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A new conception in the production of polymer injection molds

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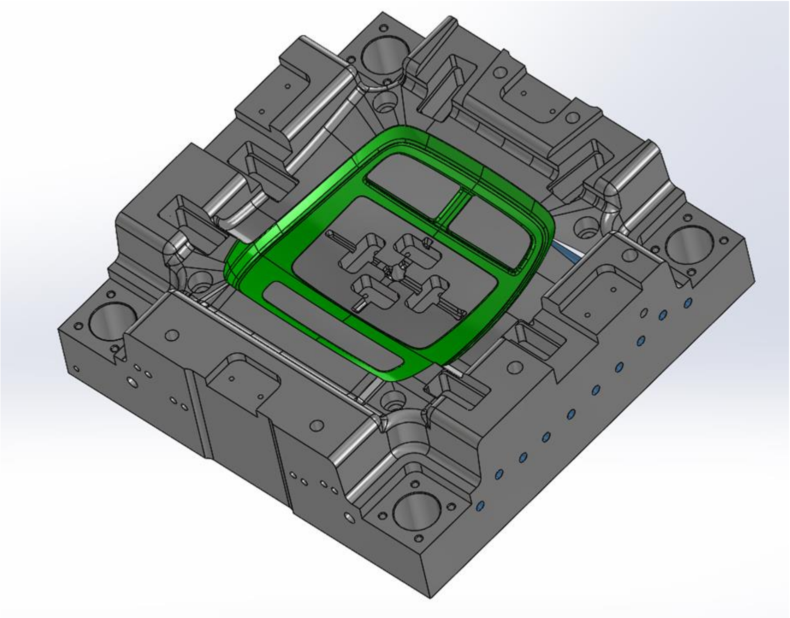
A NEW CONCEPTION IN THE PRODUCTION OF POLYMER INJECTION MOLDS

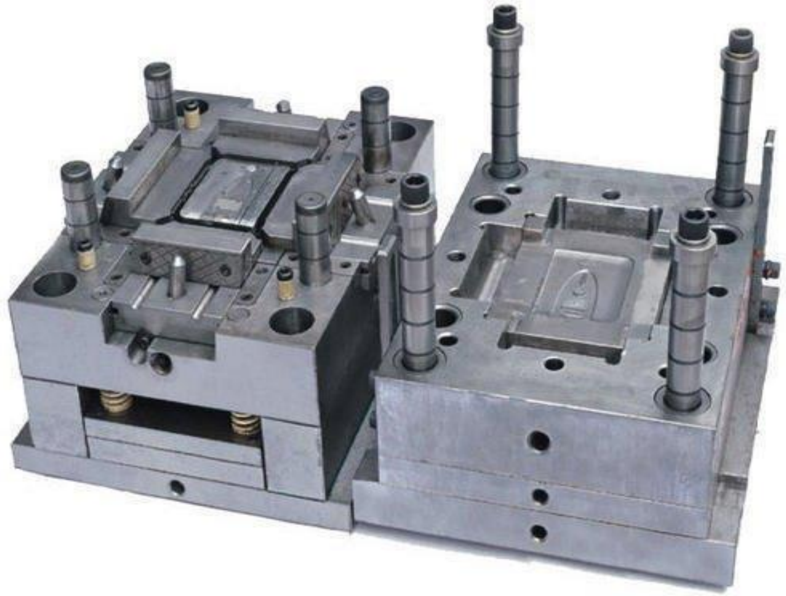


Bianka Nani Venturelli- IPT
Eduardo Albertin - IPT
Ederson de Souza – AngraTec
Marcelo Ribeiro - AngraTec

September 5th

Ferros fundidos de alto cromo como alternativa para a produção dos moldes

- Polymer injection molds are produced by machining forged blocks of tool steel, such as P20.
- The use of high-chromium cast iron alloys for the production of these molds can provide:
  - Possibility of obtaining the mold with cooling channels directly in the casting process – more efficient cooling channels.
  - Reduction in the volume of material to be removed by machining (“near net shape”).
  - Material with high wear resistance, eliminating the need for hard coatings in applications involving higher abrasive polymers.
  - Ease of recycling the material at the end of its useful life.



Example of mold for polymer injection.

High chromium cast iron

- Fe-Cr-C system alloys, with %Cr ≥ 10 and %C ≥ 1.8%.
- Chemical compositions described in the ASTM - A532 standard.

Brinell Hardness		
As cast	Annealed	Quenched
450 a 550	350 a 450	600 a 800

Convencional applications

Ball mill

Vertimill

Abrasive slurry pumping

Coal grinding

Focus: wear resistance (material) and geometries (process).

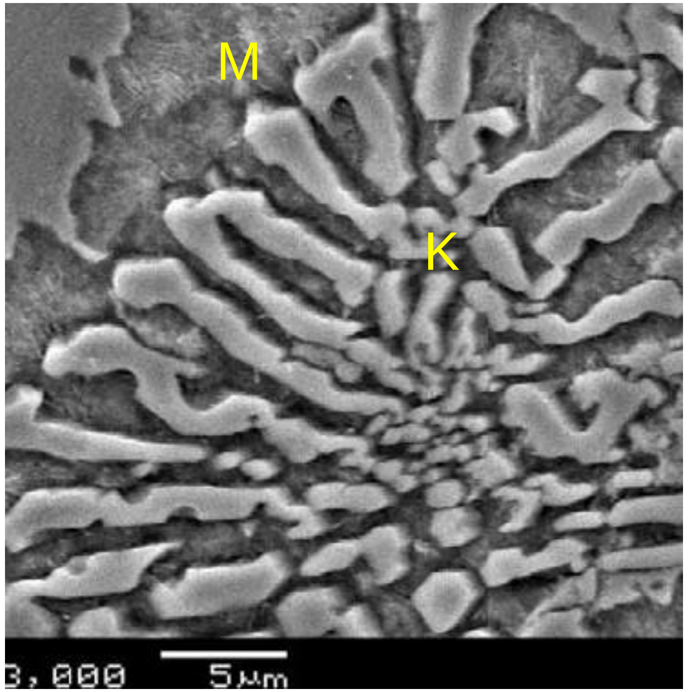
Microstructure

High chromium cast iron are natural “composites”:

- Matrix: 60 to 90% “steel”
- Mechanical resistance
- Tenacity
- “Manufacturability”: casting and machining

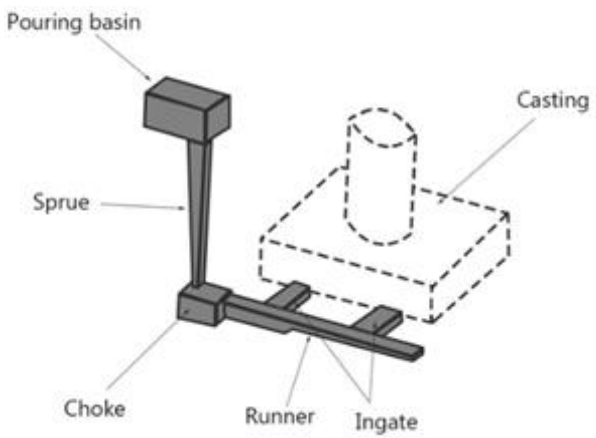
M7C3 carbides:

- 10 to 40% “ceramic”
- Wear properties



Electron microscope image indicating the region of carbide (K) and matrix (M). Doctoral thesis Eduardo Albertin.

Experimental procedure



1
Development and selection of 4 high chromium cast iron alloys

2
Production of test specimens for machinability testing

- design of the casting system
- casting
- heat treatment

3
Production of the injection mold prototype

- design of the casting system
- casting
- heat treatment

Tools for developing or selecting alloys

1) Solidification/casting

- Selection of basic Chemical composition (%Cr, %C).
- Prediction of % carbides and % dendrites.
- Prediction of the beginning and end of solidification temperatures.

