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SURFACE VEHICLE RECOMMENDED PRACTICE

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METHODS FOR DETERMINING PLASTIC DEFORMATION IN SHEET METAL STAMPINGS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

The preferred method for determining plastic strain is the circle grid and the severity curve. The scribed square and change in thickness methods may also be used to evaluate deformation during the forming of a flat sheet into the desired shape.

1. Scope—This SAE Recommended Practice describes methods for determining plastic deformation encountered in the forming or drawing of sheet steel.

2. References—There are no referenced publications specified herein.

3. Methods

3.1 Circle Grid Method—The test system employs electrochemically etched circle patterns on the surface of a sheet metal blank and a severity curve for the evaluation of strains developed by forming in press operations. It is useful in the laboratory and in the press room. Selection from the various steels which are commercially available can be done effectively by employing this technique. In addition, corrective action in die or part design to improve performance is often indicated.

The severity curve in Figure 1 has been developed from actual measurements of the major (e_1) and associated minor (e_2) strains found in critical areas of production type stampings. Strain combinations which locate below this curve are safe, while those which fall above the curve are critical. The left of zero portion of the curve (tension-compression) represents 25% change in unit area. The right side (tension-tension) defines a severity limit since no constant percent change in area will be found to be critical.

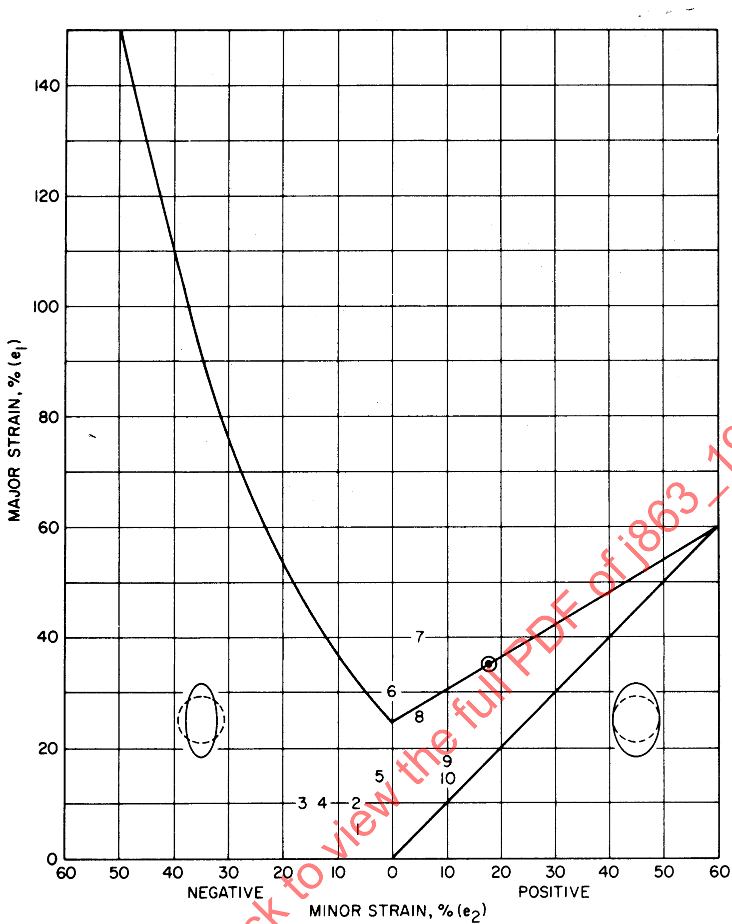

FIGURE 1—SEVERITY CURVE

4. *Procedure*

1. Obtain or prepare a stencil with selected circles in a uniform pattern. The circles may be 0.10–0.25 in (2.5–6.4 mm) in diameter; the most convenient diameter is 0.20 in (5.1 mm) because it is easy to read and the gage spacing is short enough to show the maximum strain in a specific location on the part.
2. The sheet metal blanks should be cleaned to remove excess oil and dirt; however, some precoated sheets can be etched without removing the coating. The area(s) to be etched should be determined from observation of panels previously formed; generally, the area which has a split problem is selected for etching. Normally, the convex side of the radius is gridded. If sufficient time is available, the entire blank may be etched, since valuable information can be obtained about the movement of metal in stamping a part when strains can be evaluated in what may appear to be noncritical areas. Additionally, for complex shapes it may be desirable to etch both surfaces of blanks so that the strains which occur in reverse draws can be determined.
3. The etch pad is saturated with an appropriate electrolyte. Various electrolytes are available from suppliers of the etching equipment. Some electrolytes are more effective than others for etching certain surfaces, such as terne plate and other metallic coated steels. A rust inhibiting solution is preferred for steel sheets.

