Twist warp—causes and remedies

Axel B. Wennerblom

An ultrasonic method is used to measure fiber orientation angles of linerboard and to establish the influence of fiber orientation on twist warp.

Warp is still the boxmaker's most serious quality problem. Of all forms of warp, twist warp is perhaps the most dangerous because it makes it especially difficult for feeders in converting and packaging machines to function properly.

SCA Nordliner AB, a producer of kraft linerboard, became involved in customers' problems of twist warp a few years ago. Earlier the company had received only sporadic questions, but in 1988-89 it received complaints of twist warp from some customers. In cooperation with our customers, we made a number of trials in order to find the reason for these problems. We developed new testing methods both for the paper and the corrugated board. The results of the test methods considerably increased our understanding of the phenomenon of twist warp. The knowledge gained in the course of these trials is summarized in the present paper.

Theory

Definition of ordinary warp

Figure 1 shows how a complicated curved form of corrugated board can be divided into three components: MD warp, CD warp, and twist warp. CD warp is the most common form.

In Sweden, ordinary warp is defined as the inverse radius of curvature, **Fig. 2** (*1*). Thus, the unit is m^{-1}. As a convention, upwarp is given a plus sign and downwarp a minus sign. Figure 2 also shows the mathematical relationship between the inverse radius definition of warp and the definition that uses the bending (bulge) out distance *U*.

Definition of twist warp

The phenomenon of twist is well known also in the multiply paperboard industry, although the term warp is then not added. In **Fig. 3**, a mathematical definition of paperboard twist (*2*) is translated into twist warp for corrugated board.

In this "pure" form of twist, the MD and CD edges are straight. A line parallel to one edge, and following the surface, successively changes its slope over the sheet area. The definition of twist warp is based upon this change of slope.

Anticlockwise twist in MD, as in Fig. 3, is given the plus sign. The unit here is also m^{-1}.

Because twist warp is also often called "diagonal" warp, we developed a simpler definition according to **Fig. 4**, upon which we also developed a test method, described in the Experimental section.

What makes a corrugated board sheet warp?

The reasons for the occurrence of ordinary warp are well known. Basically, warp is caused by dimensional changes in the liners, normally due to moisture variations, but sometimes due to tension changes. The dimensional changes caused by moisture variations are much larger in the CD than in the MD direction. This is due both to the general fiber alignment in the MD direction on the wire, and to the higher tension in the MD direction in the drying section of the paper machine—a set of conditions that make CD warp a much more serious problem than MD warp.

What makes a corrugated board sheet twist?

From Fig. 1 it is obvious that, in order to explain twist, we must imagine the dimensional changes can have a dominating direction deviating from CD. But how can such changes be created? Can, for example, uneven tension in any of the webs during production of the corrugated board create such dimensional changes? This was suggested by Langston in their well-known booklet "How to improve corrugated board quality and operating efficiency" (*3*). We cite:

"Diagonal or twisted warp is frequently caused by excessive tension on the single face web—either at the preheater or by an overloaded bridge."

Or, can the dominating fiber orientation in the paper be at an angle to MD? This has been shown to be behind twist in multiply paperboard (*4*) and was proven by Whitsitt and Hoerschelman (*5*) to be one reason for twist warp in corrugated board. We cite:

"When the liners having oppositely oriented polar angles and equal moisture contents are made into combined board at 50% RH, large twist warps occur as the combined-board moisture is changed. For this case: The degree of twist warp increases as the polar angle difference between liners increases."

