The metal casting industry is one of the most energy-intensive manufacturing sectors, with the melting process accounting for over half (55%) of its energy consumption (American Foundry Society). Although high energy expenses have been a significant concern of metal casters, the industry continues to use melting technologies offering poor energy efficiency, often sacrificing energy efficiency for product longevity. In this manufacturing environment, where energy costs are driving innovation and productivity, crucible thermal performance is being tested every day. With a goal of generating longer service life and increased energy savings, extensive lab and field testing was conducted on the new line of “Syncarb Z2e2” crucibles. Through this research, the Syncarb Z2e2 (e2 = Energy Efficiency) is designed specifically for aluminium melting and holding applications. The results show an operational performance that meets and more often surpasses other manufacturer’s “Product X” crucibles in both reduced energy consumption and longevity.

The ceramic-bonded hybrid Syncarb Z2e2 crucible was designed specifically to provide good chemical resistance against fluxes and excellent thermal conductivity in aluminium melting and holding applications. Other properties include outstanding oxidation resistance, high refractoriness and good thermal shock resistance. These measured properties are used to develop energy transfer models to help demonstrate how important small differences in crucibles really are. These results along with field studies are then used to develop Total Cost of Ownership (TCO) models at aluminium casters.

**Laboratory Results**

**Mechanical Properties**

The Syncarb Z2e2 offers 56% higher transverse breaking strength than the other manufacturer’s “Product X” crucible as shown in Figure 2.1. Syncarb Z2e2 crucible maintained integrity at relatively higher values, most likely due to the granulation of the mix, processing parameters and advanced materials.

![Figure 2.1: Showing the dramatic 56% difference in 3-point transverse bending strength of Syncarb Z2e2 crucible versus another manufacturer’s “Product X” crucible.](image)
Oxidation Resistance

In any crucible, one of the leading causes of failures is the oxidation of its elements. In particular, as shown in Equation 1, the breakdown of carbon into CO and CO2 create voids, reduce its mechanical strength and lead to poor thermal conductivity.

Equation 1 Oxidation of Carbon at High Temperatures:

\[ 3C + 2O_2 \rightarrow 2CO + CO_2 \]

Through its advanced glaze technology, Syncarb Z2e2 showed average 10% increase in oxidation resistance in both five and ten day lab tests as shown in Figure 2.2.

Thermal Conductivity

Through advanced research, the Syncarb Z2e2 has been developed and scientifically proven by an independent lab to achieve superior thermal conductivity while maintaining a standard thinner wall thickness than many other manufacturers’ crucibles. This achievement directly correlates to increased energy efficiency and savings to the metal caster in aluminium holding and melting applications. A graph comparing thermal conductivity and operating temperatures of the Morgan Syncarb Z2e2 vs. another manufacturers’ “Product X” crucible is shown in Figure 2.3.

\[ Q = 2k\pi h \left( \frac{T_1 - T_2}{\ln \left( \frac{r_1}{r_2} \right)} \right) \]

\( Q \) = Energy transfer (thermal flux) (W)  
\( k \) = Thermal Conductivity (W/m K)  
\( h \) = Height of cylinder (m)  
\( T_1 \) = Temperature (outer crucible wall) (°C)  
\( T_2 \) = Temperature (inner crucible wall) (°C)  
\( r_1 \) = Outer Radius (m)  
\( r_2 \) = Inner Radius (m)

Comparison – Field Tests

Morgan Syncarb Z2e2 crucibles have not only proven themselves in the laboratory, but have done so in many metal melting operations throughout the world. Their ability to transfer energy efficiently and provide long and repeatable production campaigns is starting to provide major benefits to customers around the world. These benefits are being quantified in order to produce TCO models to help customers understand that the value of their products is not just in the purchased costs. Modern melting operations must take into account downtime, reliability, labour, auxiliary refractory costs, non-consuming parts, local stock, delivery, lead time and total crucible spend if they are to be competitive in today’s environment. The following two case studies and the data presented (supplied by the respective companies) are solid examples of customers realising the need for understanding the costs of production, maintenance, purchasing by working together in order to determine the best value.
Case Study 1

This customer was established in 1985 and has over 35 years of experience in the automobile and automotive Aluminium component manufacturing. They have more than 24 plants globally and some of them are die-casting techniques like LPDC, HPDC and Gravity with electrical resistance furnaces which are catering to the melting of aluminium alloys. This group is technically diversified in India and ready to adapt the technology quickly to be the market leader, so they are always open to:

- Reduce manufacturing interruptions and radical crucible failures
- Increase crucible longevity
- Technical support
- Energy saving initiatives
- Training
- Local stock & service

As Morgan is working very close to various die-casting plants in India and knows well the operating condition of these sites, MMS India proposed them to install Syncarb Z2e2 in their LPDC division. The trials were carried out in one of the ten holding electric resistance furnaces against standard product and other manufacturer’s (“Product Y”). The expected lifetime in normal conditions is about 5.5 months for both, the standard and Product Y, and their appearance at the end of the life shows oxidation at the top and various defects along the external wall (see Figure 4.1 – Product Y). Syncarb Z2e2 has shown already a lifetime of 7 months but looking at the crucible conditions after removal, customer could use it for longer time. Indeed, the external wall has no visible defects, the material structure and the glaze status is still optimal. Overall the customer benefited from energy saving, due to no oxidation in Syncarb Z2e2, and longer lifetime for more than 27% compared to the Product Y and standard one.

