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Research the Formation Mechanism of Burr on the Surface of the Wood Processing

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The author uses softwood *Pinus koraiensis* and hardwood *Acer mono* which are the common tree species to be the experimental materials in this paper, and the author mainly discussed several factors affecting the morphology of wood surface burr. In addition to macro factors which are mechanical parameters, feeding speed, rotating speed of cutting tool, tool shape, cutting tool shape Angle, the sharpness of cutting tool and wood moisture content, this paper is to study the effects of microstructure of wood internal burrs morphology on machining surface. The burr morphology of two species trees under different conditions were observed by scanning electron microscope, and then the author summarize the effects of wood microstructure on the burr processing surface, the microstructure of wood includes trees density and the early wood and late wood at the same species, wood surface texture, angle of processing surface etc. These are to establish the mathematical model of wood burr, and to prepare subsequent for laser ablation, and they can provide research foundation for the laser sanding on the surface of wood products.
Keywords: Wood burr; Burr morphology; Microstructure

1. Introduction

As one of the three major energy sources in the world, wood plays an important role in daily life and national development (ZHANG et al, 2000). Wood in the production and processing is essential for removing the burr, so the analysis of burr formation is great significant (LI et al, 2014). Most researchers study the formation of burr only considering the macro factors, ignoring the role of micro factors, but with the fine degree of wood production process requirements, the role of micro factors on the formation of burr is becoming more and more important.

Wood is a composite of organic matter, mainly composed of cellulose, hemicellulose and lignin, which are together with water and carbohydrate sticky liquid constitutes the whole wood. Wood burrs are usually produced in wood surface of wood fibers or poly wood fiber, and they cannot be completely eliminated in the machined surface. In exceptional circumstances, wood fiber may also be pulled out of the surface.

2. Macro factors analysis of wood burr formation

2.1 Processing of mechanical parameters

The mechanical parameters are the most important macroeconomic factors to produce burr, so the burr can be minimized by adjusting the mechanical equipment parameters (A. Malkoçoğlu, 2007). These parameters include feeding rate(Murat et al, 2005;I.Korkut and M.A. Donertas, 2005), RPM (Revolutions per Minute), and the number of cutting head and so on. Comprehensive consideration, the most effective method to reduce the burr is to determine the appropriate mechanical parameters(Iris et al, 2010).

The mechanical parameters can be described using the following formula, using milling and planning and cutting processing(JIA et al, 2013), the theoretical value of the workpiece surface roughness is calculated by Formula 1.

$$h=2.5\times10^5\times U^2/(n^2\times Z^2\times D) \quad (1)$$

In the formula：h—Cutting depth, the unit is mm; U—feed speed, the unit ism/min; n—cutter rotating speed, the unit is r/min; D—Cutting tool cutting circle diameter, the unit is mm；Z—Number of cutting edge face.

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In theory, this formula must meet the following four assumptions: (ⅰ) The rigidity of cutting tool spindle is great, and precision of the smooth movement is high, there is no radial runout and pendulum. (ii) Each edge of cutting tool circle to the center of the distance is completely same, the dynamic balance correction of the cutter head is accurately. (iii) The cutting feed rate is constant. (iv) The contact between the workpiece and the cutting tool is in contact with the rigid body, without any deformation. But in the current actual woodworking factory, milling machine or planer is difficult to achieve the above conditions.

2.2 Wood Moisture Content

Wood moisture content is the percentage of the weight of the moisture in the wood and the absolute dry weight of the wood(ZHOU and SUN, 2013). Moisture content can be calculated by using the weight of the dried wood as benchmark, and the numerical value is called absolute moisture content. The numerical value is called absolute content, and moisture content for short（W,%）. Calculation formula is the following.

$$W = (Gs - Ggo) / Ggo \times 100\% \qquad W1 = (Gs - Ggo) / Gs \times 100\% \qquad (2)$$

In the above formulas: W—Absolute moisture content of wood; W1—Relative moisture content of wood; Gs—The weight of wet wood; Ggo—The weight of absolute dry wood. The national standard of absolute moisture content of wood is 3.0%-10.0%.