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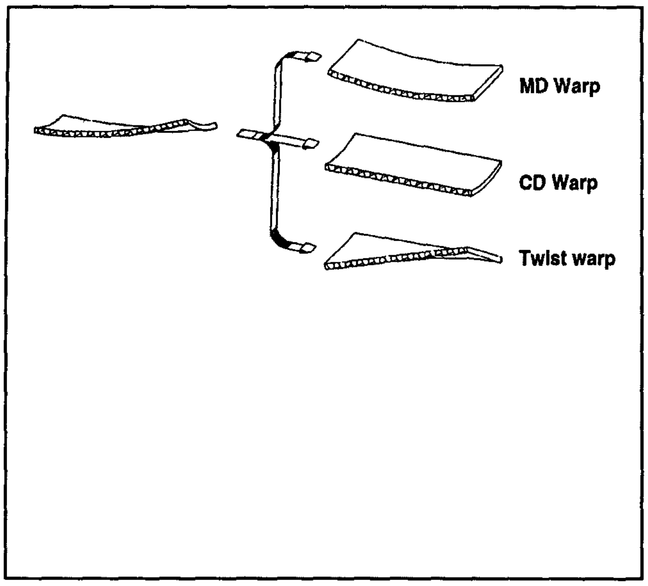
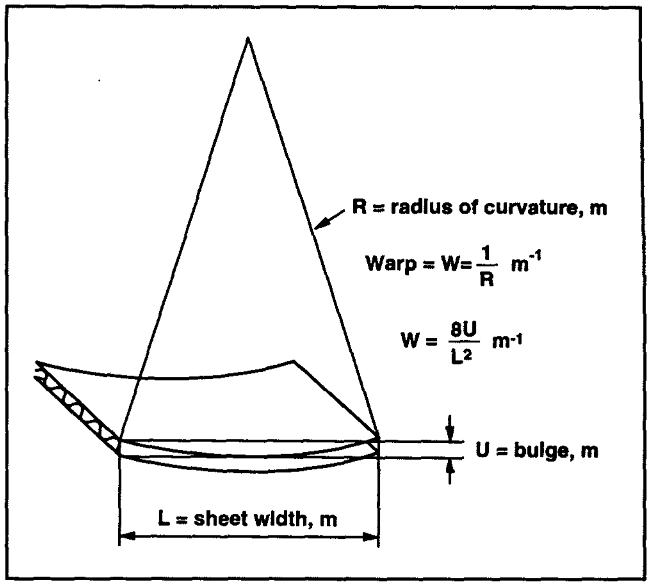
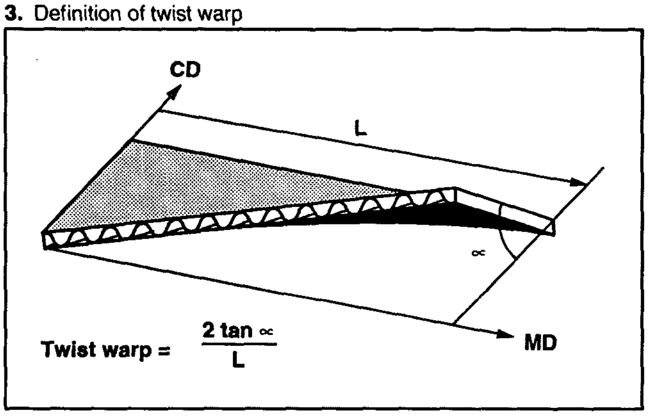
1. Different forms of warp



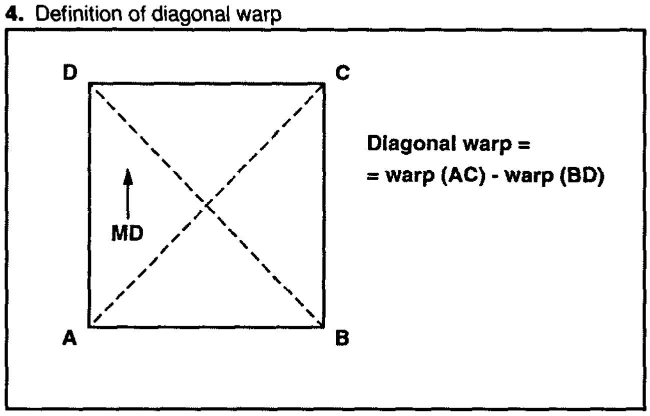
2. Definition of ordinary MD or CD warp



3. Definition of twist warp



4. Definition of diagonal warp



We will return to these questions in the next section of our paper.

Results and discussion

We will begin with a very important factor that influences twist warp, namely, the climate, or the moisture content of the board.

How does the climate influence the twist warp?

