INVESTIGATIONS ON WOOD-PLASTIC COMPOSITE MACHINABILITY DURING DRILLING

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Abstract

The paper presents results of studies on the workability during drilling of polyvinyl chloride and polyethylene-based WPCs with filler in the form of wood meal in the amount of 50%. The aim of investigations was to determine proper machining work and thrust force when drilling selected WPC materials and to compare them with the proper machining work and thrust force when drilling the following wood species: alder, birch and beech. The experiments were carried out on a universal OUS-1 machine tool equipped with a drill torque meter. Polyethylene-based WPC was found to be better workable than the remaining materials and its machining was better than such wood species as alder, birch and beech.

Key words: *WPC, wood-plastic composite, proper machining work, thrust force.*

INTRODUCTION

One of the most promising wood-derived materials at present is a wood polymer composite, also known as Wood-Plastic Composite (WPC). This material is characterised by combination of the best properties of wood and polymer plastic as well as attractive appearance.

A composite is made up of at least two constituents, raw materials of plant origin in the form of wood shavings, fibres or meal and thermoplastic material constituting the filler binding agent. Meal derived from wood or annual plants (hemp, flax, rice hulls, and nut shells) is used as filler. Another good filler material is meal from wastewood derived from discarded household articles or from demolition of wooden constructions. Polymers used to bind composites include various kinds of thermoplastic materials: polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC) etc. In addition, thermoplastic materials derived from recycling are also employed for WPC production. Quantitative proportions of wood shavings to polymer are selected within the range of 40 - 60% depending on requirements connected with elasticity, bending strength, impact resistance as well as resistance to atmospheric factors [Fechner 2007].

Composite constituents are characterised by macroscopically visible boundaries between them and composite mechanical properties are better than those of its components separately. WPC hardness depends on the degree of filling with wood meal; the composite is considerably harder than the comparable wood materials applied as fillers [Gozdecki, Kociszewski, Zajchowski 2005]. WPC is highly resistant to moisture; its absorbability during a 24-hour soaking test does not exceed 2% and this value depends on the composition of the composite and the method of its manufacture. It is characterised by high moduli of elasticity and dimensional stability. It is possible to dye, shape and structure it, coat it with different foils or substances protecting it or hardening its surface [Feschner 2007]. It is also exceptionally suitable as a lining and construction material intended for external application due to its biological resistance.

The most popular and, at the same time, the simplest methods of obtaining wood-plastic composites is their extrusion in well-known extruders for plastic materials.

Wood-polymer composites find application on terraces, landings, decks, platforms as well as footbridges mounted with the assistance of quick release couplings or using traditional screws and bolts. However, there is no information concerning their workability, in other words, susceptibility of the composite to machining.

RESEARCH OBJECTIVE

The aim of the research project was to determine the proper machining work and thrust force during machining of selected WP composites manufactured from 2 polymers: PVC and PE and to compare with the proper machining work and thrust force during machining of selected kinds of wood in common use in Poland.

METHODOLOGY

The investigations were carried out on a universal OUS-1 machine tool which makes it possible to secure a constant rate of feed of a drill torque meter in relation to the rotating borer, in other words, a constant feed per rotation. A drill torque meter allows measurements of machining resistance during drilling, i.e. drilling moment and the thrust force thanks to equipping it with BIMETR inductive sensors connected to a two-channel x-t recorder TZ 4200. Measurements were taken at a constant rotational speed of the spindle amounting to ω=64.4s^{-1} and feed rate of u=0.10 mm/rot. [Wieloch, Pohl 1991;Wieloch, Pohl, Hoffman 1998].

Experiments were conducted on two kinds of WPC materials:

- 50% wood meal + 50% PVC of ρ=1350 kg/m^3 density,
- 50% wood meal + 50% polyethylene of ρ=1245 kg/m^3 density and for comparative purposes on three kinds of wood,
- Alder of ρ=645 kg/m^3 density,
- Birch of ρ=586 kg/m^3 density,
- Beech of ρ=734 kg/m^3 density,

of two anatomical directions: tangential and radial.

Experiments were made with the assistance of a drill bit for metal made of HSS steel of 8 mm diameter and the following angle parameters of the edge (Fig. 1).

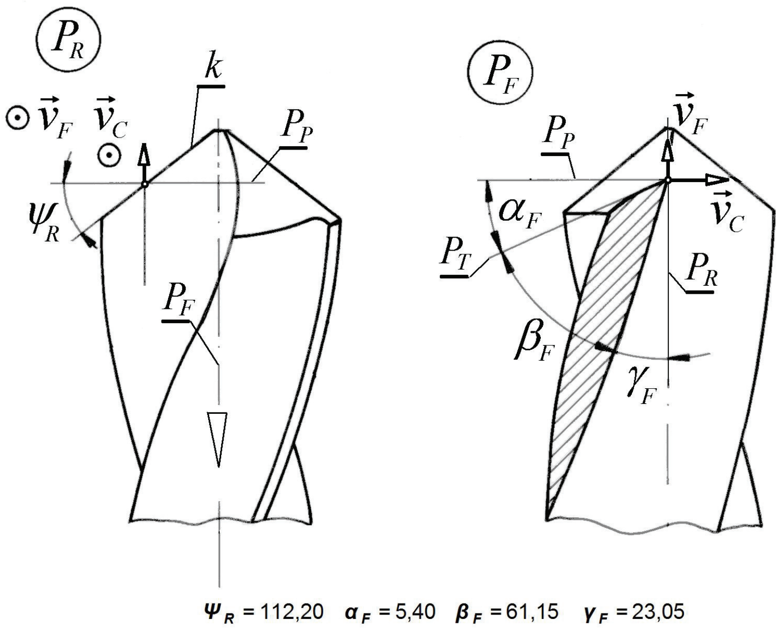

Figure 1. Screw metal drill bit from HSS steel and its angle parameters.

