A New Component for Packaging

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Abstract

While some areas of the Graphic Arts are stagnating the packaging area is increasing in volume. In the accelerating web commerce more and more goods are shipped directly to the customers in packages. In packaging the ubiquitous box made from corrugated paper is dominating. The corrugated paper is simple to manufacture and cheap in comparison to many other materials. As it is made from paper it can be recycled and what is more important: it is made from renewable materials. It is also lightweight and in conclusion it has advantages over many other materials used for packaging. In this paper we will show alternative structures to corrugation that may lead to a packaging material with

- Uniform strength regardless of orientation
- Improved strength/weight ratio
- Lighter design, lower transportation costs
- Better print quality on liner (no wash boarding)
- The surface structure can also be used as a design feature

The research and development in this traditional area is quite active and many patents continue to be filed.

Introduction

In conventional board there is a core of corrugated material, usually made of paper, which is glued together with a liner. Sometimes liner on both sides surrounds the core. This gives additional strength to the composite material. The corrugation forms so-called flutes that give the material a three dimensional form and a thickness that is approximately the top to bottom size of the flutes. From being a flat piece of relatively thin paper with low bending resistance the combined structure is more resistant to bending. The strength is uneven however. The bending strength perpendicular to the flutes is high but along the corrugation it is not. The lacking symmetry means that to achieve a certain over all bending strength one has to dimension it according to the weakest orientation, along the flutes. The actual strength also depends on the liner and its orientation (CD or MD). Figure 1 below shows conventional corrugated boards where the corrugation has a sinusoidal form and is surrounded by liner on both sides.

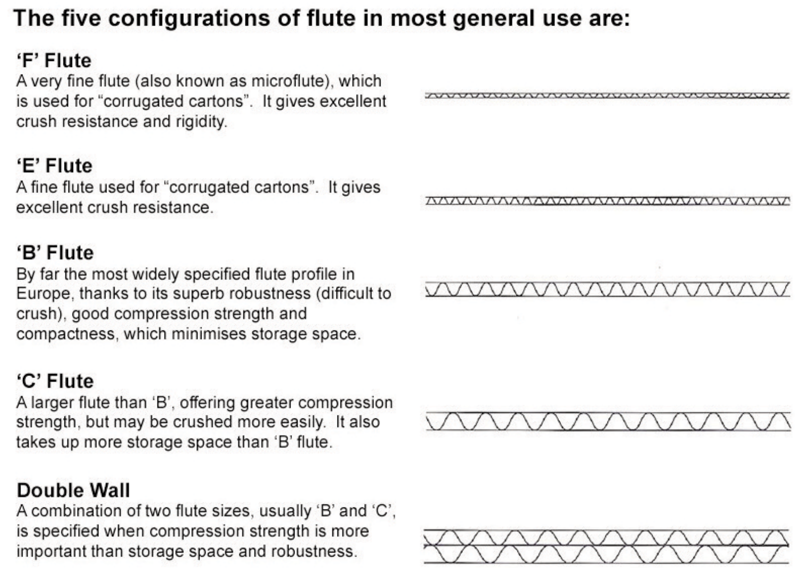

Figure 1. *Standard flutes. (http://www.paper.org.uk/information/pages/fact_sheets.html)*

Patents

The idea of using paper as a protection for shipping goods is old. In the packaging industry a need arose to use wrapping material and boxes made from corrugated paper in the 19th century. The first issued patent originates from the middle of that century. The 20th century saw a renewed interest in the area and numerous patents were issued. This interest is continued into the present century.

The main objective to produce new forms of corrugation is strength and looks. We will now give a, by necessity, brief survey of patents. Most of the present day corrugations are still using the old form of corrugation with flutes. A new interest in the "green" aspects of packaging has recently generated new weight and strength optimized designs.

The first patent that should be mentioned was made by Barthelet (1904). In his patent he argues that the ordinary flutes that are in a sense one-dimensional are inferior to a two-dimensional approach. In his patent he describes it as giving the paper a form of a waffle (gaufrage, fr.). The form is build from star-, octagonal- and circular-shaped sub-patterns. As shown in Figure 2 the sub-patterns are organized in an orthogonal, hexagonal or octagonal pattern in the structure.

