Folding Thick Materials Using Lattice Hinges

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Abstract

When applying origami, a traditional Japanese play, to industrial products, materials that cannot be ignored in thickness are used. Therefore, Ku (2017) devised a new hinge pattern to realize origami made of thick materials. By using this hinge pattern, even a thick material can be bent up to 135 degrees. It also works stably. However, to realize this pattern, there is a problem that a process of bonding a laser-cut board and paper is essential. Based on the previous research, we propose an origami structure that uses a lattice hinge as a new hinge pattern that does not require processes such as laminating materials, which is a hinge pattern that applies a technique that can be bent like a hinge by processing a pattern called a lattice hinge on a thick material with a laser cutter. Then, it is shown that the origami structure can be realized by actually using a laser cutter. Furthermore, a folding box is proposed as an application example of a hinge pattern using a lattice hinge.

Keywords: *Lattice hinge, Structural origami, Laser-cutter*

1. Introduction

Origami is known as traditional Japanese play, but it is sometimes applied as an industrial product. Usually, the paper is used for origami, but its thickness is negligible. However, industrial products use materials that cannot be ignored. Therefore, origami cannot be applied to industrial products. Therefore, Ku (2017) proposed a method of origami with thick paper in order to realize origami with thick materials. It is a hinge pattern consisting of three layers of MDF and paper. The paper is inserted between two MDFs processed by a laser cutter and bonded together with a bond. By using this hinge pattern, even a thick material can be bent up to 135 degrees.

Figure 1 Ku (2017)'s structural origami

However, in order to realize this pattern, a step of bonding a laser-cut plate and paper is essential. It is more complicated than paper origami. Based on this previous research, we have proposed an origami structure that uses a lattice hinge as a new hinge pattern that does not require processes such as laminating materials.

Lattice hinge is a hinge pattern processed by a laser cutter and can bend a thick material. Origami structures using lattice hinges have a bending radius and can be bent up to 180 degrees. Furthermore, a folding box is proposed as an application example of the origami structure using the lattice hinge. It is an example of using an origami structure to create a three-dimensional object by simply folding a thick material.

2. Background

2.1 Lattice Hinge

Lattice hinge is to give one-dimensional flexibility to a plate-like material by machining a slit-like hole using a laser cutter or the like so that the original plate can be bent. Although there is no particular designation of the material, it is necessary to make slit-shaped cuts on ordinary boards, so wood and metals that can be processed by CNC or laser cutters are examples. There is no Japanese name, and it is called a lattice hinge in the overseas digital fabrication community, and in this paper, it is called a lattice hinge. Lattice indicates a partition that is arranged periodically. Hinge is a part that can be opened and closed by a hinged door or lid. In other words, the lattice hinge is a mechanism that applies a periodically arranged grid to the hinge. Lattice hinges have to be processed individually for each material and are not suitable for mass production. However, it is a very effective processing method for digital fabrication that produces small quantities for multiple purposes.

Figure 2 Lattice hinge

2.2 How a lattice hinge works

Lattice hinges are separated by parallel cut patterns, and lattice hinges are continuous patterns. Each row is twisted along its length. By twisting about the axis of these twisted links allows the plate to bend. The flexibility of the joint is determined by the material properties of the plate and the geometry of the torsional link (overlapping cut length and cross-sectional area). There are several parameters to control the lattice hinge. Arbitrary angles and bending radii can be realized by setting parameters obtained from Figures 3 and 4.

