

A Study on the Technique and Process of Bending Wood¹

Hyung-Goo Kang²

ABSTRACT

Materials are such an important factor in designing furniture. Wood is the biggest part of furniture materials. While wood is soft, eco-friendly and natural material, it is variable because it is characterized by severe expansion and contraction. Thus, if the changeable characteristic of wood is not considered in furniture design, the good design of furniture cannot be produced. As one of the skills dealing with woods, bending is such a useful way for making various forms of furniture. While it has been used in furniture-making for a long time, wood processing techniques like steaming bending, bending with ammonia and high frequency bending has been advanced. As wood is a viscoelastic material and has some plasticity, beautiful curves can be created when force is applied. Therefore this paper studies the types of bending methods for furniture and each characteristic of them. Furthermore, this study classifies wood process according to suitability for mass production or small-scale production and researches the proper wood process by the forms and the way of furniture production. Also this study aims to help furniture designers and cabinet makers with wood bending.

Key words: Wood bending, Design, Furniture.

요약

가구를 디자인하는데 있어서 재료는 매우 중요한 요소이다. 목재는 가구 재료 가운데 가장 많은 부분을 차지하고 있다. 목재는 자연 재료로 부드럽고 환경 친화적인 반면에 수축과 팽창 같은 변화가 심해 목재가 지닌 특성을 고려하지 않으면 올바른 디자인을 할 수가 없다. 목재를 다루는 기술 가운데 휨 가공법은 가구의 다양한 형태를 만들어내는데 매우 유용한 기술 가운데 하나이며, 오래 전부터 가구제작에 사용되어 오면서 증기, 암모니아, 고주파 등 가공방법에 관한 기술적 발전을 가져왔다.

목재는 점탄성 물질로 약간의 가소성을 가지고 있어 힘을 가하면 아름다운 곡선을 만들 수 있는 재료적 특성을 가지고 있다. 따라서 이 논문은 지금까지 가구제작에 사용되어 온 휨 가공법의 종류와 그 특성들을 조사하여 대량생산 또는 소량생산에 적합한 방법들을 체계적으로 분류하여 가구의 형태와 생산방식에 따라 어떠한 가공법을 사용하여야 되는지를 연구하고자 한다. 이번 연구를 통해서 휨 가공방법의 장점은 가구디자인에서 디자이너의 다양한 아이디어를 표현할 수 있는 기술적 방법의 한 가지라 할 수 있다. 분석결과 증자처리 휨 가공은 다품종 소량생산에 적합하고, 암모니아 휨 가공은 스프링 백 현상이 없으며 다양한 자유곡선의 형태 가공에 적합한 방법이라 할 수 있다. 대량생산에서는 고주파 가공이 많이 사용되며, 거단 휨 가공은 작업방법이 용이했고, 적층 휨 가공은 가장 일반적인 가공법으로 소량 또는 대량생산에

Received for publication: Jun 30, 2010 ; Reviewed: Jul 25, 2010 ; Accepted: Nov 17, 2010.

1) This study was supported by the Research Grant of Kyungil University 2010, Kyungsan, Korea.

2) 2 Dept. of Crafts Design, Kyungil University, Kyungsan, Korea (E-mail: kanghg67@hotmail.com).

모두 적합한 가공법이라 할 수 있다. 또한 이 연구를 통해 많은 가구 디자이너와 제작자들이 목재의 휨 가공에 도움을 주는데 목적이 있다.

1. INTRODUCTION

1-1 Purpose of Study

The understanding of material property and process is essential to designers in furniture making. Wood has been known as the oldest material which was used by human. It is also a familiar, universal and high -quality material comparing to other materials. Wood process and furniture making techniques have been advanced. Above all, bending wood makes it possible to curve wood in various desired shapes. In addition to furniture, wood bending methods has been used to make tools like musical instruments, ships, bows and wheels that are necessary to human life. Especially in the end of the 19c, Bent-wood chair by Michael Thonet created a new style of furniture with distinctive design as well as laid foundation for mass-production furniture.

Now that I regard wood bending methods as a crucial technique for furniture design, this study aims to analyze wood bending methods and their characteristics and help with furniture design and making. Also I hope this study will be of some help in figuration technology of design in general as well as wood craft and furniture design techniques. So much the better, if this study becomes the foundation for the development of working on wood bending.

1-2 Range and method of study

This study deals with general consideration about bending wood and analysis the kinds of bending wood methods which are used in fields like furniture makers, small-scales of carpentry shops and schools and analyzes the properties of their each process.