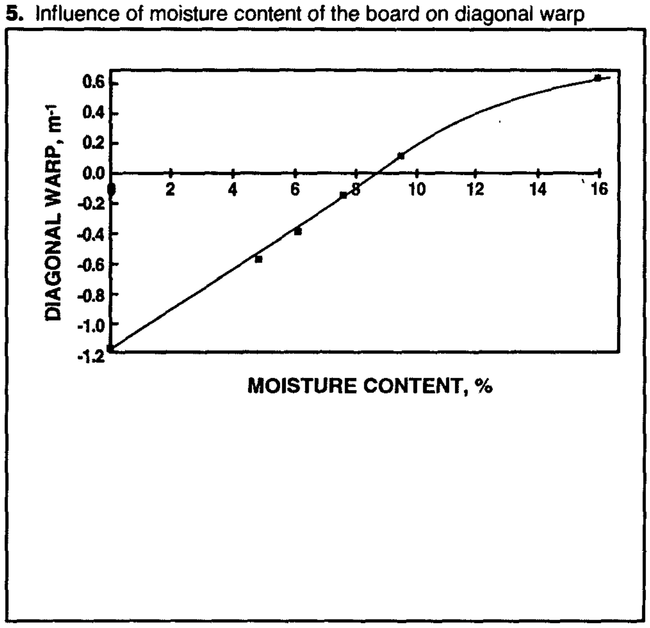
It is obvious that a climatic change cannot in itself give rise to twist warp. There must be some basic "defect" in the board.

Figure 5 shows an example of how the diagonal warp, created by such a defect, can change with the moisture content of the board.

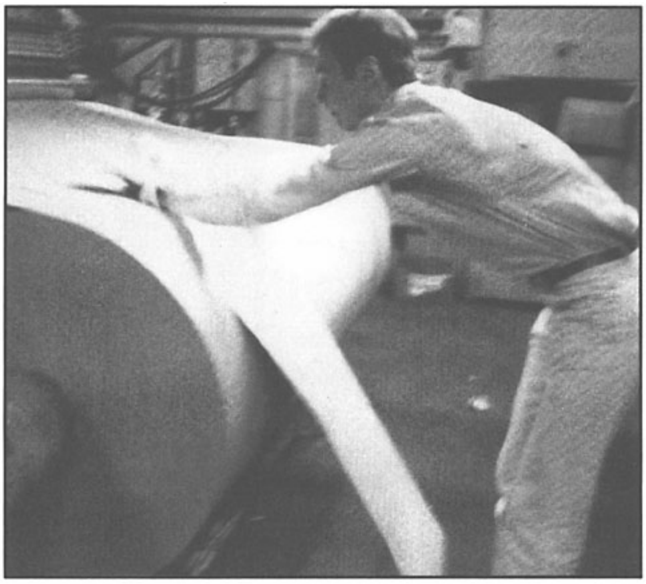
The correlation is almost linear, crossing the X axis at a moisture content of about 9%. This moisture content must be interpreted as that of the board when the bond between the single-faced web and the double-backer liner was formed on the hot table, since the board was then flat.

This example shows that twist warp increases with

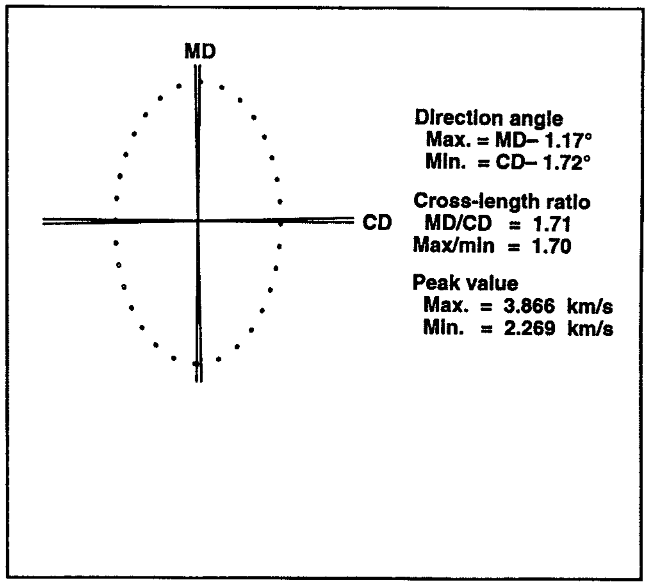
5. Influence of moisture content of the board on diagonal warp



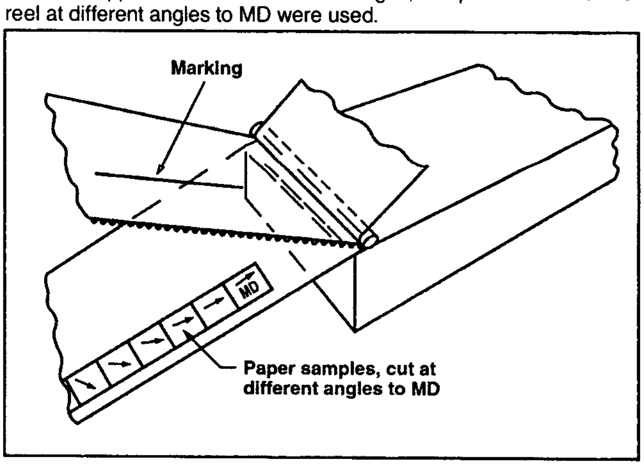
6. To prepare samples of corrugated board from paper sheets you start by sticking a strip of combined sheets to the double backer liner with double adhesive tape.



