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INFLUENCING FACTOR ANALYSIS OF CHINESE HONEYLOCUST SPINE DAMAGE RATE BASED ON ORTHOGONAL TEST

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In order to reasonably set the working parameters of the Chinese Honeylocust Spine Deburring Machine, based on the results of single factor test, three factors and three levels are selected for orthogonal test. The optimal combination at the given factor level is that sawing speed is 1400 r/min, feeding speed is 24.5 mm/s, the ratio of the branch root diameter to the blade diameter is 0.6. Finally, experimental dates were analyzed, the minimum damage rate of spine is 12.105%. This study provides a theoretical basis for the setting of working parameters of the mechanical deburring equipment of Chinese Honeylocust Spine.

Keywords: Chinese Honeylocust Spine; Rotary sawing; Deburring machine; Test analysis.

1. Introduction

Chinese Honeylocust Spine, alias Saponin, Saponin Needle, is the dry spine of the deciduous leguminous arbors Chinese Honeylocust tree, and traditional Chinese medicine. Traditional Chinese medicine is commonly used in the treatment of diseases such as carbuncle gangrene and abscess [1]. Chinese Honeylocust occupy planting areas in China, which were mainly concentrated in hilly and mountainous regions [2]. As the population ages in China [3-5], it can be help the ecological function developed steadily [6].

It is an effective way to promote the development of the Chinese Honeylocust Spine industry to carry out mechanized operation in the process of removing spine from branch. It is very difficult to harvest the spines, which will hurt the body without attention. During harvesting, protective equipment such as thick gloves should be worn and people cut the spines one by one with scissors [7]. According to the manual deburring method, the deburring machine should have the basic functions of clamping feed and cutting separation. The cutting

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mechanism and feed mechanism are the key behavioral components of the machine, and their parameters have a more direct impact on the picking speed of Chinese Honeylocust Spine, the flatness of the separation section of branch and spine and the damage rate of spine. At present, the researches on stem cutting of agricultural and forestry crops are as follows: Wang Biao et al. used roller, annular saw blade and piston hydraulic rod cylinder to form wood feeding and pruning mechanism, and studied the influence of feeding speed on wood pruning rate through virtual prototype modeling and simulation experiment [8]. Shao Weixing et al. studied the factors affecting the damage rate of oil bracts on the separation device for spike and branch of prickly ash, and obtained the influence of rotary speed of annular blade on the harvesting effect [9].

Dorokhov et al. presented the procedure and results to determine the force action of the separating surface of the developed device on the potato tubers [10]. Jahanbakhshi et al. discussed and stressed upon the importance of these properties in determining the size of the machines, particularly that of the separation, transfer and sorting equipment [11, 12]. Todd west analyzed machine capabilities and productivity regressions to extrapolate existing models to steep slope harvesting of trees up to 115cm diameter [13]. Jyoti Bikram carried out to investigate the effect of blade thickness, approach angle and shear angle on specific cutting energy and cutting index. The results showed that specific cutting energy increased significantly at approach angle(γ) of 30° and shear angle (β) of 20°, and the effect of blade thickness on energy requirement of cassava was not significant [14]. Eduardo Navas established both a design criterion for cutting grippers and a quantifiable way to evaluate and classify a harvesting tool for a specific crop [15]. Since the growth environment and growth characteristics of agricultural and forestry crops are different, it is necessary to conduct independent experimental studies on Chinese Honeylocust. The effects of sawing speed, feeding speed and the ratio of the branch root diameter to the blade diameter on the spine damage rate were studied to improve the deburring performance.

2. Test materials and equipment

2.1 Test materials

The test samples were collected from the planting base of Chinese Honeylocust trees in Song Country, Henan Province, China, and the Chinese Honeylocust tree's species is "Song Country No.3 spine". The sampling time was November 5, 2021. The obtained branches were as straight as possible without diseases and insect pests. The large end of the sample's branch varied in diameter from 4 mm to 14 mm, and the sample's length is cut to 595 mm-605 mm. The branches segment within 600 mm from the trunk are usually relatively straight, suitable for mechanized deburring, and the content of saponin powder in the spines is high, while the branches segment more than the 600 mm away from the trunk are too curved and not suitable for mechanized deburring, and the spines are small, economic value can neglect. After harvesting, the diameter of the branch root and the total number of spines of the branch were recorded on the label, and the number of spines with peeled bark and the number of spines with epidermis remaining on the branch were recorded on the label at the end of deburring work, and the labels were pasted on the branch top. The part of the material that is expected to be used is its spines. The saponin powder in the spines can be used to make traditional Chinese medicine, so the spine must be separated from the branch first. According to the standard (GB/T 1931-2009), the actual measured moisture content ranges from 34.05% to 40.34%. Test materials are shown in Fig. 1.

