The Influence of Microwave Pretreatment to Poplar Mechanical Properties

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Abstract. This paper focuses on the changes of mechanical properties of poplar wood after the microwave pretreatment with different microwave intensity and different irradiating time. The results show that the mechanical properties of poplar wood, such as the modulus of elasticity and the bending strength have decreased when the microwave pretreatment gets lower intensity and shorter irradiating time. But, with the higher microwave pretreatment intensity or longer irradiating time, the mechanical properties of poplar wood has been improved, which is arising from the release of growth stress of poplar wood. After the microwave pretreatment, something have been changed in microstructure of poplar wood, such as the formation of tiny cracks and the membranes rupture, those are contributed to release the growth stress of poplar wood, thereby improve the mechanical properties.

Introduction

In recent years, the wood-processing domain has more and more draw on the microwave pretreatment technology¹¹ to improve the properties of wood, so the wood can be applied better in practical. In order to achieve this goal, the researchers of domestic and overseas have taken many studies and acquired great achievements. For example, in 2011, the research of Vinden and Torgovnikov² showed that the pine had been preserved better after proper microwave pretreatment; Xian-jun Li³⁵ has gotten an achievement in the process of microwave pretreatment to wood and the influence on properties of wood with microwave pretreatment; Kang Xu et al.⁶ have studied the process of wood high-intensity microwave pretreatment based on response surface methodology; Tao Jiang et al.⁷ have discussed the effects of microwave pretreatment on the permeability of eucalyptus grandis; Sheng He et al.⁸⁹ have researched the improvement of wood liquid impregnability by microwave pretreatment and its mechanism, beyond that, they have also researched the application in functional modification after microwave treated wood. In 2014, the research of Yuan Chai¹⁰ about characteristics and mechanism of poplar wood during high-intensity microwave pretreatment indicated that proper microwave pretreatment had a huge influence on permeability and drying properties of poplar wood. The research also showed the microwave pretreatment could make the microstructure of poplar wood change. In 2007, Zhi-Fang Zhou et al.¹¹ found that proper microwave pretreatment could improve the mechanical properties of larch wood.

The poplar wood has spread widely in China, but the application of poplar wood has been limited for looser ingredient, lower strength and rigidity of poplar wood and so on. The mechanical properties of wood is connected with moisture content and permeability of it. In this paper, the microwave pretreatment technology is used to dispose poplar wood to make microstructure and mechanical properties of its change, and the influence of microwave radiation intensity and irradiating time to poplar mechanical properties is also discussed.
Microwave Pretreatment

Experiment Material
The experiment material of this paper comes from the poplar wood growing forest in Yi Yang of China, the size of slab is: 2500mm (length) × 200mm (width) × 25mm (thickness). The moisture content of the slab is above 80% and no obvious flaw. According to the technical specifications, cutting the slab into standard specimen with a saw before microwave pretreatment, which the size is: 300mm (length) × 100mm (width) × 20mm (thickness).

Specimens Grouping and Dispose
Dividing the specimens into eight group and each group has four specimens in microwave pretreatment experiment. There were four group disposed separately by different microwave radiation intensity (including 5kw, 10kw, 15kw and 18kw) and same irradiating time (65s). There were three group disposed separately by different microwave radiation time (including 30s, 50s and 80s) and the same intensity (10kw), another group do not get microwave pretreatment for comparison with the above disposed.

Before microwave pretreatment experiment, making the moisture content of all specimens to the same level. To prevent the moisture loss nonuniformly in horizontal and vertical directions of wood specimen, which may reduce the effect of microwave pretreatment, on both ends for every specimen were disposed with intermixture that combine the ethoxyline with curing agent named T31, which the proportion is 1:0.5. At the same time, using the plastic to wrap the specimen up to reduce the influence by surrounding to moisture content of it until the microwave pretreatment beginning. The prepared specimen is shown in Figure 1.

Experiment Instrument
The instrument of microwave pretreatment experiment named MDF-N40 is shown in Figure 2. The instrument designed and manufactured by Central South University of Forestry and Technology and SYNOTHERM Corporation in Changsha City Hunan Province. The instrument gets the energy from two devices that the largest power of each device is 20kw and the working frequency is 915 MHz. The total power of the instrument can get 40kw. The highest rated radiation intensity can get 2000kw/m². The whole system composed by seven subsystems, they are microwave source system, wave-guide transmission system, cooling treatment system for water circulation, ventilate-hydrofuge system, temperature measurement system, material handling system and electric control system. The instrument have many advantages, such as the bigger microwave power, the higher rated radiation strength and degree of automation, safer operation and so on.