Wood is placed in a certain air condition, after a long enough time, its moisture content will tend to a balanced value, said the environment of the equilibrium moisture content (EMC). The moisture content of the wood will reach a stability of absorption or desorption of moisture stable, called the equilibrium moisture content of the wood (wood moisture steady state). In different regions, the value of wood moisture content and equilibrium moisture content are different.

At a certain time, the cell cavity of wood has evaporated, but the cell wall is full of water, which is called "fiber saturation". At this time the moisture content is about 30%. For convenience, the moisture content of 30% is defined as "the saturation point of the fiber". Experiments showed that moisture content is below fiber saturation point to process wooden pieces, can minimize the burr on the surface of the wood. Woodworking machinery and wood products under the condition of high moisture content, will lead to serious burr, especially in the process of cutting and grinding. Wood products should be as far as possible dry, so that the equilibrium moisture content is between 6% and 8%, which make minimize damage of woodworking machinery, reduce burr phenomenon. Moisture content of wood is too high will lead to additional extrusion.

In addition, the shape of machining tool, processing angle, cutting tool's sharpness and so on are the macro factors that affect the burr.

3. Micro factors analysis of wood burr formation

In wood processing, the cutting tool can make the wood reverse bending, produce corrugated, groove mark and fiber fracture, and make the crack deepen, make the difference of the wood surface become very greater (PENG et al, 2012). In addition, the microstructure effect on machining burrs morphology on the surface of the wood is more complicated. The dissect molecule of softwood is relatively simple, regular arrangement, which is mainly composed of the axial tracheid, wood ray, axial parenchyma and resin canal, and the axial tracheid is called tracheid which is the major constituent molecules of coniferous wood. Compared with softwood, hardwood structure is relatively complex, which is composed of catheter, wood fiber, axial parenchyma, wood ray and hardwood’s tracheid, and the pores between them are very well developed. Each cell accounted for 15% or more of the volume of hardwood trees, and the arrangement is irregular, the material is uneven, and the shape, all kinds of cell shape, size and wall thickness are different. In short, the nature, size and distribution of tree cells can affect the surface burr morphology of wood (HAI and Leon, 2009).

3.1 Preparation for experimental sample

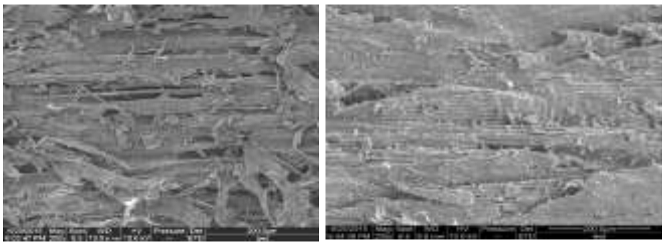
In the experiment, the work is to measure the burr of *Pinus koraiensis* (Pinus koraiensis Sieb. et Zucc) and *Acer mono* (A. mono Maxim.) after processing. Panel’s size is 20 cm × 15 cm × 2 cm, taking milling, choosing wood tangential section, and processing the wood according to three directions, that is horizontal, parallel and inverse grain. Sample whose size is 10 mm × 8 mm × 1 mm, require the sample surface level off, smooth, without defects, such as cracks and flaws, knots, decay and so on. In the dry process of the actual production of the factory, the moisture content of all the test material is 6% to 8%.

3.2 Experimental method

In this paper, the processing surface of the wood was observed by scanning electron microscope, and the micro stereoscopic structure of the wood was fully understood. The study of this paper is to use the Quanta200 environment scanning electron microscope in the high vacuum (HV) work mode, to observe the composition of microstructure of wood, density, whether it contains tyloses, the direction of the wood texture and so on, to analyse the effect of the above factors on the wood surface burr morphology.

