# Container and dummy block interaction

The challenge in extrusion container design is to achieve full thermal and dimensional stability to enable transfer of temperature or energy as it is created. The Castool QR container range provides a robust solution based upon a sound application of physics.

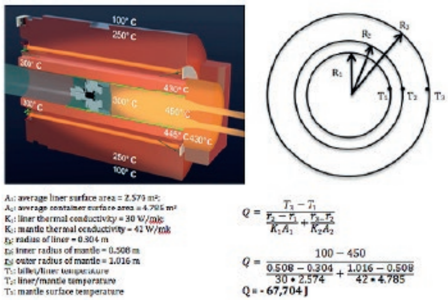
The role of the tooling system in the extrusion process is deceptively simple. A hot billet is inserted into one end of the liner and pushed out the other end. This is done repeatedly and as quickly as possible. Extrusions should be made rapidly and repeatedly, one after another, without interruption or delay. Its successful operation depends on a number of factors. For example, press alignment, both thermal and physical, lubrication, maintenance, and so on. The most important factor is the interaction with any dummy block with a round, straight, thermally and therefore dimensionally stable container.

Containers are probably the most misunderstood press tooling. During extrusion, there is a tremendous amount of heat generated within the container depending on the billet length, billet temperature, alloy types, extrusion speed and extrusion ratio. The temperature increase can be as much as 150°C near the die region - therefore it induces surface cracking, affects extrusion run-outs, and disturbs alignment, resulting in a reduction of the container liner. The clearance between the dummy block and liner also changes, and results in variable skin thickness and alloy build up. Simply put, nothing in extrusion is uniform.

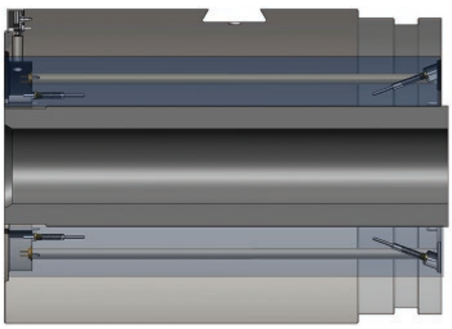
## Thermal stability

Castool's QR container has cartridge heaters positioned close to the liner to create a stable thermal gradient. The mantle becomes a large thermal heat sink to extract heat. A high thermal conductivity AISI 4340 mantle is used to take away a large amount of heat to stabilise the liner temperature. The relatively cooler mantle provides a better interference fit during extrusion. The liner exit temperature can be stabilized and maintained at approximately 30°C below billet temperature at all times to reduce direct billet surface inflow onto the profile, reducing scrap from surface finish. The mantle will not be over heated and the useful life of mantle is increased. The energy consumption is reduced.

The ideal temperature gradient of a container is to have its housing at around 100°C, container mantle surface at 250°C. This creates a thermal gradient in the container and dissipates heat as soon as it is created during extrusion. The calculation shows that the thermal gradient provides the container with an intrinsic heat extraction at 67,704 J. It allows heat to dissipate from the liner without using auxiliary cooling or air groove. Figure 1 depicts the stable thermal gradient of the QR container and its temperatures in different areas.




*1 Stable thermal gradient of the QR container and its temperatures in different areas.*



*2 The Castool QRL long container ( 48 in - 60 inch long) has extra rigidity.*

## Materials selection

Ultra high-strength steels have superior toughness, strength and fatigue strength compared to any hot work tool steel below 500°C. The choice of a hot work tool steel for the mantle does not make any sense, since the mantle temperature in proper extrusion operation should never go above 500°C. For example, AISI 4340 (800 Mpa fatigue strength) will be more appropriate for the mantle.

The most important factor is the interaction with any dummy block with a round, straight, thermally and therefore dimensionally stable container. The gap between the container liner ID and expanded dummy block OD cannot exceed 0.6 mm at all times.

The deflection of the container liner is much affected by the extrusion pressure, container length, and container design. The QR container design can reduce the liner deflection, because it has more of an interference fit due to a comparatively colder mantle than liner:

*Small sized containers (7 inch and below)*
*QRC – Quick Response "Compact"*
Small sized containers with a liner diameter from 7" and under, with 2 individually controlled heating zones can create the thermal gradient required to have good thermal stability. The top and bottom heating zones cover approximately 2/3 of the area from the die end. The natural temperature tapper at the ram end would be able to create the thermal gradient as desired.

*Regular sized containers (7 in - 12 in)*
*QR – Quick Response*
Medium sized containers require 4 individually controlled heating zones with 4 double acting thermocouples located equidistant between the heating elements and liner. It is recommended for liner diameters from 7" - 12". The heating zones are positioned in die end top and bottom, and entrance top and bottom. It provides the container with the ability to control and maintain a stable thermal gradient from top to bottom, and exit to entrance to quick heat dissipation.

