LIGHT WEIGHTING OF STEEL BEVERAGE CANS

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Introduction

Despite the continued growth of the aluminum beverage can market to the dominant position it holds today in the USA, Europe and SE Asia, steel companies have been consistent in their belief that with the right combination of forming technology, steel specification, infrastructure and market conditions the steel beverage can could again enjoy a significant share of this important market.

For this to happen a number of key issues needed to be addressed.

- Establishment of a recycling infrastructure for steel cans
- Suitable steel specification for D&l
- Favorable comparative can stock pricing
- Light weight steel can technology

Recycling

Steel has traditionally been a heavily recycled material; however, the U.S. aluminum producers pioneered the development of an infrastructure to specifically recycle used aluminum beverage cans directly from the general public (encouraged by the high cost of primary aluminum production).
No complementary infrastructure was in place specifically for used steel beverage cans and consequently aluminum became a preferred material from the standpoint of a consumer "recyclability perception".

In 1988 U.S. steel producers, through the AISI, set up the Steel Can Recycling Institute (SCRI) to develop the necessary infrastructure. In the short time SCRI has been in existence steel can recycling (steel cans of all types) has reached 54% and is targeted to achieve a 66% recycling rate for all steel containers by 1995.

Since 1993 there has been a substantial change in the pattern of recycling of aluminum cans, away from "buyback centers" in favor of "curbside collection" where municipalities take responsibility for collection, segregation and material recoveries. This move takes the direct financial advantage of recycling used beverage cans away from the consumer.

**Suitable Steel Specifications for D&I**

As container manufacturing facilities have become faster, they have become more sensitive to variable quality of metal feedstock; therefore, significant attention and investment has been made to improve the quality and consistency of steel can stock for D&I cans.

The two key requirements for consistent high quality D&I can production are:
- gauge consistency
- "cleanliness" (absence of non-metallic inclusions [NMI])

Tin plate producers supplying D&I can stock have significantly improved their gauge control capabilities and in addition invested heavily in their manufacturing practices for producing "clean steel" (free of NMI). These two qualities are considered to be important to reducing the incidence of "tear-offs" at the bodymaker.

**Favorable Comparable Can Stock Pricing**

Historically steel can stock prices have been remarkably stable. Not so aluminum where significant volatility exists. It is the current high price of aluminum can stock (3004 alloy) which has triggered a serious review of their current dedication to aluminum by can makers and fillers so it is worth spending a little time examining the comparative prices and forecasts for the next few years.

Since 1988, when aluminum can stock (RCS) price was last at its peak, prices have fallen steadily through January 1994 when RCS was about 78 cents per pound, caused by a combination of compounded low margins experienced by the aluminum can sheet producers, world supply surplus, speculation in primary aluminum on the world commodity markets. The price was further impacted by the introduction of a 32 cent per pound rolling (or conversion) charge by the mills.
By January 1995 and coinciding with a 100% conversion of the U.S. beverage market, the price of aluminum can stock rose to $1.23 per pound, an increase of over 50% within 12 months.

Lid stock (5182 alloy) similarly increased but at an even higher rate.

For can makers, raw materials (mainly can stock and lid stock) make up about 70% of total production costs so such an increase was impossible to offset. Can makers were now experiencing a finished can and end price increase of $15-$17/1,000, roughly 28%. With low operating margins the can makers had no ability to absorb or cushion these extras and consequently passed the increase directly to the fillers, creating a 1.5 cent per can extra cost to the filler.

Forecasts for the next few years see aluminum can stock prices remaining at these high levels.

**Light Weight Steel Can Technology**

Substantial research and development has been undertaken largely by the tin plate producers in U.S. and Europe to reduce the overall weight of the steel D&I beverage can. Several articles have been published recently describing the outcome of these various development programs and the significant reductions which are able to be made in overall can body weight.
In the interests of providing an understanding of this research and the important contribution the finishing material supply industry can make to ensure the success of the new light weight steel beverage can, I will describe the various light weighting activities.

Two approaches have been taken to reduce the total metal usage of the steel D&I can. Both have come from research conducted by collaborative programs in Europe between Hoogovens Steel, Rasselstein and British Steel and between Sollac and Weirton Steel.

The first group proposes a combination of small blank diameter with increased ironing. The age hardening properties of the SR steel are important in achieving the required base buckle performance of these light weight cans after forming and finishing. Age hardening is the property exhibited by some steel grades where an increase in tensile strength occurs after the formed can when it is thermally cycled through the decorating and lacquering operations.

The second group proposes a different solution, that of retaining the existing blank diameter, substantially downgauging the input steel and compensating for the reduction in metal gauge by using the high tensile properties of DR (or double reduced) steel to achieve the required base buckle performance.

Both approaches are consistent with achieving the lightest weight can. The significance is that although aluminum cans may be further reduced in weight by a
further 4-5% in the next few years, the light weight steel can has the potential to reach over 30% further light weighting.

This slide shows the comparative base material gauges over the past ten years with a projection for light weight DR steel cans.

It can be seen that both metals show a progressive reduction in base material gauge, achieved by a combination of more closely controlled can production operations, development in base dome designs to optimize geometries which improve container strength and reduced variation in the can stock.

A comparison of finished can weight shows how significant reductions may be achieved with new light weight steel can technology.