Fig.1 Test materials

Fig.2 Carbide annular serrated blade used in the test

2.2 Test blade

In the process of mechanical deburring of Chinese Honeylocust branch, it is required that the Chinese Honeylocust spines should be cut along the section parallel to the axis of branch without stubble. According to the principle of wood cutting, the cutting method is rotary sawing, and the annular serrated blade should be selected as the sawing blade. As the sample diameter is less than 14mm, we chose a blade with 15mm aperture for sawing test. The diameter of the tested branches is selected according to the experimental factor “Diameter ratio”. According to this, the test blade shown in Fig. 2 is selected, and the structural dimension parameters are shown in Table 1. The sharpening degree of the blade is in line with common cutting wood cutters.

Table.1

Structural dimension parameters of annular serrated blade

Items	Parameter
Aperture (mm)	15
Taper	1:4
Number of teeth	12
Depth of sawtooth (mm)	2
Rake angle (°)	-10
Relief angle (°)	25
blade material	Cemented carbide

2.3 Test equipment and working principle

The overall structure of the self-made test bench for deburring spines from Chinese Honeylocust branch by sawing is shown in Fig. 3, which mainly includes: Chinese Honeylocust branch deburring machine frame; SW-6236 C tachometer, its accuracy is ±(0.05% + 1), resolution 0.1 RPM; gear reduction three-phase asynchronous AC motor ZV 200-5-S-G1-LD (220 V, 1400 r/min) type, three-phase asynchronous AC motor Y 80 M2-4 0.75 kW-4 (380 V, 1400 r/min) type, frequency converter JTE 330-SM KA0007M1 (0.75 kW, 220 V) type and SKIV100A-7D5G/011P-4 (7.5 kW, 380 V) type; rollers for feeding, etc.

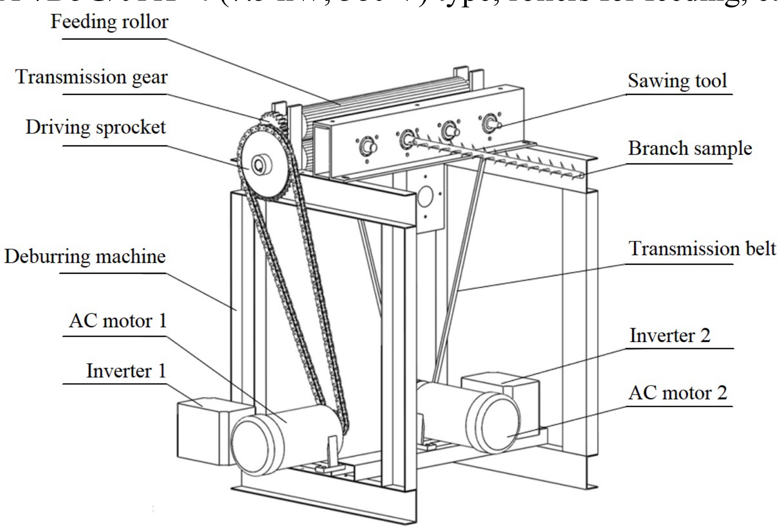

Fig.3 Structure schematic of test bench for deburring

As shown in Fig. 3, the test was carried out on the branch deburring machine. The feed roller was used as a material feeding component and was assembled directly behind the annular serrated blade. The power was transmitted between the two feed rollers through gear transmission. The AC motor1 is connected with the frequency converter and tachometer, and is provided with stable voltage by 220 V power supply. It is fixed on the ground and transmits power to the two feed rollers through chain drive. The blade is fixed on the V-grooved pulley by bolts, the AC motor2 is connected with the frequency converter, and the stable voltage is provided by the 380V power supply. The motor is fixed to the platform on the underside of the frame and transmits power to the V-grooved pulley through tape drive. During the test, firstly, using the tachometer and the frequency converter to adjust the AC motor to the designed speed; secondly, using the frequency converter to adjust the AC motor to the designed speed; thirdly, manually aligning the test sample with the annular serrated blade inlet, and then feeding the branch into the feed rollers, cutting off the front spines by man-machine cooperation until the feeding roller clamps the branches and the branches can be automatically fed; finally, feeding the material automatically by the two feed rollers until a deburring operation is completed. During the sawing process, the position of the branch is manually fine-tuned, so that the curved branch segments can smoothly passed through. The test bench realizes that the blade can be replaced, the feeding speed and sawing speed can be adjusted and can be measured.

