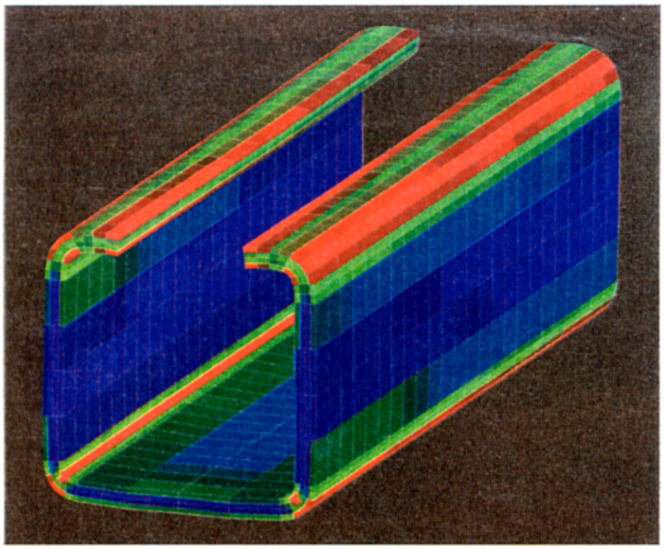

Predicting stress and strain in roll formed profiles

Three methods to help prevent roll tool modifications

By Roland Brandegger

Roll forming is a continuous bending operation in which sheet or strip metal is formed gradually in tandem sets of rollers until the desired cross-sectional configuration is obtained. Tracking single points of the cross section can reveal movements on curves, which reveals the different strains and stresses on the material lengths.

As long as these stresses occur within the elastic bounds, strain disappears again after the profile leaves the final roll forming stand, and the desired profile form can be obtained. However, if yield stress is exceeded, the strain remains, and the resulting excess material causes rippled edges in symmetric profiles, as well as twists around the longitudinal axis or curving in nonsymmetric profiles. Time-consuming and expensive modification of the roll tools is needed to correct the problem.

Three software-based quality control options can help designers predict and track strain and stress to prevent costly modifications down the line.

Stress of Band Edge

A long-standing approach to predicting strain and stress is to describe the band edge curve by a mathematical function. Software can display the results in a bar diagram. The length of each bar shows the relative stress between two stands related to the yield point of the material (see **Figure 1**). A red bar warns that the stress is going to exceed the yield point.

While the designer optimizes the flower pattern, the bar diagram is updated simultaneously. That way, the designer can check the relative stress while modifying the bend angles.

Profile Stress Analysis

With another software-based method, profile stress analysis (PSA), the sheet surface is divided into small, rectangular shell segments. The user can define the segment width and precision of calculation. Critical areas like the bending zones can be calculated with higher resolution.

While running through the roll forming machine, the rectangles are formed to general quadrilaterals. From lengthening or shortening of the edges, the expected strain and stress can be derived. The stress related to the yield point of the material is assigned to a color in the range of blue (0 percent), green (50 percent), and red (100 percent). In the 3-D model, critical areas can be detected by red-colored shell segments (see **Figure 2**). The designer can use the mouse wheel to rotate and zoom the model to examine any detail.

PSA works without finite element analysis (FEA), so the results are available immediately after keystroke.

PSA calculates longitudinal stress in the whole profile cross section. This is important if maximum stress is not at the band edge, for instance, if folded edges are bent up. It also calculates quickly and can be used during the design process.

Finite Element Analysis

FEA simulation of the roll forming process enables a designer to get very precise information about stress and strain within the profile while it runs through the roll forming machine and after it leaves the final stand of the machine (see **Figure 3**). FEA simulation also calculates the profile shape formed by the designed rolls.

Once the rolls are designed, the input files with the simulation model for the FEA system are created by keystroke. In general, a thin-shell model is used, which is optimal for sheet bending.

However, the shell width can be selected depending on the desired accuracy, either general or user-defined. General accuracy means that for each type of profile element (line and arc), a constant shell width can be preset. User-defined means that for each profile element selected, shell segments can be divided individually. This enables the user to define a higher accuracy for certain parts of the profile.

