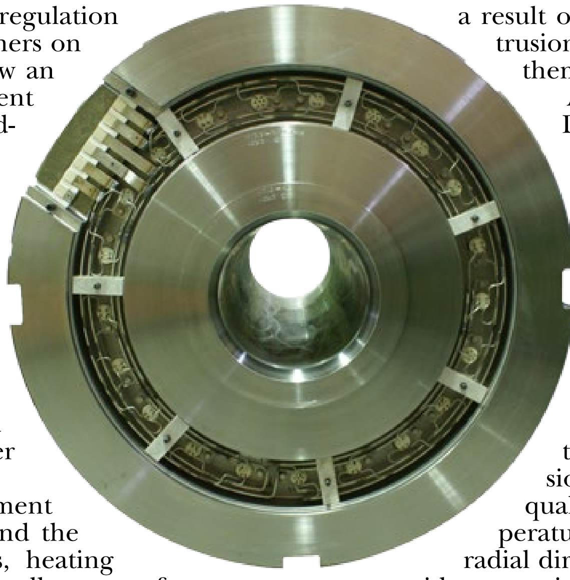
Design, Regulation, and Positioning of Modern Container Heating Systems

By Christian Eckenbach, Marx GmbH & Co. KG



A precision temperature regulation system for billet containers on extrusion presses is now an industrial requirement due to constantly increasing product demands, faster process flows, frequent changes of billet alloys, as well as the always present desire for longer tool life. The decades long goal of isothermal extrusion makes the need for a precision temperature regulation system all the more important, as isothermal extrusion provides: uniform product quality, greater productivity, and longer service life for container and die.

In addition to the development of improved tool steel quality and the geometric design of containers, heating and cooling are essential tools for all aspects of modern extrusion technology. The coordination of these key elements in extrusion operations is critical in terms of productivity, extrusion quality, and those components of heating and cooling that influence the service lives of containers and press tools. Depending on tool steel quality used and structural design, uncoordinated process control is a decisive factor in terms of the service life of the container, as inappropriate heating and cooling stress the container to the point of bursting.

Wilfried Kortmann, who currently works for S+C ETS GmbH and formerly with Thyssen Special Steels affirms, "Process parameter changes significantly affect container designs. In particular, large temperature differences are of importance, due to the different thermal expansion of the hot work tool steels, thereby changing the predetermined shrinkage stresses. Large temperature changes can lead to overloading of the container parts or, as a result, to the shifting of components. It is important to note that monitoring of extrusion process parameters during the extrusion process needs to be maintained so as to achieve consistent temperature control to as uniform a degree as possible. This is necessary not only for the quality of the material to be extruded, but also to avoid damage to the container and the hot work steels from which it is constructed."

Since at least the 1980s, there has been considerable progress in extrusion equipment manufacture, engineering, conversion, and upgrading. Whereas, previously only the billet temperature and heating behavior throughout the extrusion process seemed to be important, there has been continuous development due to increased billet diameters and lengths, as well as changes in extrusion load requirements, alloys, and volumes—all leading to rethinking of billet container requirements. It became clear that all changes to the container itself had to be seen in a thermal context with regard to its effects on the extruded product. Thus, losses of prescribed hardness, deformation, geometric distortion of mantle and inner liner, linear elongation, wash-out within the inner liner, and funnel-shaped expansion of the inner liner on the tool side have been detected in billet containers as a result of thermal interactions during extrusion, with quality defects attributed to them.[1]

According to Dr. Sören Müller, Department for Material Science and Technology at the Technical University Berlin, "Modern extruded materials in the light metal sector represent an increased level of stressing of tools and components during extrusion and require a more precise process control. In addition to setting a very accurate billet operating temperature before extrusion, in particular, the heat balance during extrusion significantly affects the product quality. In this respect, a precise temperature control in the longitudinal and radial directions of the container that provides an optimal temperature distribution over the length of the billet and the diameter of the container is essential."

Design of Modern Extrusion Container Heating Systems

Presently in modern extrusion presses, internal resistance heaters are usually used to control the heating of the container. Only the development of long lasting, high-performance heating cartridges have enabled containers with multi-zone heating systems to be operated successfully. The size of the container, working temperature, and process parameters are crucial for the subsequent design of a reliable heating system, i.e., the number of heating cartridges, required heat output, and layout and positioning of heating zones.

In these heat transfer calculations, it is absolutely indisputable that the heating system used must be able to heat the colder zones in the billet container to a proper temperature. To achieve this goal, the internal heating cartridges have traditionally been placed as close as possible to the cold zones in the billet container, as is the case today. As a rule, this means that the heating system is placed within the mantle or, if applicable, in the intermediate liner when large containers having a diameter of 2-3 m are involved. The arrangement of the heating cartridges in close proximity to the inner liner does not make sense for the following several reasons.

To understand what constitutes an optimal container heating system for the extrusion process, we need to keep in mind the basic objectives to be achieved with a heated billet container. Negative experiences with unheated billet containers have shaped these goals. Overall, the quality of the extruded product, press productivity, and tool life, especially of the container mantle are all dependent on the effects of temperature conditions within the container.