4. A ground clamp from the transformer of suitable amperage (10–50 A is usually used) is fastened to the blank and the second lead is attached to the etch pad. Although the current may be turned on at this time, caution should be taken not to lay the pad on the sheet blank as it will arc. It is advisable to refrain from touching the metal of the etch pad and the grounded sheet blank.
5. The stencil is placed with the plastic coating against the sheet surface in the area to be etched. Wetting the stencil with a minimum amount of electrolyte will assist in smoothing out the wrinkles and gives a more uniform etch. The etch pad is now positioned on the stencil and the current turned on, if it is not already on. Apply suitable pressure to the pad. Only the minimum time necessary to produce a clear etched pattern should be used. The etching time will vary with the amperage available from the power source and the stencil area, as well as the pad area in contact with the stencil. Rocker type etch pads give good prints and require less amperage than flat surfaced pads. Excessive current causes stencil damage.
6. The etching solution activates the surface of the metal and may cause rusting unless it is inhibited. After the desired area has been etched, the blank should be wiped or rinsed, dried, and neutralized.
7. The etched blank is now ready for forming. The lubricants and press conditions should simulate production situations.
8. If a sequence of operations is used in forming a part, it is desirable to etch sufficient blanks so that each operation can be studied.

4.1 Measurement Of Strain After Forming—After forming, the circles are generally distorted into elliptical shapes (Figure 2). These ellipses have major and minor strain axes. The major strain (e_1) is always defined to be the direction in which the greatest positive strain has occurred without regard to original blank edges or the sheet rolling direction. The minor strain (e_2) is defined to be 90 deg to the major strain direction.

There are several methods for determining the major and minor strains of the formed panel. Typical tools are a pair of dividers and a scale ruled in 50ths of an in (0.5 mm). For sharp radii, a thin plastic scale, which can follow the contour of the stamping, can be used to determine the dimensions of the ellipses. (Scales are available to read the percent strain directly.)