The material properties are defined by the stress-strain diagram. Furthermore, the step interval for mass scaling can be preset, which helps accelerate the computing procedure. A recommended step interval is calculated, depending on the minimal shell width and material properties.

The FEA simulation process should run on a separate computer, since it takes between several hours and several days, depending on how complicated the profile is and how many roll forming stands are used. This process should not block the designer's computer-aided design (CAD) workstation.

The FEA system performs explicit calculations and can consider oil-canning effects that often occur when thin sheet is formed. With the explicit method of calculations, which tracks the curve in small steps

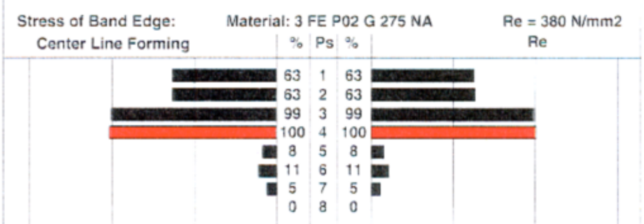

Figure 1

The results of the mathematical determination of stress and strain are displayed by software in a bar diagram.

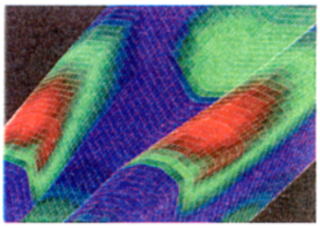

Figure 2
In the 3-D PSA model, the stress related to the yield point of the material is assigned a color.

to get the function value and is robust enough to stand up against jumps, a user of FEA simulation doesn't have to be an FEA expert. If the software relied on implicit calculations, which use the Newton method to arrive at function values, the user would have to be able to recognize the reason for breakoffs when jumps occur and take special measures to prevent it (for example, viscous damping in the FEA model).

The simulation allows the designer a first look at the shape of the profile after it leaves the final stand. This drawing then can be compared with the designed shape. If allowances do not match, the designer can browse through the different time intervals within the machine to track the error.

Colors on the drawing show positions of high stress and remaining strain. This enables the designer to locate the reason for unwanted deformations and shows which rolls need to be modified.

Since FEA simulation requires more computing time than the other quality options, it makes sense to use the FEA simulation at the end of the design process.

Confidence in Design

The goal of these three quality methods is to systematize the roll form design process rather than relying on the designer's experience, giving the designer confidence that the designed rolls will be able to form the profile shape with the desired allowances.

All three options can be combined excellently to help decrease or eliminate time-consuming redesign of expensive roll tool sets. The band edge method can be used during the design process and gives approximate stress values at the band edge only, whereas PSA gives more information about the whole profile and is available on keystroke. FEA gives precise information but should be used at the end of the design process.

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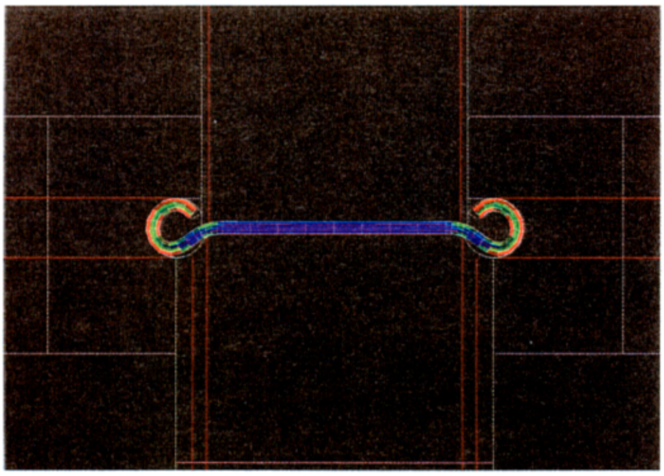

Figure 3
FEA simulation enables the designer to get precise information about stress and strain within the profile while it runs through the roll forming machine and after it leaves the final stand.