

The Evolution of the Smart Container: Achieving Isothermal Control in Extrusion

By Joseph C. Benedyk, Editor

Introduction

For many years, one of the major goals of the aluminum extrusion industry has been the achievement of isothermal extrusion, a quest that has inspired a variety of solutions, usually involving taper heating or quenching of billet with several attempts made to control temperature in the container. The decades long development that has resulted in the market introduction of the Smart Container by Marx GmbH & Co. KG of Iserlohn, Germany—now partnered with Lake Park Tool & Machine, Inc. of Youngstown, OH, U.S.—offers extruders an optimal and robust solution to not only achieve isothermal extrusion, with all the attendant quality benefits, but also increase press productivity and gain longer container and tool life.

At the recently held ET '08, the ceo of the Marx company Wolfgang Eckenbach, one of the principal developers of the Smart Container, presented a paper on the subject entitled, "Process Controlled Containers—Smart Containers," which has received wide attention, especially in view of the recent announcement of a Lake Park/Marx partnership. In this article, a summary is presented of the development of the Smart Container along with details of its use in extrusion plants in Europe, Asia, and the U.S.

Isothermal Extrusion: A Decades Long Evolution

The worldwide demands put on the operators of extrusion presses have increased considerably over the last 20 years, necessitating clear concepts for achieving isothermal conditions in extrusion. Extrusion experts have long known the benefits of maintaining a uniform temperature in the extrusion process in terms of metallurgical uniformity (grain size, precipitate dissolution, and longitudinal weld quality in hollows), uniform mechanical properties throughout the length of an extrusion, surface quality, and better press productivity. To achieve this in commercial practice, however, a number of technological leaps needed to be made in order to provide the benefits of isothermal extrusion to extruders at minimum maintenance and operational costs.

The Quest Begins

The Marx company has been active in this field since 1962 and has been a determining factor in the development of various technical approaches to isothermal extrusion solutions. It was determined quite early that, in order to synchronize the diverse requirements for isothermal extrusion and to design a workable and robust solution, cooperation between the extrusion press manufacturers, tool manufacturers, and also manufacturers of thermal devices for tool heating, billet heating, billet container heating, etc. was absolutely necessary.

Thus, early in the R&D phase, Marx actively sought the cooperation of the largest extrusion press manufacturer, SMS Schloemann Siemag, as a supplier and developmental partner of what became a project that lasted for decades. The person Marx claims was essential for the creative conception of a viable isothermal extrusion technology was Dr. Karl Behrends, the SMS director of heating technology. The question originally posed to Dr. Behrends by Eckenbach was: How to manage the temper-

ature profiles in the range of billet/container/tool configurations used by the extrusion industry such that an isothermal extrusion condition was assured? Thus began a long standing collaboration that began with a series of experiments conducted with the goal of achieving more productive and higher quality press performance.

At that point in time in the 1960s, the resistance cartridge heating systems being used for heating billet containers had been taken out of service because the stability of such cartridges was poor and their heating behavior, which depended basically on heating by radiation could not be regulated properly within such a large mass.

The Induction Heating Solution

However, earlier in the 1950s, when low frequency induction heating of containers was developed, with induction coils soldered into the container in a very resilient manner, it was possible to heat the container in a relatively short time with some degree of control. In individual cases, especially for multi-section billet containers, heating devices were already placed in the middle or even inner liner of a multi-section billet container in order to be able to create the necessary heating on the inner liner, closer to the working surface of the billet container. The disadvantage of induction heating was, however, that only an overall heating of the container could take place and there was no actual provision for multiple heating zones within the container itself.

Besides the lack of zone heating control with induction heating of containers, soldered joints between the induction coils and container components were prone to failure. In the 1960s, Marx introduced welded joints, resulting in a significant reduction in downtime (Figure 1). Nonetheless, there was an immediate recognition, especially for extrusion presses with larger billet container diameters and longer container sizes, that a slow runout of the billet itself as, for example, with hard alloys, or the shortening of the billet loading time always led to overheating in the front third of billet containers, which countered attempts to cool the remaining length of the billet container.



Figure 1. An example of a type of aluminum extrusion container with internal induction heating coils welded in place.

Induction Heating Gets Assistance

Since no induction heating system had been developed that could make a zone heating system with an adequate performance possible, additional resistance cartridges were installed in the intermediate and inner liner. Alternatively, an external mantle heating system consisting of radiation heaters mounted on the outside of the container was developed (Figure 2 a,b).