Measurements of proper machining work during drilling were performed by measuring the machining moment and converting into the proper machining work value according to the following dependence [Pohl, Biniek 2002]:

$$k = \frac{L}{V} = \frac{M\phi}{As} = \frac{Fl\phi}{urs} = \frac{2Fl\phi}{ur\phi r} = \frac{2Fl}{u(\frac{d}{2})^2} = \frac{8Fl}{ud^2}\left[MPa\right]$$

where:
k – proper machining force (work),
L – machining work [J],
V – wood shaving volume [m^3],
M – machining moment [Nm],
ϕ – rotation angle [rad],
A – cross section area of the machined layer measured perpendicularly to the vector of feed velocity [m^2],
s – machining distance [mm],
u – feed per rotation (0.10 mm/rot.),
r – drilling bit radius [mm],
d – drilling bit diameter [mm],
F – measured values of force [N],
l – length of arm (107 mm).

Ten replications were carried out for each measurement of the machining moment and thrust force and mean values, standard deviation as well as coefficients of variability were calculated.

RESEARCH RESULTS

Figure 2 presents results of measurements of proper machining work of WPC plastics as well as different kinds of wood during drilling with an HSS ∅ 8 mm steel drilling bit. Figure 3 collates graphically results of investigations of the thrust force during drilling of the examined materials using an HSS ∅ 8 mm steel drilling bit.

The coefficient of variation for the proper machining work amounted to 7.5% and for the thrust force – 16.2%.

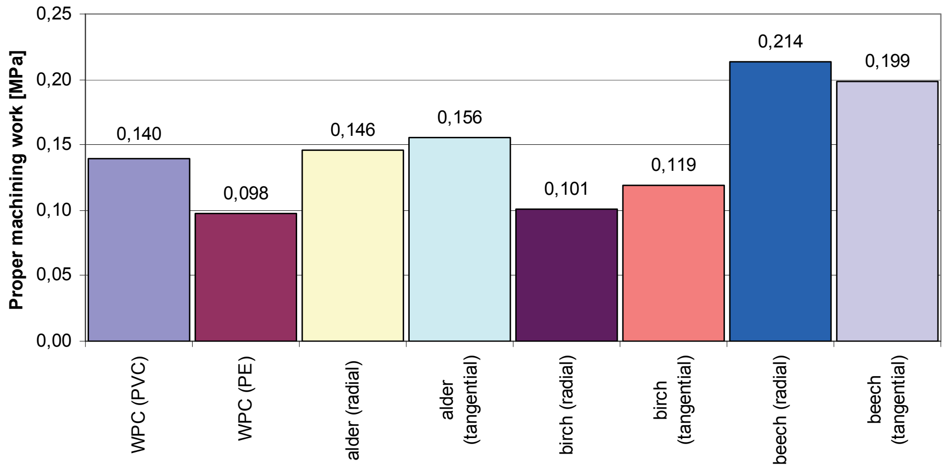

Figure 2. Research results of the proper machining work of WPC plastics and selected wood types.

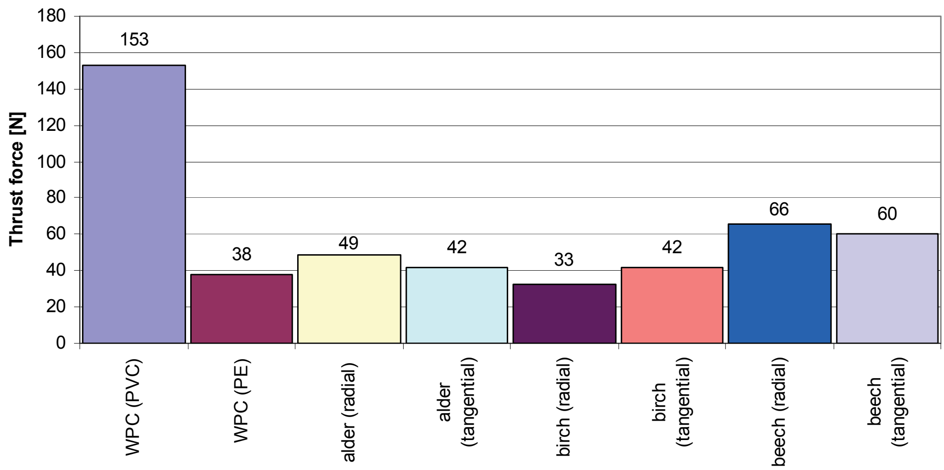

Figure 3. Research results of the thrust force during machining of WPC plastics and selected wood types.

CONCLUSIONS

Analysing the research results presented above, it was concluded that the smallest proper machining work was required when drilling was conducted in polyethylene-based plastic (WPC (PE)) material. This value was similar to the values of the proper machining work for birch wood.

On the other hand, the polyvinyl chloride-based (WPC (PCV)) plastic showed values of the proper machining work similar to alder wood.

The highest thrust force was determined in the case of WPC containing 50% polyvinyl chloride which exceeded four times the machining thrust force of the polyethylene-based WPC. Thrust force values of the polyethylene-based WPC were comparable with the thrust force of alder and birch wood in both anatomical directions.

On the basis of the above-presented results it can be concluded that PCV-based composite is more difficult to work; it is characterised by a higher machining work and considerably higher thrust force in the course of machining. The above results show that WPC (PE) is easier to work than the examined wood species, despite its almost twice higher density.

The high values of the proper machining work as well as thrust force determined for the PCV-based WPC could have been caused by incorrect geometrical parameters of the edge for this kind of plastic. The problem requires further investigations.

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