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Experimental Evaluation on Shape and Control of Chip in Milling of PE WPC

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Abstract

This paper the regular patterns of chip flow, chip curler radius and thickness under different cutting parameters when processing PE WPC with different wood flour contents under the condition of up milling and down milling. Compared with up milling, down milling has greater impact on chip flow direction and cutting speed. However, there are more dust-shaped chips in the up milling. In the down milling, chip curler has less change with cutting parameters. Only when the feed speed is 14m/min or the cutting speed is 1800m/min, the chip curl radius is larger. The chip thickness increases when the feed speed or the cutting width increases and decreases when the cutting speed increases.

Keywords: *PE WPC; milling; chip flow; chip curler; chip thickness*

1. Introduction

The application of PE WPC covers the fields such as plated materials, furniture materials, interior decoration materials, automotive interior and so on [1-2]. The quality issue of secondary processing is increasingly prominent [3]. Chip controlling is an important process in the milling which is one of the main secondary processing methods [4]. It will pollute the environment if it forms chip powder. So we need to study the chip flow, chip curler, chip thickness and so on to improve the green processing of PE WPC [5-6].

Researches on the wood and WPC chip are main about the formation mechanism, cutting shape and so on. In the aspect of chip formation mechanism, Guo [7] studied the chip formation mechanism, cutting force, milling dust and chip flow in the cutting process of MDF. He used high-speed camera technology and microanalysis of materials technology to do the orthogonal cutting experiment, analyze the basic characteristics of chip formation process and set up the MDF cutting mechanism model. Yang [8] used high-speed camera technology to record the bamboo cutting process and analyze the chip types in different cutting directions, physical properties and cutting parameters. In the aspect of chip shape, Su [9] studied the impacts shank cutter spiral angle, feed speed and milling depth to chip formation and energy consumption in the process of wood milling. According to the chip shapes, we divide the chips of helical shank cutter into four sorts: flake type, a splinter type, flow type and granule type. It will easier to produce flake type and a splinter type chips as the increase of feed speed and milling depth. However, it is much easier to produce granule type chips when the helix angle increases. Su [10] studied the influence of straight shank cutter blade angle to chip shape during the process of wood portrait and end milling in 2003. The chip shapes are divided into five sorts: spiral chip, splinter chip, flow chip, thin chip and granule chip. For the two kinds of wood, it will produce a lot of flow chip and thin chip no matter which milling form or which angle. Compared with end milling, it is easier to produce granule type chip in portrait milling.

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In this paper, we research the influence pattern of milling parameters to chip flow, chip curler and chip thickness in the condition of up milling and down milling, of 60% and 70% wood flour content in the process of PE WPC milling.

2. Experimental Setup

2.1. Experimental Materials and Equipments

The experiment uses the PE WPC which is developed and made in State Key Laboratory for Materials of Northeast Forestry University. It is mainly made up with PE and wood flour. The Specific parameters are shown in Table 1.

Table 1. PE WPC Mechanical Properties

Material	Wood flour content	Size(length×width ×thickness) mm	MOE(MPa)	Poisson ratio
PE WPC	60%	500×120×20	2435	0.35
	70%		2875	0.49

Experiment uses CNC milling, experimental equipment is shown in Figure 1. The machine tool is MIKRON UCP 710. Cutter is indexable insert cutter made by Leitz. Shank cutter is WL101-2-040854. Blade is HW-05-005161. The experiment used KEYENCE VHX-1000. The chips of the experiment are shown in Figure 2.

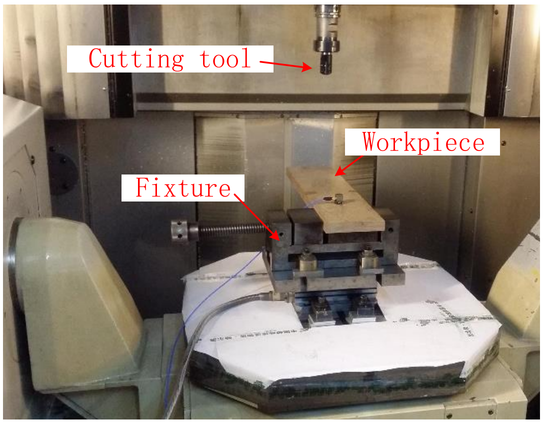


Figure 1. Experimental Equipment

Figure 2. Chips and Workpieces

2.2. Experimental Strategy

Down milling and up milling are compared in the experiment. During the up milling, the chip thickness increases big and the milling process is relatively stable. However, during the down milling, the chip thickness turn small. So the attack is relatively bigger. The experiment studied the feed speed, cutting speed and cutting width(Concerning the material is sheet, cutting depth is without consideration). Table 2 shows the milling parameters of PE WPC. It concludes single factor experiment of feed speed, cutting speed and cutting width.