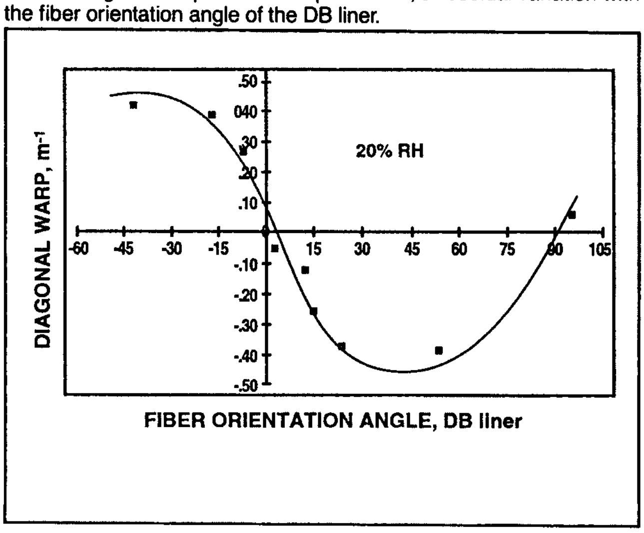
9. One example of a report of the ultrasonic instrument



7. In this application of the method in Fig. 6, samples cut from a liner reel at different angles to MD were used.



8. The diagonal warp showed a spectacular, sinusoidal variation with the fiber orientation angle of the DB liner.



increasing moisture content, but we could as well have shown examples where it decreases. In practice, a high negative value is, of course, as bad as a high positive value.

We have numerous examples of situations where the board came out flat from the corrugator but became seriously twisted afterward, in a different climate.

This result with twist warp differs a little from what happens to ordinary warp when the climate is changed. Starting with a balanced board, i.e., the same grade of liner on both sides, a flat board will stay flat in a different climate. An unbalanced board, however, may well change from flat to warped in a different climate.

How does the paper influence the twist warp

In the recently cited paper (*5*), the fiber orientation angle of the liner was said to be very important for the formation of twist warp. Within SCA Nordliner AB, we had similar indications and suspicions already before we read this article, and we performed an interesting experiment to test our suspicion.

In that experiment, we applied a very useful and handy method to prepare corrugated board from paper samples in sheet form. The following two figures will explain.

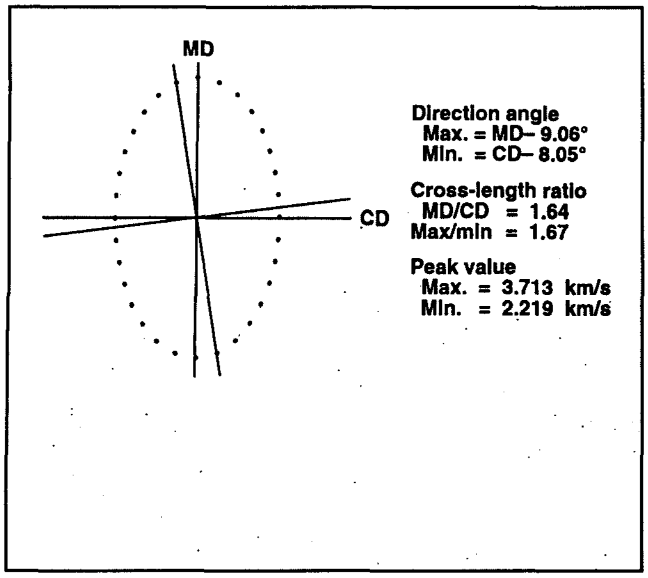
The basic idea is to stick the paper samples with tape to the double-backer liner, as shown in **Fig. 6**. In the actual application, we simply cut paper samples from a liner reel, at varying angles to the MD direction. With these samples, we prepared board in the corrugator as depicted in **Fig. 7**.

