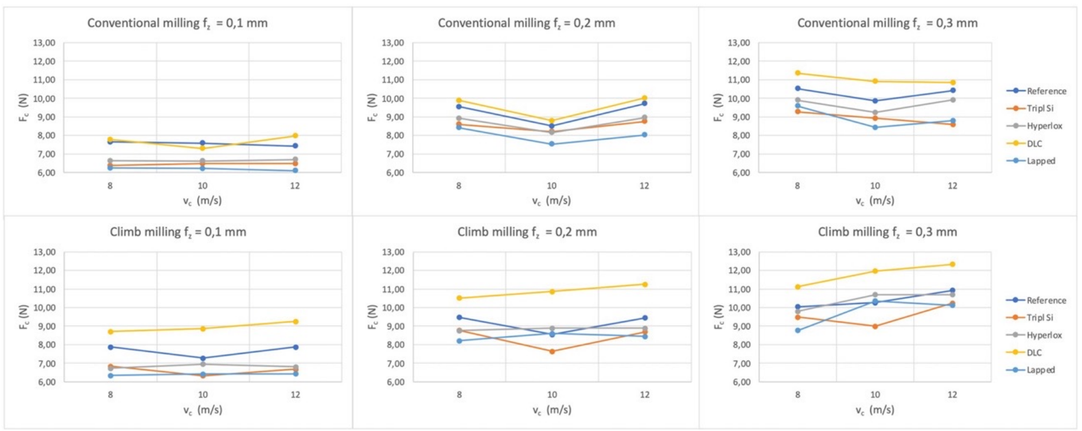

Fig. 4 Average values of cutting forces as a function of cutting speed

The Scheffé test confirmed statistically significant differences in cutting forces across feed per tooth values and coatings. Higher feed per tooth values increased cutting forces due to greater chip thickness and tool-material friction. The study highlights the superior performance of the lapped and TripleSi coatings, which reduced cutting forces effectively. This performance could improve energy efficiency, though the lapped surface may have durability limitations.

CONCLUSION

This research identifies key parameters for optimizing CNC milling of MDF. It concludes that a feed per tooth of 0.1 mm, a cutting speed of 10 m/s, and the use of TripleSi-coated tools are optimal for minimizing cutting forces.

MENDELU
Faculty of Forestry and Wood Technology