![Image of Syncarb Z2e2 and Product Y](image)

**Figure 4.1 (Left two pictures) : Comparison of new SYNCARB Z2E2 crucible and “PRODUCT Y” showing condition of crucible after life. Z2e2 of seven month life, if top protected properly it would have been last longer. Z2e2 crucible still external body looks like new crucible and product Y showing many holes on the crucible body.**

**How the crucible properties are degraded during its use?**

During the use of the crucible the high temperature and the presence of oxygen will oxidise the carbon from the crucible material. Although the external glaze has the aim of protecting the material from this phenomenon, its efficiency will degrade along the time.

The reduction in carbon content due to oxidation leads to reduced mechanical strength and thermal conductivity. Please see figure 4.2

![Graph showing degradation of crucible properties](image)

**Figure 4.2 : comparison showing bulk density and transverse breaking strength reduced at top portion of both the crucibles when crucible got oxidised in use. This data also confirming even though Morgan Syncarb Z2 e’s crucible performed 27.27% over “Product Y” and degradation is lower than product “Y”.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before Use Z2 e2</th>
<th>After use Z2 e2</th>
<th>After use “Y” Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Content</td>
<td>40</td>
<td>13.15</td>
<td>39.6</td>
</tr>
<tr>
<td>Density gm/cc</td>
<td>2.28</td>
<td>1.56</td>
<td>2.28</td>
</tr>
<tr>
<td>TBS MPA</td>
<td>13</td>
<td>1.55</td>
<td>12.22</td>
</tr>
</tbody>
</table>

![Graph showing comparison of energy consumption](image)

**Figure 4.3 : Showing benefits of Z2e2 product provide lower energy consumption over product “Y”.**
After analysing the “total cost of ownership” (TCO) of the crucibles, this division was able to demonstrate that the use of an energy efficient crucible would reduce dramatically the TCO thanks to the strong benefit on the energy consumption side.

These benefits are shown in Figure 4.4 constitute ‘Material Savings’, ‘Manufacturing Downtime’ (due to the crucible change) and ‘Installation, Labour, Refractory’ for a total cost savings to 1444 INR K to this division.

Case Study 2

This customer was established in 1986 to meet captive requirement of Bajaj group. Along the last 30 years they expanded their operations following the ever-growing and demanding need die casted components for the automotive industry. Morgan is whole and sole supplier of industrial engineering consumable like crucible and accessories to their PDC and GDC divisions since the inception of the company.

Morgan has selected GDC division, where they have 30 melting - holding electric resistance furnaces with different capacities – 250kg (5), 300kg (8), 500kg (13) and 700 kg (4). The trial was conducted on a 500kg furnace with the aim of comparing the new Syncarb Z2e2 vs Morgan standard product “A”. While present crucible “A” lifetime was approximately 6 months, the Morgan Syncarb Z2e2 obtained 11 months (see figure 4.5). The next step agreed with the customer has been to check also the energy efficiency of the crucible especially after the 6th month. For this reason a second Syncarb Z2e2 was installed in a furnace equipped with an energy meter and data logger system in order to monitor temperature and energy consumption.

The 83% crucible life improvement in relation to “A” has delivered significant financial benefits to this foundry considering the high costs of production, labour, refractory installation and crucible price. This customer calculated their savings to be in excess of 1800 INR K as shown in Figure 4.7.

Conclusion

The findings of this report are a result of the collaborative efforts of research, development and application engineering. The analysis was carried out in the laboratory as well as in various metal casters in comparison to various other manufacturers’ crucibles.

The laboratory analysis highlighted that Syncarb Z2e2 has a 56% higher 3-point transverse bending strength which means that it is more tolerant to mechanical stresses during operation and mechanical damage during handling than other crucibles. The oxidation tests, where the samples were exposed to an oxidising atmosphere for 5 and 10 days at 750°C, resulted in Syncarb Z2e2 having lower losses. Thermal conductivity tests were also carried out by the laser-flash technique to 1600°C and showed that Syncarb Z2e2 had a higher thermal conductivity at all operating temperatures. This higher conductivity and better oxidation resistance implies more efficient heat transfer for a given thickness of crucible over a longer period of time.

As global metal casting competition becomes fiercer, Total Cost of Ownership (TCO) models have begun to play a significant role in advanced metal casting facilities purchasing practices. These facilities have begun to understand that the cost of a purchasing decision is much more than the initial price paid for a product. While laboratory investigation provides controlled analytical results, field trials connect theory with reality. As part of this on-going study of the benefits of Morgan Syncarb Z2 e2, two medium to large metal casters, first customer and second customer case study were evaluated. At these sites, Syncarb Z2e2 showed significant longevity improvements over the other manufacturers’ crucibles which decreased their annual total cost of ownership (TCO) by more than 1400 and 1800 INR K respectively.

Morgan continues to lead the way through its cutting-edge technology and application support to provide advanced products such as Syncarb Z2e2 and to help metal casters worldwide select the best crucible for their individual and specific application.