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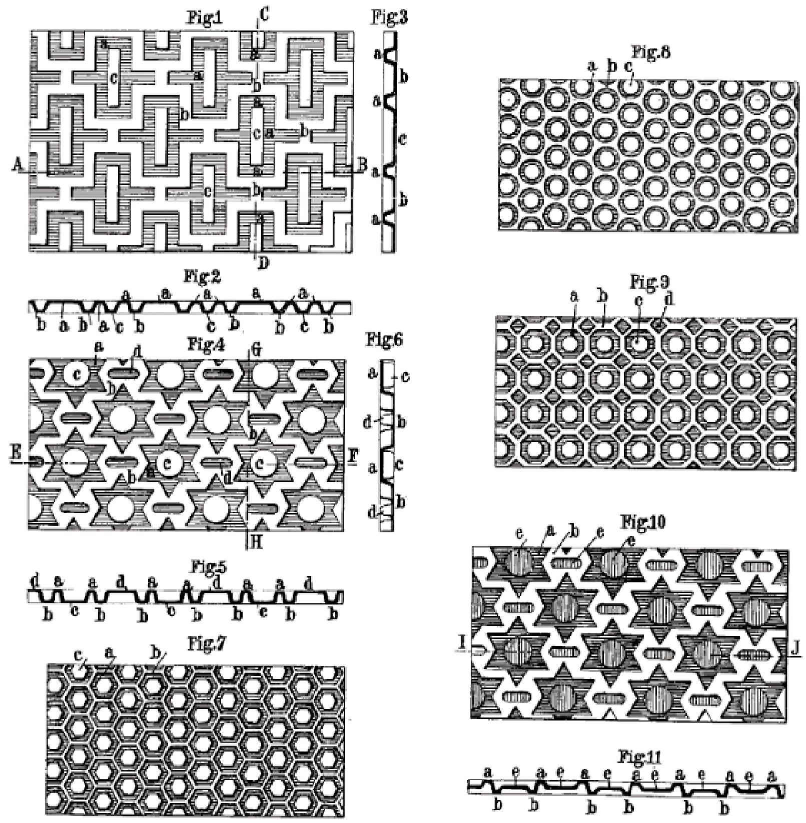

Figure 2. Patent FR342237

The next patent in this exposé is a German patent that dates from 1923, Reichspatentamt (1923). The ordinary straight flutes are here curved in a meandering fashion. Again it is argued that this two-dimensional pattern shown in Figure 3 will increase the strength of the product. The Figure 3 actually shows a piece of machinery that can produce the pattern in a sheet of paper.

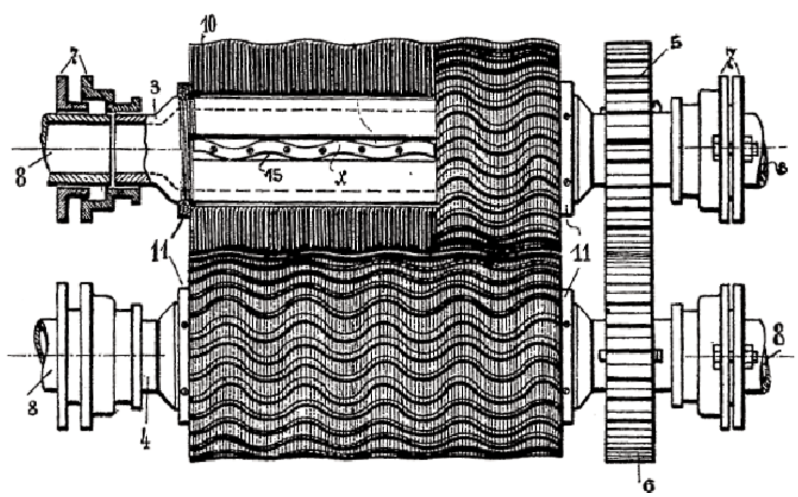

Figure 3. German Patent 381240

In Haren(1964) still another two-dimensional structure is used in order to gain strength. The basic pattern is used together with a mirrored copy of itself so that they fill the surface together. See Figure 4. The arrangement has symmetry lines in the horizontal and vertical. Symmetry lines like this make the strength vary due to orientation. In the first patent by Barthelet (1904) there are two, four and six symmetry lines.

Babinsky (1994) describes a variant of the Barthelet (1904) sub patterns. See Figure 5. There are symmetries also in this layout of sub-patterns. One aspect of the patterns should be noted: the non-circular patterns have very sharp corners. The small radius of curvature is critical for forming paper by embossing since the fibers of the paper may easily break. This undesirable property is shared with the Barthelet (1904) patent.