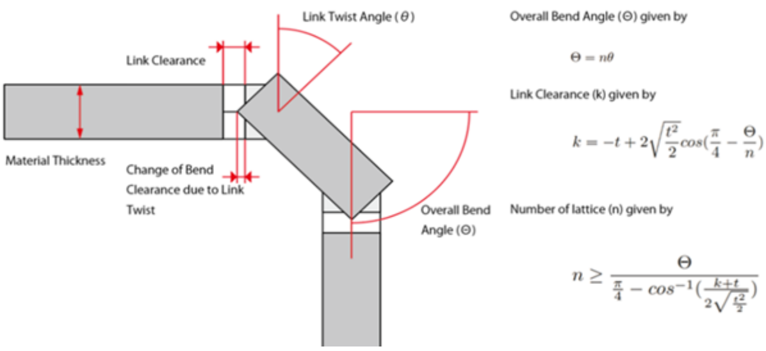

Figure 3 Lattice hinge mechanism

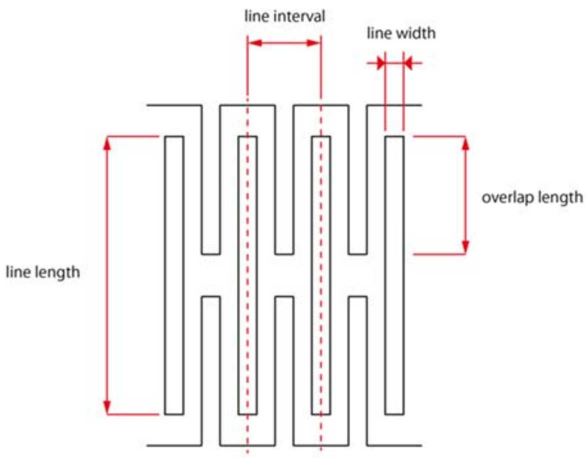

Figure 4 Lattice hinge parameter

3. Material and Methods

3.1 Structural Origami with Lattice hinge.

In order to apply origami to industrial products, the thickness of the material cannot be ignored. Considering the thickness, origami, which had been considered as a plane, must be considered as a three-dimensional object. Since the MDF board used as a material in this study has a thickness, the act of "folding" itself is physically impossible. However, it is possible to fold a thick material by modifying the fold pattern. We thought that by using a lattice hinge for the fold pattern, it would be possible to fold the MDF board like origami.

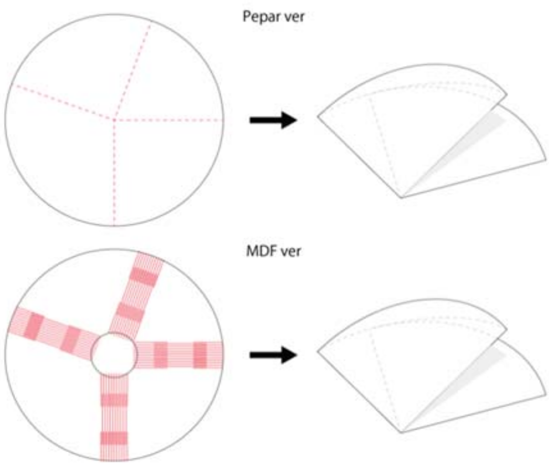

Figure 5 How does folding paper and MDF

3.2 Experiment Structural Origami MDF version.

Based on the findings obtained in the previous section, the model reproduced on a 4mm MDF board is shown in Figure 6, applying the lattice hinge model to the origami structure. We tried to reproduce an origami model using a lattice hinge with an MDF model with thickness. In order for the lattice hinge to behave like a fold, the bending angle of the lattice hinge must be 180 degrees, and the bending radius must be close to 0. Therefore, there are various parameters.

