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APPLICATION ORIENTED OPTIMISATION OF SUBSEQUENT REDRAW PROCESSES FOR CIRCULAR CONTAINERS

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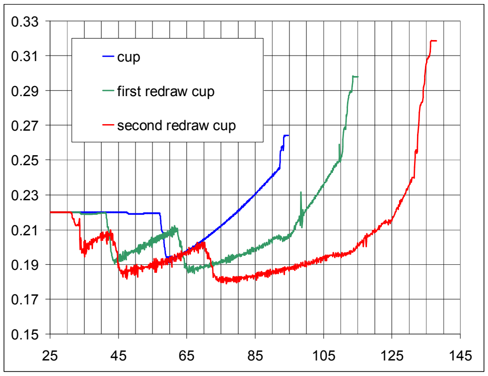
ABSTRACT

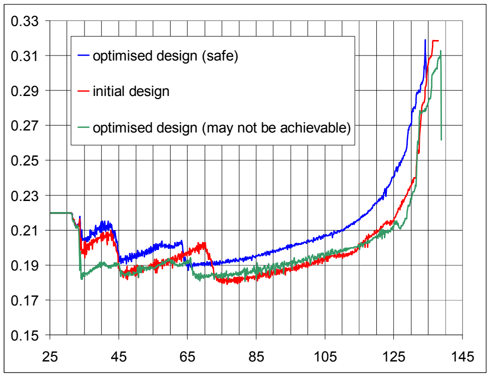
The accuracy of numerical simulation of deep drawing of thin packaging steel was in the past not satisfactory, especially when Protact® was used. Protact® of Corus is a polymer coated steel where a multilayer polymer film is directly extruded onto the metal sheet. Within the project described here, a highly accurate, cost effective, axisymmetric, parametric draw-redraw model was developed and validated for polymer coated sheets. The requirement for accuracy was to be able to feed the resulting cup into further models of the subsequent redraw stages, and eventually, into wall ironing stages if they are present in the manufacturing process. In a subsequent cupping process, besides prediction of stresses and strains, the wall thickness profile has to be predicted with high accuracy. The amount of the largest thinning above the punch radius is an important measure of the robustness of the process, as too much thinning in this area later can cause wrinkling issues for further redraw operations in practice. The top wall thickness shall not deviate either, especially if wall ironing is present in the later stage. The redraw stage will take the inaccuracy further to the first ironing die, where if the input thickness is larger, the reduction will be larger, which eventually yields to increased tool forces and greater die expansion. The result is a thicker wall, or at the worst case, a tear off of material. Further, the cup height prediction must be accurate, as the product needs to achieve the required can height and thus fill volume. Therefore strict requirements for the accuracy of the prediction were formulated, of which some are unusual to finite element modelling. The cup is normally thickest at 0° and 90° and thinnest at 45° (4 ear profile). Around the mid-wall the thickness approximately varies with a deviation of 10 microns due to anisotropy. Considering that the input data for the material model is mainly measured in the rolling direction, the simulation shall approach the thinnest cup wall from above by an accuracy not larger than +5% deviation, and must be smaller then the gap between the redraw punch and die! The cup must not be predicted thinner than it is by 1%. Average cup heights must be predicted within an absolute deviation of 1 mm. Tool forces must not deviate more than 10%. This is successfully achieved by the model, which is suitable to simulate the forming of both tinplate and polymer coated material. A wide range of parameter studies were performed during development and validation to find and optimise the most significant parameters among material properties of the polymer layer. The model is now capable to robustly predict average cup height and wall thickness profile in rolling direction within a remarkable 3% accuracy, and the stresses and strains present within the material. It is also possible to predict the level of shearing within the polymer layer which may lead to angel hair formation during manufacture, and the effect of changing the tool design. It is possible to incorporate simplistic anisotropic properties by averaging the r-values, which further improves the quality of the results by approximately 1%. The model exists and validated in both of the solvers used at Corus packaging, namely MSC.Marc® and Rockfield's Elfen®. The results were identical. It is possible to include stripping in the simulation if it is needed. Blank holder lift-off timing, which is necessary to avoid pinching of the polymer, is implemented. Full three-dimensional anisotropy, thus earing prediction is not yet implemented. The hardening of the material during stretch-bending is slightly over predicted by the currently

used proportional hardening description. This results in slight over prediction of wall thickness and under prediction of cup height. The usefulness of the model is not disturbed by the above inaccuracies, and can be compensated by experienced users.

The route to the product is often more important to performance than the product itself. By choosing the right production route the performance of the same product can be improved. The above described draw-redraw (DRD) model was validated on the DRD stages of a draw-redraw-wall ironed (DWI) beer and beverage can, showing wrinkling prevention, classical deep drawing in the cupping stage, and stretch drawing (to the limit) in the redraw stage. Later the same technology was used to optimise tooling for a draw-double-redraw (D^2RD) process for a cylindrical food container using criteria for wrinkling prevention and optimisation of material consumption. Our RD&T example is shown with an optimisation for the blank size with a target to reduce the initial blank diameter from ∅ 179 mm to ∅ 172 mm. For the optimisation work done, the strategy was to optimise the first two draw process to reduce thinning, and consequently, the risk of wrinkling, targeting the required blank size. Further, to apply the highest possible stretch during the final redraw stage to achieve the required cup height. The outcome of the tool optimisation process is a can, which is a result of a more robust forming process, and has the potential for further improvements. By using finite element modelling, the development time and costs were cut to an estimated quarter of the conventional tool design process. Re-designing of toolsets in the past required a lot of experience and intuition. With the help of finite element analysis, now it is possible to calculate and visualise the full DRD process, and compare numerous designs at low cost.

The figures show the thickness distribution of the initial progression set and two optimised designs of the final product respectively. The x-axis represents the measured distance from the centre of the cup base along the mid-surface of the cross-sectioned wall. The y-axis represents the wall thickness in millimetres. It can be seen that there is no thinning at the can base, where the initial material thickness of 0.22 mm can be measured. The highest thinning can be seen slightly above the punch radius. The can wall then thickens gradually towards the top due to the high hoop stresses present during drawing. Severe thickness variations do not diminish and appear as a witness line in the next operation. Note that the optimised designs require a smaller blank diameter while achieving similar product dimensions and exhibit less thinning.





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