3 Test method

3.1 Determination of test indexes

After deburring operation, the damage rate of the Chinese Honeylocust Spine and the residual length of the spine root are the main indicators reflecting the quality of the spine and the performance of the deburring machine. It's important to improve work efficiency and increase economic benefits. In the actual deburring process, the size of the maximum circumscribed circle diameter of the branch and the direction of the fiber are changing in real-time, and the traditional method for measuring the residual length does not meet our needs at this time. The shape of the cross section of the branch is not a regular circle, but a shape close to a circle, which will lead to uncontrollable measurement errors. The performance of the branch deburring machine and the quality of the Chinese Honeylocust spine are measured by the damage rate in order for easy analysis. After the deburring operation, the damage rate can be decomposed into the following formula.

$$r = r_1 + r_2 = \frac{n_1 + n_2}{n_0} \tag{1}$$

where, r is damage rate of Chinese Honeylocust Spine; r_1 is debarking rate of spine; r_2 is bark residual rate of spine; n_0 is the total number of spines. n_1 is the number of spines with peeled bark; n_2 is the number of spines with epidermis remaining on the branch.

Fig. 4 shows the judgment standard of sawing effect of Chinese Honeylocust Spine.

(a) spines with peeled bark (b) spines with epidermis remaining on branch (c) spines of completely cut off

Fig. 4. Judgment standard of sawing effect

3.2 Determination of test factors

The Chinese Honeylocust tree involved in this study is a typical woody plant, and its macroscopic mechanical performance of branch is orthogonal aeolotropy [16]. According to the difference of the cutting edge and the main motion relative to the wood fiber direction, the free cutting of timber is divided into three main cutting directions: longitudinal, transverse and end-grain cutting [17]. Obviously, the cutting of branch is end-grain sawing, as shown in Fig. 5.

In the research of agricultural machinery, cutting is divided into supported cutting and unsupported cutting according to different support conditions. At the beginning of the cutting process, the front parts are cut by manual clamping and feeding until the branch enter the automatic feeding mechanism, and then the branches are clamped and fed by the feeding mechanism. During sawing, the spines are cut from the branches and dropped into boxes for storage, while the branches are carried through the hole of the cutting tool by feed rollers. The sawing blade is works on the principle of single-ended support cutting. Therefore, the size of its linear velocity of the blade and its matching degree with the feeding speed will directly determine whether the root stubble produce tearing phenomenon [18]. The knowledge about cutting resistance, bending stiffness, and impact strength of the energy plants is very important [19]. In order to control the differences in biological characteristics, the same batch of test samples were randomly collected from the same height of a specific Chinese Honeylocust tree, with a uniform length of 600 mm (± 5mm) and a diameter within the range of 4 to 14 mm.

(a) Sawing cross section of branch (b) Sawing cross section of spine

Fig.5 Schematic diagram of sawing cross section

During the feeding process, the ratio of the branch diameter to the blade diameter is reduced in a certain range, which makes the branch have a certain adjustment space when it is sawed, and has a great effect on the sawing of the branch with different bending degrees. Due to its biological characteristics, the real-time diameter of the branch gradually decreases from the main trunk. Therefore, the factor investigated in this study is t the ratio of the branch root diameter to the blade diameter (abbreviated as diameter ratio). During the branch deburring operation, the branch root is firstly sawed, and finally the top is sawed to ensure that the branch will not get stuck in the serrated blade due to the excessive diameter and cause an accident.