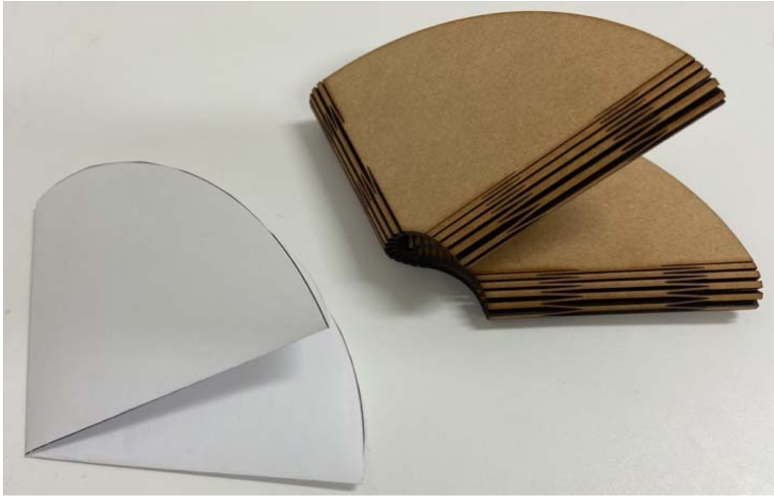

Figure 6 Folding model with lattice hinge

4. Result and Discussion

4.1 Result

By adjusting the parameters of the lattice hinge, as shown in Figure 6, an origami structure using the lattice hinge could be realized.

The details of the origami mechanism that uses the lattice hinge are described below. It depends on the relationship between the object to be produced and the thickness of the board used. In general, it can be said that it works without breaking if the board is thin and the work is large.

4.2 Difference between paper and MDF board

When trying to achieve 180-degree folding, the paper has no concept of thickness, so it is possible to fold 180 degrees completely. However, when using a lattice hinge, there is the thickness of the material, so it is impossible to fold 180 degrees completely. There will be some fold radius at the fold. Also, in the case of paper, the folded state can be maintained by creased paper. Nonetheless, in the case of the lattice hinge, when folded, the material acts like a spring that tries to return to the unfolded state. In some cases, an external force may be required to maintain the folded state.

4.3 Crosspoint pattern in Lattice Hinges

The intersection of the lattice hinges can be made to work by cutting the half-line from the intersection, as shown in Figure 7. However, if the angle between adjacent lattice hinges is too small, it will be difficult to function because the overlapping parts will increase. For example, it can be said that the loss is the least when two lattice hinges intersect at 90 °. In the model shown in Figure 5, the crossing center is cut in a circular shape.

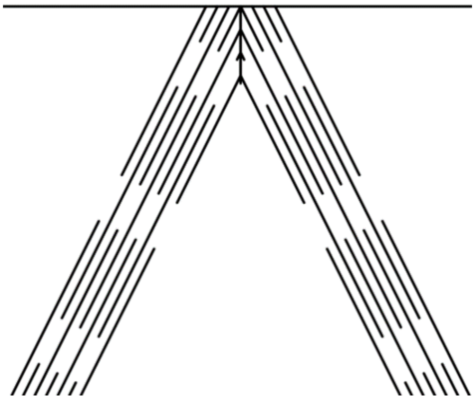

Figure 7 Cross point of lattice hinges

4.4 Width of Lattice Hinge

In order to operate the lattice hinge stably, a certain length of the lattice is required. Besides, the lattice and the width of the lattice are also important, and one lattice hinge should have at least two of these parts. In other words, an ideal Lattice hinge has a certain minimum length.

4.5 Folding Box

A folding box is proposed as an example of applying a hinge for an origami structure using a lattice hinge.

The Folding Box is completed by applying a lattice hinge to the hinge part and folding it from one place. A key shape is used to connect the end planes, and this is a connection method unique to thick material. Processing data is shown in fig.8. Fig.9 shows the assembled Folding Box.

Also, since the Folding Box is designed by the program using the Python function of Rhinoceros, it is possible to generate various types of Folding Box from one program by adjusting the size parameters such as height and width. is there. Fig.10 shows how the program is executed.