In the case of same woods, this study analyzes pros and cons of bending process according to the properties of materials like solid wood, plywood and M.D.F and also searches method of application depending on processing methods.

The study was done by considering domestic and foreign bending-related literature, collecting data such as internet materials and other thesis they might be helpful and by analyzing various works of different designers. And above all, this study was achieved by visiting furniture makers directly.

2. Main Discourse

2-1 General consideration of bending

As bending wood is such an important skill that makes it possible to curve wood in various desired shapes, it has been used to make tools like musical instruments, ships, bows and wheels that are necessary to human life. The bending wood process is called bent wood, it is made by applying artificial bending-force depending on uses and shapes, not bent naturally.

Windsor chair might be the beginning of bentwood furniture that was built in the local big town of Windsor, England, in the beginning of 1730s(In Kwon Kim 2000) and it became the origin of mass production furniture in the middle of the 19th century.

With the introduction of steam bentwood furniture in The London Great Exhibition in 1851, Michael Thonet had an effect on developing a steaming process for furniture. After then, he set up a furniture making factory with mass production methods and began to produce innovative

bentwood furniture in large numbers. The <no.14> chair was considered representative bentwood chair, which was produced in large numbers. Also, John Henry Belter from German, he highlighted the bold embellishment of furniture using laminated bentwood. Thin layers of rose wood (1/16inch) were glued and pressed together with the grain running in opposite directions, then steamed in a mold to produce a desired curved form. He called the laminated bentwood 'plate type', drilled the hole through the bentwood and carved decorations on it. His specific process made existing ways of working simple and made it possible to carve more finely and deeply. (Kyung Jik Yang 1986)

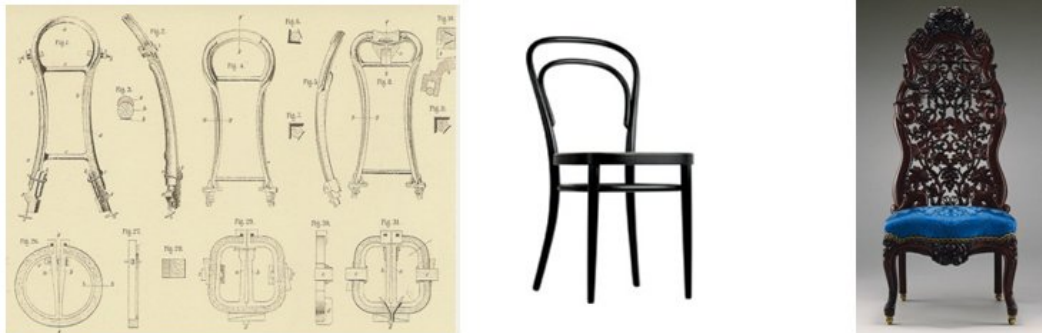


Fig. 1. steam bending forms(1856) and NO. 14 chair(1812) of Michael Thonet, (left) slipper chair of John Henry Belter, 1850-60 (right).

The bentwood process appeared in the 19th century influenced advanced designers like Otto Wagner and Josef Hoffman to develop many forms of furniture. Otto Wagner designed 'armchair' in 1906 and Hoffman designed <model no.330> and < no.670> in 1902 and 1908 respectively.(Han Min Jung, Kim Jin Woo ,2003)

In the 1930s, with the bentwood skill, Alva Alto, Finland, made a profound difference in furniture in Scandinavia. And Karl Mathsson and his son Bruno Mathsson, Sweden, expressed smooth forms with solid structure through the bentwood process.



Fig. 2. armchair of Otto Wagner, 1906(left), chair No. 670 of Josef Hoffman, 1908(middle), paimio armchair of Alvar Aalto, 1931(right)

2-2 Types and properties of bending

2-2-1 Steam bending

Boiling hot water process or steam bending uses steam or boiling water to plasticize the wood

so that it can be bent. When wood is steamed, the heat and moisture soften its fibers and permit the piece to bend. But pressurized steam doesn't help much, because it makes the wood compressed wrinkled or the resistance of curvature increases with moisture less. Steam bending is always subject to spring back. The distortion caused by steam bending tends to bring the bent piece back to its original shape after drying. To minimize it, the wood is forced around a mold and clamped in position until it is dry.

But the advantage of steaming is getting more beautiful, longer and clearer grain than curved wood by band-sawing because the grain of the wood follows the curve of the surface, thus wastes little or no materials (William A. Keyser 1989)



Fig. 3. steam box for wood bending.