Mechanical Properties Experiment
Test Specimens Grouping
According to the method of sample logs sawing and test specimens selection for physical and mechanical tests of wood (GB/T 1936.2-2009), issued by General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ). All the
specimens that have no obvious flaw after microwave treatment were processed into standard mechanics specimens. The specimen size of mechanical experiment is: 300mm (length) × 20mm (width) × 20mm (thickness) which is shown in Figure 3. Mechanics experiment group corresponds to the microwave pretreatment group and each group has five specimens.

Test Method and Instrument
After the moisture content of mechanics specimen has gone down to about 10% by air-seasoning, the mechanical properties experiment has been done according to the national standard named (GB/T 1936.2-2009). The elastic modulus of bending and bending strength are measured with the instrument named MWD-W10 produced by Ji Nan Shi Jin Group Co. Ltd. Firstly, putting the specimen on the instrument as shown in Figure 4. The span of instrument is 240mm, loading rate is set to 5mm/min and along the chordwise. The curvature radii of the pressure head and the bearing ends are 30mm. The elastic modulus of bending experiment is shown in Figure 5, and the bending strength experiment is shown in Figure 6. The data output is completed by computer directly.

Results and Discussion
The Influence on Mechanical Properties of the Poplar Wood after Microwave Pretreatment with the Same Radiation Intensity and the Different Irradiating Time
With the same microwave radiation intensity and different irradiating time, the results of elastic modulus of bending and bending strength for microwave pretreatment specimens and no microwave
pretreatment specimens are shown in Table 1. The data are the average value of the five mechanics test specimens of each group under the same experiment conditions.

![Figure 5. Bending test of elastic modulus.](image1)

![Figure 6. Bending strength test.](image2)

Table 1. The mechanical properties comparison of untreated group and treated group with same radiation intensity and different irradiating time.

<table>
<thead>
<tr>
<th>Experiment Parameters</th>
<th>Bending Modulus of Elasticity (GPa)</th>
<th>Bending Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation intensity (kw)</td>
<td>Irradiating time (s)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>5.16</td>
</tr>
<tr>
<td>10</td>
<td>65</td>
<td>4.08</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>3.15</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>3.25</td>
</tr>
<tr>
<td>Untreated</td>
<td></td>
<td>3.61</td>
</tr>
</tbody>
</table>

From Table 1, when the microwave irradiating time within 50s, the elastic modulus of bending and bending strength of poplar have slightly decreased with microwave pretreatment, the decrease range is from 8% to 13%. The main reason to reduce is the formation of tiny cracks in poplar by microwave. The elastic modulus of bending and bending strength of poplar have been improved when the microwave irradiating time gets longer, which mainly due to the enough releases of growth stress by tiny cracks in poplar, that makes up the loss of tiny cracks to material strength, thereby improves the mechanical properties.

Table 2. The mechanical properties comparison of untreated group and treated group with the same irradiating time and different radiation intensity.

<table>
<thead>
<tr>
<th>Experiment Parameter</th>
<th>Bending Modulus of Elasticity (GPa)</th>
<th>Bending Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treated</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irradiating time (s)</td>
<td>Radiation intensity (kw)</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>18</td>
<td>5.51</td>
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<td>65</td>
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<td>Untreated</td>
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<td>3.61</td>
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</tbody>
</table>

**The Influence on Mechanical Properties of the Poplar Wood after Microwave Pretreatment with the Same Irradiating Time and the Different Radiation Intensity**

Under the conditions of same irradiating time and different radiation intensity, the results of elastic modulus of bending and bending strength of the poplar wood for microwave pretreatment specimens and no microwave pretreatment specimens are shown in Table 2.

From Table 2, the elastic modulus of bending and bending strength of poplar have slightly decreased with microwave pretreatment when the microwave radiation intensity within 5kw, the decrease range is from 8% to 9%. The main reason for reducing is the formation of holes in poplar by microwave, making the flexibility of cytoderm increase. But, when the microwave radiation intensity gets higher, the elastic modulus of bending and bending strength of poplar have been improved. The elastic modulus of bending has increased remarkably as strength attains to 18kw, the
range reached to 52.6% and the bending strength increased by approximately 20%. The primary reason to that is the high power microwave radiation changes the internal structure of poplar into lengthways unimpeded network structure, so the water inside of wood diffuses faster and more equilibrium, thereby improves the mechanical properties.

Conclusion

The influence of microwave pretreatment to poplar mechanical properties are changed with the microwave radiation intensity and irradiating time. When the radiation intensity below 5kw and irradiating time less than 50s. The mechanical properties of poplar reduced slightly, the decrease range was from 8% to 13%. However, when the microwave radiation intensity gets higher or irradiating time gets longer, the elastic modulus of bending and bending strength of poplar have been improved. According to the results, it is effectively to change the rheological property of poplar by microwave pretreatment method. There is great economic significance and application prospect to make poplar contributing to the national construction.

Acknowledgement

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References


