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# Troubleshooting Formability Problems Using Strain Analysis

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STRAIN ANALYSIS is a technique to assess the degree of stamping process robustness as it relates to the sheet properties of the incoming blank used to form the part in question. The analysis is typically done on parts formed from known sheet properties, but it is possible to extrapolate the forming behavior when the steel properties are at the low end of the ordered grade and thickness. Strain analysis is also useful during tool development to help limit problems during production. Although parts on day one may “hold water,” strain analysis can highlight those areas that may need some tooling work to ensure that the ordered steel or aluminum grade and the forming process, together, are sufficiently robust to produce a split-free panel over the entire property range associated with the particular sheet material grade. Strain analysis can help determine if a change to a more formable grade or heavier gage is warranted to reduce the potential for splitting. Similarly, strain analysis can help determine if a less formable grade (which is typically less expensive) or lighter gage (also a cost-savings opportunity) can be used.

This article describes techniques that can help with troubleshooting production process discrepancies. If supposedly symmetrical areas on a given part are not behaving the same way (e.g., the left side splits but the right side works), strain analysis can help determine if the locations in question are actually forming the same way and undergoing the same deformation. These differences in strain distribution can then be used to determine the root cause of the observed performance differences.

Once a robust condition has been achieved at the beginning of production stamping (or during the production stamping life cycle), a “reference panel” can be established with the aid of strain analysis techniques. This reference panel documents all properties, settings, and conditions that produced a good panel, such that these parameters can be replicated if issues are encountered during production. Using the strain distribution information from the reference panel, strains/thicknesses at selected areas

can be checked intermittently during ongoing production. Tracking these data as a function of time can be used as a statistical process control and quality-monitoring tool, providing indication of part/process consistency as well as raising a “red flag” if something with the material, tooling, and/or process setup is going out of control.

The same strain-analysis techniques described in this article thus provide a useful and versatile tool that can be used in troubleshooting formability and process discrepancies throughout the entire tooling development and production stamping cycle: initial die tryout, tooling buyoff, home pressline die tryout, and ongoing production stamping.

## Strain Calculations

Strain calculations can be visualized using the circle grid method by picturing a circle on a surface of a flat blank. After the blank is formed, the circle from the flat blank will become an ellipse (unless deformation is not pure biaxial stretching). The longest dimension of the ellipse is the major axis, and the dimension perpendicular to the major axis is the minor axis. Knowing the exact dimension of the starting circle as well as obtaining an accurate measurement of the length of the major and minor axes

(Fig. 1) allows for the direct calculation of the engineering major and minor strains, where:

$$e_{ma} = \text{Major strain (\%)} = 100 \times \left( \frac{L_{ma} - L_i}{L_i} \right)$$

$$e_{mi} = \text{Minor strain (\%)} = 100 \times \left( \frac{L_{mi} - L_i}{L_i} \right)$$

The major strain is always positive and always greater than the minor strain. In the sketches shown in Fig. 2, the shape of the initial circle is shown as a dashed line. After forming, there are three possible descriptions of the shape of the resulting ellipse.

In this process of metal deformation, a unit of material maintains a constant volume before, during, and after forming. This allows for calculation of a thickness strain ( $e_t$ ), because the major, minor, and thickness strains in that unit of material multiplied together must equal 1, such that:

$$(e_{ma} + 1) \times (e_{mi} + 1) \times (e_t + 1) = 1, \text{ or}$$

$$e_t = \left[ \frac{1}{(e_{ma} + 1) \times (e_{mi} + 1)} \right] - 1$$

A nomograph of this is shown in Fig. 15 of the article “Formability Testing of Sheet Metals” in this Volume. As an example, consider a 0.100 in. diameter circle that was deformed into an ellipse with the longest dimension of 0.125 in., and

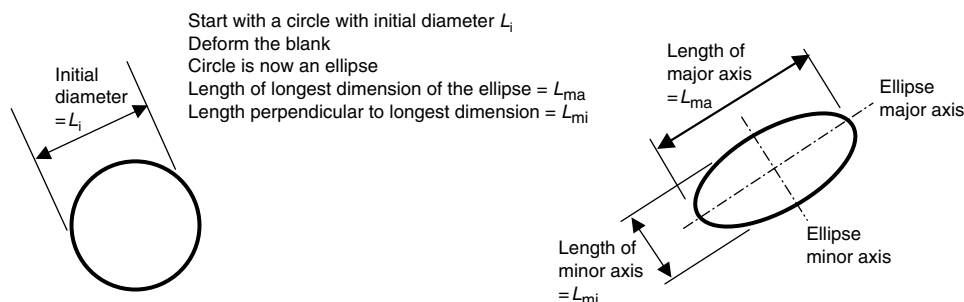


Fig. 1 Definition of major strain and minor strain