CORRELATION BETWEEN SHEET METAL TEXTURE AND DRAWABILITY FOR ALPHA BRASS

E. Shapiro and J. Crane

INTRODUCTION

Since the work of Lankford, et al [1] and Whitely, [2] R has been considered the primary materials variable controlling, by "texture strengthening", [2, 3] the deep drawability of sheet metal. Extensive research in the ferrous metals industry recently summarized by Blickwede [4] has demonstrated the direct correlation between high R and good drawability. While factors other than texture strengthening were shown to influence forming characteristics, the overwhelming statistical trends revealed in Blickwede's compilation single out R as the principal materials variable in predicting deep-drawing behaviour of ferrous-alloy sheet.

A similar body of knowledge does not exist for the nonferrous metals. Both positive correlation between R and formability as well as exceptions to this relationship have been reported in the literature [5, 6, 7]. The paucity of published data of this kind does not permit a statistical analysis to identify a clear pattern of behaviour. The authors attempted, therefore, to examine the correlation of changes of R with changes in the formability of alpha-brass under very restricted conditions wherein R was varied and the tensile properties and grain size held constant.

EXPERIMENTAL MATERIAL AND PROCEDURES

A lot of alloy 260 (29.45% Zn, major impurities 0.01% P, 0.22% Fe, 0.01% Ni, 0.005% Ag, balance copper) was obtained as commercially-produced, hot-rolled plate at 9.1 mm gauge. Cold rolling and annealing were carried out in the laboratory to obtain the desired variations of R at 0.76 mm gauge.

ASTM standard sheet tensile specimens were cut at 0°, 45°, and 90° to the rolling directions. Whitely's [8] nomograph and the relation:

\[ \ln \left( \frac{w_f}{w_o} \right) \]

\[ R = \ln \left( \frac{1-w_f}{1-w_o} \right) \]

were used to calculate R values in the 0°, 45° and 90° directions. The subscripts o and f refer to the original and final measured dimensions of width, w, and gauge length, l. The R values thus determined at 0°, 45° and 90° to the rolling direction were used to calculate R by the relationship:

\[ R = \frac{(R_0° + 2R_{45°} + R_{90°})}{4} \]

* Olin Corporation, Metals Research Laboratories, 91 Shelton Avenue, New Haven, Connecticut 06504, U. S. A.
Experimental Results and Discussion

Table 1 lists the mechanical property data and grain sizes for material conditions where only \( R \) was varied and all other materials factors remained essentially constant. LDR and \( R \) values are listed in Table 2, and LDR versus \( R \) is plotted in Figure 1. The increase in LDR with increasing \( R \) for each set of experiments is evident. It can be seen that increasing \( R \) improves drawability over a wide range of grain sizes, elongations, strengths, and \( \eta \) values.

The dashed lines in Figure 1 represent a plot of a theoretical relationship between LDR and \( R \): \[
\ln (\text{LDR}) = \frac{1}{4 \eta} \left( \frac{1 + R^2}{2} \right)^{1/2}
\]

The quantity \( \eta \) is an empirical friction factor in this expression and takes on values between 0.2 and 0.3. The slope of the experimental and theoretical plots of LDR versus \( R \) are in reasonable agreement when \( R \) is the only factor varying. Hosford suggests that agreement can be improved by accounting for planar anisotropy [11]. For experimental conditions where no attempt was made to isolate \( R \) as the only variable, large discrepancies between the theoretical and experimental slopes were noted. Similar discrepancies have been reported elsewhere [12].

It should be emphasized that for substantially different materials characteristics it cannot be assumed that a direct correlation between \( R \) and LDR exists. In fact, the partially recrystallized metal of experiments Cc shows an LDR of 2.22 at an \( R \) level of 0.92 in contrast to B and D which have higher \( R \) but lower LDR. This implies that other variables, aside from \( R \), exert an influence on the drawability of brass sheet.

The higher drawability of partially recrystallized metal compared to fully-annealed metal at the same \( R \) value points out the error of the commonly held notion that the highest deep drawability is achieved with fully-softerned metal. Aside from the few examples illustrated here, numerous instances, particularly in deep drawing aluminum alloys, can be found to show that fully-softerned material is not always superior to partially-recrystallized or even cold-worked material.

Conclusions

1. Increasing the \( R \) values of alpha brass sheet increases the Limiting Draw Ratio (LDR) under conditions where \( R \) is the only materials factor which varies.
2. The magnitude of the increases in drawability correlate with theoretically derived LDR versus \( R \) relationships.
3. Under conditions where other materials factors were varied along with \( R \) correlations between R and LDR were less reliable.

Acknowledgements

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References

Table 1 Mechanical Properties and Grain Size for Material Processed to Vary R

<table>
<thead>
<tr>
<th>Item</th>
<th>0.2% UTS</th>
<th>UTS</th>
<th>Grain</th>
<th>Grain Size (Avg)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>100</td>
<td>337</td>
<td>0.45-0.50</td>
<td>0.06</td>
<td>62</td>
</tr>
<tr>
<td>b</td>
<td>100</td>
<td>333</td>
<td>0.45-0.50</td>
<td>0.06</td>
<td>61</td>
</tr>
<tr>
<td>c</td>
<td>75</td>
<td>316</td>
<td>0.45-0.50</td>
<td>0.14</td>
<td>93</td>
</tr>
<tr>
<td>d</td>
<td>78</td>
<td>339</td>
<td>0.45-0.50</td>
<td>0.13</td>
<td>94</td>
</tr>
<tr>
<td>e</td>
<td>257</td>
<td>431</td>
<td>0.30-0.35</td>
<td>0.28</td>
<td>76*</td>
</tr>
<tr>
<td>f</td>
<td>181</td>
<td>444</td>
<td>0.30-0.35</td>
<td>0.28</td>
<td>76*</td>
</tr>
</tbody>
</table>

*PR = partially recrystallized.

Table 2 Comparison of LDR and R Values

<table>
<thead>
<tr>
<th>Grade</th>
<th>R</th>
<th>LDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.93</td>
<td>2.17</td>
</tr>
<tr>
<td>a</td>
<td>0.12</td>
<td>2.24</td>
</tr>
<tr>
<td>b</td>
<td>0.97</td>
<td>2.18</td>
</tr>
<tr>
<td>c</td>
<td>0.12</td>
<td>2.24</td>
</tr>
<tr>
<td>C</td>
<td>0.24</td>
<td>2.17</td>
</tr>
<tr>
<td>c</td>
<td>0.92</td>
<td>2.22</td>
</tr>
<tr>
<td>D</td>
<td>0.98</td>
<td>2.17</td>
</tr>
<tr>
<td>d</td>
<td>0.17</td>
<td>2.24</td>
</tr>
</tbody>
</table>

Figure 1 Solid Lines Represent R versus LDR for Conditions where only R was Varied and other Materials Factors Remained Essentially Constant. Dashed Lines are Explained in the Text.