Frictional Characteristic of Micro Structures for Wooden Pallets

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Abstract

Wooden pallets are widely used in the field of logistics.Their frictional characteristics directly determine the reliability of transport. Microstructuring is an effective method to enhance the friction coefficient between the wooden pallet and corrugated box. In this study, the micro-cutting method was used to manufacture the micro grooves and pillars efficiently. 12 different sizes of microstructure are designed and manufactured on pine wood which is commonly used for the wooden pallet. The experimental results show that sample with a thickness of the groove wall 100μm has a poor structural strength and not suitable for microstructure design. The test results show that, micropillars has larger friction coefficient than grooved surface. It can lead to a 57 percent increase in the friction coefficient (from 0.21 to 0.33). This study lays the foundation for the manufacture of microstructures on wood to improve the frictional characteristic.

Keywords: Wooden pallets, Friction, Micro milling

1. Introduction

Pallet is the most basic unit in storage and transportation of goods. It has a wide range of engineering applications in the circulation of commodities. The pallet can greatly improve the logistics efficiency, stability and security, and reduce costs. The number of the tray in a country is a signature of its logistics modernization level [1]. A Survey data show that a total number of trays in China are more than 200 million and approximately 90% are wooden pallets. At the same time, China's pallets have annual growth of not less than 20 million. Quality and performance of pallet directly affect the transport efficiency and reliability [2]. Wooden pallets have many advantages, such as large bending strength, good rigidity, high load capacity, low cost, simple processing, easy maintenance, low temperature and high temperature performance. Therefore, wooden pallets are widely used and have occupied the mainstream of tray market. However, wooden pallets have some drawbacks that limit their service life. Its predisposition is to shrink and expand in response to changes in humidity and temperature. This may result in deformation and crack and weak joints. Eventually, this will reduce pallet's wear resistance, anti-sliding performance, and make it easy to be corrosion.

The functional surface has been investigated with considerable attention in the past few years and remarkable progress has been in many practical applications, such as friction reduction or increase, self-cleaning, antifogging and frosting [3]. At present, it is generally believed that under different lubricating conditions, the surface microstructures can reduce friction and wear, improve the lubrication performance, enhance load-bearing capacity, which is a potential method to resolve friction issues. For dry friction, the abrasive wear debris can be stored in the microstructures, which can also reduce the actual contact area between the interface of friction pair. These factors will help achieve the purpose of reducing friction. For wet friction, the mechanism of friction reduction is through the ability to store lubricant in the microstructures.

The purpose of this study is to investigate the effect of microstructures on the friction characteristic. The friction pairs in this study are different from conventional ones, in which the deformation of the workpiece is normally ignored. However, in this research, the corrugated box is a deformable material, which can be is compressed into the microstructures under certain pressure and results in an increase in frictional resistance. Therefore deformation of friction pair cannot be ignored in this study.

The paper will use friction coefficient between wood and corrugated box to characterise the performance f these microstructures.

Micro-milling process is an approved efficient and highly controllable method for obtaining micro structures will be used to structuring wooden pallet surface in terms of micro-grooves and pillars. By studying friction coefficient, the relationship between the friction coefficient and the groove or pillar dimension are investigated. Finally, the structure dimensions with largest friction coefficient will be obtained.

2. Material selection and microstructures design

Pine is a commonly used material for wooden pallets. Its advantages are better load-bearing capacity, beautiful appearance and low price.

The 3D model of micro-grooves and pillars are shown in Fig.1. 12 samples with different width and spacing are designed. Where, a is the thickness of the groove wall, b is the width of the groove, c is the depth of the groove, which is 200μm.

The parameters of the different grooves and pillars are summarized in Table 1.