>Thermo-Calc

> Liquidus surface Fe-Cr-C

> Thermal analysis

>MAGMASOFT®

Thermal analysis

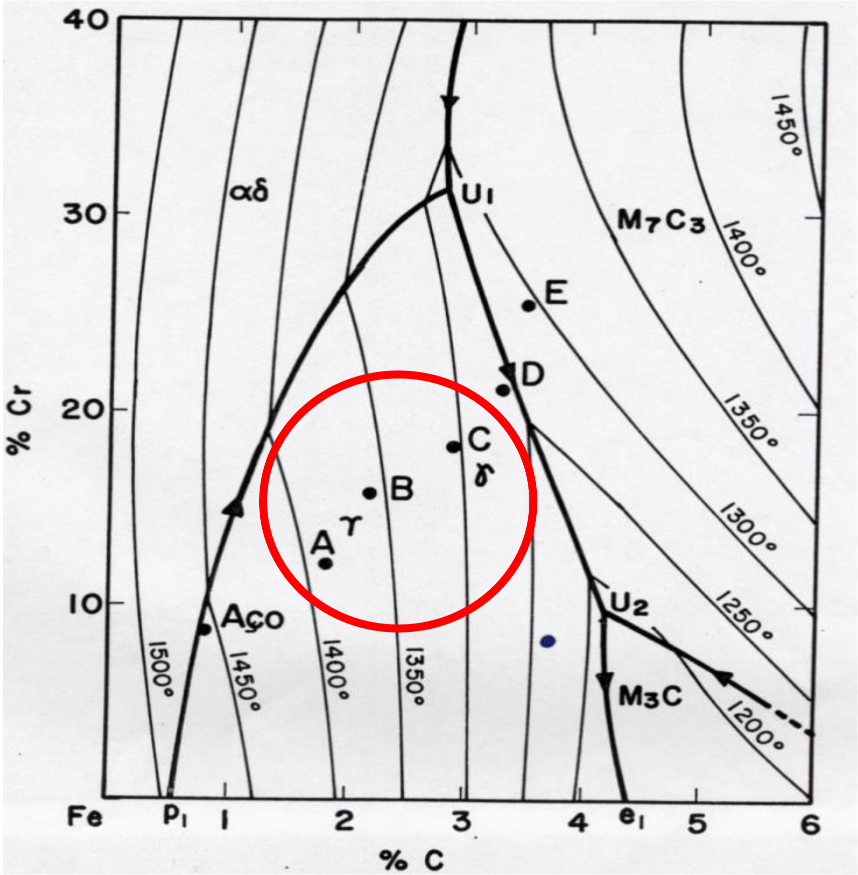
Recording the cooling curve (T x t) of the metallic alloy

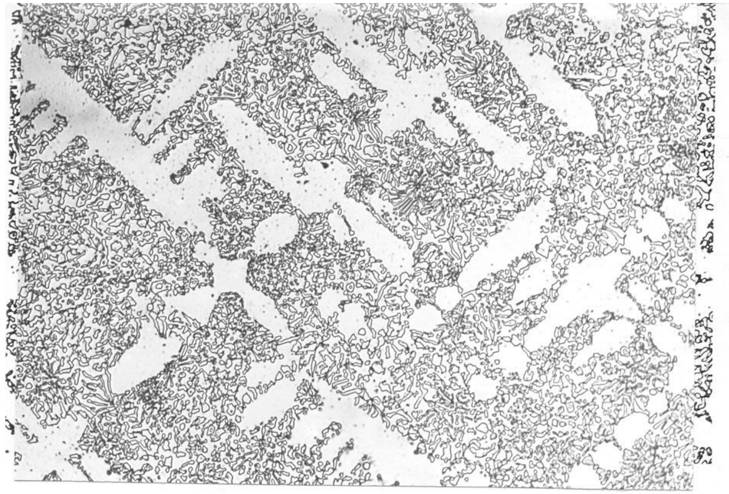
Applications - we can predict: Degree of inoculation, propensity to shrinkage, SDAS and DAS, graphite morphology, solidification microstructure.

Microstructure reproducibility/control -> mechanical properties

Liquidus surface Fe-Cr-C and Thermal analysis

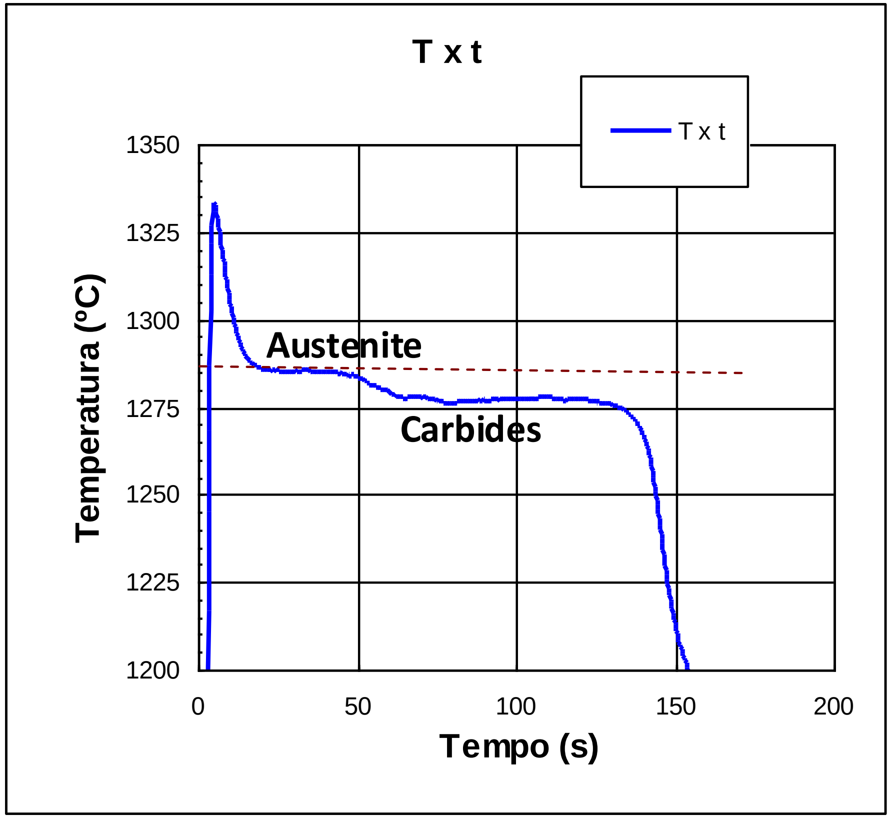
Hypoeutectic alloy





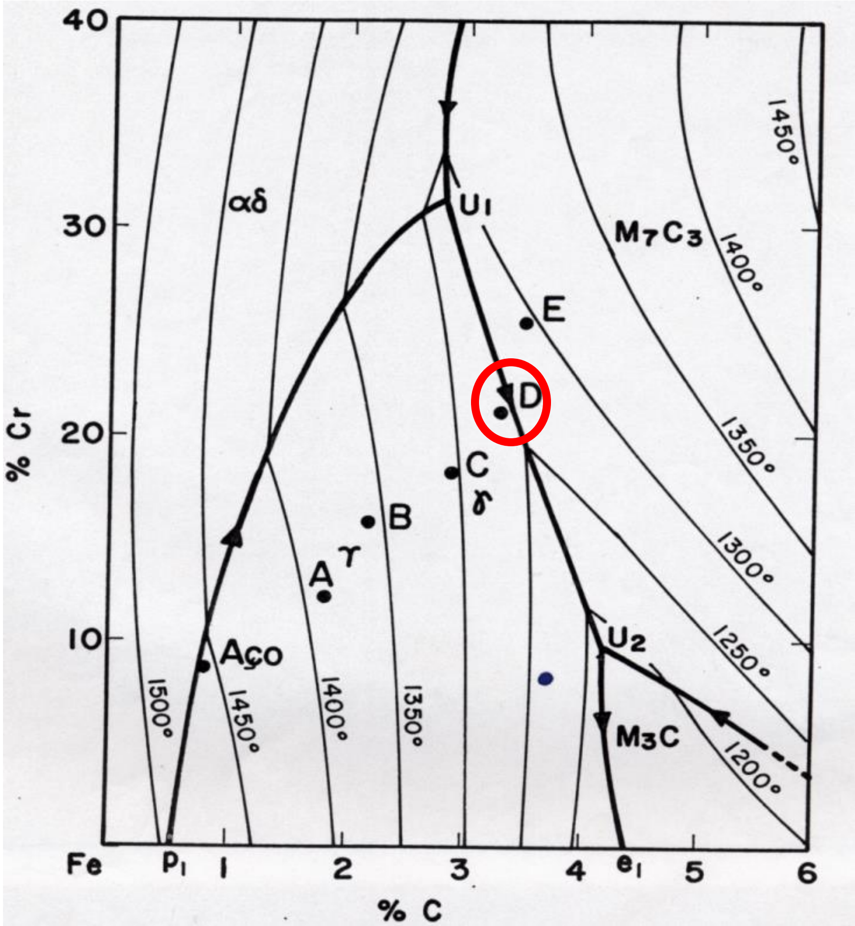
Microstructure hypoeutectic: austenite dendrites (primary phase) and eutectic carbides.