Table 2. PE WPC Experiment Parameters

Group	Feed speed f (m/min)	Cutting speed v (m/min)	Cutting width a_e (mm)	Cutting depth a_p (mm)
1	2, 4, 6, 8, 10, 12, 14	800	1	20
2	6	400, 600, 800, 1000, 1200, 1400, 1600, 1800	1	20
3	6	800	2, 3, 4, 5, 6, 7	20

3. Chip Deformation Zone

When cutting plastic material, the flow is shown in Figure 3. It is divided into three deformation zones: first deformation zone, second deformation zone and third deformation zone. Each deformation zone is shown in Figure 3.

First deformation zone: the OAM zone as shown in Figure 3 is the main deformation zone. WPC deforms from OA, the matrix shear slip is almost done to OM. We should overcome the deformation during this zone. Cutting force and cutting heat mainly come from this zone.

Second deformation zone: the II zone as shown in Figure 3, located in the rake face and chip contacting zone. Chips take off the workpiece from rake face and suffer the friction and extrusion by rake face. The heat generated by friction makes the contacting zone temperature very high and leads to the rake face broken.

Third deformation zone: the III zone as shown in Figure 3, located in the machined flat and suffers the friction and extrusion of blunt cutting edge portion and flank.

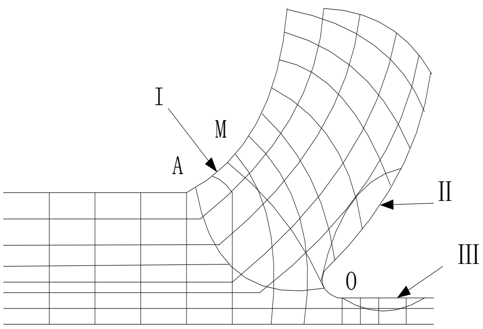


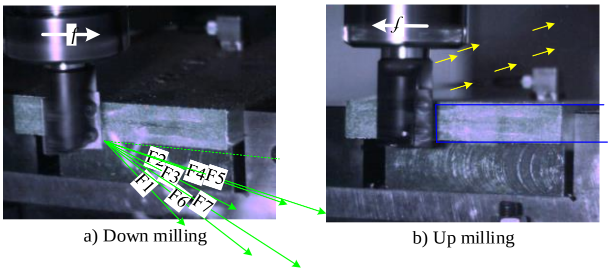
Figure 3. WPC Deformation Zone

4. Chip Flow Experiment Result

4.1. The Influence of the Feed Speed on Chip Flow

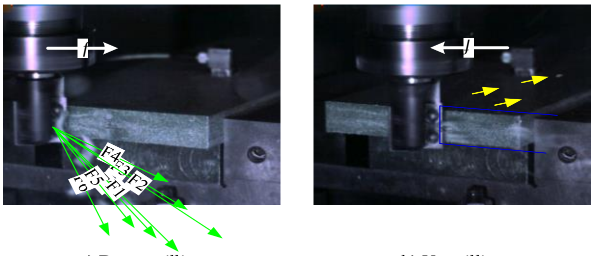
Figure 4 shows the influence of feed speed to chip flow direction and status of 60% wood flour content PE WPC. a) shows down milling and b) shows up milling. During down milling, the chip flow direction and feed speed angle decrease at first as the feed speed increases. When the feed speed is 10m/min, the figure is smallest and then goes on increasing. During up milling, the flow direction is almost stable. When the feed speed is 10m/min, chips become more and more dispersed. Compared with down milling, it gets more dust (granule chip) (yellow arrow shown in Figure 4).