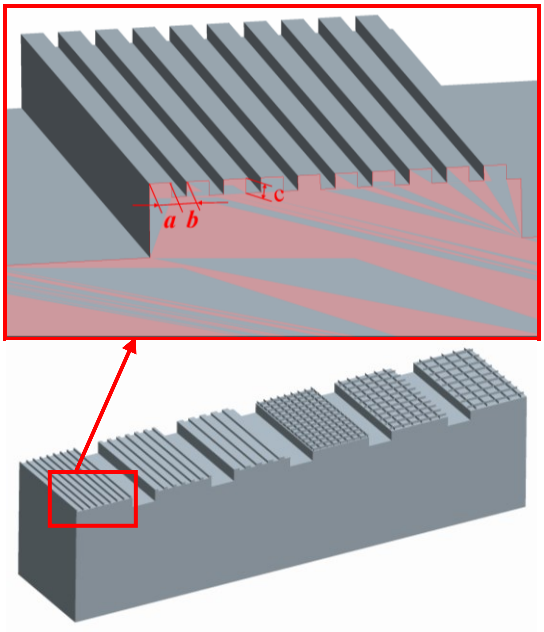


Fig. 1. 3D model of micro-grooves and pillars

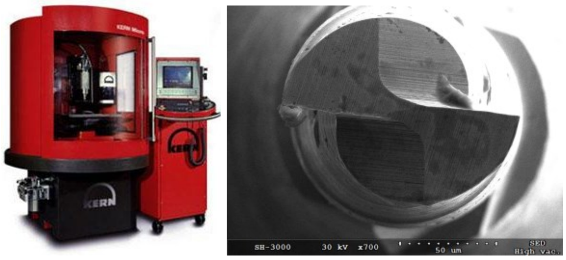
Table 1 The parameters of the different micro structures

Sample No.	a(μm)	b(μm)	Type
1	100	200	Groove
2	300	200	Groove
3	500	200	Groove
4	100	200	Pillar
5	300	200	Pillar
6	500	200	Pillar
7	100	500	Groove
8	300	500	Groove
9	500	500	Groove
10	100	500	Pillar
11	300	500	Pillar
12	500	500	Pillar

3. Experimental details

A five-axis micromachining center (KERN-2520) was employed to carry out the micro milling experiments. The maximum rotational speed is 50,000 rpm and axis travels are 250 mm for X, 220 mm for Y, 250 mm for Z, respectively. It is equipped with a laser Control NT to measure the micro milling tools.

Flat end mills with diameter 0.2mm (See Fig. 2 (b)) and 0.5mm were employed to manufacture the micro-textured surface.



(a) KERN-2520 (b) Φ0.2mm flat end mill

Fig. 2. micromachining center and milling tool

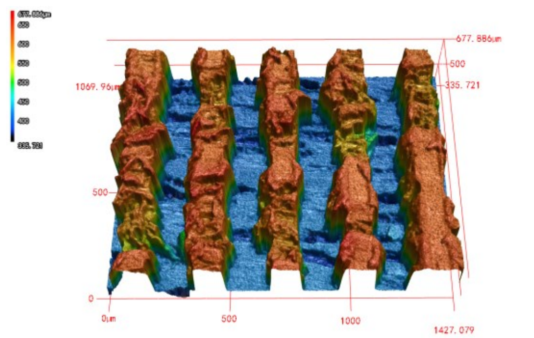
For sample with grooves, unidirectional milling was employed to generate micro grooves on the sample surface by horizontal cutting strategy. For sample with pillars, after finishing the whole micro-slotted surface on the sample, vertical cutting was then employed to obtain the pillars. The cutting conditions are shown in Table 2.

Table 2 Cutting conditions

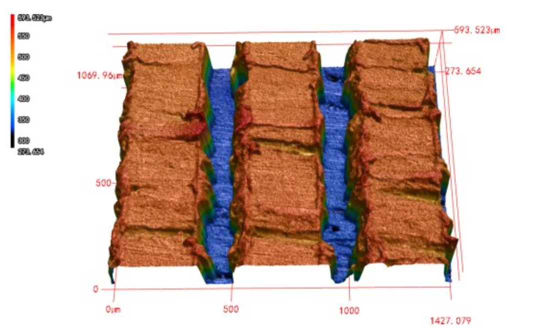
Cutting parameters	Value
Spindle speed	32000r/min
Feed rate	2μm/tooth
Axial depth of cut	50μm

4. Topography measurement of micro-grooves and pillars

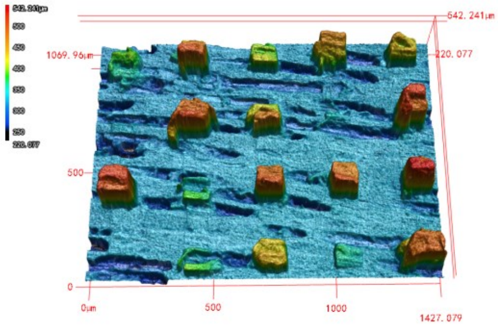
A laser microscope (Keyence VK-X250) was employed to measure surface topographies of micro grooves and pillars which were machined from the experiment as shown in Fig. 3.