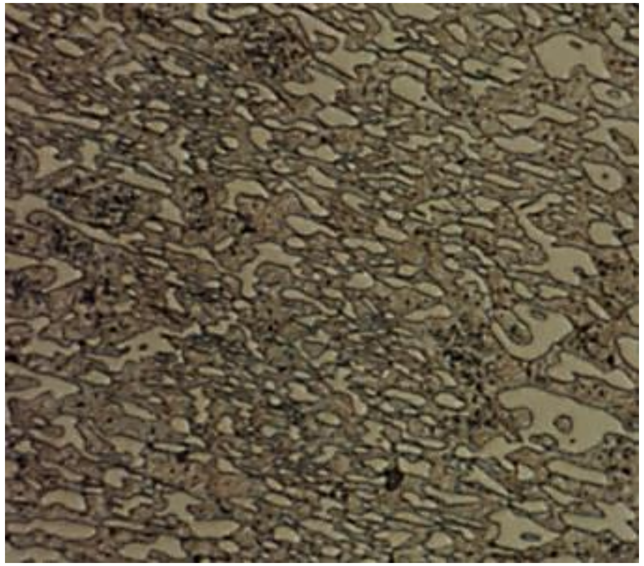
Thermal analysis results



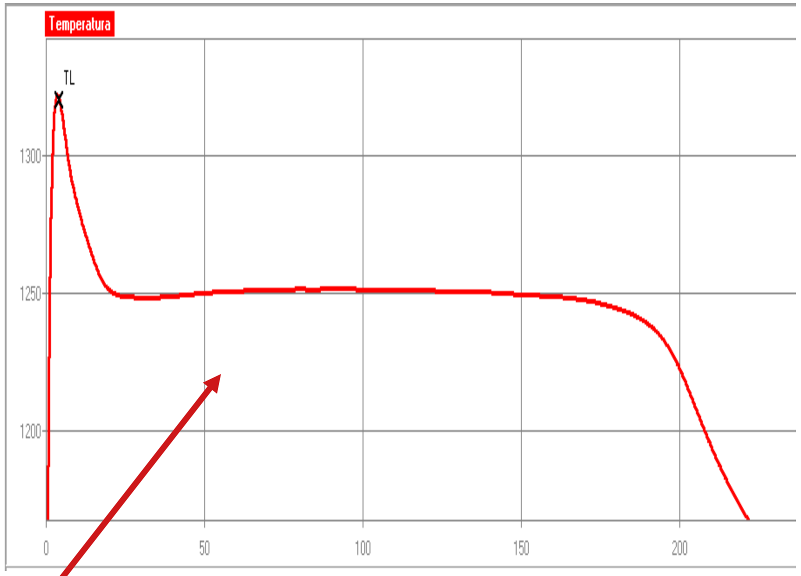
Liquidus surface Fe-Cr-C and Thermal analysis

Eutectic alloy





Thermal analysis result

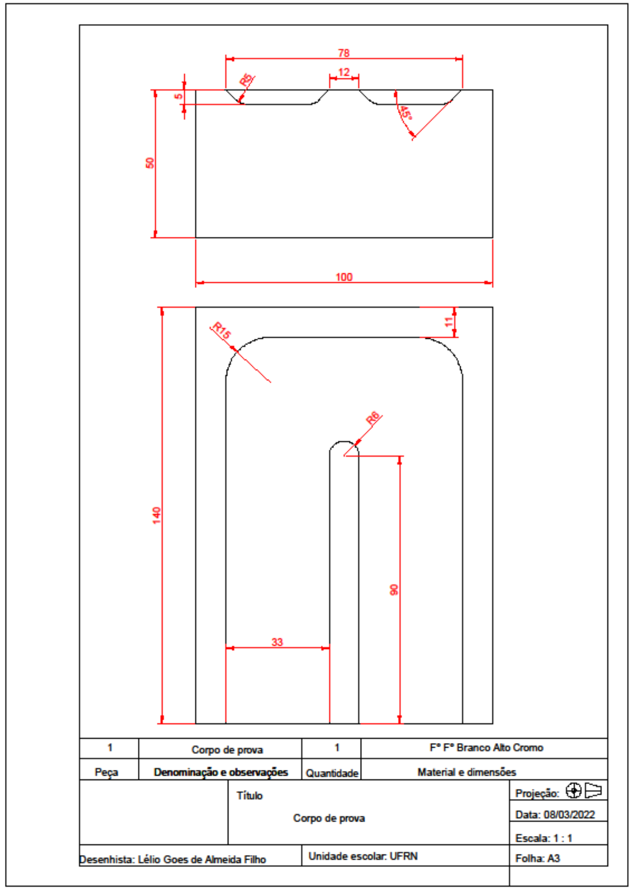


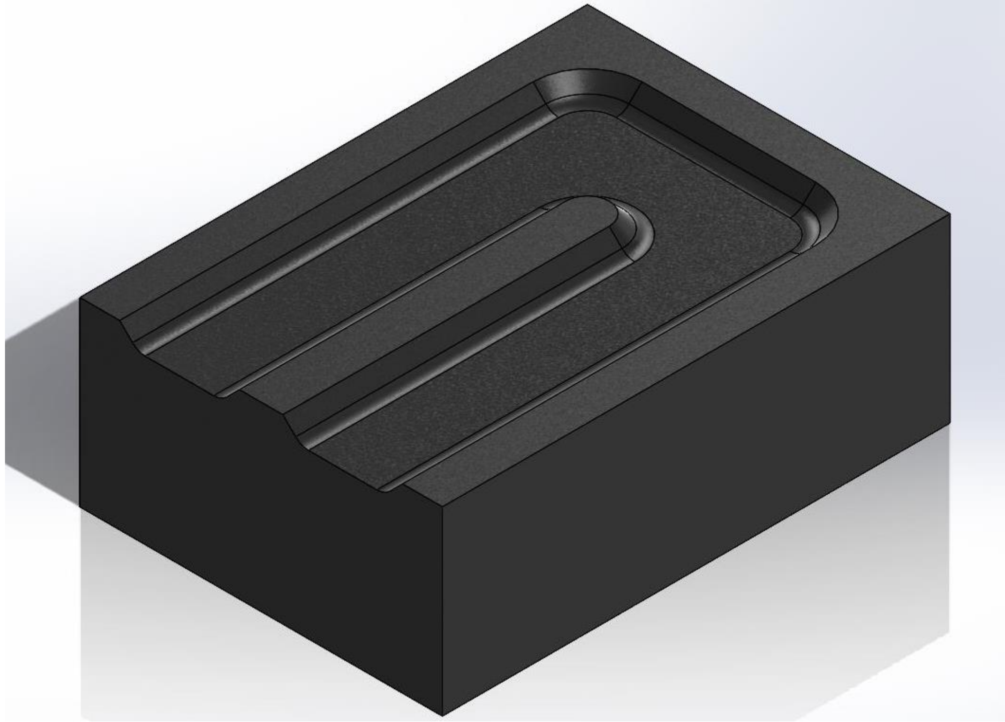
The alloy D is eutectic.

The entire liquid solidifies by the reaction: L $\rightarrow \gamma + M_7C_3$

Cast specimens for machinability study

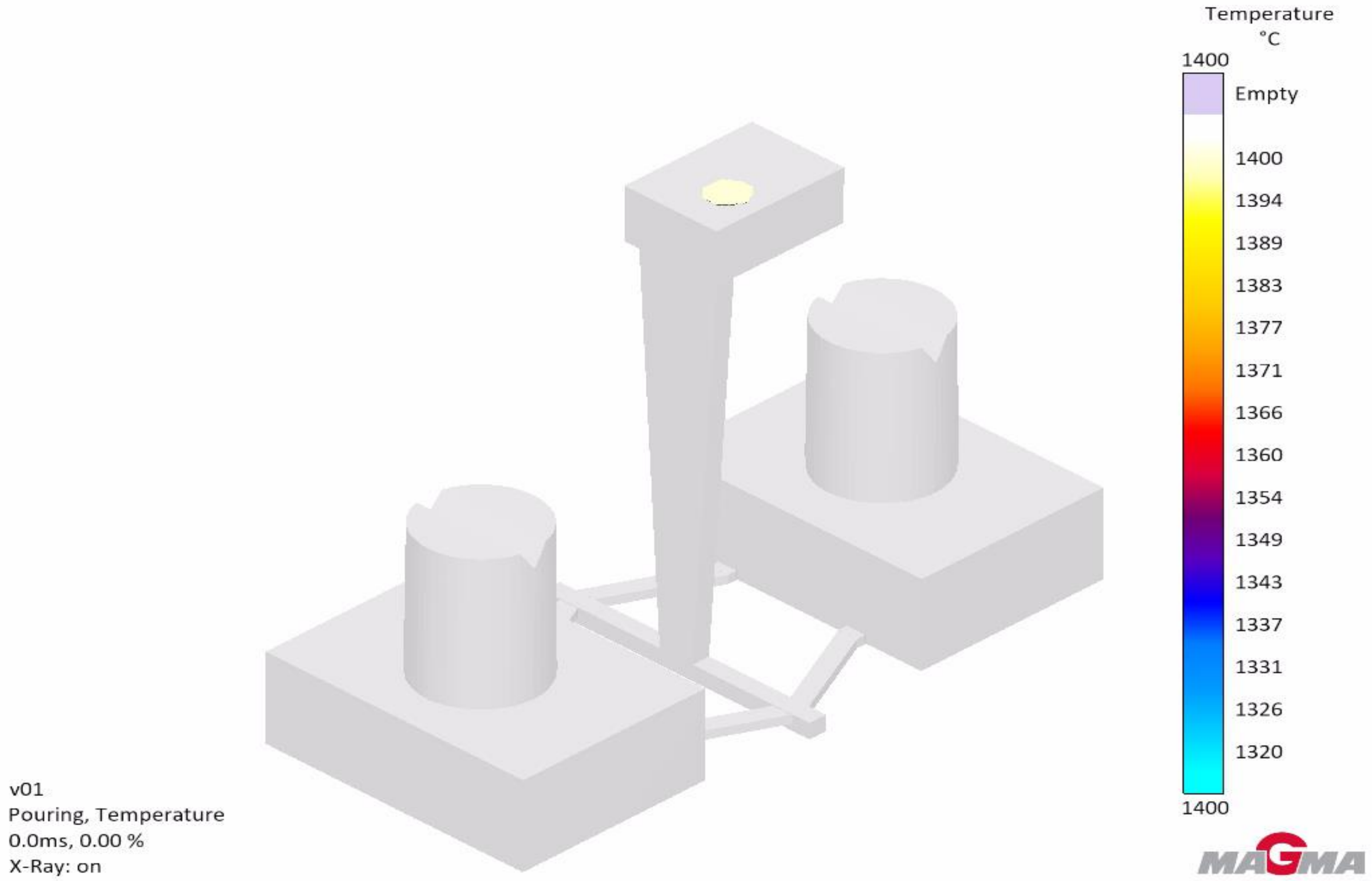
- Specimen drawing and casting design





Development of the casting system

- Simulations carried out in MAGMASOFT® to develop the test specimen casting system



