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MODELLING AND SIMULATION APPLICATIONS IN PAPERBOARD PACKAGING

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ABSTRACT

Today, simulation tools and digital twin models have taken a central role in product development at Tetra Pak. As a result, improved functionality and quality are secured in developing new packages, filling, and converting machines. First, an overview is presented on the development of paper models, followed by examples of how the paper models are used with simulation tools at Tetra Pak today. Such as the creasing and filling process related to material defects.

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Artem Kulachenko Royal Institute of Technology (KTH)

Very impressive presentations. It is quite exciting to see how far you went with simulations. I wonder about a few things regarding the calibration of the models. Some of the processes that you are using in production are done at a very high rate or at high temperatures like sealing performed at 300 degrees. In addition, you need 3-dimensional properties, which all are quite difficult to get. So how do you go about acquiring those rate-dependent and temperature-dependent 3-dimensional properties?

Johan Tryding

So far, we have measured the paperboard at 23 degrees and 50% relative humidity, so that is the calibration. Of course, we have had studies looking at what happens when you have moisture interactions when you have increased temperature. Still, we have seen that the models we are using can go quite well and indicate what is happening, despite high temperatures. When we come to forming, the filling product is about 30 degrees and very quickly cooled down the material to the same temperature, so that means that when we do the sealing, the material is around 30 degrees. We are looking into this, and in the future, we hope to have models that can also include moisture and temperature sensitivity.

Martti Toivakka Åbo Akademi University

Delamination seems to be one of the key issues in creasing and folding, so do the board suppliers consider that in the design of the boards? Do they establish what

is a quality parameter? Is there is a simple measure that would help to predict performance?

Johan Tryding

There is no simple measure, but after we have converted and filled the packaging material, we examine the packaging according to our specifications. Then we give feedback to the board supplier. We do not have any single value measure for that today. We have started developing measurement techniques to measure the whole delamination from reaching the peak mode and then the descending curve, which is included in a model. Shear delamination is more difficult to measure compared to ZD-loaded delamination. We have tentative testing methods for that, and we have published papers on it, but there is nothing in our production yet.

Martti Toivakka

Is it possible to have excessive delamination of the board if you create board that is very weak in the z-direction?

Johan Tryding

Yes, the paperboard delaminates in different places at creasing, and we have learned that even if you have multi-ply boards, it is not always that it delaminates between the separate plies. It can also delaminate inside the ply.

Jon Phipps FiberLean Technologies Ltd

I was wondering if the conclusions from your simulations have ever made you go back to your board suppliers and ask them to change their product specifications. For example, are there properties that you didn't think were important that turn out to be so, and vice versa?

Johan Tryding

That we do, we have an excellent collaboration with our board suppliers. If something is not working, we try together to figure it out. Our suppliers do trials on a board machine, and we convert and fill the new paperboard-based package material and evaluate the package according to our specifications. After that, we communicate the result with our supplier. New trial points are often needed to close the gap. Usually, several trial loops are needed. The looping takes a long time, so we have seen in some studies that we can do it much faster using this

modelling because the suppliers know what changes they can make on the paperboard parameters. They can say this we can do with a board machine and then we simulate our process to get an answer if the gap is fulfilled or not, then we have a discussion. Using simulations to evaluate the gap goes much faster to close the gap than producing a paperboard, converting, and filling it into a package, and after that evaluating it.

Jarmo Kouko VTT Technical Research Centre of Finland Ltd

I see there are also minor foldings without creasing nowadays in your packages. What kind of research do you do in that area and what kind of limitations do you see in that folding type?

Johan Tryding

We do a lot of simulation on the creasing patterns to see what works best to have this kind of folding without getting folds or cracks, so there is a large group of people working with this at Tetra Pak, and we also have an equally large group doing this kind of simulation. After a simulation, the groups cooperate to see what changes can be made to have a package performance that satisfies the specifications. Did I answer your question?

Jarmo Kouko

What kind of limitations are there?

Johan Tryding

The limitation is both on the creasing tool, the filling machine, and the paperboard. Compromise often needs to be made to meet the specifications.

Douglas Coffin Miami University

I want to follow up a little more with Artem's question. For the simulation you showed us, I would like to know how simple were they? Are they quasi-static, are they rate dependent or temperature dependent? How far did you have to take it to get what you needed?