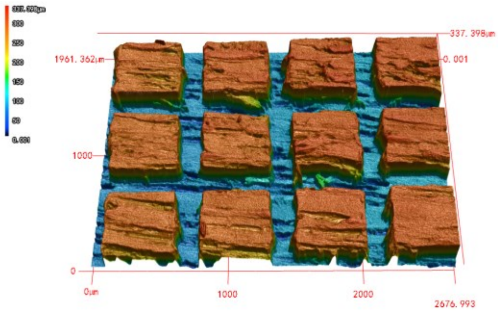
(a) Sample #1



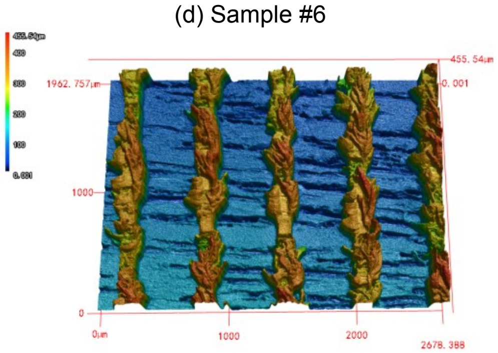
(b) Sample #2



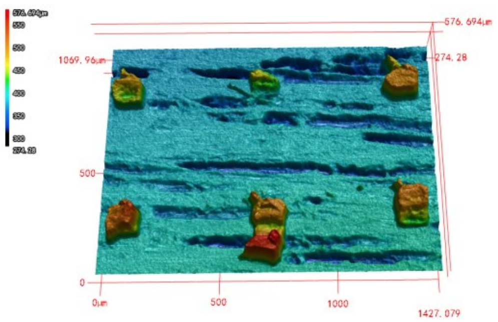
(c) Sample #4



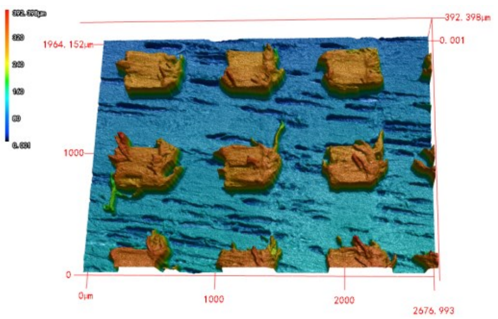
(d) Sample #6



(e) Sample #7



(f) Sample #10



(g) Sample #11

Fig. 3. Surface topographies of different samples

As pine wood is a natural fibrous material. During the manufacturing process, the internal fiber was cut off. At the same time, the cutting force also causes the fiber tear. Thus, surface tear burrs are clearly observed (shown in Fig. 3), especially, on the groove wall than other samples. The main reason is that the smaller groove wall thickness leads to serious fiber tearing effect. Moreover, samples #4 and #10 have more structural damage phenomenon due to small pillar was destroyed in the cutting process. Therefore, the strength of microstructure needs to take into account when designing, otherwise, they may get broken.

The measured geometrical parameters of micro-grooves and pillars are listed in Table 3. The deviations between the designed and measured dimensions of structures mainly due to the fiber tearing effects, tool setting error and surface burrs.

Table 3 Measured geometrical parameters of micro-pyramid arrays

Sample No.	*a*(μm)	*b*(μm)	*c*(μm)
1	104.6	192.2	203.9
2	308.3	188.6	211.1
3	505.9	207.7	205.2
4	111.7	192.4	206.7
5	292.3	208.5	200.6
6	493.9	213.1	197.3
7	139.2	482.6	236.8
8	354.7	409.1	212.3
9	452.	546.1	207.5
10	116.1	477.1	135.3
11	419.7	398.1	199.4
12	507.8	493.5	207.4

5. Friction coefficient of micro-patterned surfaces

Friction coefficients of samples have been measured by the MMW-1A vertical universal friction and wear testing machine. It has a range of test force from 10 to1000 N, and the test force relative error is about ±1%. Moreover, the range of principle axis rotation speed is 1-2000 r/min. The test setup is shown in Fig. 4. The test conditions are shown in Table 4. According to the contact area between the sample and corrugated box, 10N load force means 1.1Mpa pressure applied on the box, which is the normal pressure in working condition.