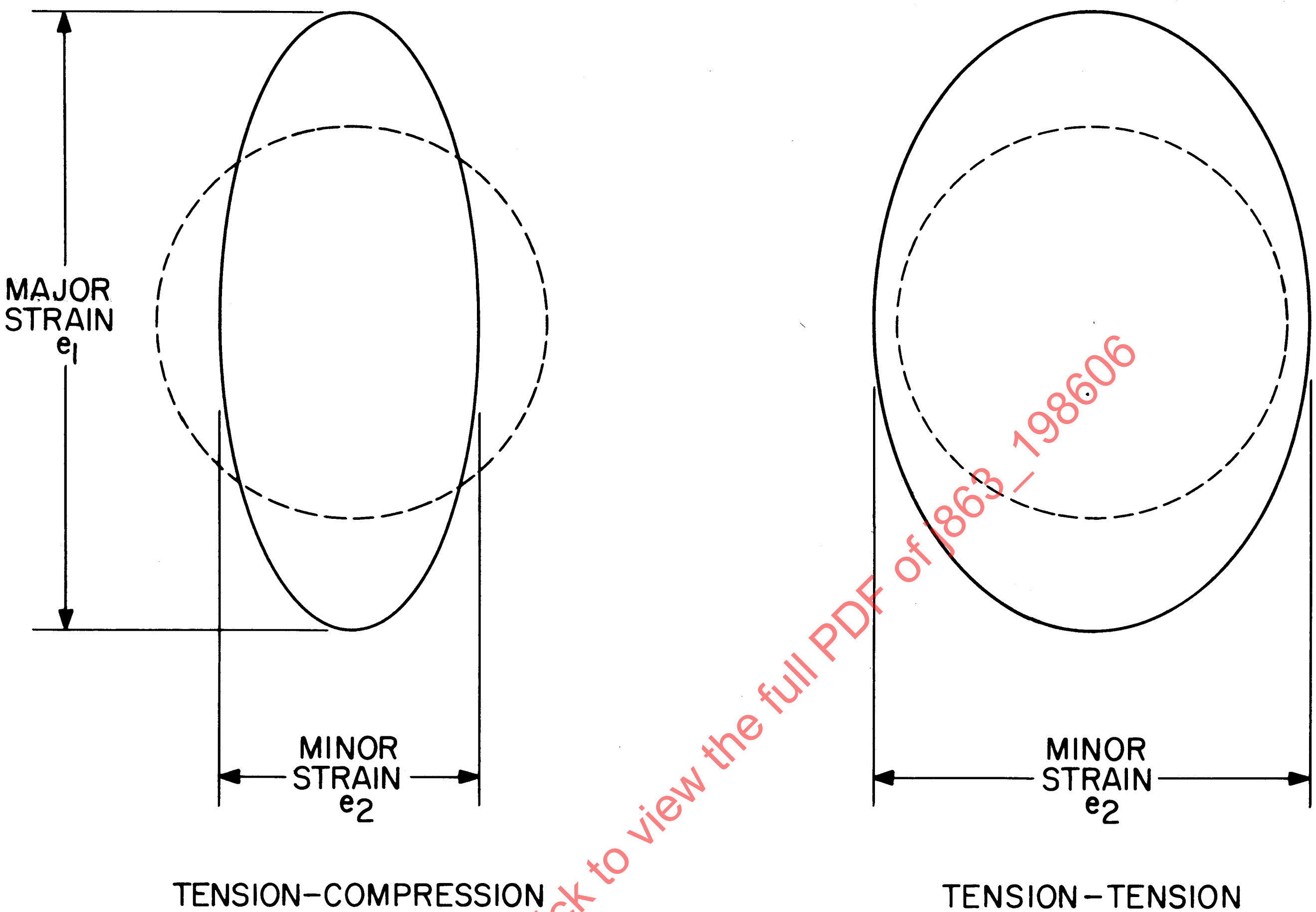

FIGURE 2—

4.2 Evaluation Of Strain Measurement—The e_1 strain is always positive while the e_2 strain may be zero, positive, or negative, as indicated on the severity curve chart (Figure 1). The maximum e_1 and associated e_2 values measured in critical areas on the formed part are plotted on the graph paper containing the severity curve by locating the point of intersection of the e_1, e_2 strains

If this point is on or below the severity curve, the strain should not cause breakage. Points further below the curve indicate that a less ductile material of a lower grade may be applied. Points above the severity curve show the fabrication has induced strains which could result in breakage. Therefore, in evaluations on stampings exhibiting high strains, efforts should be made to provide an e_1, e_2 strain combination which would lie on or below the severity curve. A different e_1, e_2 strain combination can be obtained through changes of one or more of the forming variables such as die conditions, lubricants, blank size, thickness, or material grade.

When attempting to change the relationship of e_1 and e_2 strains, it should be noted that on the severity curve the most severe condition for a given e_1 strain is at 0% e_2 strain. This means the metal works best when it is allowed to deform in two dimensions, e_1 and e_2, rather than being restricted in one dimension. A change in e_2 to decrease the severity can be made by changing one of the previously mentioned forming variables or the die design, for example, improving lubrication on the tension-tension side will increase e_2 and decrease the severity.

In addition to the severity curve, the e_1, e_2 strain measurements may be used to evaluate the material requirements on the basis of strain gradients, as illustrated in Figure 3, or by plotting contours of equivalent strain levels on the surface of the formed part. Even when the level of strain is relatively low, parts in which the e_1 strain is changing rapidly either in magnitude or direction over a short span on the surface may require more ductile grades of sheet metal, change in lubrication, or change in part design.