Discussion

Johan Tryding

We used implicit simulations in the creasing and folding simulations presented. The 3rd generation models do not have any rate or temperature dependence. What we call the 4th generation will have these rate dependencies, but that means extra calibration, so then everything expands, and if you include moisture, it expands even more. So, it is essential to know what physics to include in the models and make as accurate simulations as possible.

Douglas Coffin

So, your 4th generation will have that but what issues have you seen where you think you will need the fourth generation?

Johan Tryding

Yes, it is the case for creasing. Experimental tests have shown this. For example, the crease relaxes in the corner after folding a creased paperboard. Unfortunately, the 3rd generation model cannot capture this.

Ulrich Hirn Graz University of Technology

My question is: Some of these structures, particularly maybe in the corners, are very small, in the millimetre scale, right? And you have homogenous continuum models. So, did you observe that when you get towards these very small structures that you have to somehow consider the local unevenness of the material, like e.g. formation, local fibre orientation or density variations?

Johan Tryding

We have not come so far yet. I mean, we have just succeeded in making a corner for the 4th generation, and we can make it with the 3rd generation, but it is a bit over-stiff, so the solution sometimes stops.

Peter de Clerck PaperTec Solutions Pte Ltd

Have you determined a preferred position for the delamination in the board in terms of the percentage of penetration into the board, its thickness?

Johan Tryding

No, we see it varies between board suppliers. No general rule for delamination has so far been observed.

Robert Pelton McMaster University

I have a general question. I was blown away by the number of boxes you produce. How is Tetra Pak with the push to have recycling? I do not think your current products are easily recycled. What is the corporate stance on this?

Johan Tryding

Tetra Pak's message to customers is that in 2030 we should have the first fully recyclable and fibre-based packaging. Therefore, the company has been reorganised to allocate more resources to the 2030 goal.

Jove Joelsson MoRe Research and Mid Sweden University

I have a question about the plastic part that seals the package. Do you have any research going on to replace this plastic part?

Johan Tryding

Sure, we collaborate a lot with our board suppliers to replace plastic and aluminium foil with alternatives based on wood products. That is currently occurring, so we have special groups within Tetra Pak taking care of that.

Jove Joelsson

I think this is important.

Johan Tryding

Yes, it is.

Joel Panek WestRock – Richmond VA

Modelling of paperboard has been ongoing for decades – I believe the earliest publication was in the early 1980s by Carlsson and others, and there was a lot of active work in the 1990s. So this has been worked on for quite a while, but from my point of view, our abilities to use modelling is still limited and frustrating. There are a lot more things we would like to be able to do, but it takes a long to develop a model. And then you see results and question is this really valid and true?

Discussion

Johan Tryding

Yes, it has been hard. It is all about money also. It is also about the knowledge level. Because the anisotropy is very high for paper. The in-plane strength is between 25 and 50 MPa, whereas the out-of-plane is nearly 100 times lower than in the MD direction, i.e., 0.4 MPa. So, there are not many materials that have that anisotropic material response. Developing models that are very robust from a theoretical point of view has taken the research community a long time, as well as valid tools. Then, when the tools are ready, the industry can start to apply them. So, it is something that has developed over time also. I think these kinds of models could not have been done in the 1980s and 1990s because robust theoretical tools were lacking.

Joel Panek

I look at the development of simulating an entire process, such as going from a board all the way to package, as extremely challenging and perhaps a bit much to ask at this point. Using modelling and simulation as a virtual microscope on an isolated part of the process has value in itself. By isolating a process, you can see what is happening on a local level and better understand the mechanisms. Like a light microscope, you have to understand limitations – there can be artefacts, there can be a limited field of view and you can only see so much. But if you have knowledge on the right level for your model's capabilities, you can get further insight into what is happening and use the results properly. You can use it as a virtual microscope in a way to advance the understanding what is occurring

Johan Tryding

That is how we also see it. I mean, it is important to have this kind of virtual lab, where you can look up a specific problem and try to have measuring techniques for that and focus on that and see what the model can help us to say, and we can refine the models from that point of view as we did with creasing and folding.