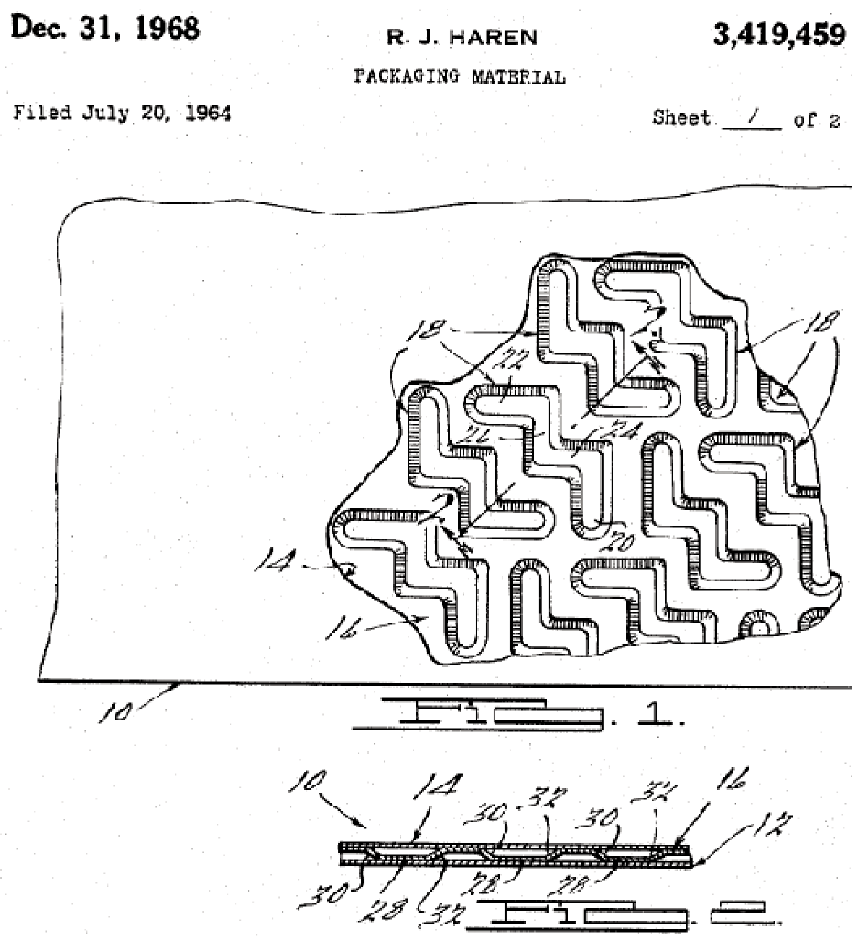

Figure 4. *Two mirrored subpatterns make up the structure.*

Finally the patent by Larsson (2004) is a variant with smooth sub-patterns with three symmetry lines. Small hemispheres of alternatingly protruding or indenturing character are arranged in a hexagonal form. See Figure 6.

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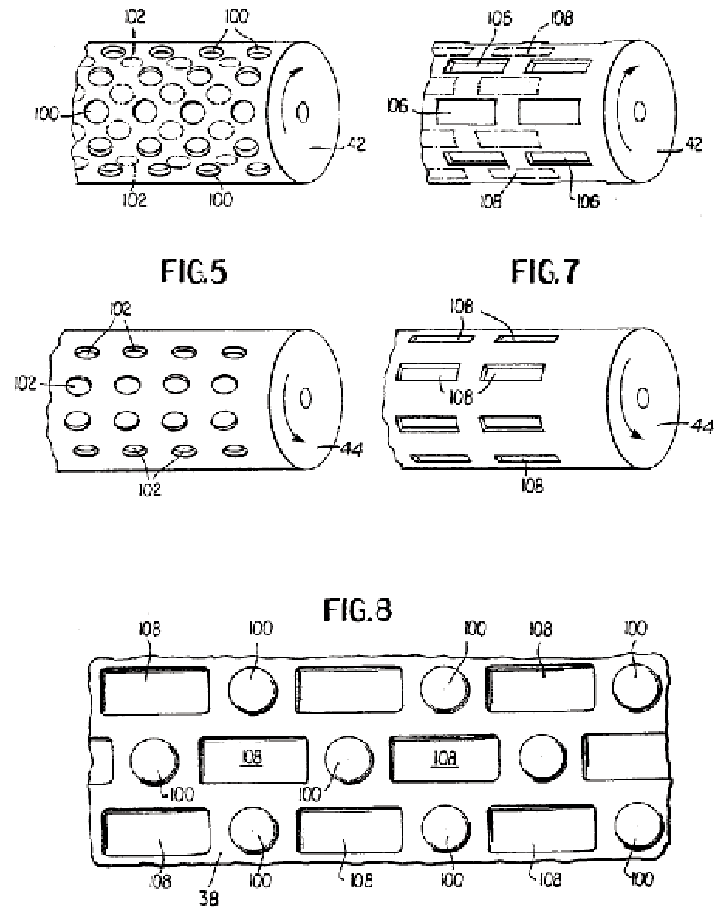