Measurements on an unheated container during production on a direct extrusion press normally show a significant drop in temperature on the stem side as well as in the radial direction. Temperature differences of more than 200°C (392°F) can arise in the axial direction, especially on presses used to extrude hard alloys. In the process, a heat build-up develops, which is dependent on the billet length, billet temperature, and extrusion sequence. For direct presses, this is about ⅓ - ¼ of the container length in front of the extrusion die; for indirect presses, this is in front of the sealing element.[2]

An unheated billet container loses temperature over the outer sheath of the mantle, during which the temperature of the inner liner rises during production and maintains a high temperature. The resulting temperature differences in the radial direction inevitably lead to compression of the inner liner. Expansion of the inner liner in the radial direction to the outside is not possible, as the pressure exerted by the cooler mantle is too large. The existing shoulders of the container restrict the expansion of the inner liner in the axial direction; therefore, the sleeve of the inner liner can only dilate inwards, causing wash-out and premature wear of the inner sleeve. This problem is well known, and has been successfully prevented via modern heating systems for years.

Another aspect worth mentioning at this point is the fact that the hot work steels used today for the mantle usually require a minimum working temperature of about 300-350°C (572-662°F) in order to achieve desired levels of mechanical properties in terms of toughness and durability. If the mantle is regularly operated below these temperatures, its service life is expected to suffer.

Ideally, the heating cartridges should be positioned at a distance of two-thirds of the diameter of the container. From this position, the heating system is able to avoid extreme temperature differences and to achieve as constant a temperature as possible throughout the container.

An arrangement of cartridge heaters in close proximity to the inner sleeve is however unhelpful. Because of the heat input introduced by the extrusion process, the inner liner is the fastest to reach the required extrusion temperature. As a consequence, this means that arranging the cartridge heaters directly next to the inner liner causes the system to switch off immediately after the heating-up phase (Figure 1). In the layout of cartridge heaters next to the inner liner, after process temperature is reached, the heating is switched off and thus production continues without any heating, with the result that the same problems occur as in an unheated container. Naturally, such a layout of cartridge heaters saves energy costs because heating is switched off during extrusion, but the wisdom of this cartridge heating arrangement is doubtful.

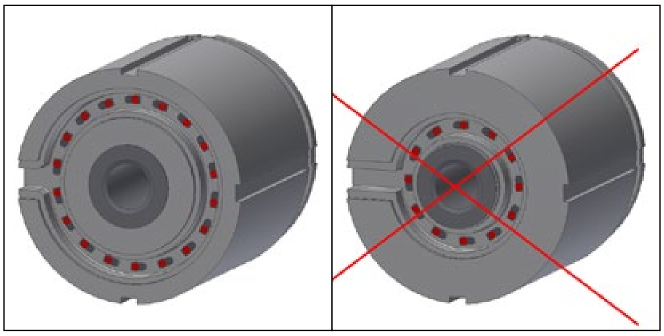


Figure 1. Comparison of the positioning of cartridge heating elements in an extrusion container: heating in the mantle (left) and close to the inner liner (right).

When heating with cartridge heaters near the inner sleeve, the heating of the entire container to a required level would be significantly prolonged and even cause comparatively higher heating costs. Similarly, when the container is kept warm during downtime, such as in press stoppages, weekends, etc., this is much more difficult to realize with the heater layout near the inner sleeve.

In addition, the temperature regulating process must be constantly monitored and controlled, and should respond as quickly as possible to process changes. Conversely, a poor cartridge heater layout can lead to overreaction and thermal stresses, which can lead to premature failure or even total loss of the container. Dave Cornelius, Lake Park Tool & Machine, Inc., says, “The number one cause for container failure is the unequal distribution of heat within the container mantle. This unequal distribution leads to mantle failure due to cracking from dissimilar forces and liner failure due to washout. This condition is most always observed in the center of the container mantle by the use of hardness testing during the reline process. Lower hardness readings indicate that annealing of the tool steel has begun. Main contributors to the annealing condition are the control of the heating source and the placement of the heating source.”

A compromise, taking into account all factors, has been required. This is offered today in containers with resistance cartridge heaters that are located within the mantle. Also, cooling systems, which are strategically located in the hottest zones of the container, may be necessary to avoid overheating. These are optimally arranged in the intermediate sleeves and not directly on the inner liners. Too abrupt transition when switching on the cooling should be avoided (thermal shock hazard). To ensure all this, a powerful control technology is required.[3]

Conclusion

For precise temperature regulation in extrusion containers, the energy supply must be coordinated to account for different billet lengths, alloys, extrusion temperatures, and extrusion times. In this connection, it is particularly important to identify different measuring point differences, combine them together and develop a regulation sequence from this that is able to provide both heating and cooling, while always keeping the objective in mind of leveling out the temperature and of ensuring linearity of temperature distribution in the whole container.

A modern container heating system aims to achieve approximately consistent temperature characteristics over the entire length of the container, and the aim for radial temperature distribution is for it to fall in a linear way towards the outside. High temperature differences are to be avoided in order to reduce thermal stresses in the container and to significantly increase the service life of the inner liner/intermediate liner/mantle.

To ensure optimal performance of such a heating system, the heating elements must be positioned in the correct place in the billet container. With a position in the hottest area of the billet container, close to the inner sleeve, these goals can never be achieved. Compliance with these principles in the design of container heaters, their layout, and use of modern high performance heating cartridges, makes it possible today to easily heat any container from 500 kg to 100 t. Also, the intended aim of achieving isothermal extrusion can be more readily achieved.

References

1. Eckenbach, W., “Prozessgeregelte Blockaufnehmer (Process-controlled Billet Containers),” Smart Containers, MARX GmbH & Co. KG, Iserlohn, Germany.

2. Bauser, M., G. Sauer, and K. Siegert, *Aluminium Fachbuchreihe Strangpressen, Auflage (Aluminum Handbook Extrusion Series), 2nd Edition*, Düsseldorf, 2001.

3. Kortmann, W., S+C Märker, private communication.