3.3 Design of single factor test

According to references [7, 18, 20, 21], three single-factor tests were carried out by selecting the sawing speed, feeding speed and the diameter ratio. Each factor took 3 levels and each level repeated 3 times. In order to exclude the influence of moisture content on the test results, the test samples are all Chinese Honeylocust branches from the same batch, and the moisture content ranges from 34.05% to 40.34%. The branch root diameter was measured with a digital vernier caliper (accuracy 0.01 mm, error ± 0.03 mm). The diameter was measured 4 times in different directions from the position where the branch was cut off and the average value of the diameters was found. The length was measured with a steel tape (error ± 0.2 mm). The length was measured 3 times and the average value of the lengths was found. The moisture content of the test sample was measured with a JN-101MA moisture meter.

(1) There is a critical sawing speed (linear velocity of sawtooth) for the cutting of spines. If the actual working speed is lower than this critical sawing speed, the blade cannot cut the wood fibers at the root of the spines, which will lead to the following phenomena: the spines are cut diagonally, the spines are cut and then skewed but not broken, the spines are split [22]. According to this, the minimum sawing speed of the blade to cut off the spines smoothly is about 370 r/min (at this time, the feed speed is 98.5 mm/s and the diameter ratio is 0.9). Therefore, 400 r/min is taken as the level's lower limit of the sawing speed in the formal test. During the test, test factor is divided into multiple levels [23], and the sawing speeds of 400 r/min, 900 r/min and 1400 r/min were respectively set to saw the spines. The AC motor drives the blade to saw spines at the set speed by adjusting the frequency converter. The test was repeated 3 times at each level, and the total number of spines, the number of spines with peeled bark and the number of spines with epidermis remaining on the branch were recorded to calculate the damage rate and take the average value. The calculation results are shown in Table 3.

(2) By adjusting the frequency converter, the AC motor drives the feed rollers to feed at the feeding speed of 24.5 mm/s, 61.5 mm/s and 98.5 mm/s. The test was repeated 3 times at each level, the damage rate and its average value were calculated. The results are shown in Table 3.

(3) According to the actual working conditions, the maximum circumscribed circle diameter range is generally 5mm-13mm after harvesting. A 15 mm diameter annular serrated blade was customized for sawing tests. The diameter ratio was set to 0.3, 0.6, 0.9, and the error range is ± 0.5 mm. The diameters of the big ends of the samples in each level are very close, and the difference is within 1mm. Due to the biological characteristics of branch, except for individual branches, in the same diameter ratio level, when the diameter difference is less than 1mm, the number of spines contained on the 600 mm branch is basically same. The test was repeated 3 times at each level, the damage rate and its average value were calculated. The results are shown in Table 3.

During the experiment, all the tested branches were randomly selected from the sample bases that met the requirements of level range.

3.4 Design of orthogonal test

On the base of the single factor test results and analysis, the sawing speed, feed speed and diameter ratio were selected to conduct orthogonal test to seek the optimal parameter combination. There is no interaction among the selected three factors through the binary table. According to the principle of "use the small orthogonal table as much as possible" in the orthogonal test, the L9(34) orthogonal table is selected for the test, and the analysis of variance is performed on the test results. The factor levels are shown in Table 2.

Table.2

Factors and levels graph for orthogonal test

Levels	Sawing speed A (r/min)	Feed speed B (mm/s)	Diameter ratio C
1	400	24.5	0.3
2	900	61.5	0.6
3	1400	98.5	0.9

4 Results and discussion

4.1 Results and analysis

All data were analyzed and processed by IBM SPSS Statistics 24, and all plots were drawn by Origin 2019b.