Figure 5 shows the influence of feed speed to chip flow direction and status of 70% wood flour content PE WPC. a) shows down milling and b) shows up milling. During down milling, the chip flow direction and feed speed angle decrease at first as the feed speed increases. When the feed speed is 8m/min, the figure is smallest and then goes on increasing. During up milling, the flow direction is also almost stable. Chips get granulated as the feed speed increases.



a) Down milling b) Up milling

Figure 4. Influence of Feed Speed on Chip Flow Direction (60%)



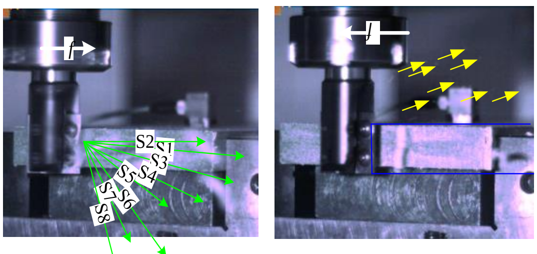
a) Down milling b) Up milling

Figure 5. Influence of Feed Speed on Chip Flow Direction (70%)

4.2. The Influence of the Cutting Speed on Chip Flow

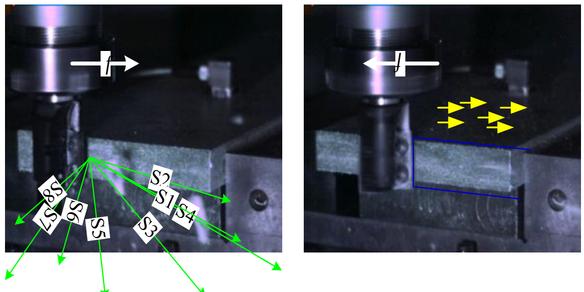
Figure 6 shows the influence of cutting speed to chip flow direction and status of 60% wood flour content PE WPC. a) shows down milling and b) shows up milling. During down milling, the chip flow direction and feed speed angle increase as the cutting speed increases. During up milling, chip flow direction and feed direction change slightly. When the cutting speed is 23.33m/s, the granule chips increase obviously.

Figure 7 shows the influence of cutting speed to chip flow direction and status of 70% wood flour content PE WPC. a) shows down milling and b) shows up milling. During down milling, the chip flow direction and feed speed angle increase obviously as the cutting speed increases. During up milling, the granule chips increase obviously as the cutting speed increases. The flow range increases obviously when the cutting speed is 26.67m/s and 30m/s. And the chip flow direction and feed direction angle change slightly.



a) Down milling b) Up milling

Figure 6. Influence of Cutting Speed on Chip Flow Direction (60%)



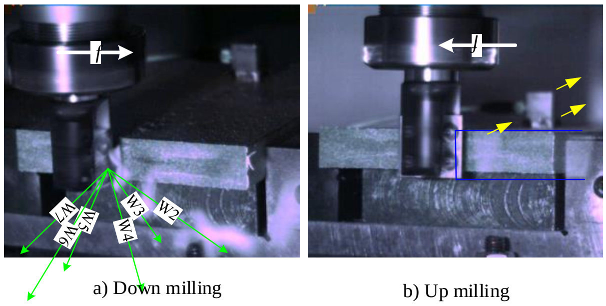
a) Down milling b) Up milling

Figure 7. Influence of Cutting Speed on Chip Flow Direction (70%)

4.3. The Influence of the Cutting Width on cChip Flow

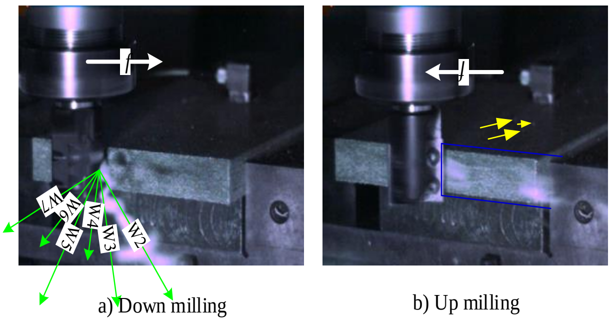
Figure 8 shows the influence of cutting width on chip flow direction and status of 60% wood flour content PE WPC. a) shows down milling and b) shows up milling. During down milling, the chip flow direction and feed speed angle increase as the cutting width increases. When the cutting width is 7mm, the granule chips increase obviously. During up milling, chip flow direction and feed direction angle change slightly as the cutting width increases. When the cutting width is over 4mm, the granule chips increase obviously.

