How can fibre bundles that stick out of the board cut face be explained?

Introduction

We have repeatedly observed that, after a shear cut, fibres are left sticking out of the cut face. The question of how this is possible arises.
Within the scope of a German AIF study (Project number 13951), we made a video of the cutting process for the purpose of being able to analyse the resultant deformation and the forces applied. Solid board 3 mm thick was used for this purpose. We discovered an unexpected phenomenon on the video that revealed how fibre bundles can stick out of the cut face.

Details

The phenomenon I am speaking about is shown in detail in Figure 1. You can see the cut edge of the board in the foreground and the fibre bundle on the cut face behind it.

Figure 1: The cut edge is clearly evident. The fibre bundle is shown in the background.

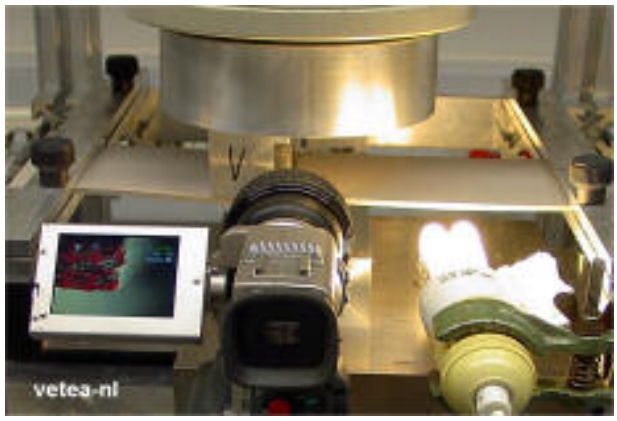

Figure 2: The hydro-press with the clamped board and video camera.

In order to cut solid board, we clamped the board in a Hydro-press that is equipped with 2 knives. The top knife was fixed and the bottom knife moved upwards. The knife angles of both knives were identical. The top knife was inclined by about 3° to provide a free angle between the knives. We drew lines on the face of the board to be able to show the deformation on the video. We have taken the most important frames from this video that reveal how this phenomenon developed.
See Figure 3.

- The first picture clearly shows the knives barely touching the surface.
- The second picture shows the deformation during the compression phase.
- The third picture shows greater compression. What is remarkable is that the deformed material on the left side of the bottom knife is still in contact with the left side of the bottom knife.
- The fourth picture shows that suddenly a bundle of fibres is pulled out of the thickness of the material. The material on the left side of the bottom knife is no longer in contact with the side of the bottom knife. A small slit is visible.

- In the fifth picture, the slit is wider still, and a bundle of fibres is being pulled out from the face of the cut. When seen along the entire length of cut, the cutting process is virtually finished. Therefore, the slit between the deformed material and the knife is wider here.
- The slit is at its maximum in the sixth picture. It is now clearly evident that the fibre bundle is moving along the cut in the direction of movement of the bottom knife. If no fibres are broken in the meantime, they will be cut by the knives that are now mechanically touching each other. The fibre bundle mentioned before is no longer fixed to the material surrounding the cut. What has happened to a fibre bundle can also happen to a single fibre. This phenomenon may also occur on the right hand side of the top knife, depending on the knife angles, tension distribution and thickness of the material.