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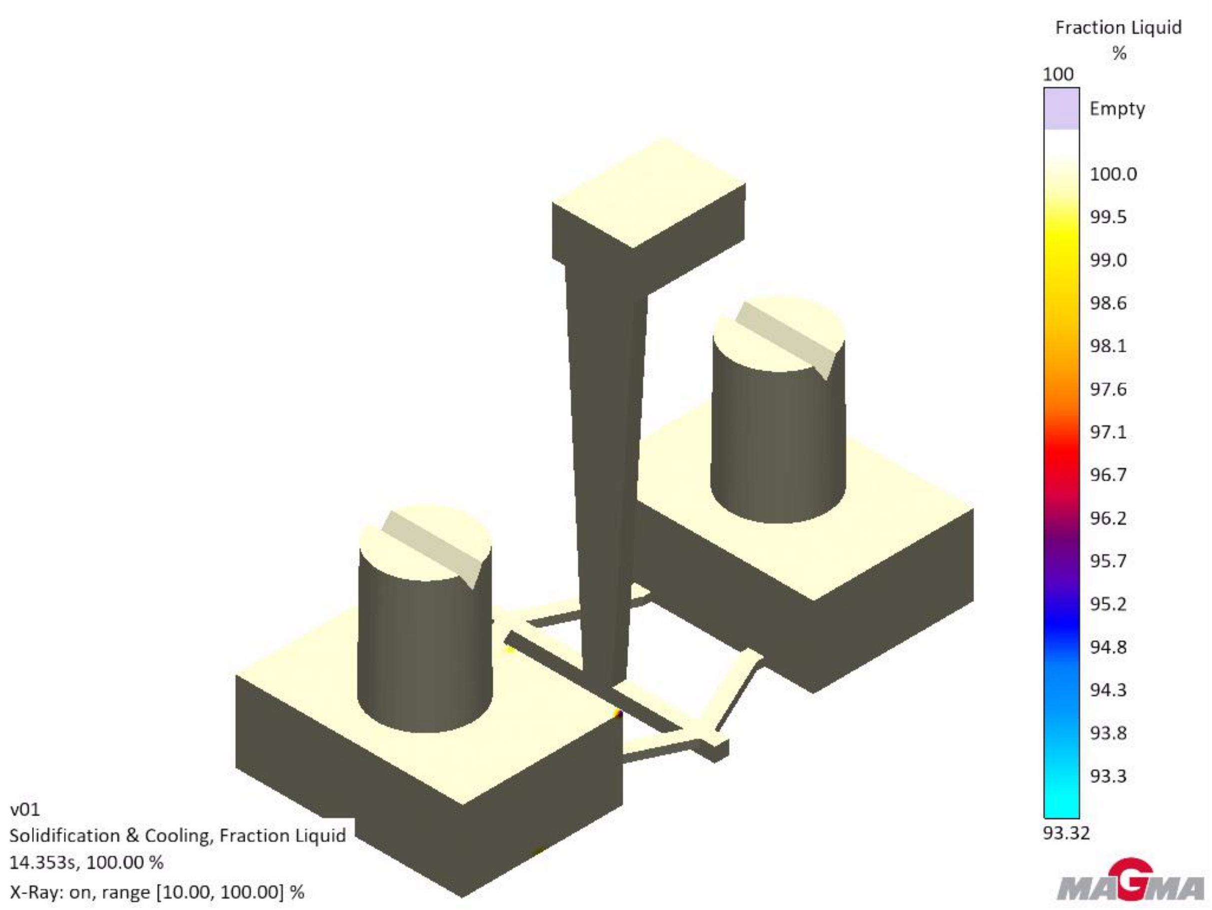
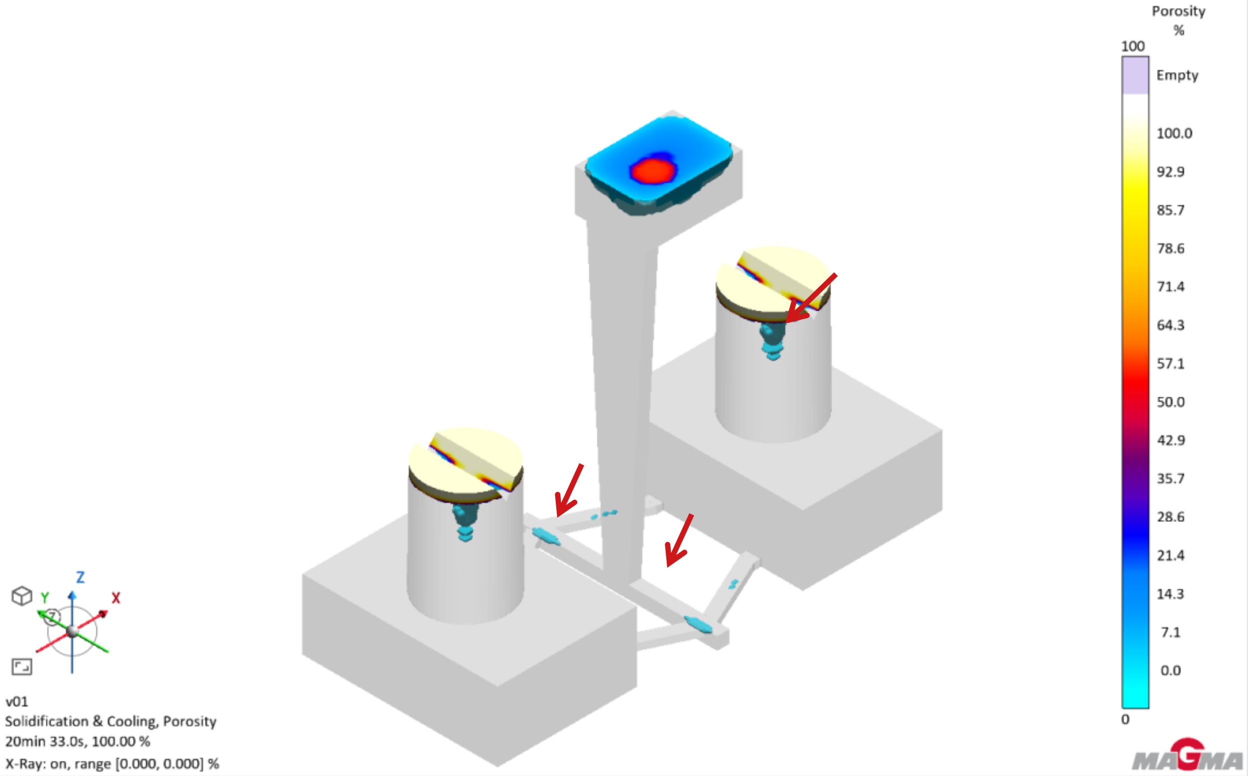




