# Mega and Giga Casting: A New Technological Paradigm for Die Material and Design

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**Abstract:** The sociotechnological transition to electric mobility requires much lighter, more economic and more sustainable life cycle Electric Vehicles (EVs). To meet with these conditions, the technological ecosystem of the automotive industry needs to develop and shape new light materials, complex and large geometries as well as functionally and compositionally graded components, at reduced cost. Aluminium based alloys are among the choice candidates to meet these requirements considering their high formability and recyclability features, as well as good combination of density, mechanical and physical properties.

According to a study carried out for the European Aluminium Association [1], the aluminium content of passenger vehicles in Europe will increase from 205 kg in 2022 to 256 kg in 2030. Very similar forecasts are also cited for American vehicles [2]. Accordingly, the decrease in demand for castings associated with the combustion engine will be largely counterweighed by the demand for new aluminium based components for EVs, such as for motor housings, BEV and PHEV battery enclosure assemblies and different structural parts. The demand for automotive structural parts, manufactured by die casting, is expected to increase sharply from 8.2 million in 2021 to 25 million in 2030 [3]. The cited studies agree that more than 50% of the projected aluminium based parts will be shaped by die casting methods in particular High Pressure Die Casting (HPDC). In these studies, the fast uptake of Mega and Giga high pressure die casting was not taken into consideration. Hence, yet much higher demand for HPDC parts can be expected than forecasted in the coming years.

The geometries of these new parts, the new aluminium alloys, and the size of the components are significantly changing the technological paradigm of the die casting process in particular die making processes. There are indisputable needs to new die design, cooling strategies, die materials, die machining and die life management technology in order to address the challenges related to the three Key Technological Enablers (KTEs) of Mega and Giga casting which are i) durability of the expensive dies and the related die components, ii) the productivity of the process (scrap rate, cycle time, production stability, etc.) and iii), the part and process quality and the related monitoring and controlling technologies.

In this paper, three innovative technologies, with significant potential to address the challenges related to the above mentioned three KTEs will be presented and discussed.

The first technology is the disruptive high thermal conductivity of hot work tool steels for die casting known as HTCS© grades which features very high thermal conductivities, namely up to 55-62 W/m·K compared to conventional tool steel grades, used as materials for dies that present much lower thermal conductivity, typically between 20-29 W/m·k.

Considering the size for Mega and Giga casting dies, new grades of high thermal conductivity tool steel have been specially optimised and further developed for these new promising casting processes. These grades are named FASTCOOL®-55, FASTCOOL®-20 and FASTCOOL®-35. The table below shows some properties of these grades compared to conventional EN-DIN 1.2344 / H13.

| Die Materials | Thermal Conductivity | Wear Resistance | Hardness Max. | Heat Treatment |
|---|---|---|---|---|
| 1.2344 (H13) | | | 54 HRc | Quench + Temper |
| FASTCOOL®-35 | | | 43 HRc | Aging |
| FASTCOOL®-55 | | | 53 HRc | Quench + Temper |
| FASTCOOL®-20 (Mainly for LPDC and Gravity Casting) | | | 420 HB | Prehardened |

FASTCOOL®-35 is particularly promising for big dies as it can be hardened by precipitation, achieving the mechanical properties optimized for dies of die casting by a simple age hardening process. This hardening method allows reducing the die making time often by more than two weeks. Additionally, the high thermal conductivity allows to significantly increase the productivity and decrease the scarp rate through reducing the cycle time and hot spots generation. Several industrial use cases that will be presented in the paper further highlight these advantages.

The second innovative technology is a disruptive additive manufacturing methods that is able to print the above mentioned high productivity die tool steels as well as carbon based conventional hot work too steels. This Metal Additive Manufacturing method, ROVALMA® MAM can print high performant die components with speeds and costs that are competitive to conventional die making by machining, in addition to the possibility to print large sizes up to 600 x 700 x 2200 mm, while offering moreover the flexibility to print conformal cooling ducts beyond the known State of Art (SoA) of MAM technology.

Furthermore, over the past few years, there has been a notable surge in the adoption of MAM technology across diverse sectors including tooling. This is attributed to the newfound design freedom they offer, allowing for the realization of optimized geometries that were once unattainable through conventional die making methods, in particular when it comes to conformal cooling systems

inside the dies. Unfortunately, most of SoA of MAM methods, in addition to the prohibitive costs of the process, do not result in the thermo-mechanical properties required from the tool. It is hence not surprising that several companies and institutes have started to invest great efforts in mitigating the present limitations of available MAM technologies, specially through combining MAM and conventional manufacturing technologies.

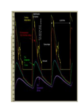
ROVALMA has charted a distinct course by introducing a groundbreaking, cost-effective MAM technology. The ROVALMA® MAM approach enables the production of large, intricately designed metal components with high performance, while maintaining a competitive production cost along with pushing the potential for environmentally sustainable manufacturing of MAM parts beyond the hereto existing technologic boundaries. This new technology allows manufacturing of dies and die components by combining conformal cooling with advanced materials featuring high thermal conductivity and tribological properties, at a considerably lower production cost and environmental impact, compared to conventionally manufactured tools, and even versus alternative MAM technologies.

Currently, there are MAM technologies that succeed in manufacturing large components, such as WAAM, but have difficulties in terms of yield, design flexibility with cooling channels and material selection (only those with good weldability). ROVALMA® MAM offers a performance that is capable of exceeding forged material counterparts and an extremely wide choice of materials can be used to manufacture large high performance components. In terms of cost, ROVALMA® MAM is often more cost-effective than conventional manufacturing for a large range of geometries, especially when part weight is to be reduced.

Nowadays, a very limited range of die components is produced with conformal cooling and additive manufacturing with disputable success rate in terms of cooling performance and durability. This is because in the majority of case, the maraging steel type EN-DIN 1.2709 is used due to the limitation of the SoA of MAM technology to print other carbon-based tool steels. However, 1.2709 steel presents a very low thermal conductivity, typically between 14-18 W/m.K and very low abrasive wear resistance, at the working temperature range of die casting. Therefore, often the improvement gained by conformal cooling is diminished by the low thermal conductivity and low durability of the die material used.

In this paper, the advantage of the combination of high thermal conductivity tool steels with ROVALMA® MAM and innovative cooling system design will be highlighted through different uses cases.

As Mega castings, casted alloys, MAM, conformal cooling and new steels are pushing the boundaries of the cooling systems and die design, a performant thermal management and monitoring of the dies are also increasingly required to monitor and extend the die life span, reduce scrape and maintain an optimised productivity considering the metallurgical characteristics of both die materials and casting alloys. In this paper, the combination of above-mentioned innovative technologies with advanced embedded sensors will be also presented. These types of sensors are multirole sensors with the capacity of measuring the temperatures of the injected alloy and die together using the most advanced temperature measuring methods. The figure bellow explains the temperature measured by one of that multirole sensors embedded to a die run on a clod chamber die casting machine with clamping force of 1650T. The casted alloy was Al-9Si-3Cu (A380). These measurements are directly related to the die and process working conditions through advanced digital technologies.



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