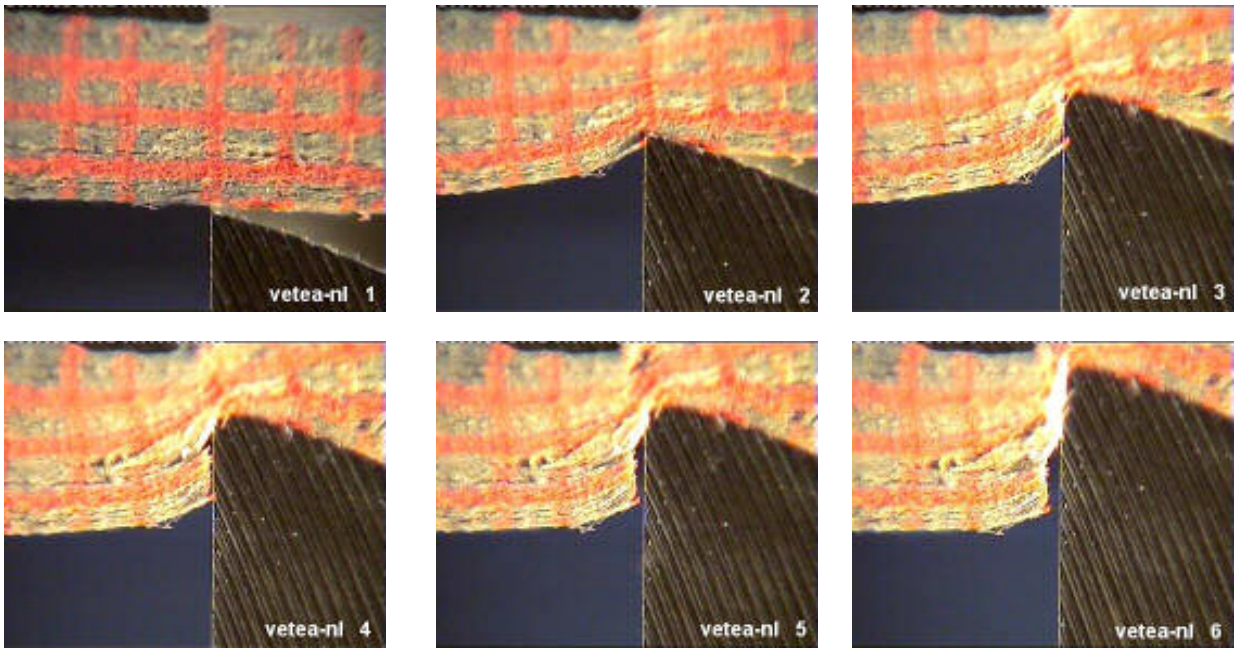

Figure 3: Cutting sequence

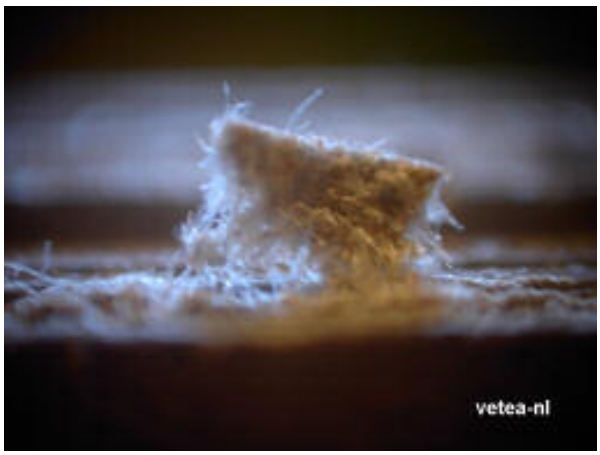

Figure 4: Fibre bundles pulled out of the face of the cut

As said before, the fibre bundle no longer is fixed in the face of the cut. It is possible to pull the fibre bundle out of the cut. I have done so, as you can see in Figure 4.
You can clearly see that this fibre bundle was cut by the knives, after it was pulled out of the cut face.

What does the cutting sequence look like when circular shear knives are used?

In the case of circular shear knives, only the bottom knives are actually driven and support the web. The top knives are only driven by friction. The speed of the top knives depends on the thickness of the web and on the coefficient of friction between

- the knives themselves, and
- the knives and the web.

The angle of the top knives is usually less than 90°. The bottom knives normally support the web; see Figure 5. The compression takes place between the top knife and the bottom knife. The deformation of the web takes place mainly on the left side of the top knife, but also may take place on the right side of the bottom knife.

Figure 6 is showing the virtual progress of compression. The web is running from right to left.

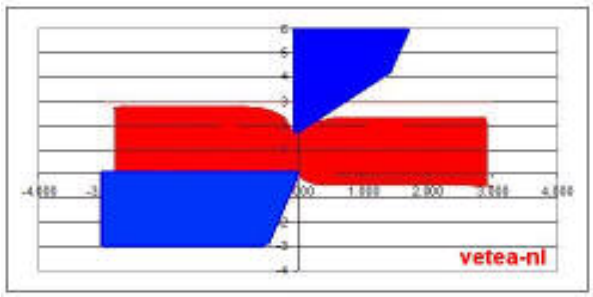

Figure 5: Cross-cut over both knives

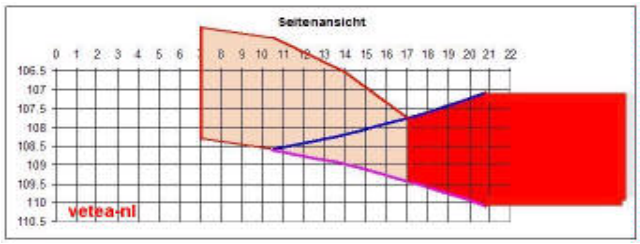

Figure 6: compression and relaxation at the ingoing nip of the knifes.

The sequence is as follows:

- The knives compress the web to about 1.35 to 1.45 kg/dm^3, depending on the fillers etc. (shown in dark-red)
- A shear cutting of the web then suddenly takes place. The knives are not yet in contact.
- It is now possible for the cut web on the bottom knife to virtually return to its original thickness. This is shown in light red. The sequence of pulling fibres out of the cut face takes place during the period between the shear cut and the moment the knives touch each other (because of the relaxation sequence, exactly as shown in Figure 3). The same relaxation sequence occurs at the top knife, although this is not shown here.

Figure 7: Top view of cut

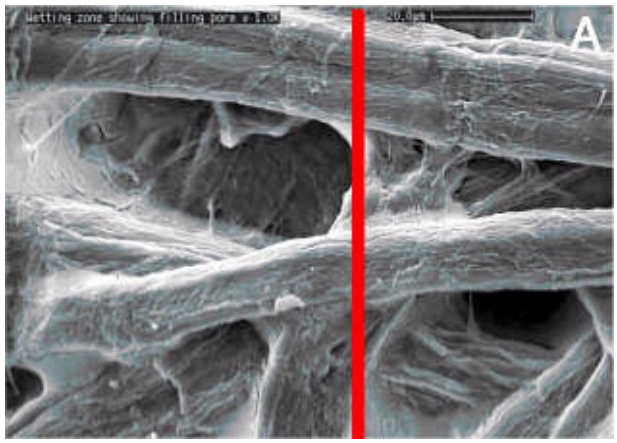

Figure 8: Cut through the web

The cut face is primarily a shear cut. The shape of the shear cut depends on:

- the tension conditions at the cut face and the resulting elastic and plastic deformation
- the fibre orientation in the web itself, and on the direction of the cut, related to the fibre orientation. See Figures 6 and 7.

Conclusion.

The explanation given above is valid for single fibres as well as for bundles of fibres. The consequence of this explanation is that the thicker the web, the more you will see fibres or fibre bundles sticking out of the cut face. This corresponds to what is observed in practice, which shows that the cut becomes worse with increasing web thickness even with the same set of knives.

Acknowledgement.

I hope to have made a contribution to an understanding of the cutting process by offering the above explanation of the phenomenon of fibre bundles sticking out of the cut face. I would like to thank PTS Munich for giving me the opportunity to participate in this AIF Project No. 13951.