Final parts with good finishing

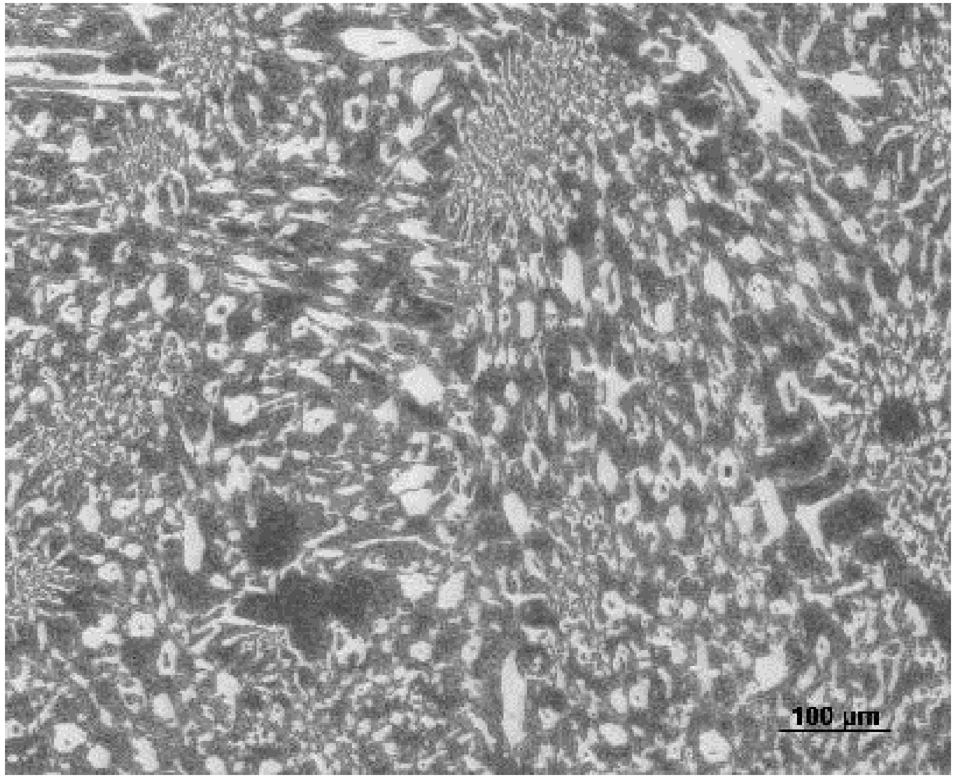
Test specimens for machinability tests

- The cast blocks were treated under the various conditions indicated in the Table.

Alloys		Heat treatment	
19 Cr	Hypoeutectic	Quenched	Annealed
19 Cr	Eutectic	Quenched	Annealed
26 Cr	Hypoeutectic	Quenched	Annealed
26 Cr	Eutectic	Quenched	Annealed

Conclusions of the machinability tests

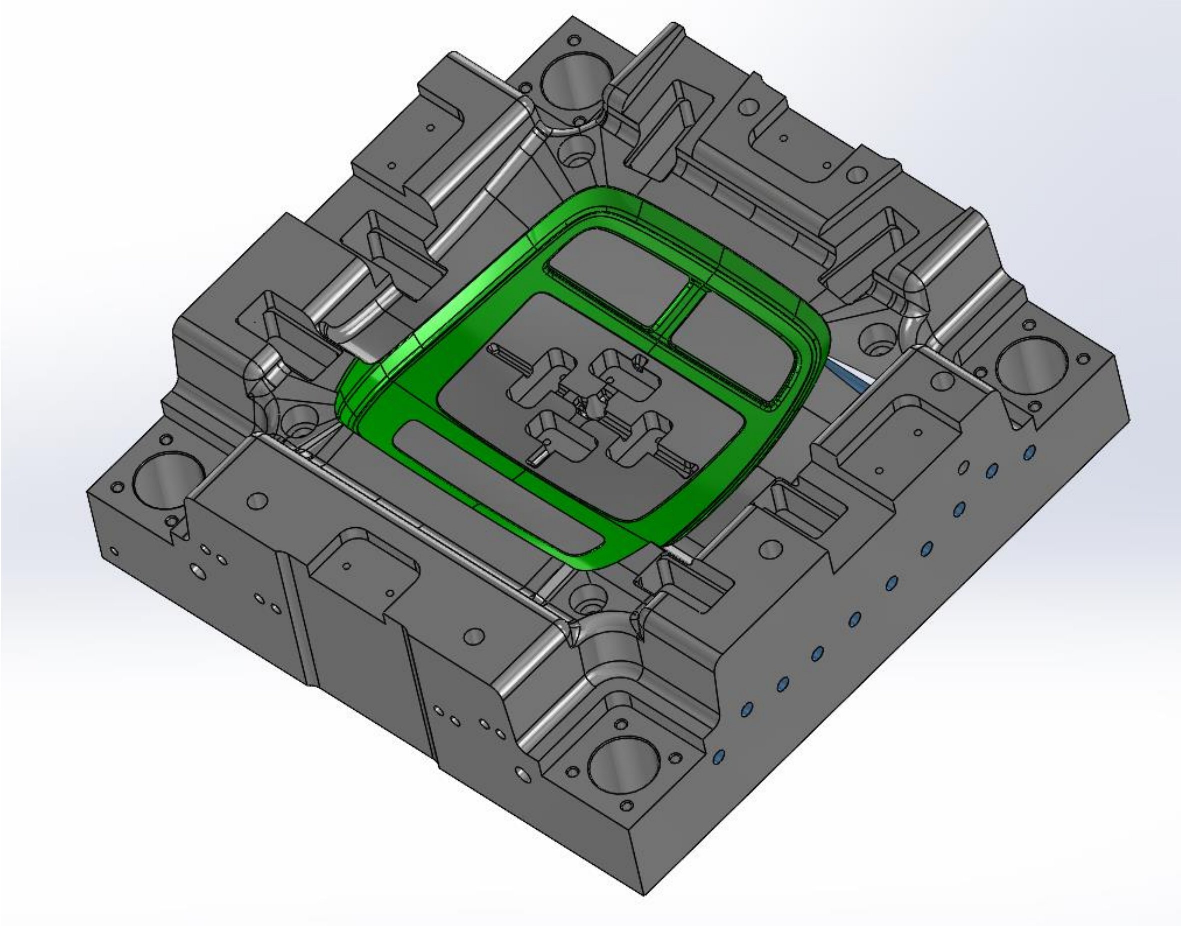
- The 19%Cr eutectic alloy was selected for the production of the prototype.
- The hardness of the alloy was controlled to 56-59HRC range, in the quenched and tempered condition.
- Next stage: Casting and heat treatment of the prototype.

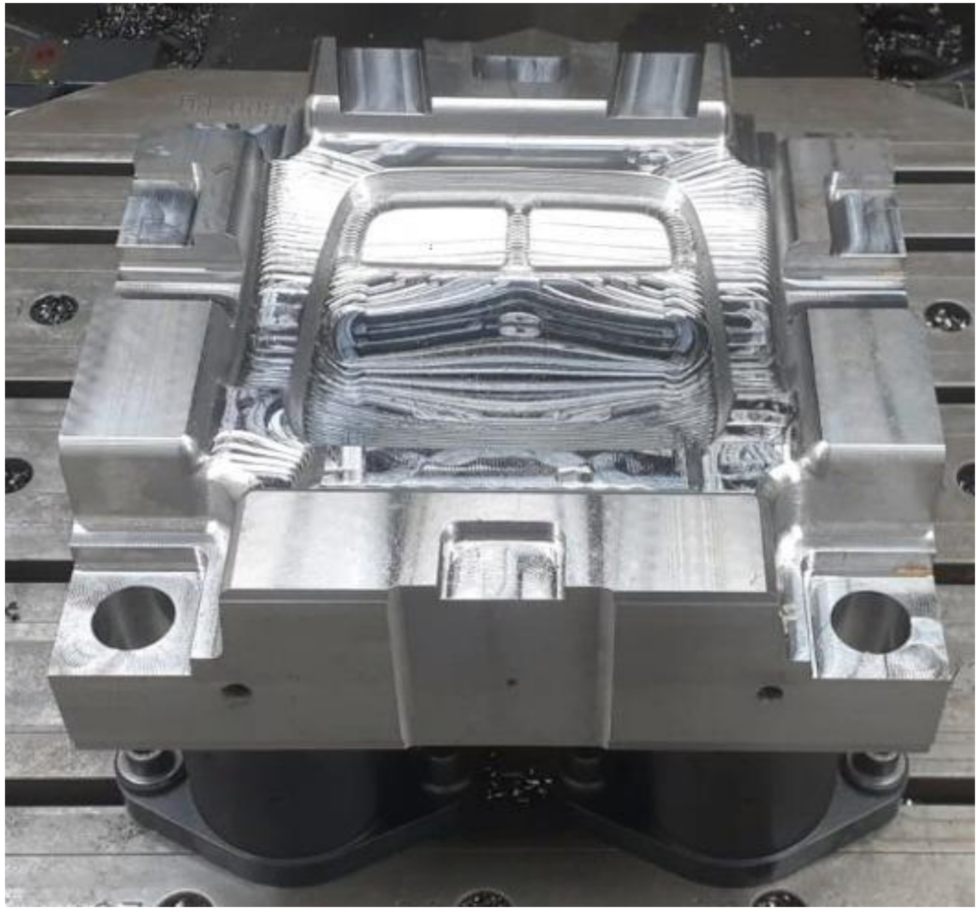


Microstructure of the test specimens, 19%Cr eutectic alloy after quenching and tempering. Original magnification of 100x, Vilela. Hardness of 58 HRC.