4. The results and discussion

4.1 The influence of different kinds of wood on the burr

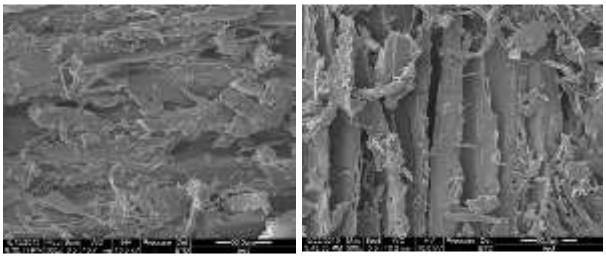


(a) Pinus koraiensis'surface *(b) Acer mono's surface*

Figure 1: a and b, burr morphology of Pinus koraiensis and Acer mono at 200 times

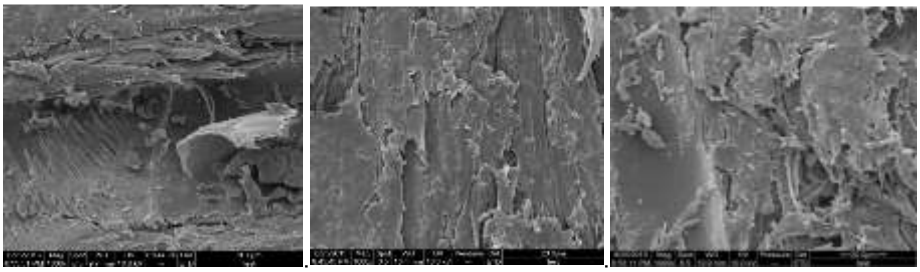
The SEM pictures in Figure show clearly that, *Acer mono* sample surface flatness is better in *Pinus koraiensis*, roughness value is smaller. *Pinus koraiensis* belongs to the low density of softwood tree species. Under the same processing conditions, the burr of processing on the surface is relatively more, and size of the burr is larger. In Figure a, the largest length of burr reaches 282.8um, the root diameter of largest also reaches the 75.79um. These are mainly due to the Korean pine tree structure itself. Softwood is made up of many radiating flat cells. Cell cavity often contains resin and tannin compounds. Cells are filled with air, so cork often has the color, texture soft, elastic, impervious, less susceptible to chemical drugs, and it is a poor conductor of electricity, heat and sound. In the same mechanical parameters and feeding speed conditions, the *Pinus koraiensis's* burr is much more and the size is different, and the direction of burr is also easily affected. Most of the burr comes from tracheid stress tear; *Acer mono* belongs to porous wood and hardwood. It grows slowly, but the texture is firm, cells packed tightly. Pore of Acer mono is small, fine, uniform structure, larger density, lower the ratio of vessel and fiber, these structural features made almost no obvious burrs on the processing surface of Acer mono. The biggest burr length is only 76.5 um, and diameter has just reached 12 um. Thus, this shows that the hardness of wood has a great influence on the shape and quantity of the burr.

4.2 Effect of wood texture on burr



(a) horizontal grain *(b) parallel-to-grain (c) against grain*

Figure 2: Pinus koraiensis's horizontal grain, parallel-to-grain, against grain burr under 500 times

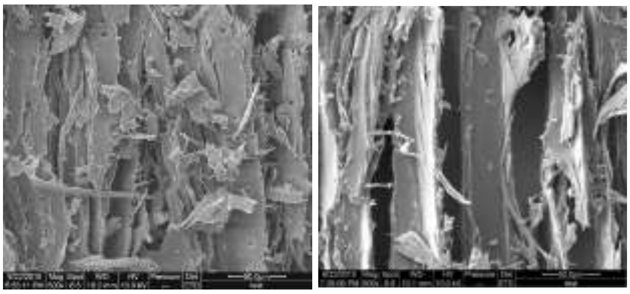


(a) horizontal grain *(b) parallel-to-grain* *(c) against grain*

Figure 3: Acer mono's horizontal grain, parallel-to-grain, against grain burr under 1000 times