Figure 9 shows the influence of cutting width on chip flow direction and status of 70% wood flour content PE WPC. a) shows down milling and b) shows up milling. During down milling, the chip flow direction and feed speed angle increase as the cutting width increases. During up milling, chip flow direction and feed direction angle change slightly as the cutting width increases. When the cutting width is 4mm and 5mm, the granule chips increase obviously.



a) Down milling b) Up milling

Figure 8. Influence of Cutting Width on Chip Flow Direction (60%)

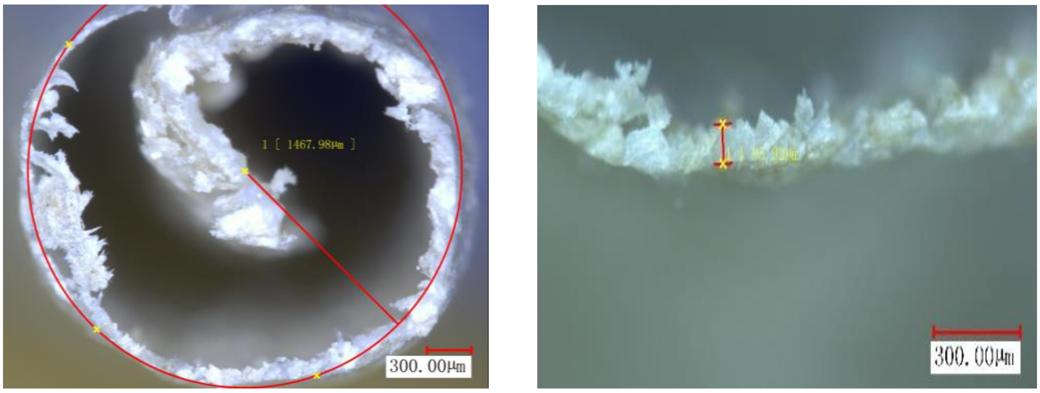


a) Down milling b) Up milling

Figure 9. Influence of Cutting width on Chip Flow Direction (70%)

5. Chip Parameters Experiment Result

By observing the macro and microcosmic status (chip curler radius and thickness) of chips, we research the influence of milling methods and cutting parameters to chips controlling. This section researches the influence of cutting parameters to chip curler radius and thickness. The text experiments are shown in figure 10a) and 10b).



a) Curler Radius Measuring b) Chip Thickness Measuring

Figure 10. Chips Measuring during Experiment

5.1. Chip Curler Radius

Figure 11 shows the influence of feed speed to chip curler radius of two wood flour contents PE WPC in down milling and up milling. We can see from the figure that the chip curler radius increases as the feed speed increases. The impact of feed speed to curler radius is greater in up milling and smaller in down milling. However, for 70% wood flour content, curler radius increases as the feed speed increases. During up milling, chip curler radius sudden changes obviously when the feed speed is 8-10m/min. During down milling, the curler radius increases obviously when the feed speed is 14m/min.

Figure 12 shows the influence of cutting speed to chip curler radius of two wood flour contents PE WPC in down milling and up milling. For 60% wood flour content, when the cutting speed is 400-1400m/min, the chip curler radius changes slightly in up and up milling. When the cutting speed is 1600m/min, the curler radius has an obvious increasing trend. When the cutting speed is 1800m/min, the curler radius suddenly increases. For 70% wood flour content, when the cutting speed is lower than 1600m/min, the radius changes slightly in up milling, but the whole trend is stable. When the cutting speed is 1800m/min, the radius increases suddenly. The impact is relatively small in down milling.

Figure 13 shows the influence of cutting width to chip curler radius of two wood flour contents PE WPC in down milling and up milling. For 60% wood flour content, the chip curler radius increases as the cutting width increases in down milling. The volatility of curler radius is greater in up milling. For 70% wood flour content, the curler radius increases as the cutting width increases in up milling. However, the chips are scraps in down milling.