(1) Sawing process

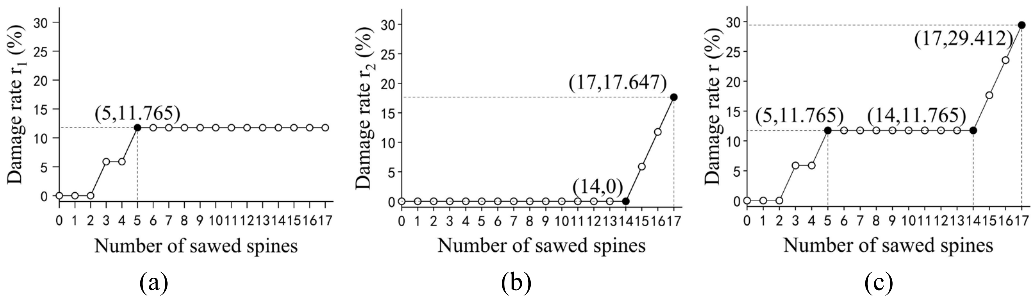

Fig.6 The curve of the damage rate of spines and the number of sawed spines

Fig. 6 is a set of curves reflecting the relationship between the damage rate of spines and the number of thorns that have been sawed, and the experimental data are derived from a random experiment. It can be seen from Fig. 6 that the damage rate increased with the advancement of the sawing process. The damage rate in the former semi-process mainly came from the debarking rate, and the damage rate in the latter semi-process mainly came from the bark residual rate. By observing the process of deburring with a high-speed camera, it is found that the diameter of the branch is relatively large in the former semi-process of the sawing. The allowable radial runout of the branch is little when the blade is sawing. The force arm of the feed thrust is small, the phenomenon of the branch being peeled is easy to occur when encountering relatively curved branch segments. The damage rate increased in the former semi-process due to the increased rate of the branch being peeled. However, due to the biological characteristic of the branch, the diameter of the circumscribed circle at the sawed part gradually decreases with the advancement of the feeding process, and the toughness gradually increases, allowing the branch to have a larger radial runout, so the damage rate gradually stabilized. In the latter semi-process, the diameter of the branch is relatively small, the allowable radial runout of the branch is large, the force arm of the feed thrust is large, it is prone to the phenomenon that spines remain epidermis on the branch when deburring branch. The damage rate increased in the latter semi-process due to the increased rate of spines with epidermis remaining on the branch. To sum up, there is a balance point in the sawing process, which makes the diameter of the branch and the toughness and bending degree of the branch most suitable, and the sawing effect is the best at this point.

(2) Single factor test

Table.3

Results of single factor test

No.	Sawing speed (r/min)	Feed speed (mm/s)	Diameter ratio	Damage rate of Chinese Honeylocust spines (%)			Average of damage rate (%)
Test 1	400	61.5	0.6	42.857	36.364	29.412	36.211
	900			18.182	26.667	21.429	22.092
	1400			14.286	20.000	12.500	15.595
Test 2	1400	24.5	0.6	14.286	13.333	12.500	13.373
		61.5		15.000	20.000	18.750	17.917
		98.5		16.667	20.000	17.647	18.105
Test 3	1400	24.5	0.3	26.667	26.667	21.429	24.921
			0.6	12.500	14.286	18.750	15.179
			0.9	20.000	15.789	21.053	18.947

The Shapiro-Wilke test and F-test were performed on the data using IBM SPSS Statistics 24 software, and the data obeyed normal distribution. Through the observation of the test process and the analysis of the data in Table 3, it is concluded that: Under the test conditions of Test1, the damage rate decreases with increasing of the sawing speed. When the sawing speed is 1400 r/min, the damage rate reaches a minimum of 15.595%. One-way ANOVA was performed on Test 1, and it was found that $F = 12.674 > F0.01\ (2, 6) = 10.93$, indicating that the sawing speed has a very significant effect on the damage rate. Under the test conditions of Test 2, the damage rate increases with increasing of the feeding speed. When the feeding speed is 24.5 mm/s, the damage rate of the spines reaches a minimum of 13.373%. One-way ANOVA was performed on Test 2, and it was found that $F = 6.150 > F0.05\ (2, 6) = 5.14$, indicating that the feed speed has a significant effect on the damage rate. Under the test conditions of Test 3, the damage rate showed a V-shaped change with increasing of the diameter ratio. When the diameter ratio was 0.6, the damage rate of the spines reaches a minimum of 15.179%. One-way ANOVA was performed on Test 3, and it was found that $F = 7.966 > F0.05\ (2, 6) = 5.14$, indicating that the ratio of the branch root diameter to the blade diameter has a significant effect on the damage rate.