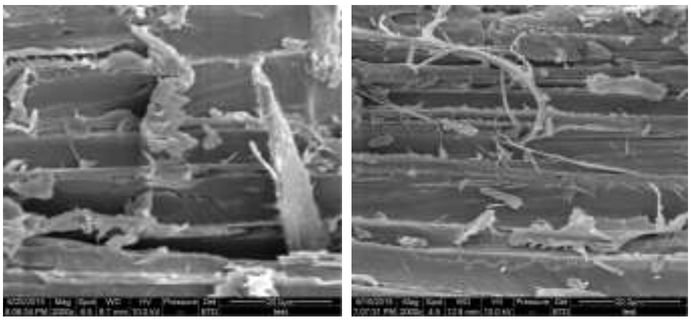
Experiments are respectively along three directions, namely the horizontal stripes, parallel to grain, against grain of *Pinus koraiensis* and *Acer mono*, to observe influence on burr form different direction of texture. Figure 2 shows three texture processing electron microscopy images of the *Pinus koraiensis* under ESEM 500 times, Figure 3 is three textures processing electron microscopy images of *Acer mono* under 1000 times. Comparing the above two groups of images showed that surface roughness of Acer mono significantly is better than that of *Pinus koraiensis*, reason has been expounded in section 4.1. Through analyzing a group of pictures of the same species, we can draw following conclusions easily: whole processing surface of *Acer mono* is better, and tiny burrs are invisible, especially processing surface along the grain, that is very good. Under the 1000 times electron microscopy to observe, we can only see the cracks that are extruded at template mechanical processing. Against grain processing surface is poorer than along the grain, burr is the most along horizontal grain processing surface. This is obvious from the picture of *Pinus koraiensis* in the Figure 2. Surface of *Pinus koraiensis* is relatively rough, and it has a lot of burr. Its cell wall cavity can be clearly seen, and burrs are formed by cell wall cavity that was tore. On the whole, the parallel-to-grain burr is the smoothest, and the burr is small and less, the size is uniform, the direction is uniform and the same as the direction of machine processing; Secondly, the morphology of burr is regular at against grain, and they are smooth. But compared with parallel to the grain, the shape of burr is larger, the flake burr is seen, and the direction is consistent and same as the direction of processing. At the same time, a small amount of tearing burr is formed. Burr shape is the most complicated by horizontal grain processing. Its form is thick and large quantity, the direction of the burr is almost disordered, and most of the burrs are formed by tearing cell wall, and a lot of flake burr appear. Therefore, in order to reduce the formation of burr and more convenient to remove burr, we should process the wood with parallel to grain and against grain to avoid horizontal grain processing.

4.3 Effect on burr of early wood and late wood



(a) early wood *(b) late wood*

Figure 4: Pinus koraiensis's burr morphology of early wood and late wood under 500 times

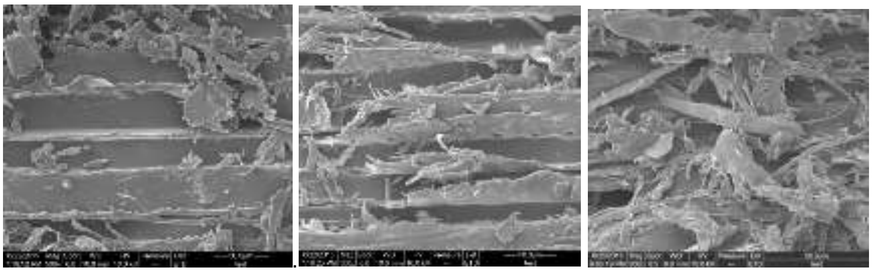


(a) early wood *(b) late wood*

Figure 5: Acer mono's burr morphology of early wood and late wood under 2000 times

