SHOT SLEEVES FOR DIE CASTING (THERMAL VARIATIONS AND ITS CONSEQUENCES)[1]

Ednelson Silva [2]
Vinicius Úbeda [3]
Wilmar Fischer [4]

Starting from a model of Shot Sleeve for Die Casting with cooling system, the use of a simulation software for metal casting will generate data for better understanding of the dynamics of deformation and wear produced by the thermal variations along these component.
During the development of this work many different cooling medias were tested as well as temperatures.
By this procedure, information that translates into more realistic results were obtained, indicating preventive and corretive actions in order to minimize process variations related to the deformations and to improve the lifetime of the Shot Sleeves and Plunger Tips.

Key-words: Silulation; Shot Sleeve; Plunger Tip; Banana effect.

1 INTRODUCTION

The components of the injection system of interest on this study (shot sleeve and plunger tip) represent elements of wear and are of critical important for the casting process.

This means that the movement of the Plunger Tip by the bore of the shot sleeve should be made with the highest degree of freedom possible, since the restrictions impose a more intense wear (wich reduces the lifetime) and loss of injection speed (parameters of high importance in the process).

The present work focus its study, by the use of simulation, on the two main mechanisms causing these problems :

- ✓ Deformation effect in upwards arch (banana or ski effect).
- ✓ Premature erosion in the hole where molten metal is poured.

1 Article to be presented at the Foundry Congress : CONAF 2009, 22 to 25 september 2009 in Sao Paulo – SP.
2 Consultant - MAGMA Engenharia do Brasil Ltda.
3 Application Engineer - MAGMA Engenharia do Brasil Ltda.
4 Mechanical Engineer– WFischer Técnica Ltda.

2. MATERIAL AND METHODS

2.1. Material:

On the present work, a 3D modeling was used for the shot sleeve, fixtures to hold to the plate of the die casting machine, cooling jacket and plunger tip, according to figure 1.

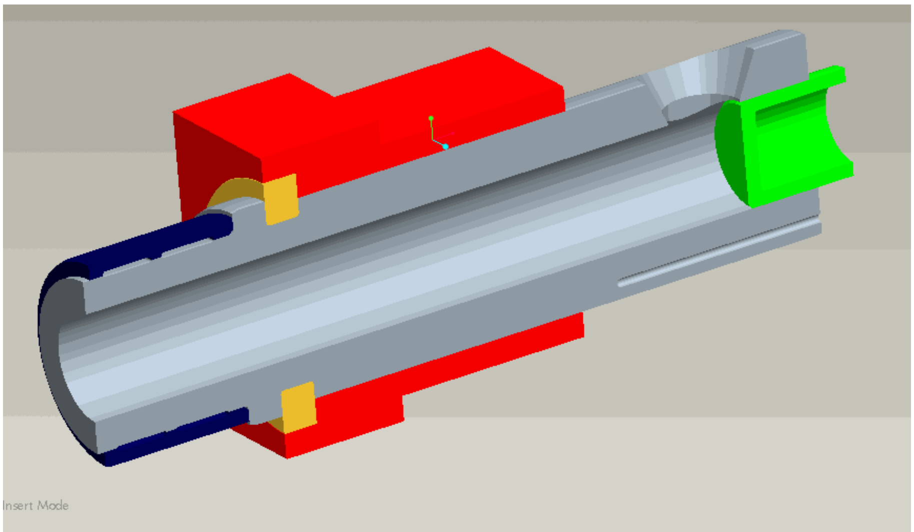


Figure 1. Image of modeling with cross section showing the shot sleeve (grey), flange (yellow), plunger tip (green), cooling jacket (blue) and fixture component (red).

The coolant media (water or hot oil) applied for cooling of the shot sleeve and the temperature related (30 or 140°C) are variables according to table 1.

On situation 5, besides the type and temperature of the cooling media, a sleeve of tungsten was added in the pour hole area, according to the figue 2.

Table 1. Cooling conditions for each simulation model.