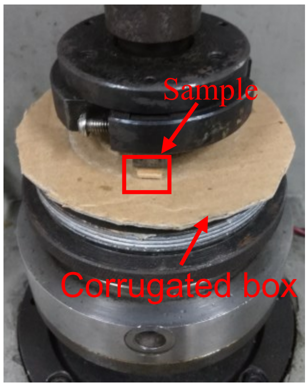
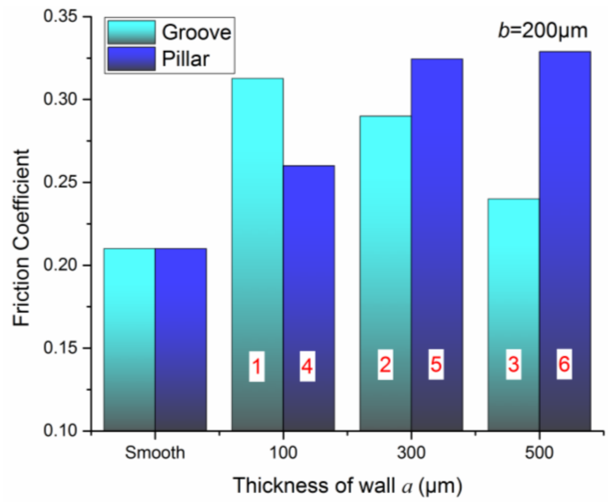


Fig. 4. Friction coefficient test

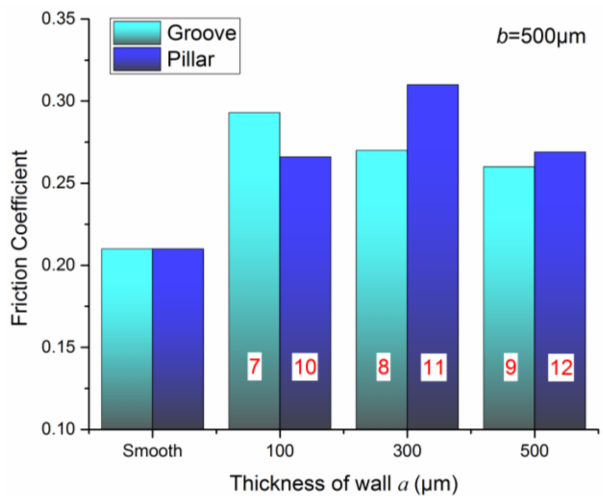
Table 4 Test condition of friction coefficient

Load force (N)	Time(min)	Rotation speed (r/min)
10	3	60

In this research, the friction coefficient of the smooth surface is also being investigated. Thereby, it is possible to exhibit the increase of the frictional resistance of the microstructure. The friction coefficient test results of different samples are shown in Fig. 5.



(a) Samples #1 to #6



(b) Samples #7 to #12

Fig. 5. Friction coefficient of different samples

From Fig. 5, it can be seen that friction coefficient between the smooth wooden pallet and corrugated box, which exhibit a friction coefficient about 0.21, are smaller than micro-patterned ones.

Therefore, microstructures can increase the friction coefficient, due to the corrugated box belong to easily deformable material and has lower elastic modulus. In Fig. 5 (a), for samples #1, #2 and #3, sample #1 has the larger friction coefficient due to it has more burrs and structural damage than others. Samples with pillars, such as samples #5 and #6, has larger friction coefficient than grooved samples #2 and #3. However, Sample #4 has smaller friction coefficient than sample #1 mainly due to the pillars of sample #4 (see Fig. 3 (c)) are damaged and has weak structural strength. Therefore, for spacing with 200μm samples, sample #6 has the largest friction coefficient, compared with the smooth one its friction coefficient was significantly increased by 57% (from 0.21 to 0.33). Fig. 5 (b) shows similar trends with Fig. 5 (a). For spacing with 500μm samples, sample #11 has the largest friction coefficient, which is 0.31.

All of these results show that micro-cutting is an effective method to increase the friction coefficient of wooden pallet surface. More important, the reasonable dimension of micropillars can enhance frictional characteristic obviously. For pine wooden pallets, the dimensions of samples #6 and #11 should be selected in the future design of microstructures.

4. Conclusions

In this research, the wooden pallets with micro-structures are machined by a micro-milling process. Then, the frictional characteristic between the wooden pallet and the corrugated box has been investigated. The experimental results show that sample with a thickness of the groove wall 100μm (samples #4 and #10) have a poor structural strength and not suitable for microstructure design. Moreover, the test results show that, after the micro-cutting process, micropillars (samples #6) can lead to a 57 percent increase in the friction coefficient (from 0.21 to 0.33).

Future work needs to develop the high-efficiency cutter to manufacture microstructure in the wooden pallet surface, such as copying tool or forming technology, which can be used to mass production with a low cost.

Acknowledgements

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