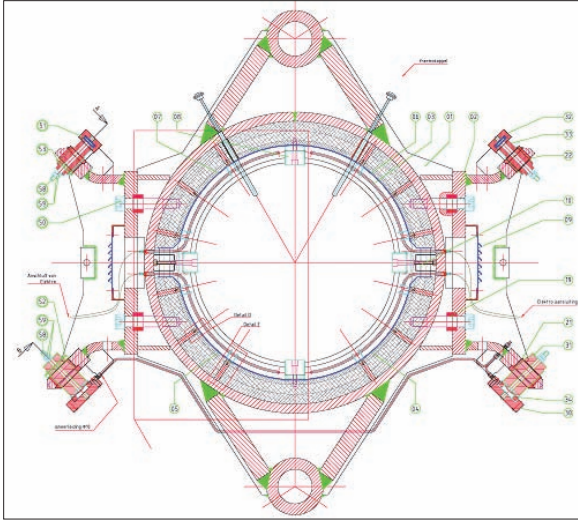


Figure 2a. External container mantle heating system shown schematically mounted in the container holder.



Figure 2b. Radiation heaters that are part of the container mantle heating system ready before installation.

With a multiple heating arrangement, the first temperature controlled container system was made operable by utilizing thermocouple feedback and on/off switch devices. Together with SMS and Alusuisse (now Alcan), the first intelligent billet container of its time was supplied by Marx. It featured sectional and compartmentalized resistance heating of the container mantle mounted in the container holder for a 5,000-ton press, induction heating in the billet container itself, as well as additional resistance heating cartridges placed in the inner liner. At the same time, measurement engineering was enhanced by several thermocouples, of which the feedback was coordinated by an automated regulator.

The production experience gained with the various container heating systems in the 1970s indicated the following:

- Exterior radiation heaters were found to be extremely detrimental to the container steel itself due to overheating up to 750°C (1,382°F), which led to temper softening of the container mantle and the eventual total failure of the billet container (Figure 3).

- The induction heating system, although an effective means of heating, is too difficult to regulate, sometimes leading to overheating and eventual temper softening of the steel; also, even with resistance heating elements on the front side of the billet container, a sufficient rate of heating was not produced at that zone.

- The temperature regulation control systems available in the market at that time, without any software and only turning on or off at a given set point, were not suitable in allowing a container to approach its prescribed temperature profile in order to be able to improve the extrusion press performance based on isothermal extrusion conditions.



Figure 3. Overheating of container due to aggressive exterior radiation can cause weakening and cracking in the surface of the container as shown here.

Emergence of the Smart Container

Thus, at that time, the decision was made to abandon the exterior radiation heating system, and new solutions to container heating systems were sought that could meet the requirements of segmented zone heating with a high heating capacity and a heating rate that would not require a large number of drilled holes in the mantle and intermediate and inner liner. In addition, for the first time, thought was given towards implementing a cooling option for the reduction of the temperature in overheated areas of the container.

Depending on the container design, these cooling systems were placed within the liner holder, or even in the mantle or inner liner. Marx quickly coordinated and tried out mechanical solutions with the manufacturers of billet containers active in this market. Whereas only single convoluted cooling coils were originally placed on the liner holder of the container when such trial sessions began, these were positioned and placed in grouped segments at a later point in time leading up to the Smart Container (Figure 4), which provided for air flow zone cooling in support of the heating system to maintain temperature control.

Heating Cartridge: Much more difficult, however, was the development of a suitable heating unit that could live up to the requirements vis-à-vis existing systems such as induction heating units, but nonetheless allowed segmented zone heating. The only heating cartridge of good quality that was available on the market during the 1970s was a product that had a maximum life of one year and also had inadequate heating capability; thus, Marx engineers continued with the development of a superior type of electrical resistance cartridge heater.

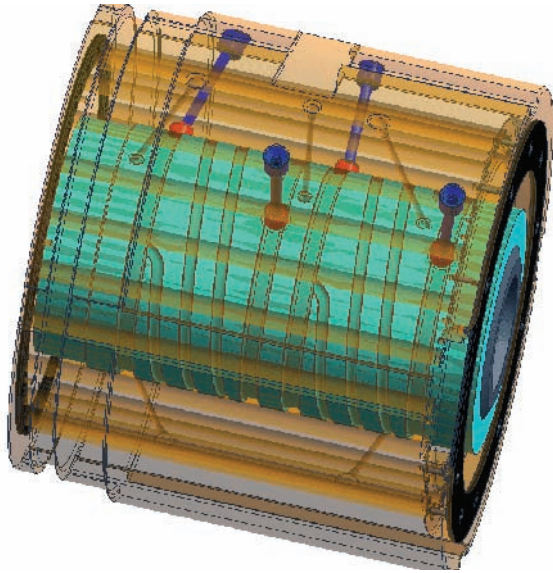


Figure 4. Schematic representation of grouped airflow channels that provide cooling in the Smart Container.