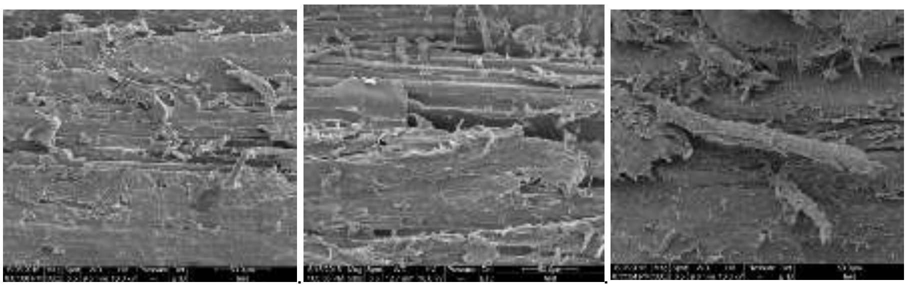
The trees grow into the wood in the early days of the year at temperate and frigid zone or in the rainy season at tropical zone are called early wood. It has the features of high ambient temperature, moisture content, the fast cell division rate, the thin cell wall, the large body, the soft material, the shallow wood color and so on. At the autumn in the temperate and frigid zone or in dry season at tropical zone, the trees nutrients flow is slow, and nutrients of trees flow slowly. Cell of cambium gradually is weakening. Speed of cell division slow down and eventually stop. Cell cavity is small and walls turn thick. Wood color is deep, organization is compact. The wood is called the late wood. In wood rings, material of early wood is loose and soft, easy to be tore when processing, which has made section burr and rough; Material of late wood is dense and hard, which made section small and less burr, the surface is smooth. These conclusions can be obtained clearly from Figure 4 and Figure 5. To sum up, structure difference of the early wood and late wood can cause different shape of burr, machining surface of late wood is significantly better than that of early wood surface.

4.4 Effect of the angle of the machining surface on the burr morphology



(a) 0 degrees *(b) 30 degrees* *(c) 45 degrees*

Figure 6: The burr of Pinus koraiensis's horizontal grain at different angles of machining under 500 times



(a) 0 degrees *(b) 30 degrees* *(c) 45 degrees*

Figure 7: The burr of Acer mono's horizontal grain at different angles of machining under 500 times

The angle of processing is different, the surface roughness is also different, and then the burr shape is different. In order to make better compare, in this paper horizontal grain is chose to process, the angle of the processing surface is 0 degrees, 30 degrees and 45 degrees. Observing the above two groups of images, we can get the followings: In Figure a, the angle of processing surface is 0 degrees, it is flat. After processing, the surface is smooth and flat, and burr shape is small. The burr is in the shape of a cone, and the size is more uniform. In Figure 6 a, the part in the above picture shows the processing of debris, not burr. The angle of processing surface is 30 degrees in Figure b, there are more burr than 0 degree. The direction of the burr is basically consistent, small, and easy to remove. In Figure c, the angle is 45 degrees, the roughest surface is obtained, the burr shape is larger, the majority is flaky, uneven size, and direction is out of order.

On the above, the angle of processing surface has a great impact on the roughness of surface. Smoothness at 0 degrees is best, the machining curved surface generate more burr. And with the increase of angle of curved surface, processing surface is most rough, and burr shape is the greater, and it is easy to produce the tore burr. So wood processing should be used as far as possible to the flat surface processing, for the inevitable surface processing, such as the relief of furniture. We must adjust processing speed, select the reasonable size of the tool, and try to reduce the surface roughness to avoid large burr.

5. Conclusions

There are many factors that affect burr shape on the surface of the wood, such as mechanical parameters and wood moisture content. In addition, burr is also greatly affected by the microstructure of wood, such as trees density and the early wood and late wood at the same species, wood surface texture, angle of processing surface etc. The main conclusions are as follows:

(i)The processing surface roughness of hardwood is better than softwood.

(ii)The same kind of tree species, the flatness in late wood is better in early wood.
(iii) Wood texture has a great influence on the number and shape of burr. In general, the parallel-to-grain burr is the smoothest. Against grain processing surface is poorer than along the grain, burr is the most along horizontal grain processing surface.
(iv) The angle of the machined surface has great influence on the burr. That is, the greater the machining surface angle, the greater the roughness, the more the burr.
In short, through the analysis of the factors of the formation of wood burr, these are to establish the mathematical model of wood burr, and to prepare subsequent for laser ablation, and it can provide research foundation for the laser sanding on the surface of wood products.

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