Prototype Casting System

Simulations carried out in MAGMASOFT®

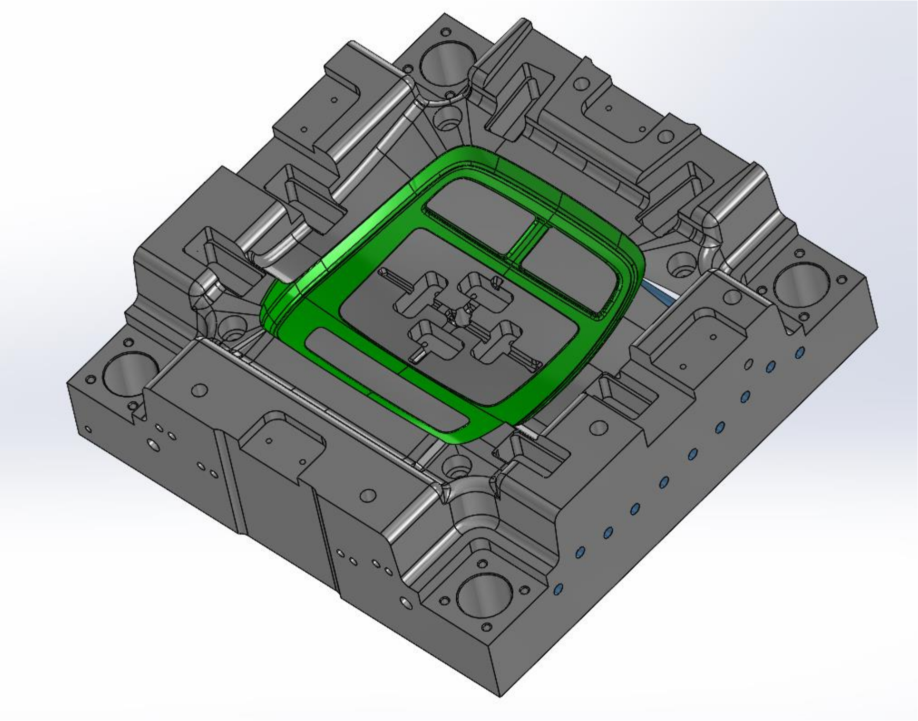




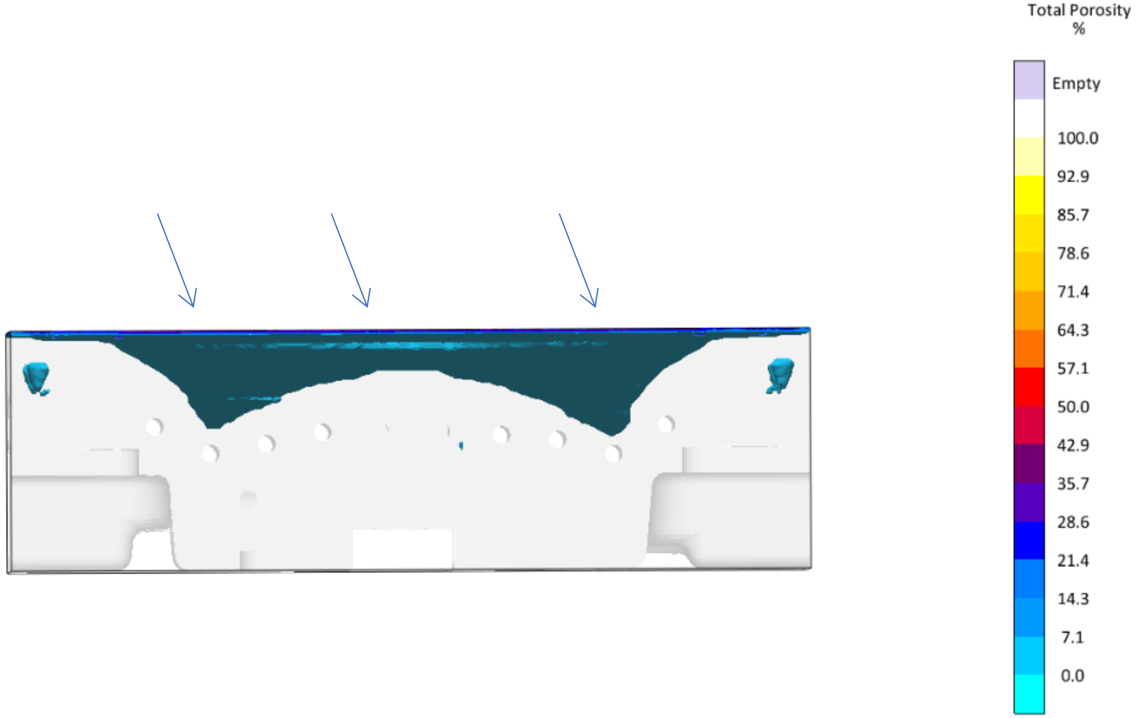
Prototype Casting System

Simulations carried out in MAGMASOFT®

- Preliminar avaliation

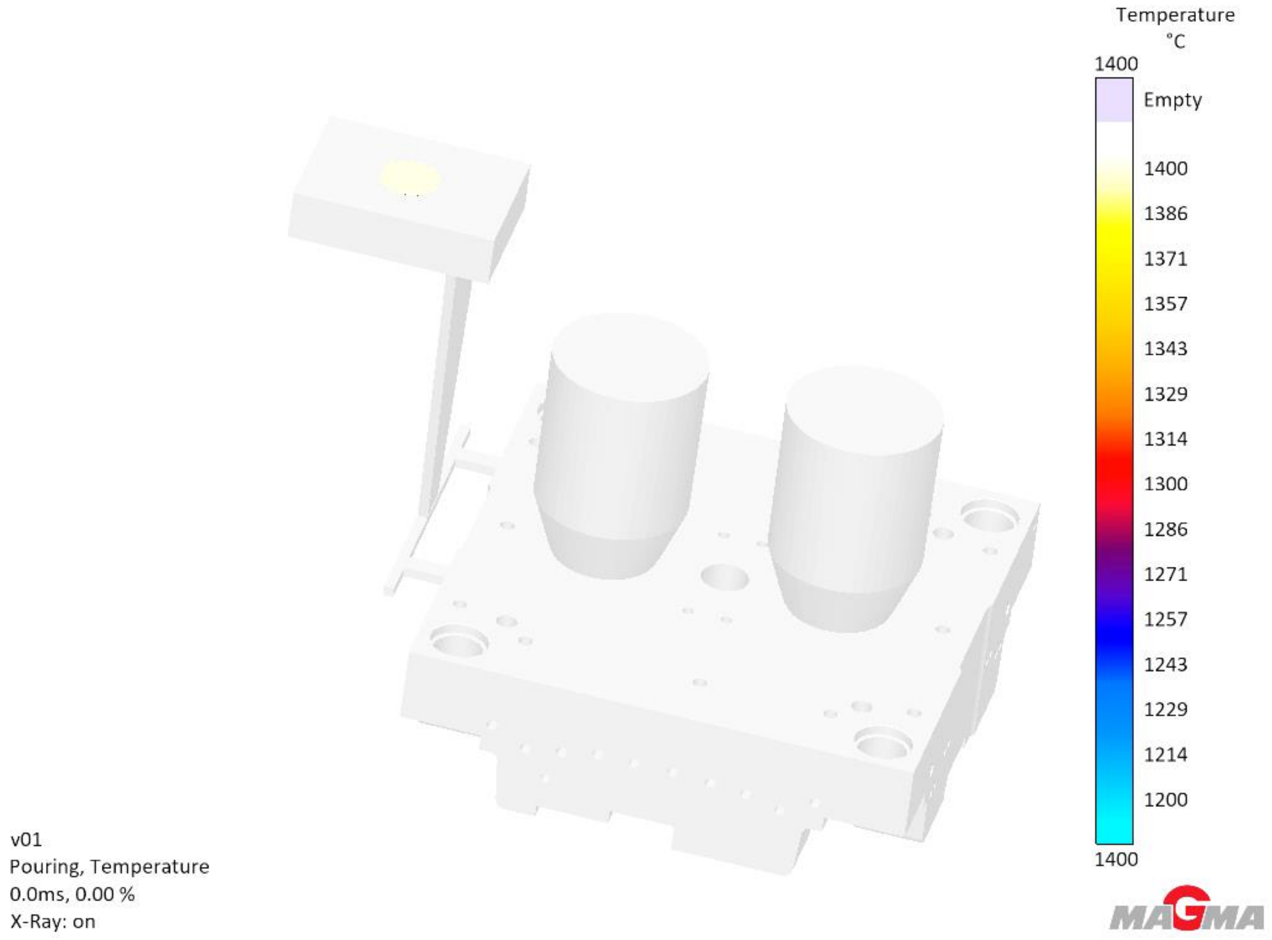


Natural solidification: Regions subject to shrinkage during solidification of the prototype