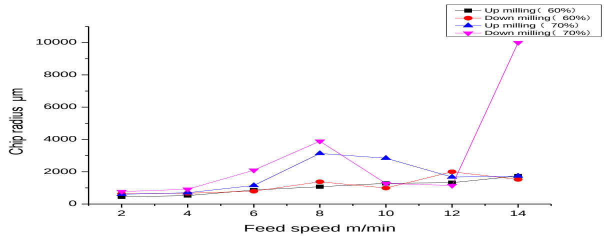


Figure 11. Influence of Feed Speed on Chip Radius

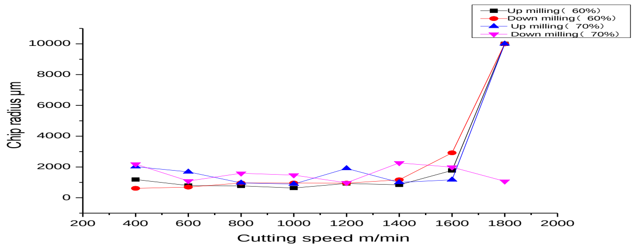


Figure 12. Influence of Cutting Speed on Chip Radius

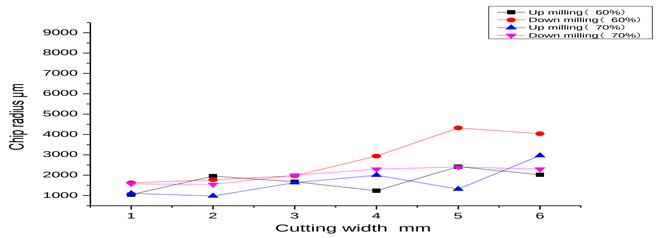


Figure 13. Influence of Cutting width on Chip Radius

5.2. Chip Thickness

Figure 14 shows the influence of feed speed on chip thickness of two wood flour contents PE WPC in down milling and up milling. For 60% wood flour content, the chip thickness increases as the feed speed increases. For 70% wood flour content, the chip thickness shows an increasing trend in down milling. The chip thickness change regularity is general in up milling.

Figure 15 shows the influence of cutting speed on chip thickness of two wood flour contents PE WPC in down milling and up milling. For 60% wood flour content, the chip thickness decreases as the cutting speed increases. When the cutting speed is lower than 800m/min, the thickness is relatively bigger. When the speed is more than 1000m/min, the decrease width of thickness is smaller. For 70% wood flour content, the chip thickness decreases as the cutting speed increases, and almost linear.

Figure 16 shows the influence of cutting width on chip thickness of two wood flour contents PE WPC in down milling and up milling. For 60% wood flour content, the chip thickness increases as the cutting width increases. And the increase tend is almost the same. For 70% wood flour content, the chip thickness increases as the cutting width increases in up milling. The chip thickness shows an increase tend but the volatility is big.

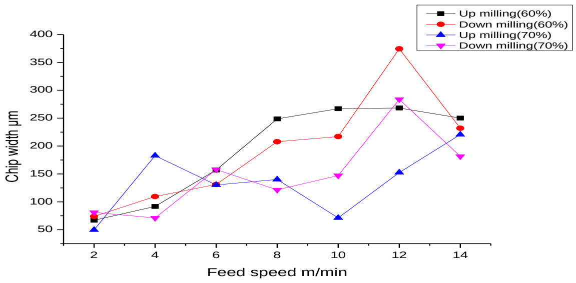


Figure 14. Influence of Feed Speed on Chip Thickness

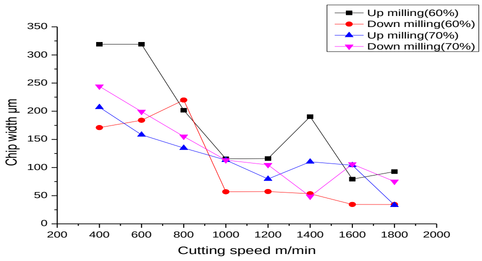


Figure 15. Influence of Cutting Speed on Chip Thickness

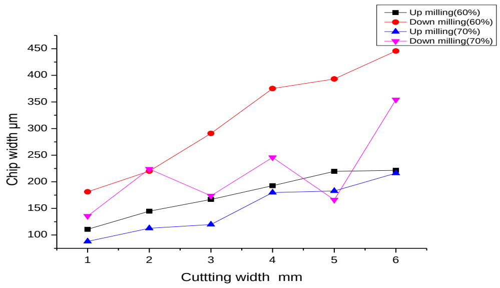


Figure 16. Influence of Cutting width on Chip Thickness

6. Conclusions

We can get the conclusions by the influences of cutting parameters to chip flow, chip curler and chip thickness when processing different wood flour contents PE WPC in up milling and down milling.

1) Compared with up milling, down milling has a greater impact on chip flow direction and a much greater impact on cutting speed. There are more dust-shaped chips in up milling.

2) The impact is small on cutting parameters to chip curler. Only when the feed speed is 14m/min or cutting speed is 1800m/min, chip curler radius is big.

3) The cutting thickness increases when the feed speed or cutting width increases but decreases when the cutting speed increases.

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