**Determining Factors**

The key determining factors which define the extent of light weighting for the can body are

- Base buckle pressure
- Axial load
Base Buckle

The industry has defined 92 psi (6.5 bar) as the minimum base buckle performance for the current 206 can which is required to maintain stable can geometry through the combined internal pressure, exerted by carbonation of the pack contents and reasonable abuse resistance. Improvements in base profiles have achieved continuing opportunities for downgauging. As can ends have been successively reduced from 209 through 206 to the new 202 diameter, can base design modification has been required to retain can stability when stacked. The newer can bases, designed to stack with 202 diameter ends potentially offer improved geometric rigidity and hence light weighting opportunities.

Can base design has become a very sophisticated engineering process and studies of the effect of internal can pressure on the base and the modes of failure are typically modeled using Finite Element Analysis.

These examples show the effect of increasing pressure on the base of a can designed to stack with a 206 diameter end and with a base compatible with a 202 end. The change to the use of double reduced steel alters the way the can base reacts to increasing internal pressure and this effect may be observed by examining the stress distribution.

The calculated minimum metal thicknesses required to achieve a 92 psi base buckle performance for each material are:
Axial Load

Axial load requirement has generally been specified by can fillers as 250 lb. although the force applied to the can during filling and double seaming is approximately 140 lbs. To provide for handling and transport abuse this 140 lb. minimum needs to be raised to around 220 lbs. to provide a reasonable margin of safety. Over time the 250 lb. axial load specification has been relaxed and cans are now being supplied at axial load performance closer to 220 lb.

The projected minimum thin wall required to achieve 220 lb. axial load capability is:

- Aluminum (3004) 0.0039" (0.10 mm)
- Steel 0.0026" (0.065 mm)

Light Weight Steel Can Forming

In order to take advantage of the increased tensile strength of double reduced (DR) steel, research was necessary to understand the process conditions required to iron such high tensile materials.
For a better understanding of the effect of tensile strength on the forming process the table shows the tensile properties of typical can stock - aluminum, single reduced (SR) and double reduced steel (DR).

<table>
<thead>
<tr>
<th>Material</th>
<th>Temper</th>
<th>Tensile (ksi)</th>
<th>Yield (ksi)</th>
<th>% Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>H19</td>
<td>42.1</td>
<td>37.7</td>
<td>4</td>
</tr>
<tr>
<td>Steel (SR)</td>
<td>T4</td>
<td>60</td>
<td>55</td>
<td>15 - 20</td>
</tr>
<tr>
<td>Steel (DR)</td>
<td>9</td>
<td>90</td>
<td>-</td>
<td>0.2 - 1</td>
</tr>
</tbody>
</table>

The ironing conditions required to form DR9 tin plate are very different and focus mainly on the configuration of the ironing die geometries and the reductions taken at each ironing die.

The schematic shows the wall iron process with redraw die 1st 2nd 3rd ironing rings.

This is a typical setup for aluminum and SR steel.

Typical die geometries are shown in the insert where the die inlet angle, land and exit angle are altered to accommodate the higher tensile strength of DR9.
Ironing for the U.S. 12 oz. (355 ml) DR steel can is achieved in two rings as compared to the more usual three. The land length of the die is reduced to reduce friction. It is at this point a key difference in material behavior occurs.

As the can stock enters the die, the inlet angle provides a compressive load on the metal and plastic deformation occurs. At the exit of the die it is usual to experience a significant elastic recovery for aluminum and SR steel of up to 20%. However with DR steel this elastic recovery is substantially less at 8%.

The statistics of this light weight DR steel process are therefore very different from either aluminum or SR steel

- 1st iron sidewall reduction 38.3%
- 2nd iron sidewall reduction 47.4%
- Overall sidewall reduction 67.5%
- Resulting thin wall 0.0025"
- Resulting thick wall 0.0044"

This can be shown more dramatically in the following can schematic.

Using high temper can stock would lead one to assume that subsequent mechanical working of the neck of the can to achieve the diameter reductions for a 202 neck would present insurmountable problems. This is not the case.
Examination of the tensile properties of the metal in the sidewall of the ironed can show very similar tensiles for single reduced (SR) steel as for DR.

Tensiles taken both radially and longitudinally show remarkably similar results.

<table>
<thead>
<tr>
<th>Starting Tensile (Can Stock)</th>
<th>Bodywall Tensile (Can After Forming)</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR Steel 60 ksi</td>
<td>116.4 ksi longitudinal</td>
<td>94</td>
</tr>
<tr>
<td>DR Steel 90 ksi</td>
<td>120.7 ksi longitudinal</td>
<td>34</td>
</tr>
<tr>
<td>SR Steel 60 ksi</td>
<td>123.3 ksi circumferential</td>
<td>106</td>
</tr>
<tr>
<td>DR Steel 90 ksi</td>
<td>124.5 ksi circumferential</td>
<td>38</td>
</tr>
</tbody>
</table>

It has always been accepted that the tin coating acts in the ironing process as a high pressure lubricant under the high compressive loads and consequent high temperatures experienced at the can stock/die interface.

The result of this high level of working is a disturbed and discontinuous tin coating on the finished can.

These photomicrographs show the tin coating distribution of the inner bodywall after ironing and demonstrates that protective lacquers are required to adhere to a variable tin rich, tin depleted and iron rich surface of the steel.
Production Line Conversion

To capture the benefit of this light weighting technology and conversion of D&I can production facilities to steel will require the installation of an additional spray lacquer and curing pass to achieve the required lacquer coverage. In current steel D&I beverage can installations in Europe two pass lacquering is commonplace and therefore we need to draw on this experience.