Development of the casting system

Simulations carried out in MAGMASOFT® to develop the parts casting system

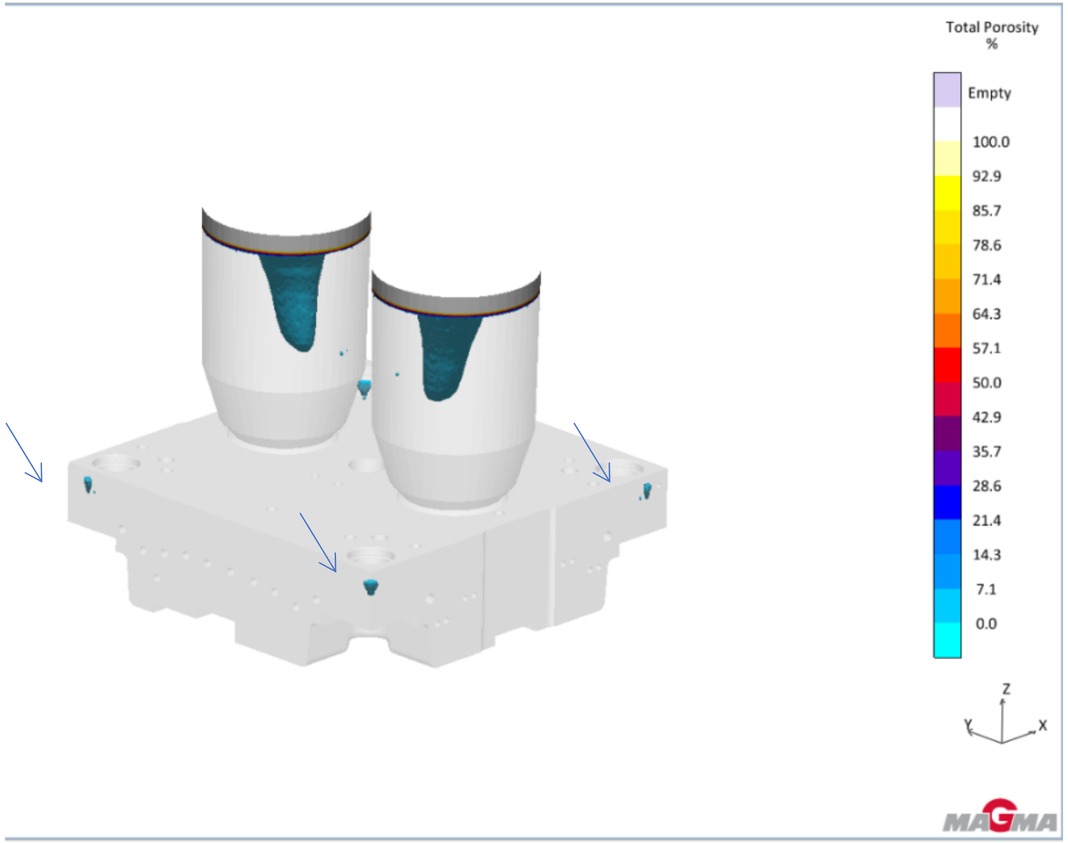


Mold prototype casting system - Study WITH MAGMA

System design and sizing:

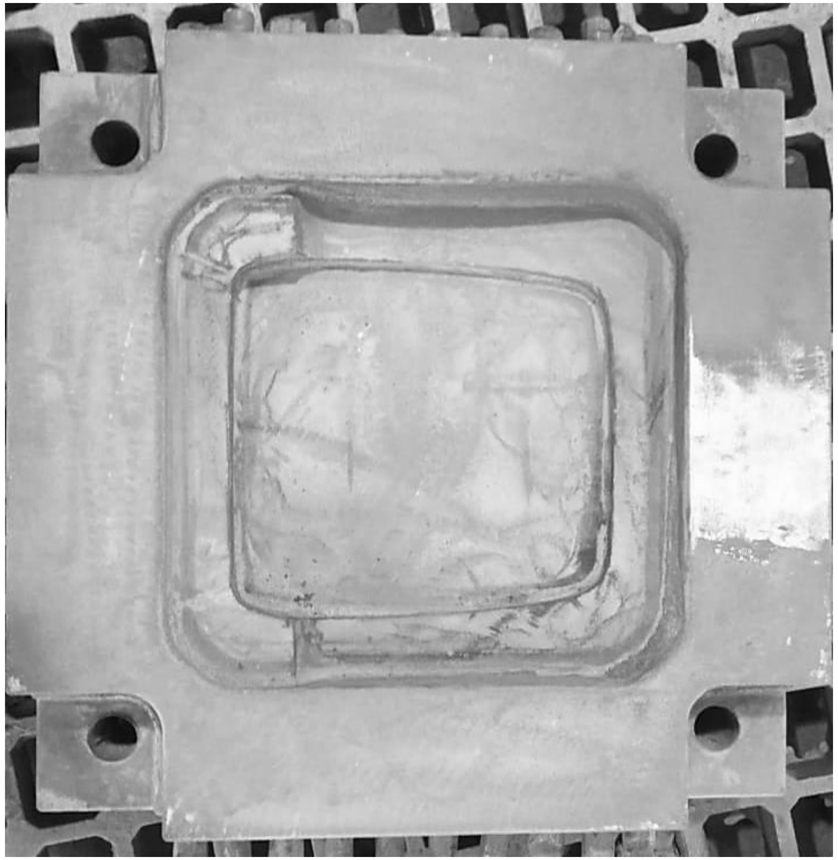
- The simulation shows small volumes of shrinkage (contraction) in the four corners of the part, resulting from the existence, in these regions, of thin walls that limit the flow of the metal.

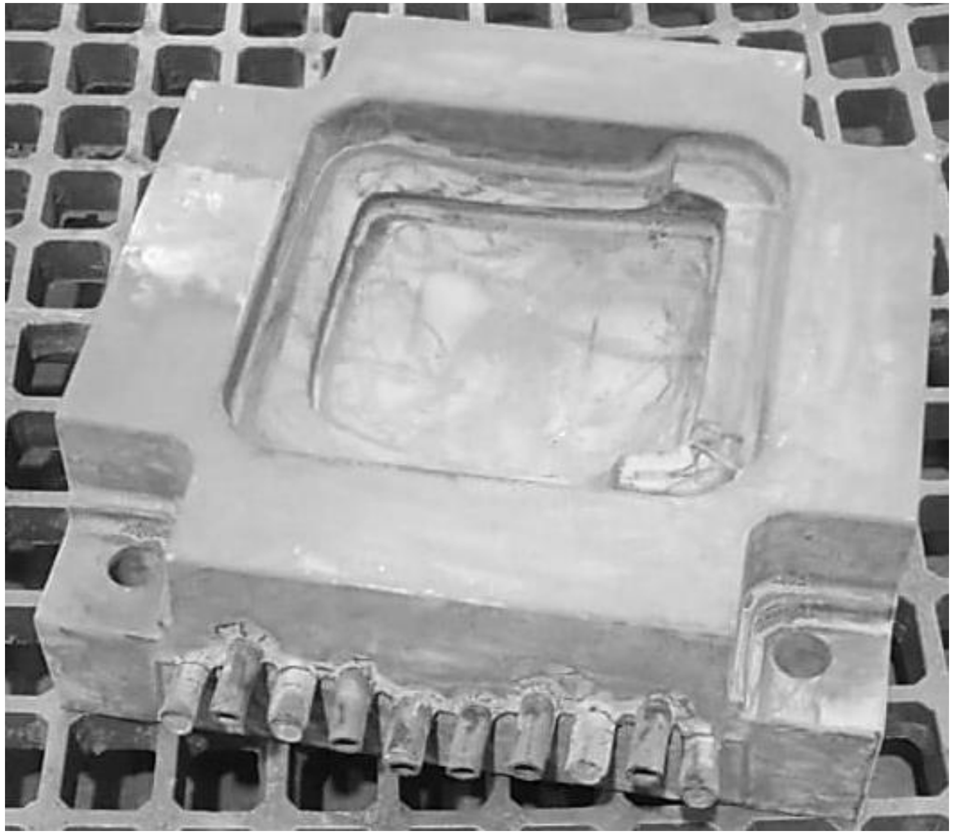
- It has been assessed that these imperfections will not affect the performance of the part in service.