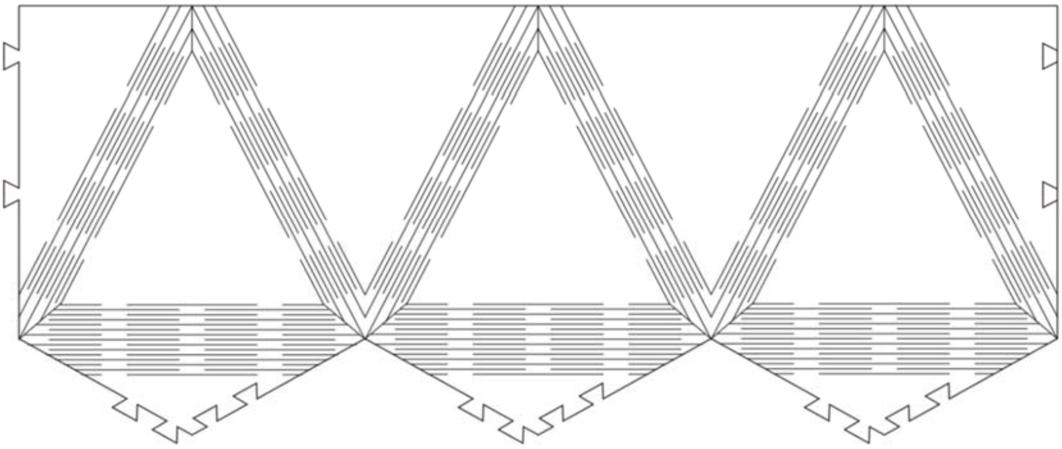

Figure 8 Draw for folding box

Figure 9 Folding Box

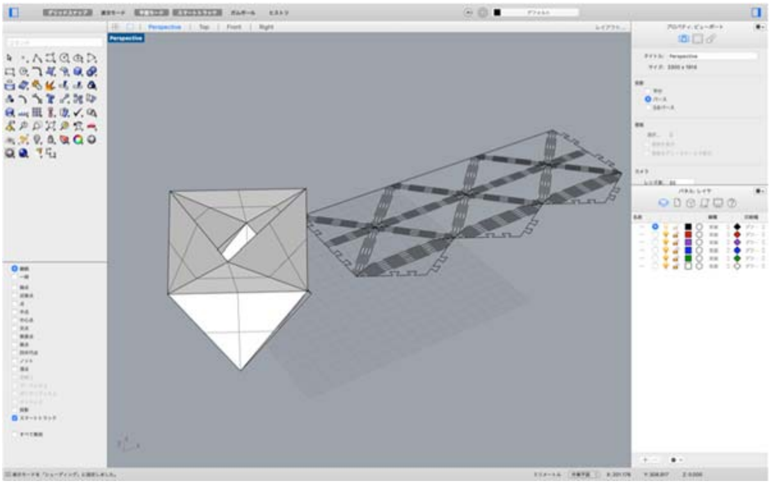

Figure 10 Rhinoceros with python

5. Conclusion

5.1 Conclusion

The hinge using the Lattice hinge can be easily manufactured as compared with the folding mechanism proposed by Ku(2017), and the bending angle can be adjusted by appropriately adjusting the parameters of the Lattice hinge. Also, a folding box was proposed as an example of applying a Lattice hinge.

5.2 Advantage

The bending angle can be adjusted by adjusting the length of the lattice hinge.
The hinge can be made only by laser cutting.

5.3 Disadvantage

Due to the bend radius, it cannot be bent exactly like paper
Since the parameters of the required length of the hinge differ according to the material. Verification is required every time the material changes.

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7. References

Ku, J. (2017). *Folding thick materials using axially varying volume trimming.* Proceeding of the ASME IDETC/CIE, p. 1-7, Cleveland, USA. Retrieved February 1, 2019 from *http://jasonku.mit.edu/pdf/THICKHINGE_ASME.pdf* .

Jackson, P. (2012). *Dezaina no tameno ori no tekunikku ,heimen kara rittai he. デザイナーのための折りのテクニック,平面から立体へ(Origami technique for designer, from surface to solid).* Translated by Mitani Jun 三谷純. Tokyo:Bunkashuppankyoku.

Patrick, F. (n.d.). *Lattice Hinge Design - Choosing Torsional Stress*. Retrieved February 1, 2019, from https://defproc.co.uk/blog/lattice-hinge-design-choosing-torsional-stress/