Figure 5. Drawing from the Babinsky(1994) patent.

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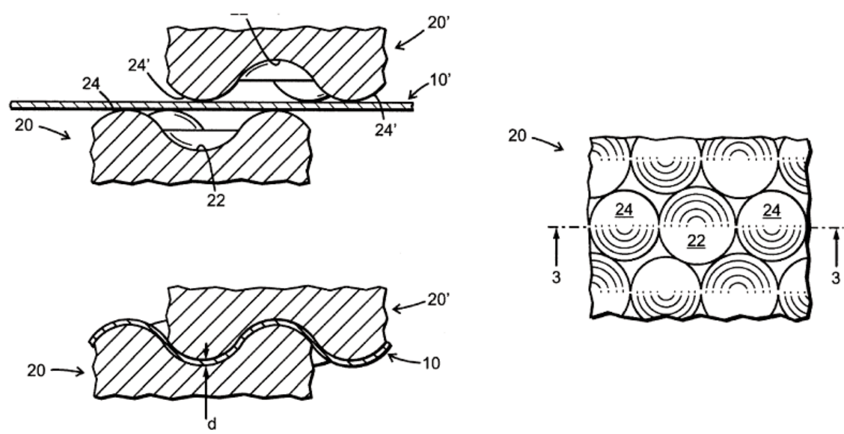

Figure 6. Drawing from the Larsson (2004) patent

Common to all the patents that have been described so far is their property of increasing the strength by using sub-patterns with variation in two dimensions. The variation is accomplished by arranging sub-patterns in a larger pattern. Virtually all exhibit symmetry lines that cause the strength to vary depending on orientation. Some patterns share the property of not being smooth as their sub-patterns exhibit small radii of curvature that may cause the fibers to break.

The last patent that will be described is original in that it is not a repetitive structure of basic sub-patterns. The McGuire (2006) patent describes the use of an amorphous pattern that is built up by irregularly shaped sub-patterns. Figure 7 shows one of the basic patterns proposed. As can be seen from the Figure 7 the patterns are not smooth and the variation of the sub-patterns is quite high. The interesting property of the pattern is its random nature. There are no symmetry lines that would result in a lower strength.

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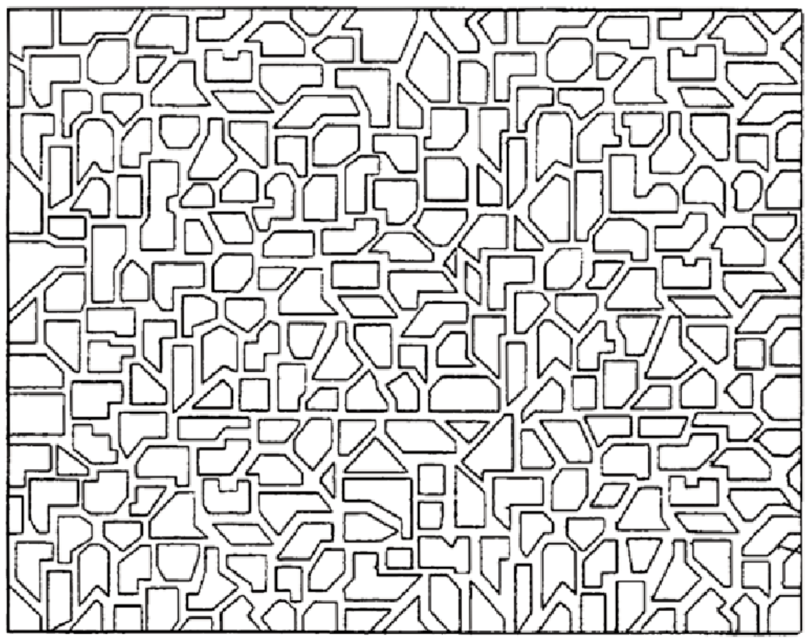