*Long container (48 in - 60 in)*
*QRL – Quick Response "extra rigidity"*
For a longer container like the one in Figure 2, the liner will deflect more evenly if it is under the same extrusion pressure. A 3-piece subliner design with interference fit can further reduce liner deflection by approximately 35% using AISI 4340 at 34 - 38 HRc. The shaded area in the container in Figure 2 shows where the subliner is implemented, to increase the rigidity of the container.

**Mantle Mechanical**

| | Fracture Toughness (MPa/m$^{1/2}$) | Critical Crack Length (mm) | Fatigue Limit (MPa) |
|---|---|---|---|
| WNr.1.2343 | 38 | 0.6 | 350 |
| WNr. 1.2344 | 38 | 0.6 | 350 |
| AISI 4340 (WNr. 1.6582) | 60 | 2.0 | 795 |

**Mantle Thermal**

| | Thermal Expansion (X $10^{-6}$) | Thermal Conductivity (W/mk) | Thermal Stress (MPa) $10^6$ W @ 10 cm |
|---|---|---|---|
| WNr. 1.2343 | 12.6 | 24 | 110.25 |
| WNr. 1.2344 | 12.6 | 24 | 110.25 |
| AISI 4340 (WNr. 1.6582) | 12.1 | 42 | 60.5 |

*Table 1. Steel properties to consider in mantle material selection*

*Large sized containers (12 in and above)*
*QRX – Quick Response "X Pattern"*
For such a large container it is recommended to have 6 individually controlled heating zones with 6 double acting thermocouples. There are 4 zones (top, bottom, left and right) at the die end, and 2 zones (top and bottom) at the entrance. The additional zone heating gives the extruder an unprecedented ability to control the extrusion profile shape and dimensions, as well as surface quality.
A simple calculation shows that for a 12 inch container, there is enough space and distance to manipulate temperatures.

The temperature between the adjacent zones could be as high as 65°C, therefore the temperature of a die can be controlled and manipulated. The run-out variance across the cross-section of large and complex profiles can be corrected. QRX gives extruders the unprecedented ability to correct/control the extrusion profile, extrusion run-outs and extrusion surface quality. Imagine the advantages for those extruders making an HSR profile and other large and wide complex extrusions.

At steady state the temperature between zones is described by the steady state heat flux equation as follows:

$$Q = \frac{k}{L}(T_1 - T_2)$$

Q: power density of heating element ( 46,000 W/m$^2$)
k: thermal conductivity of 4340 mantle ( 42 W/m°C)
L: distance between zones (0.119 m)

The ability to adjust each temperature zone at die end up to 65°C difference is unprecedented.

## Conclusions

The demand for ever-higher productivity can only be met when extruders understand the fundamental impact of press tooling. The challenge with the container is to have complete thermal and dimensional stability. Nothing in extrusion is uniform. All we can hope for and design for is stability. A thermal gradient using the right design and materials allows us to move temperature or energy as it is created during extrusion. Energy consumption is reduced and the liner, mantle and dummy block life are extended. Die performance is increased and profile surface finish is improved. A three piece subliner interference fit is implemented when the container is long and/or the extrusion pressure is high. All of the above benefits are obtained using simple physics to stabilise the container's thermal profile.
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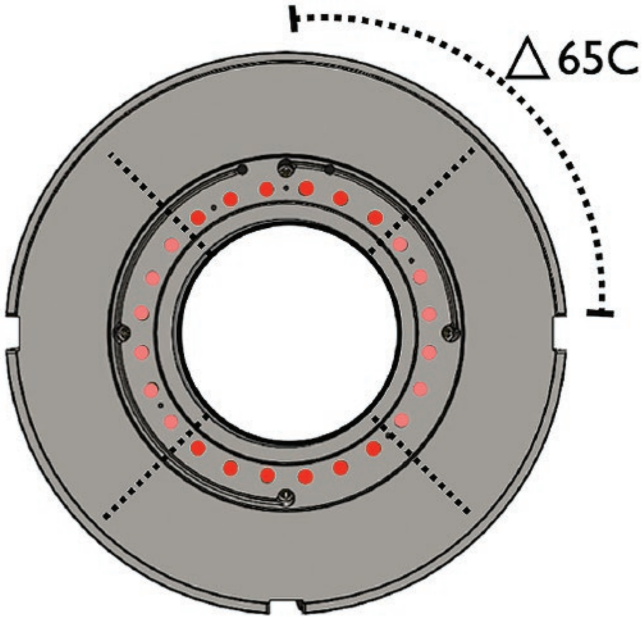

3 The temperature between adjacent zones could be as high as 65°C on a 12 inch container.

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