High chromium cast iron

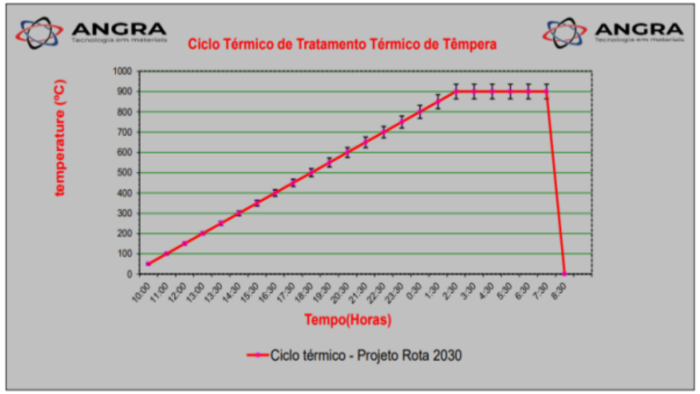
Condition: as cast

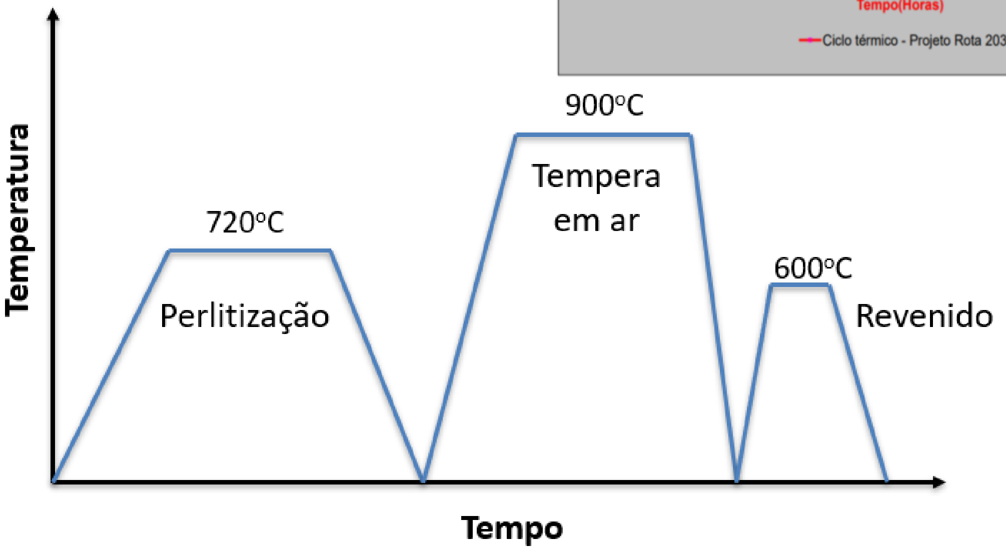




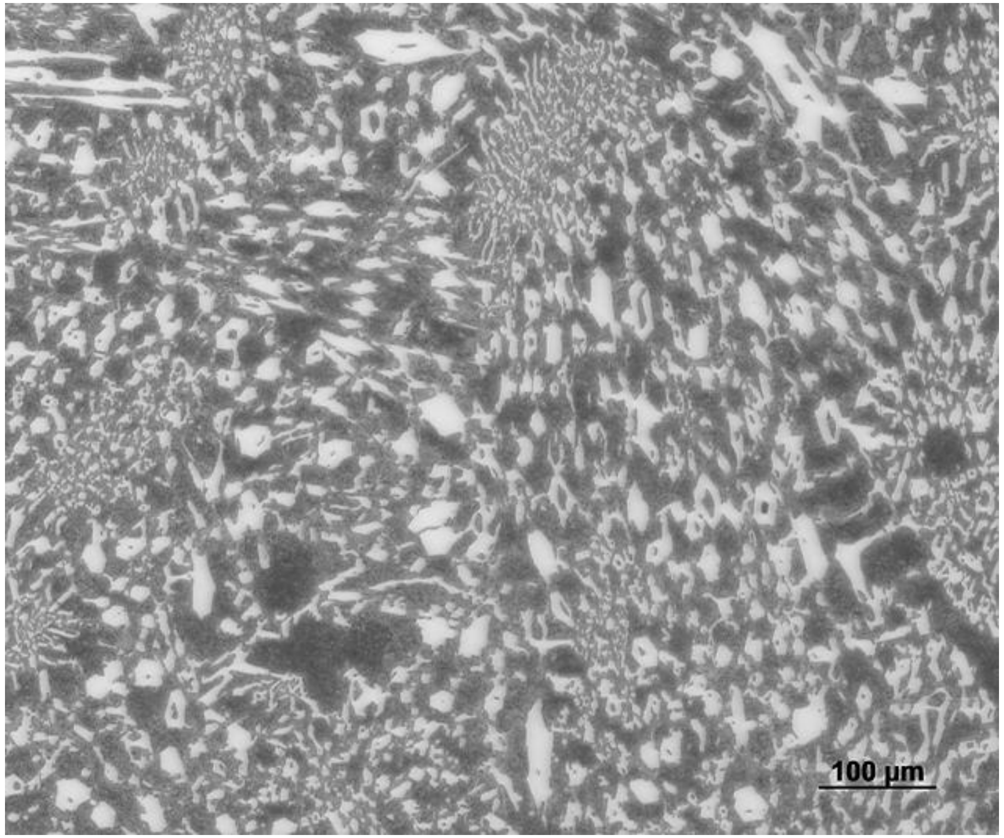
Heat treatment

Annealing, quenching and tempering





Heat treatment cycle carried out on the prototype.



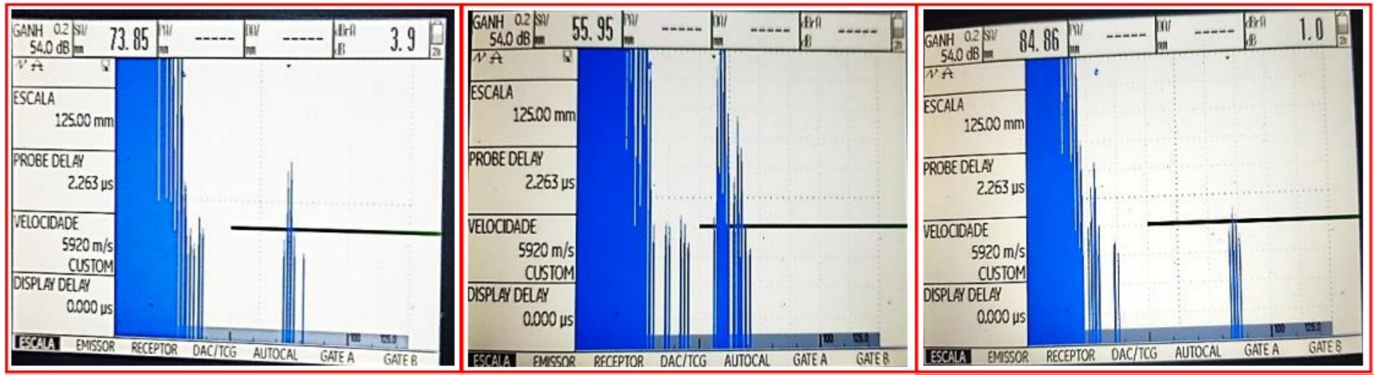
Microstructure of the prototype, 19%Cr eutectic alloy, after quenching and tempering. Original 100x magnification.

Ultrasound Test

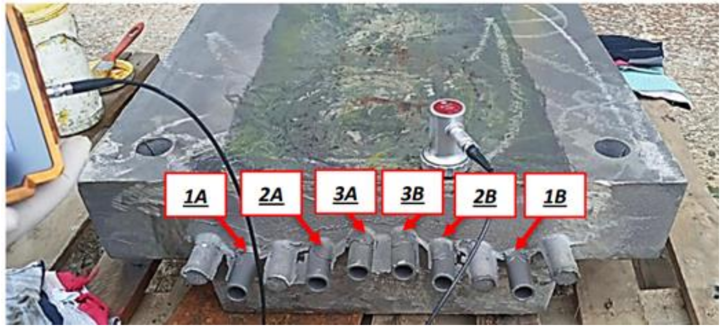
Measuring the depth and location of pipes

- The tubes generally have the same depth at the entrance and exit, only in the center of the matrix there was a small drop of +/- 20mm.

- The internal location of the tubes was maintained as expected, without relevant changes.



TUBOS 2A E 2B – PROF. 74MM	TUBOS 3A E 3B – PROF. 56MM	TUBOS 1A E 1B – PROF. 85MM



Conclusions

- Test specimens were produced to select the high chromium cast iron alloy with the best performance in machinability tests for the production of prototype molds for polymer injection.

- The cast prototypes did not present gross casting defects, such as shrinkage and porosity.

- It was possible to cast high chromium cast iron prototypes, using cooling channels with a more efficient geometry than forged P20 steel molds.

Future activities:

- Optimization of the casting system so that tubes do not shift.
- Testing prototypes on industrial equipment.

References

[1] J. Wang, et al., “Effects of high temperature and cryogenic treatment on the microstructure and abrasion resistance of a high chromium cast iron”, Journal of Materials Processing Technology 209, pp. 3236-3240, 2009. DOI: http://dx.doi.org/10.1016/j.jmatprotec.2008.07.035.

[2] PÖSTCH, G., MICHAELI, W., “Introduction”, Injection Molding, chapter 1, New York, USA, Hanser Gardner Publications, 1995.

[3] R. Blickensderfer, J. H. Tylczek and J. Dodd, “The effect of heat treatment on spalling of Cr-Mo white cast iron”, Wear of Materials, pp.471-476, 1983.

[4] F. Marathray, R. Usseglio-Nanot, Atlas: Transformation Characteristics of Chromium and Chromium-Molybdenum White Irons, Paris: C. M. S.A. (Ed.), pp. 149-152, 1970.

[5] Ö. N. Doğan, J. A. Hawk, “Effect of carbide orientation on abrasion of high Cr white cast iron”, Wear 189, pp. 136-142, 1995. DOI: http://dx.doi.org/10.1016/0043-1648(95)06682-9.