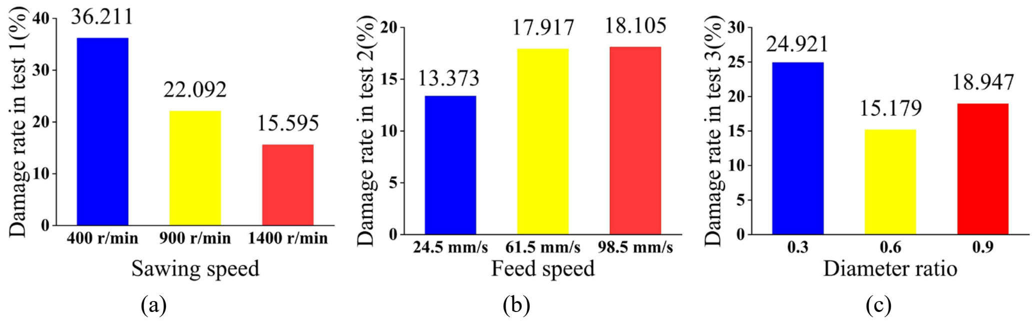

Fig.7 The diagram of index average - factor levels at different tests

As shown in Fig. 7: With increasing of the sawing speed in Test1, the damage rate showed a downward trend, especially when the sawing speed increased from 400 r/min to 900 r/min, the damage rate decreased significantly. With increasing of the feeding speed in Test 2, the damage rate showed an upward trend, especially when the feeding speed increased from 24.5 mm/s to 61.5 mm/s, the damage rate increased significantly. With increasing of the diameter ratio in Test 3, the damage rate firstly decreased, and then increased.

(3) Orthogonal test

Nine groups of multifactor tests were carried out according to Table 2, and the results were visually analyzed. The data are shown in Table 4.

Table.4

Results of orthogonal test

No.	Sawing speed A	Feed speed B	Diameter ratio C	Blank column	Damage rate (%)
1	1	1	1	1	31.579
2	1	2	2	2	25.000
3	1	3	3	3	37.500
4	2	1	2	3	15.789
5	2	2	3	1	23.529
6	2	3	1	2	31.818
7	3	1	3	2	13.043
8	3	2	1	3	19.048
9	3	3	2	1	12.500
K_1	94.079	60.411	82.445		
K_2	71.136	67.577	53.289		
K_3	44.591	81.818	74.072		
R	16.496	7.136	9.719		

where, K_1 represents the sum of the values of the test indicators corresponding to the "1" level, K_2 represents the sum of the values of the test indicators corresponding to the `2` level, and K_3 represents the sum of the values of the test indicators corresponding to the "3" level.

The data in Table 4 shows that the damage rates in the No. 1, 3, and 6 tests were significantly higher than that in other groups; test No. 3 had the highest damage rate of 37.5%; test No. 9 had the lowest damage rate of 12.5%. According to the comparison of the range R value, the primary and secondary factors are the sawing speed > the ratio of the branch root diameter to the blade diameter > the feeding speed. Factor A is the most important factor. The No.3 level of factor A is selected for the test, and the results are better. The second important factor is factor C. The No.2 level of factor C is selected for the test, and the results are better. The effect of factor B on the test results is relatively small. The No.1 level of factor B is selected for the test, and the results are better, that is, A3B1C2 is the best test combination at the given levels. Shapiro-Wilk test of the data in Table 4 shows that the data obeys the normal distribution. The data of orthogonal test were analyzed by variance analysis, and the results were shown in Table 5.

Table.5

Variance analysis of orthogonal test

Factors	Standard deviation square SS	Degree of freedom df	Mean square MS	F	P	Significance
Sawing speed A	408.898	2	204.449	109.624	0.009	**
Feed speed B	79.157	2	39.579	21.222	0.045	*
Diameter ratio C	150.235	2	75.117	40.277	0.024	*
Error e	3.730	2	1.865			
Total	642.020	8				

where, values with * represent significant ($0.01 \leqslant P<0.05$), and values with ** represent very significant ($P<0.01$).

The analysis of variance showed that the factors "feeding speed" and "diameter ratio" had significant effects on the damage rate ($P<0.05$), but the effect of diameter ratio was more significant than the feeding speed; the factor "sawing speed" has a very significant effect on the damage rate($P<0.01$), which is consistent with the primary and secondary order of the influence of the factors on the spines damage rate obtained by the range analysis.

The A3B1C2 test combination did not appear in the orthogonal test, so it was verified by the additional test. The damage rates were obtained as 12.000%, 6.667%, and 17.647%, respectively, with an average of 12.105%. Comparing the average value of spines damage rate of test A3B1C2 with the data in the orthogonal test, it is found that the damage rate of this test combination is the smallest, that is, the intuitive analysis conclusion verifies the data results of the single factor test and the orthogonal test.