In the course of the 1990s, Marx engineers were successful in developing an electric resistance heating cartridge that permitted a division of zones into various heated and non-heated zones, which could be manufactured up to a length of two meters (~5.5 ft) and attained a maximum internal cartridge temperature of 750°C-800°C (1,382-1,472°F). This helped lead to a breakthrough that enabled a durable specific power rating for this cartridge of approximately 3-6 W/cm² while also allowing the possibility (with the use of cartridges with a rating of up to approximately 4 W/cm²) to increase the distance between the heating cartridges from the drilled holes. This also eliminated another problem with the usage of heating cartridges. The prior technology was based on designing the lead end of the heating elements to be flexible and with a screw thread for emplacement to enable a simple exchange of individual cartridges. This was based on the fact that these early model heating cartridges had a maximum lifespan of six to twelve months, which made regular maintenance and changeover of the heating system necessary.

Marx then developed a welded nickel wire connection, which guaranteed a long-term fixed electrical connection to the cartridge and in turn enabled installation of a cartridge of the same length within shorter times in cases where an exchange of a defective cartridge was necessary. This development was so positive that a useful life of up to eight years could be attained, although typically a life of at least five years could be guaranteed if the operational instructions were correctly followed. These cartridges, shown in Figure 5, are now the basis of the Smart Container zoned heating system and are available with either 3



Figure 5. High performance and long lasting electric resistance Smart Container cartridge heaters for zone heating.

or 6 W/cm² power ratings that assure the heating of steel containers at rates of 45-60°C/h (81-108°F/h). Typically, these power loads are enough to heat up containers weighing from 500 kg (1,100 lbs) to 100 tonnes at 45-60°C/h (81-108°F/h).

Temperature Monitoring: An additional necessity was the development of new thermocouples that could be used either in temporarily placed arrays within sections of billet containers or mechanically installed in the billet containers as permanent components. This ended up being a huge advantage, because a very movable, thin 3 mm (0.118") model could be used and these thermocouples could be equipped with a double measurement capability such that twice the temperature measurements could be obtained within a particular drilled hole in the billet container (Figure 6). As such, the basic prerequisites for the development of modern, intelligent Smart Container systems were developed.

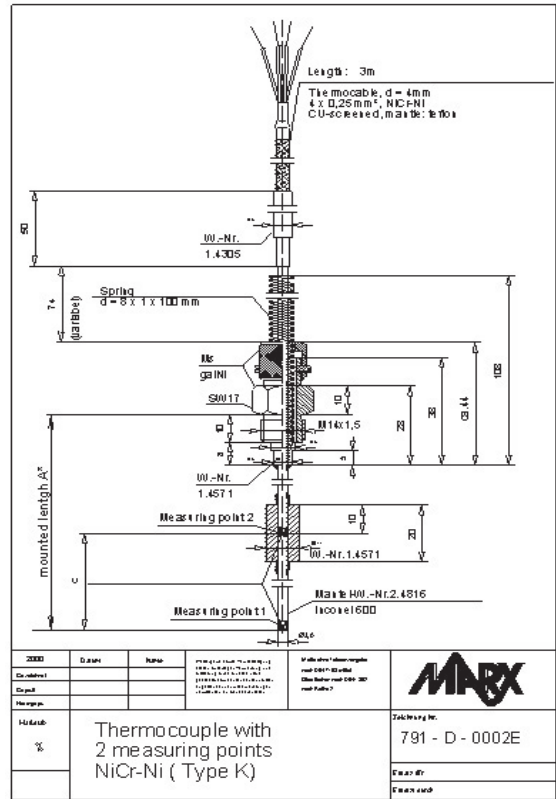


Figure 6. Thermocouple with two built-in temperature measuring points for use in the Smart Container.

