References


**DISCUSSION**

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For some time, the importance of mechanical anisotropy to deep drawing has been realized, but this has been attributed primarily to the resultant degree of resistance to straining in the through thickness direction. As a result of the work of Moore and Wallace [5] and the present study, it is evident that mechanical anisotropy affects, in addition, the amount of stretching which the material may undergo before it necks down and fractures.

The significance of this to press forming operations is evident. The orientation of the blank in the press can have a pronounced effect on press performance. Modifications in tool and die design and in lubrication procedures can result in improved or impaired press performance depending on the mechanical anisotropy of the deforming part. Also, if the critical subtangent can be determined at critical locations on the pressing, then it should be possible to predict the performance of any material to be used for the same pressing provided that the strain distribution is reasonably the same for the different materials.

Unfortunately, although considerable potential is indicated, the theory cannot be applied without refinement to the majority of conditions occurring during press forming.

The expressions derived by Moore and Wallace and by Mir and Hillier in the present work do not allow for the determination of the critical subtangent except where the principal axes of stress and of anisotropy coincide. To do so for the general case would require the treatment of an expression for the yield criterion which includes a shear term, i.e.,

\[ \sigma = \frac{1}{2} \left[ \frac{(G + H)\sigma_\text{st}^2 - 2H\sigma_\text{st} + (H + F)\sigma_\text{st}^2 + 2N\tau_{st}^2}{F + G + H} \right]^{1/2} \]

using Hill's terminology.

The development of this expression to give a general equation for the critical subtangent is probably unreasonably complicated. The assumption that the ratios of the coefficients of anisotropy remain constant during deformation is not unreasonable. However, a more serious drawback is the necessity to assume that the stress ratios remain constant during deformation. This is seldom the case. Keeler, in studies of the deformation of blanks to which grids were applied before pressing, has noted fracture in regions which had apparently undergone only minute deformation. In fact, it was discovered, by carrying out the pressing in stages, that the material in question first underwent extensive compression followed subsequently by an almost equal amount of tensile deformation along the same axis. Since deformation processes are not reversible in the thermodynamic sense, the strain path cannot be ignored.

The present work is significant in that it points out the importance of mechanical anisotropy to the amount of useful ductility in a press forming operation. It is hoped that Professor Hillier and his students will continue studies in this field in the hope of broadening the realm of application.

2 Research Department, The Steel Company of Canada, Ltd., Hamilton, Ontario, Canada.

3 Keeler, S. P., private communication.