4.2 Discussion

A single factor test was carried out with three levels to study the effects of sawing speed, feeding speed and diameter ratio on the spines deburring effect of

Chinese Honeylocust branches. Under the set test conditions, the influence of various factors on the spines damage rate was found. When the sawing speed is 900 r/min-1400 r/min, the feeding speed is 24.5 mm/s and the diameter ratio is 0.6, the deburring effect is remarkable. When the sawing speed is lower than 900 r/min, or the feeding speed is higher than 24.5 mm/s, or the diameter ratio is too small, the deburring effect is significantly worse. The reasons for this problem are as follows:

(1) Under the condition of satisfying the minimum sawing force, the deburring efficiency becomes lower when the sawing speed lowering, at the same time the smoothness of the separation section become worse, which leads to increase the damage rate.

(2) The higher the feeding speed, the less times the spines are sawed per unit time, resulting in uneven wound surface, which leads to increase the damage rate.

(3) If the diameter ratio is too small, the branch has large movement space in the serrated blade, and the spines will escape to the direction of low resistance when sawing. The spine tends to be broken off, rather than sawed off, resulting in a part of the epidermis remained on the branch after sawing, which increases the damage rate. If the diameter ratio is too large, the branch has small movement space in the serrated blade, and when the branch exceeds the bending limit, the branch will be stuck at the blade edge and be peeled off before it can pass the blade, increasing the damage rate.

(4) If the diameter of the branch varies greatly per unit length, only relying on the own weight of the upper feed roller to cooperate with the lower feed roller to clamp and feed the branch, it is easy to appear the situation of insufficient clamping force, which leads to the idling of the feed rollers, and the branch rotates with the blade at a high speed, increasing the damage rate.

To summarize, the following methods can be used to reduce the damage rate. For example, adjusting the rake angle of the annular serrated blade makes the blade sharper. Increasing the elastic coefficient of the reset spring at the upper feed roller, thereby increasing the clamping force of the feed rollers. Therefore, the damage rate will be further reduced, and the branch deburring performance of the deburring machine will be further improved.

5 Conclusions

(1) A test platform was set up to measure the damage rate of Chinese Honeylocust spines on the Chinese Honeylocust branch deburring machine. The branches of the tree species "Song Country No. 3 spine" with a moisture content of 34.05% to 40.34%, a length of 600 (error ± 5) mm, and a large end diameter of 4 to 14 mm were subjected to sawing and deburring.

(2) Through the observation and analysis of the branch deburring process, it is found that the damage rate increased with the advancement of the sawing process. The damage rate in the former semi-process mainly came from the debarking rate, and the damage rate in the latter semi-process mainly came from the bark residual rate.

In the former semi-process, the diameter of the branch is relatively large, the movable space of the branch in the hole of the cutting tool is relatively small, the force arm of the feed thrust is small, the spine is relatively hard and the branch has poor toughness, and it is easy to cause the branch to get stuck at the blade edge and be peeled off when encountering relatively curved branch segments. At this time, the damage rate was mainly derived from the rate of the branch being peeled.

In the latter semi-process, the diameter of the branch is relatively small, the movable space of the branch in the hole of the cutting tool is relatively large, the force arm of the feed thrust is large, the branch has strong toughness, and the spine is prone to be broken off and the branch is prone to remains epidermis. The damage rate mainly comes from the rate of spines with epidermis remaining on the branch.

(3) The single factor test results show that: the sawing speed of the blade has a very significant effect on the damage rate, and with increasing the sawing speed, the spines damage rate decreases; the branch feeding speed has a significant effect on the damage rate, and with increasing the feeding speed, the damage rate increases; the ratio of the branch root diameter to the blade diameter has a significant effect on the spines damage rate, and with increasing of the diameter ratio, the damage rate of the spines first decreases and then increases.

(4) The orthogonal test results show that the primary and secondary order of the factors affecting the damage rate of the spines are: the sawing speed, the ratio of the branch root diameter to the blade diameter, and the feeding speed. When the sawing speed is 1400 r/min, the feed speed is 24.5 mm/s, and the diameter ratio is 0.6, the spines damage rate reaches a minimum of 12.105%. At the time, the damage rate is relatively low, and the deburring performance of the Chinese Honeylocust branch deburring machine is relatively well.

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