Testing the board sheets at 20% RH gave the spectacular results in **Fig. 8** It is difficult to find more convincing proof.

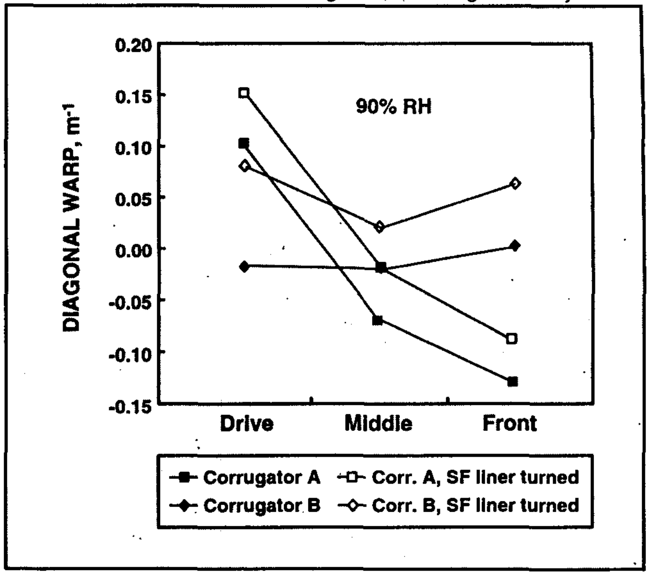
At the same time it is, of course, confirming earlier results (*5*) beyond doubt, now using a better test method for the twist warp. It is important to note that the results at 50% RH (not shown here) were not as conclusive.

But this was artificially produced angles of fiber orientation. Is it really possible to obtain such angles in practice? To answer that, we must know how to measure the fiber orientation angle in paper. Fortunately,

10. Another example showing a more extreme fiber orientation



11. Diagonal warp over the machine width, before and after turning the SF reel. Results from two corrugators, behaving differently.



ultrasonic testing has made this task easy nowadays. We use a Japanese instrument (*6*), and there is also a recent Swedish supplier (*7*) on the market.

A report from the Japanese instrument, **Fig. 9**, gives the ultrasonic velocities and also "directional angles." Strictly speaking, these angles refer to the ultrasonic velocities but, for the purpose of easier understanding, we refer to them as "fiber orientation angles." The example in Fig. 9 shows very small angles, which is the normal situation. In a more exceptional case, one can, however, get directional angles with larger deviations from zero, as in **Fig. 10**.

Such a liner would be in the risk zone of creating problematic twist warp.

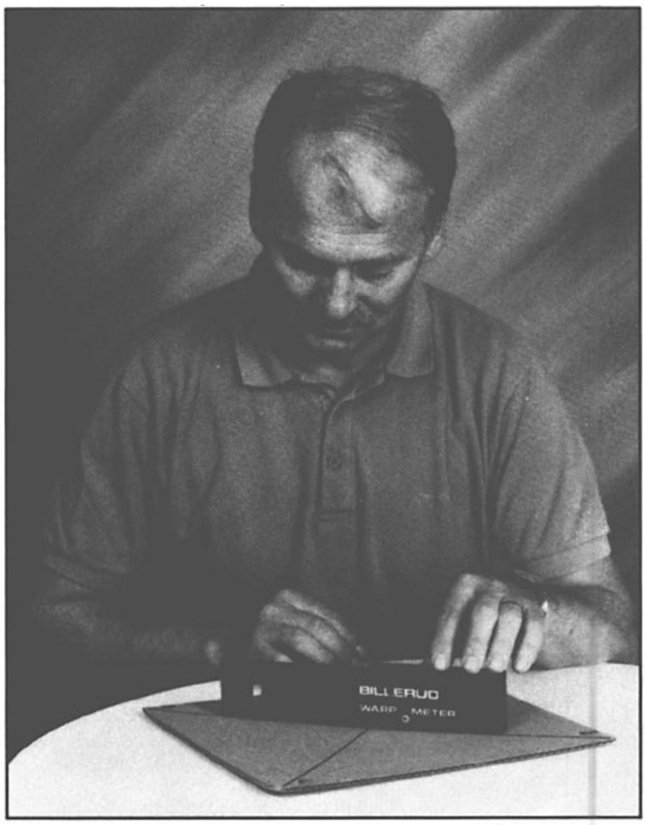
In a balanced single-wall corrugated board, it is rather common to use the same liner grades on both sides. If the two liners are in the risk zone, perhaps from the same supplier and of the same uniformity, they can very probably deviate in the same direction from the MD direction. Putting the liner reels in the reel stands the normal way, i.e., both with their top sides out, will make them work against one another and create more twist than if one of the liner reels had been perfect. If, on the other hand, the two liners have opposite angles, they will create less twist. This explains why, sometimes, one can get less twist if one of the reels is turned. In practice, this method is a short-sighted cure.