Figure 7. *Drawing from the The McGuire (2006) patent*

The patent further describes alternatives and improvements on the basic invention. The primary differences are the area distribution of elements and their radii of curvature. This can be seen from Figure 8. The set of elements are more homogenous in terms of size and do not display very sharp angles. An interesting fact is the similarity of the Figure 8 pattern with patterns occurring in nature. Figure 9 shows one example of a pattern from the giraffe.

Turing (1952) explains the mathematical background of pattern generation under certain circumstances in mixing of chemicals. Meinhardt(1982) elaborates on biological pattern formation with reference to the mathematics behind a large set of different pattern types. Typical patterns include the zebra and the tiger.

The novel structure

The key problem is to design a structure that isn't linear. A pattern with a certain controlled randomness is desirable. The existence of such patterns is evident from nature as we have seen in Figure 9. The random character of the patterns makes lines of symmetry virtually non-existent. Another desirable property of the pattern is that it should be smooth in the sense that the outline of the elements that build the pattern should have slowly varying orientation. The stress imposed on the paper fibers during embossing is reduced to a minimum as compared to the patterns with pointed elements or otherwise sharp character. The pattern described in Kruse(2012) is a pattern with curve linear flutes with smoothly varying orientation. It does not contain sharp corners and the flutes are randomly distributed. The strength of the corrugation has no preferred direction. The pattern is accomplished by applying a non-linear filtering to a start pattern with random elements. The resulting binary pattern is filtered again to obtain a 3D structure with x-height, y-width and z-height. Analysis of the pattern shows that the number of transitions in different orientations is not precisely equal but with a relatively small variation around a mean. The variation depends on the resolution of the basic pattern. An example of the set of patterns is shown in Figure 10 below. In Figure 11 the variation of the number of transitions in different orientations of this specific pattern is shown. Due to the random nature of the flutes there is a variation above and below the average. The number of crossings can be seen as one way of characterizing the bending strength in each orientation. The strength is not constant but is certainly more uniform than the simple linear flute pattern.

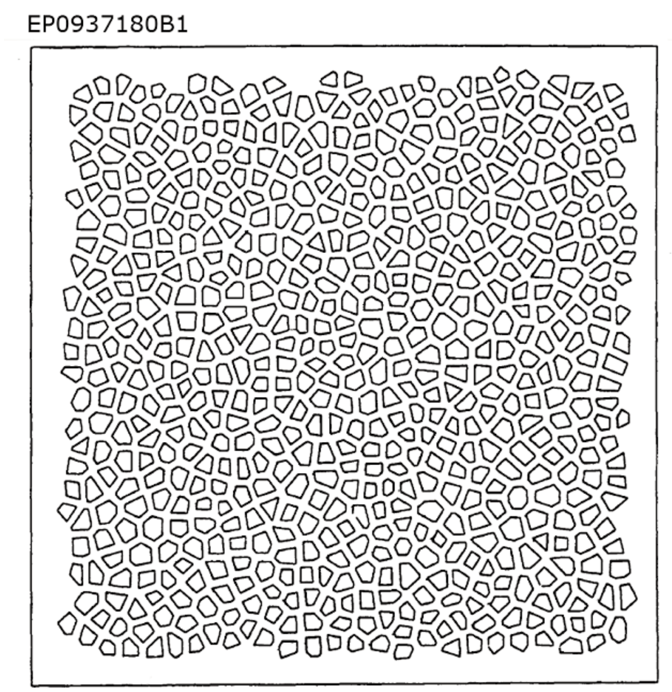

Figure 8. *An improved pattern from from the The McGuire (2006) patent*

Figure 9. *Pattern from nature: a giraffe.*

The manufacturing of the corrugated paper is accomplished by embossing using two rollers. The rollers come in a pair, one positive and one negative. The Figure 12 below shows such a pair. In the manufacture of the rollers it is vital that the pattern, when wrapped around the circumference of the roller, shows no discontinuities. After a full turn it must meet itself without showing a border. This character of the pattern is inherent in the process of creating it.