Fig. 4. Steam bent wood bench, Se-Hwa Bae.

2-2-2 Bending with Ammonia

Among the bending techniques, using of liquid ammonia is known as a good way to plasticize lignin in the green wood as well as to soften the matrix bonds in wood by swelling cellulosic hydrogen bonds in cell walls.

The liquid ammonia technique of wood plasticization turns gaseous ammonia into ammonia vapors. After prolonged exposure to the ammonia vapors, wood is softened. Bending with ammonia removes spring back unlike other bending processes and has an advantage of curve reducing the radius of curvature. In other words, liquid ammonia permeates the matrix bonds in cells and dissolves the lignin matrix. In the end, wood is softened and it might be curved depending on the force. Ammonia plasticizes the fibers more quickly and more completely, yet the wood treated with ammonia tends to be curved under even a little pressure. In the process, it is important to note that liquid ammonia is chemically pure NH_3 , whereas household ammonia is a dilute solution of ammonia gas in water. Bending process with household ammonia will not bend wood. Also ammonia vapors are extremely dangerous to the eyes and the lungs and during vaporization, lots of

smog caused by heating can damage to the body.

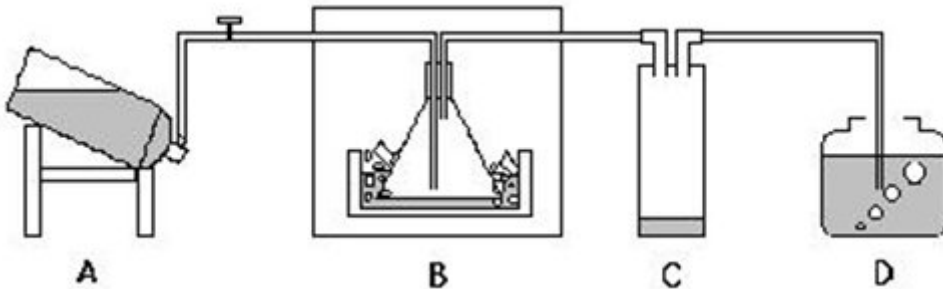


Fig. 5. Equipment of extracting liquid ammonia. A bombay ; B refrigerator; C water tank; D solution water.



Fig. 6. sample works.

2-2-3 High Frequency Bending

High Frequency Bending is a method of generating microwaves of 100~120 degrees from a high -frequency generator and bending wood by press with high pressure (120~1500 kg/cm²). Thin slices of wood such as veneer, M.D.F and various sheets like HPM and LPM are held by a glue and put into the wooden mold or metallic mold to bend the desired shape. When high frequency waves go through wood, heat is caused by the movement .

The heating process is done using these high frequency waves. When the high frequency microwaves flow into the wood, it causes electricity. The molecules constructing the material itself, has a bipolar characteristic. These bipolar molecules respond to the direction of the electric field comes from the external source, but when the frequency becomes higher, they become more independent resulting a friction between the vibrating and rotating molecules. The friction generates heat to the wood. Using the heat, the wood can be curved.

As the high frequency shaping has a possibility of second distortion, precise wooden mold or metal mold is necessary to prevent the problem. Adhesive and process technique is the highest degree of skill that can be got only through the long experiment and experience. Without technical know-how of skilled and experienced workers, curved plastic products could not be completed.

The existing way heating wood is that external heat sources are transferred to heat the surface by heat ray, radiant heat or heating plates contact and pressure. There were lots of problems with it, because heat conduction is extremely low inside. However, as High Frequency waves heat the inside of the material, the internal temperature is heated more rapidly and uniformly than the surface.

So regardless of the thickness of wood, molding can be done with surface undamaged.