Getting Smarter

At this point in the development, a brain was needed for the Smart Container that could intelligently manage all the gathered data and regulate the entire range of system possibilities: heating, cooling, sectional activation/deactivation, temperature measurement compilation, and data storage. This so-called brain is based on process control systems that go beyond simple on/off switching of devices in response to displaced temperature. Rather, it compares all the temperature information and assigns tasks to the heating and cooling devices so that a desired production process temperature procedure is regulated via comparative and differential value control. Thus, full automation of the supporting isothermal process procedure is enabled. Since the 1980s, Marx has been developing and implementing the respective controls and guidance systems that have led to what is today the container's brain (Figure 7).



Figure 7. The brain that processes information and data and maintains linear control of radial and axial temperature distributions in the Smart Container.

Press Applications

The Smart Container has been adapted to suit the various requirements of extruders. On the one hand, there are very small billet containers and extrusion presses that produce such fine products as multi-port hollows for condenser applications, heat exchanger tubing, or subtle shapes of exacting dimensional tolerances. On the other hand, large presses such as are used for extrusion of hard alloys require massive containers that can accommodate the large billets and high pressures used in extruding products of large cross section.

With its flexibility in design and its ability to intelligently regulate temperature in containers with a minimum of one zone and a maximum of eight zones (Figure 8), the Smart Container now enables isothermal extrusion of all these products, irrespective of container size, by means of coordinated temperature management of billet temperature profiles and control of tooling temperature. Isothermal extrusion process control helps avoid non-uniform metal flow and the well-known quick running of products in the upper half of the billet container or—in the case of larger profiles—avoid the so-called “banana effect,” i.e., a profile is longer on one side than the other. Uniform metal flow and temperature within the cross section of the extrudate assures high product quality in terms of properties and microstructure as well as high press productivity.

200 MN Press at Samara: The Smart Container is now operating on the 200 MN (22,480 ton) extrusion press at the Samara aluminum extrusion plant in Russia which is now owned and operated by Alcoa (Figure 9). This project began when Wolfgang Eckenbach was invited to the Samara plant, then operated under Soviet Union man-

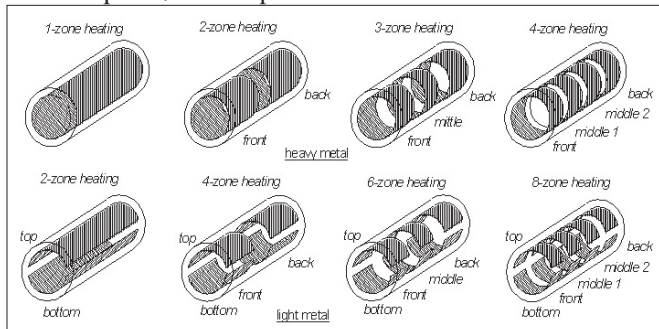


Figure 8. Multiple zone heating control options with the Smart Container for light metal extrusion.

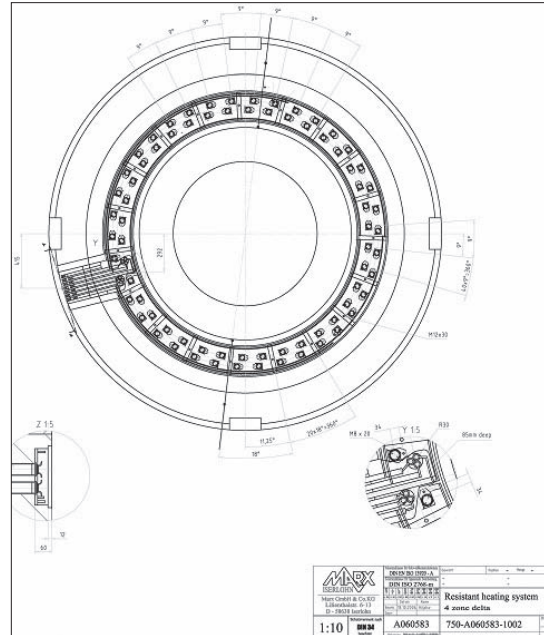


Figure 9. Engineering drawing of four-zone Smart Container with a 400 kW power rating used on the 200 MN (22,480 ton) hard alloy aluminum extrusion press in Samara, Russia.

agement, and recommended a changeover to the new container from the resistance heating system then in use. The 100 tonne Samara container used in the extrusion of hard alloy billets had a diameter of 3 m (118”), a length of 2 m (79”), and processed billets of 650-1,100 mm (25.6-43.3”) diameter.