But how can such fiber orientation angles be created in a paper machine? Well, it has been shown that they can arise from cross directional streams in the headbox. We cannot go into details here, but the literature is fairly full of references, e.g., (*8, 9*).

How does the corrugator influence the twist warp?

The foregoing explanation of the fiber orientation is insufficient. We have seen a number of examples where a box plant has got twisted sheets although the papers were in perfect order regarding orientation angle, measured ultrasonically. In one such example, we tested certain reel

12. Picture illustrating the diagonal warp test



combinations before and after turning one of the reels. Obviously, had there been something wrong with the paper, we would have expected the twist warp profile over the machine width to change. In practice it remained the same, as shown in **Fig. 11**.

Figure 11 also shows the result from another corrugator, where "sister" reels were used, i.e., reels run in the same paper machine position, and close in time. In both corrugators, the general level of diagonal warp is low, but the differences in profiles are clear.

Although we have in some similar cases proved that the twist warp must somehow be created in the corrugator, we have not been able to pinpoint exactly where and how. The Langston statement regarding the influence of tension, cited earlier (*3*), may well be true, although we have not succeeded in provoking twist warp by running the single-faced web with uneven tension. We have, however, heard of box plants, where they have improved the twist warp situation by adjusting unaligned stands, preheaters, rolls, and similar items.

Conclusions

1. Twist warp in corrugated board can be measured easily.
2. The fiber orientation angles of the liners can play a decisive role in the formation of twist warp.
3. Twist warp, however, can also be created, somehow, in the corrugator.
4. If the prerequisites for twist warp are at hand, then the climate, or rather the moisture content of the board, plays a large role for the level and sign of twist.

Recommendations

From what has been learned, it is fairly easy to make recommendations for remedying twist warp. We would like to start with the following two:

1. Establish a test method that gives you numbers of the twist warp, and use it.

Do not think that you can solve the problem by just estimating the twist visually.

2. Remember the tremendous influence of the moisture content of the board. You must measure the twist at a different moisture content than the one you get out of the corrugator.

Now you can begin to try to find the reasons for your twist warp problem. The first thing to do is:

3. Establish whether the basic reason is the paper or the corrugator.

This can be done in several ways. One is to test—with an ultrasonic instrument—whether one or both of the liners have an exceptional fiber orientation angle. It has been shown (*10*) that this testing can be made on the corrugated board as conclusively as on the free liners.

If an exceptional angle is found:

4. Ask your paper supplier to decrease the fiber orientation angle of his liner.

With the present technology in the headbox area it is not possible to avoid small angles, but it is certainly possible to avoid the occasions of exceptional angles that can create unacceptable twist warp. We know that from our own experience.

If, however, you are unlucky and find that the reason behind your twist warp is probably in the corrugator, we cannot give you exact recommendations at present, although the following may be useful hints:

5. Run the board as flat as possible and at a "normal" moisture content, say, 7-9%, out of the corrugator.
6. Eliminate uneven draws wherever they occur.

Experimental

Determination of twist warp

For paperboard, a commercial instrument was developed by Lorentzen & Wettre in cooperation with the Swedish Packaging Research Institute (*2*). This instrument is based on optical scanning of the sample. It can also be used for corrugated board but is rather complicated for routine testing, so we use a method based upon the diagonal warp definition, shown in Fig. 4.

To be able to measure warp along the diagonals, we use a simple warp meter (*11*) developed by Billerud, a Swedish paper producer. **Figure 12** shows how the test is done. A more complete description can be obtained from the author.

This method is extremely simple, but one must be careful to remember the signs of the warp values. To separate this method from optical testing of twist warp, we call it "the diagonal warp method."

In our experience, an absolute diagonal warp figure below about 0.20 m^{-1} normally does not create problems.□

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