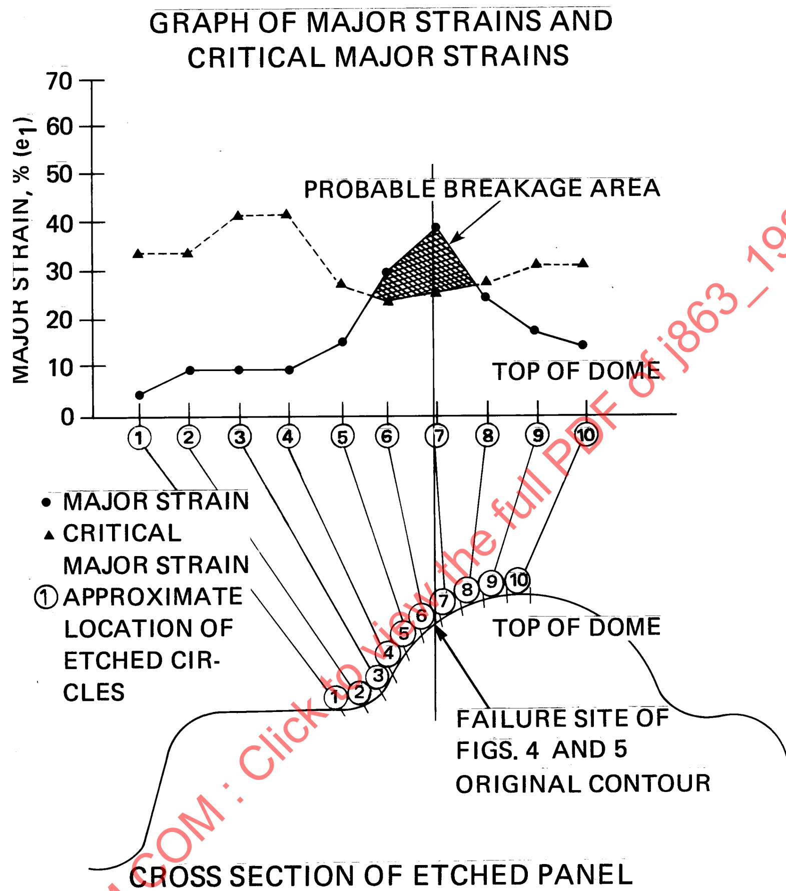

FIGURE 3—

4.3 Example Of Major And Minor Strain Distribution—A formed panel (Figures 4 and 5), with a cross section as shown in Figure 3, is used to illustrate major and minor strain combinations. A plot of the major strain distribution is made by finding the ellipse with the largest major strain (circle 7 in Figure 3), corresponding to the fracture area shown in Figure 5, original contour, and measuring the major and minor strains in the row of ellipses running in the direction of the major strain. The solid dots (Figure 3), are the measured major strains for each ellipse. The x's are the critical major strains as determined from the severity curve at the corresponding minor strain (intersection of the measured minor strain and the severity curve, the numbers on Figure 1 are the major and minor (e_1, e_2) strains for the measured circles of 3).

Usually, a row of ellipses will suffice to determine the most severe strain distribution. The resulting strain distribution plot (Figure 3), illustrates both severity of strain compared to the critical strain limits and the concentration of the strain in the stamping. Steep strain gradients should be avoided because they are inherent fracture sites.

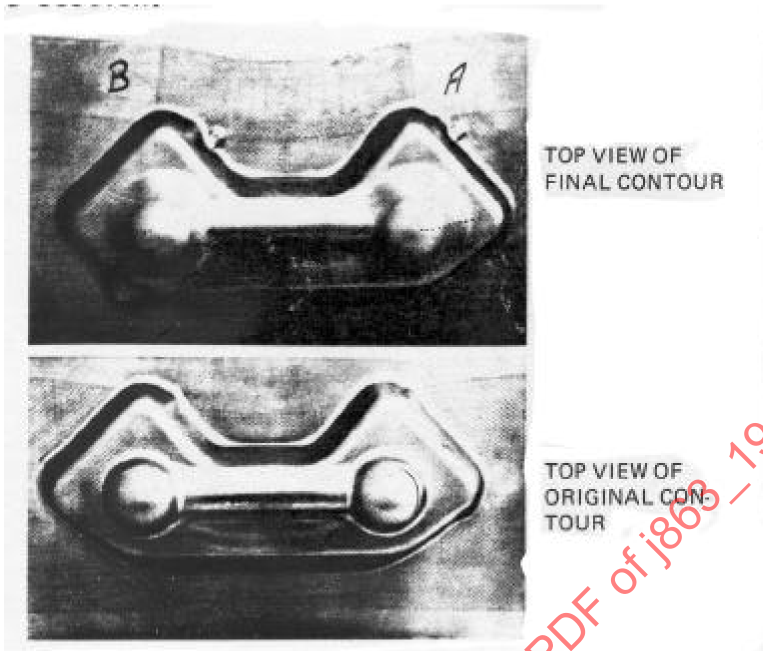

FIGURE 4—

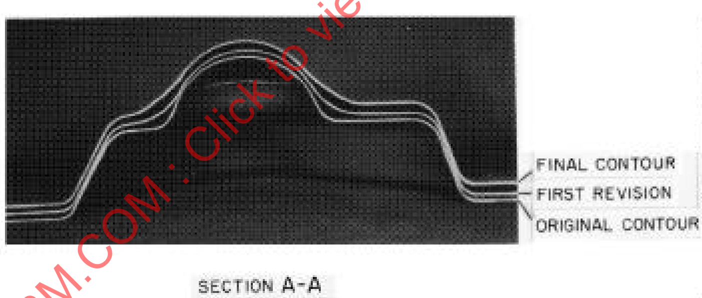

FIGURE 5—

The lower picture in Figure 4 is a top view of the original contour shown in Figure 5. The final contour (upper picture) shows the line of dots indicating the row of ellipses measured for the strain evaluations. A corresponding row was measured on the original contour with the results as shown in Figure 3.

4.4 Example For Reducing Splitting Tendency—The splitting tendency in such an area as represented in Figures 3 and 5 (original contour) can be reduced as follows: If the radius of the part in the region of circle 1 is increased, some strain can be induced to take place in this area which will allow the strain combination in circle 7 to be modified to bring it within a "safe" range. By changing the radius as shown in Figures 4 and 5, the strain combination in the critical area was changed from 40 x 5% to 35 x 17.5% (dot in circle of Figure 1) which is now just in the "safe" area.

This course of action requires no building nor re-shaping of the punch, only grinding the radius of the die.