After the Samara plant changed ownership in 2003, the press was re-equipped in 2007 over to a four-zone Smart Container rated at 400 kW. The changeover resulted in a significant reduction in the scrap rate, which now averages a manageable 4-5%, noteworthy for any aluminum extrusion plant.

Mid-sized Presses: For the mid-size range of aluminum extrusion presses, the Smart Container has resulted in increased productivity and enhanced quality as well. In Europe, a four-zone container is being used on two 24 MN (2,700 ton) aluminum extrusion presses, one in Bellenberg, Germany and another in Lichterfelde, Belgium.

In the U.S., a four-zone container of 1,556 mm (61”) diameter and 1,535 mm (60”) length today operates on a 66 MN (~7,500 ton) aluminum press that extrudes billets having a nominal diameter of 420 mm (16.5”) and nominal length of 1,450 mm (57”). This press operates 24 hours a day, all year long. Previous to the introduction of the new container, cartridge heaters with set point control tended to overheat the container, softening the hot work tool steel, and required as much as 28 hours to reach target temperature from room temperature. Inner liners on the older containers malfunctioned due to wash-out within approximately six months, and two of the three older containers cracked after only one year of operation. Marx equipped these presses with a four-zone Smart Container (Figure 10) as a replacement. Its introduction raised the life of the inner liners to 16 months and significantly improved billet sealing. The lifespan of the heating system on the two delivered containers is guaranteed at five years for continuous operation 24/7.

To Cool or Not to Cool

There is some controversy about the need to cool containers based on the assumption that the large container size and thermal diffusivity of the hot work steel used in its construction, balance the heat input during the ex-

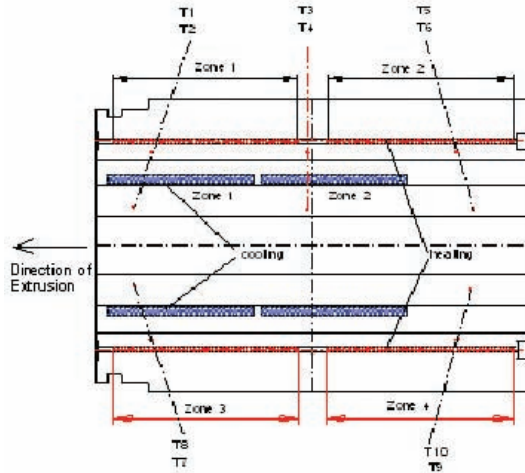


Figure 10. Four-zone design in operation on a 7,500 ton press in the U.S.

trusion process and the heat loss through the exterior surface of the container. This assumption precludes the need for exterior heating of the container mantle, as only the liner holder and inner liner need to be heated. Marx maintains that this assumption conflicts with actual physical circumstances in practice, for their engineers have seen the large number of billet containers worldwide that have cracked because they were not equipped with intelligent monitoring and control management systems and, as such, lacked all sorts of automation possibilities.

Systems like these can, according to the Marx company, only function when the engineer, as the person responsible for production, wisely establishes and controls the technology. However, it makes more sense for engineers to dedicate themselves to the operation and not to mind-

ing a machine. Any technological experiences gained in the course of automating processes such as extrusion should be left to the software-hardware control system.

Marx and Lake Park Form an Extrusion Tooling Team

The overriding Marx philosophy has asserted itself in many ways. As Eckenbach has stated, "The Marx company will do everything possible in the future to live up to our motto: research and development is the most important prerequisite and foundation towards always being a step ahead of the competition, to be at service to our customers and the technology we represent." As a major equipment and tooling source to the North American aluminum extrusion industry for over 55 years, Lake Park has built or refurbished more than 10,000 extrusion containers and now, in partnership with Marx, brings to extruders some of the best technology available for achieving uniform temperature in extrusion.

Wolfgang Eckenbach, ceo of Marx GmbH & Co. KG and Oscar Lund, president of Lake Park Tool & Machine, Inc., together signed an agreement on July 1st, 2008 to jointly deliver extrusion press tools with integrated Smart Container technology to extruders in the U.S.

Joseph C. Benedyk (Dr. Joe) is a research professor at the Illinois Institute of Technology (IIT) working to establish cooperative industry/university research programs in the fields of heat treatment, casting, and extrusion of aluminum and aluminum alloys. Dr. Joe has contributed many articles to Light Metal Age on aluminum and magnesium developments and now serves as editor covering applications and technology of light metals.