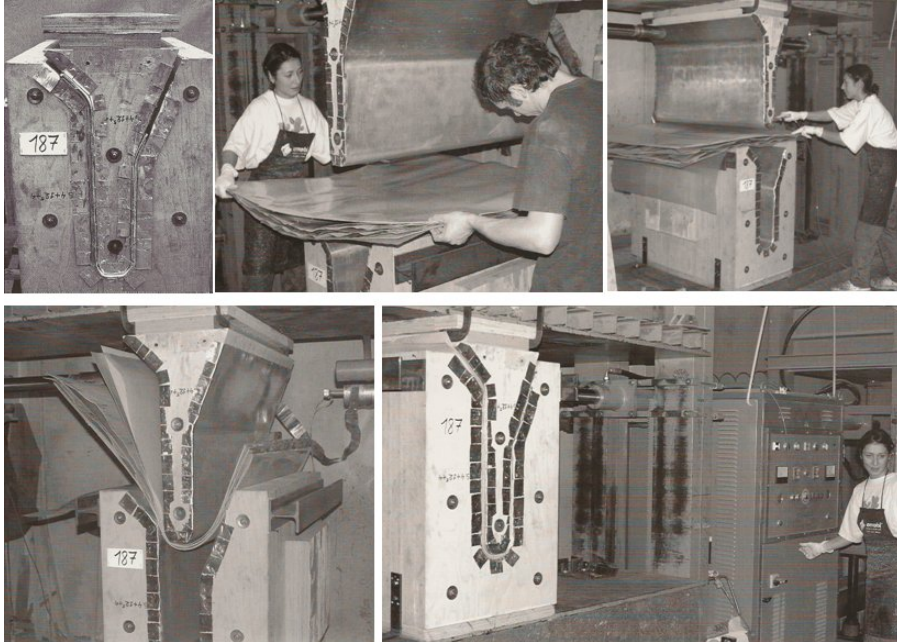


Fig. 7. process of high frequency bending.

2-2-4 Kerf Bending

Kerf bending is to make a saw kerf on the inner surface of the material to bend wood. It is also used in 'Woon Gak' - of our traditional small portable table.

As the wood can be bent after drying when kerf-cuts are done on the concave side of the piece, it is so simple and economic method. Kerf bending is possible without a mold and especially suitable for a S-shaped curve. This is usually used in 'bull nose step' of stair or round pillars of cabinet corner, that is, the part where only one side is exposed. One notice about Kerf bending is the gap calculation between sawing and reinforcement work after bending. In order to make a uniform curve, sawing should be done at regular intervals and at the beginning spot of curve, saw cuts should be done with at least 3mm left in the direction of thickness of wood. (albert jackson etc. 1996) As glue is applied so that the saw cuts are filled, that is, just on the cuts, it has a weak adhesive strength comparing to other bending skills. In order to reinforce this problem, pattern wood is glued on the inner side of the curve with the grain paralleled.



Fig. 8. Kerf bending process.

2-2-5 Bent Laminations

Bent lamination is a process to glue thin layers of wood pressed in the frame of mold each wants. The layers are made by bending and gluing parallel grained layers of wood into the desired shape unlike plywood with the grained crossed .Thus the layers can be curved with a small radius and cutting plane of the layers follows the curve. And if the layers are built up with different woods, it's possible to get a variety of visual effects. This is also suitable for bending boards like plywood other than hard woods. However, there is one visual shortcoming in this method. Sealing lines are supposed to be exposed when the sides are grinded out or are cut so that the both side would be narrow.

This method has a difficulty in making a frame correct. And it is so crucial to fix the layers while pressing the frame with presses and clamps. Generally it is desirable to make both male and female mold for bending, yet, in the case of smooth curves, bending can be done with only a male mold.

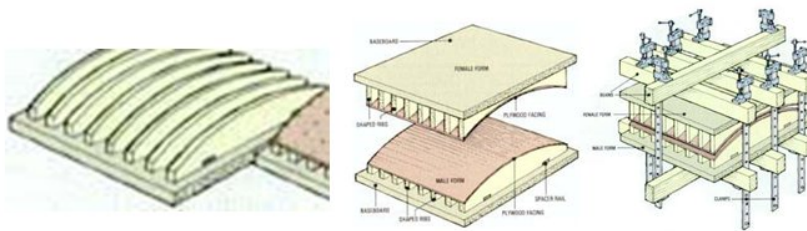


Fig. 9. laminated bending process.

2-2-6 Analysis according to the types and works





The five types of wood bending have their own strength and weakness. This chart shows the properties and pros and cons of 5 types of wood bending. Steam bending is suitable for a small sized production as well as mass production. Bending with ammonia has an advantage of curve reducing the radius of curvature and no spring back. High frequency bending is the best way of mass product. Kerf and laminations bending are suitable for small wood studio and working man-made boards.