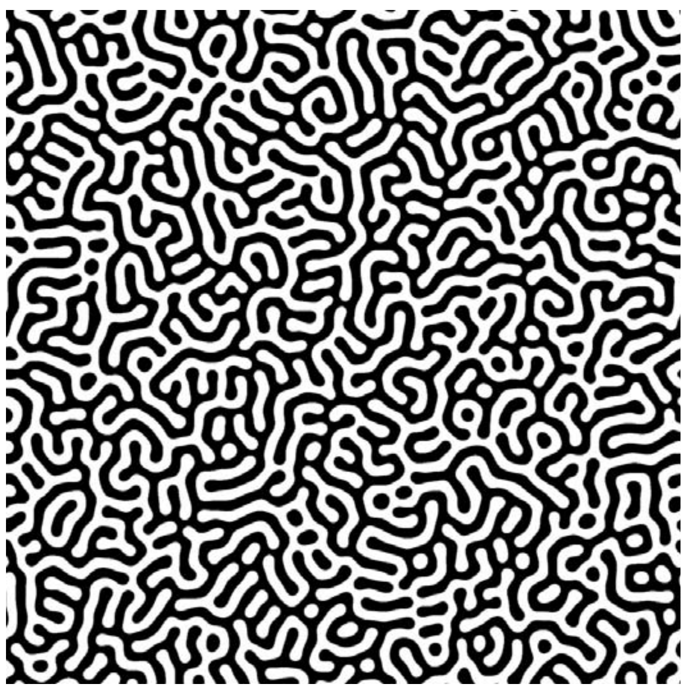

Figure 10. *The new flute pattern (one part).*

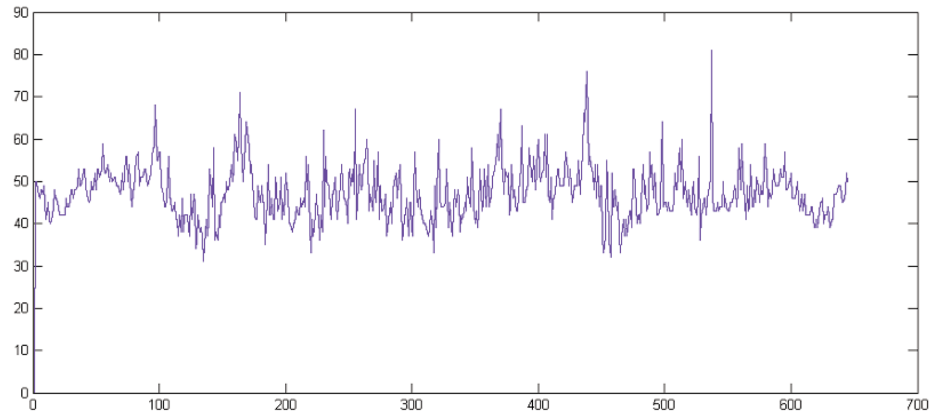

Figure 11. *The number of orientation dependent transitions. The scale corresponds to 180 degrees.*

The rollers are manufactured using what use to be called rapid prototyping. From a digital CAD drawing the pattern of the two rollers is printed in 3D. In our case the 3D plotter lays down thin layers (approximately 0.1mm) one after the other to build the 3D shape. It is a time consuming operation but it has only to be done once for the creation of the rollers. In our laboratory exercises the rollers have been mounted in a small test rig that is shown in Figure 13. The rollers are controlled so they rotate without contact and with the same speed. The paper is fed through and is thereby getting embossed with the actual pattern.

Figure 12. *The rollers for embossing the material*

Figure 13. *The experimental machine*

Figure 14. *Part of an embossed paper.*

The random nature of the pattern is favorable in yet another way. When the composite is glued together with the liner and printed, ordinary flutes tend to create undesirable stripes (washboard patterns) that are easily seen in the print. This doesn't happen with the new structure since it is not linear and the randomness tends to diminish the visibility of the washboard.

The "organic" look of the pattern may be used to advantage in the design of the packaging application. For all practical purposes there is no limit to the size of the pattern. The other way of extending a basic design is by tiling. The rollers in Figure 3 are by necessity made from tiles that connect around the circumference of the drum as has been described above.

Conclusions

We have described a new type of paper based packaging material (patent pending) that has certain advantages over ordinary corrugated board. The key to the new component is the irregular "organic" flute design. The properties of having a uniform bending resistance, requiring less materials and a better surface for printing (with liner) makes it a good candidate for advances in packaging.

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