Table 1. characteristic of bending method

Types	characteristics	merits	faults
bending with steam	<ul style="list-style-type: none"> - bending with steam - curves follow the grain - different curves according to the sort of wood - used for a hard wood 	<ul style="list-style-type: none"> - simple installation - suitable for a small sized production as well 	<ul style="list-style-type: none"> - subject to spring back - limits depending on materials
bending with ammonia	<ul style="list-style-type: none"> - bending with liquid ammonia - different curves according to the sort of wood - used for a hard wood 	<ul style="list-style-type: none"> - no spring back - a variety of curves 	<ul style="list-style-type: none"> - harm to the body - limits to materials

<p>high frequency bending</p>	<ul style="list-style-type: none"> - bending with high frequency wave of 120~1500kg/cm² - wooden or metal mold needed - good for mass production - good for both a hard wood and man-made board 	<ul style="list-style-type: none"> - heating uniformly for a short time - able to be chosen partly and heated effectively - used widely thanks to ease in process 	<ul style="list-style-type: none"> - high cost of equipment - bad for small sized production - waste of electricity
<p>kerf bending</p>	<ul style="list-style-type: none"> - bending with saw cuts - used for a hard wood 	<ul style="list-style-type: none"> - molds not required - ease of process 	<ul style="list-style-type: none"> - weaker than other methods - finishing work needed because of sealing lines of body sides
<p>laminated bending</p>	<ul style="list-style-type: none"> - bending with the thin layers molded - molds absolutely needed - good for body a hard wood and man-made board 	<ul style="list-style-type: none"> - suitable for small studio of woodworkers - suitable for a small sized production as well 	<ul style="list-style-type: none"> - a correct wooden mold needed - subject to spring back

Table 2. example of bending works

Types	bending works	
<p>bending with steam</p>	 <p>Se-hwa Bae, steam_10</p>	 <p>Se-hwa Bae, meditation</p>
<p>bending with ammonia</p>	 <p>Hyung-goo Kang, drawer</p>	 <p>Hyung-goo Kang, chest</p>

<p>high frequency bending</p>	 <p>Sun-tae Kim, bowl</p>	 <p>Kyung-won Kim, sides</p>
<p>kerf bending</p>	 <p>Takeshi Daimon, chair</p>	 <p>Ken Picou, mirror</p>
<p>laminated bending</p>	 <p>Alvar Aalto, stool</p>	 <p>Hyung-goo Kang, book holder</p>

3. Conclusion

Wood bending methods started from the steaming bending using hot vapors in the middle of the 19th century. This technology has been developed in many ways and nowadays it is used furniture, musical instruments, interior fittings that are need for the life. Regardless of the historical background of the bending, the skill has not been widely adopted other than mainly in the part of chair in craft. By classifying a variety of bending skills and analyzing their bending methods and properties respectively, this information of the study is expected to helpful for the younger students to make products for life as well as furniture.

According to the analysis of the research, steam bending is suitable for a small sized production as well as mass production. Bending with ammonia has an advantage of curve reducing the radius of curvature and no spring back. So, it is the best way of working perfect forms. High frequency bending is the best way of mass product. Kerf and laminations bending are suitable for small wood studio and working man-made boards. One of the advantages of bending is a kind of skill with which designers can express their ideas and thought. In order to acquire this skill, it is necessary to understand the problem of choice of materials, process methods depending on the materials and how to preserve the shapes after process. Finally, through this study, I hope that various bending skills will be developed systematically.

4. Bibliography

- Ho-Yang Kang • Hyung-Goo Kang. 2001. Design Using Bent Wood Plasticized with Liquid Ammonia. Korea Furniture Society, vol. 12. no.2.: 13.
- In- Kwon Kim. 2000. A Study on Bent Chair Design. KunKooK University, Master's thesis: 23.
- Kyung-Jik Yang. 1986. A Study on Bent Chair. Hongik University, Master's thesis: 8.
- Min-Jeong Han • Jin-Woo Kim. 2003. A Comparative Study on the Characteristics of Chair Design of Alvar Aalto&Arne Jacobsen. Korea Furniture Society, vol. 14. no.1.: 94.
- Albert Jackson etc. 1996. The Complete Manual of Woodworking. Alfred A Knopf : 251.
- Bariska etc. 1969. Studies of the Wood-Anhydrous Ammonia System. Wood Science 2 : 65-73.
- Bill Keenan. 1989. Fine Woodworking on Bending Wood. The Taunton Press: 15.
- Dung Ngo. Eric Pfeiffer. 2003. Bent Ply. Princeton Architectural Press: 24, 34, 93-99.
- William A. Keyser. 1989. Fine Woodworking on Bending Wood. The Taunton Press: 16.