Situation	Description
1	Without cooling
2	Water at 30º C in the sleeve and cooling jacket
3	Water at 40º C in the sleeve and cooling jacket
4	Oil at 140º C in the sleeve and cooling jacket
5	Oil at 140º C in the sleeve and cooling jacket plus tungsten sleeve

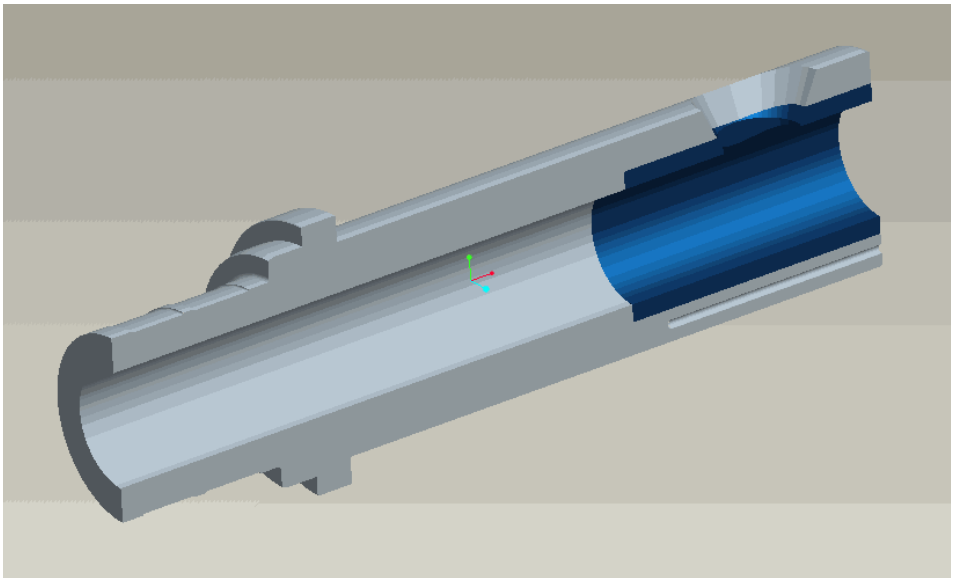
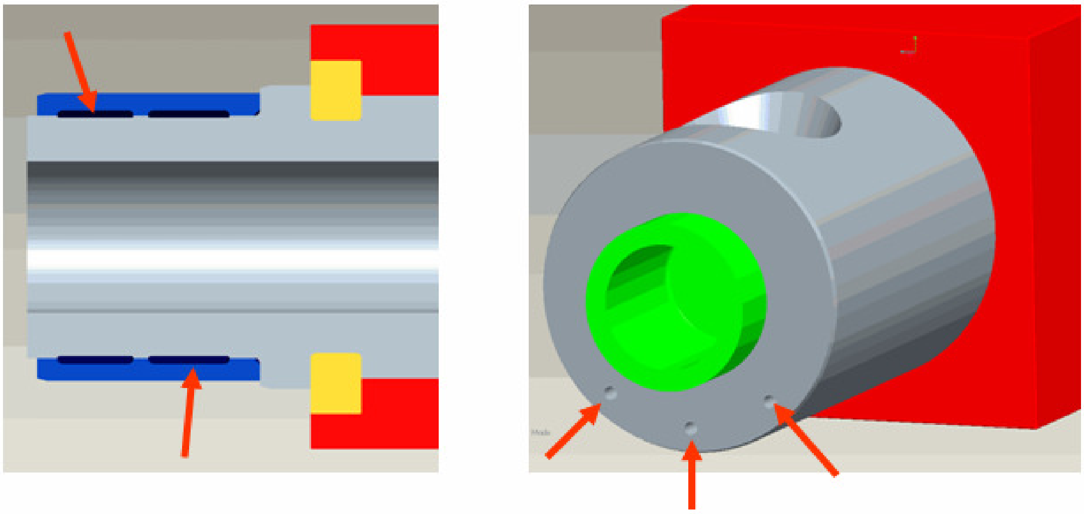


Figure 2. Image of modeling with cross section showing the tungsten sleeve (blue) in the pour hole area.

The cooling (when used) was applied in the shot sleeve areas pointed in the figures 3 and 4.



Figures 3 and 4. Cooling jacket at the biscuit area and cascade cooling lines in the pouring hole area.

In order to proceed the simulations, the following parameters were used :

- ✓ Plunger Tip diameter : 150mm;
- ✓ Biscuit thickness : 40mm;
- ✓ Shot weight per cycle : 30kg;
- ✓ Number of cycles simulated per situation : 20;
- ✓ Each cycle time (aproximated) : 100s;
- ✓ Solidification time : 25s;
- ✓ Temperature of poured aluminum at shot sleeve: 670°C;
- ✓ Material of components (except tungsten sleeve) : H13 steel

3 RESULTS

3.1. Solidification Analysis (at start of the cycle, before pouring)

3.1.1. Simulation of situation 1 (without any cooling) :

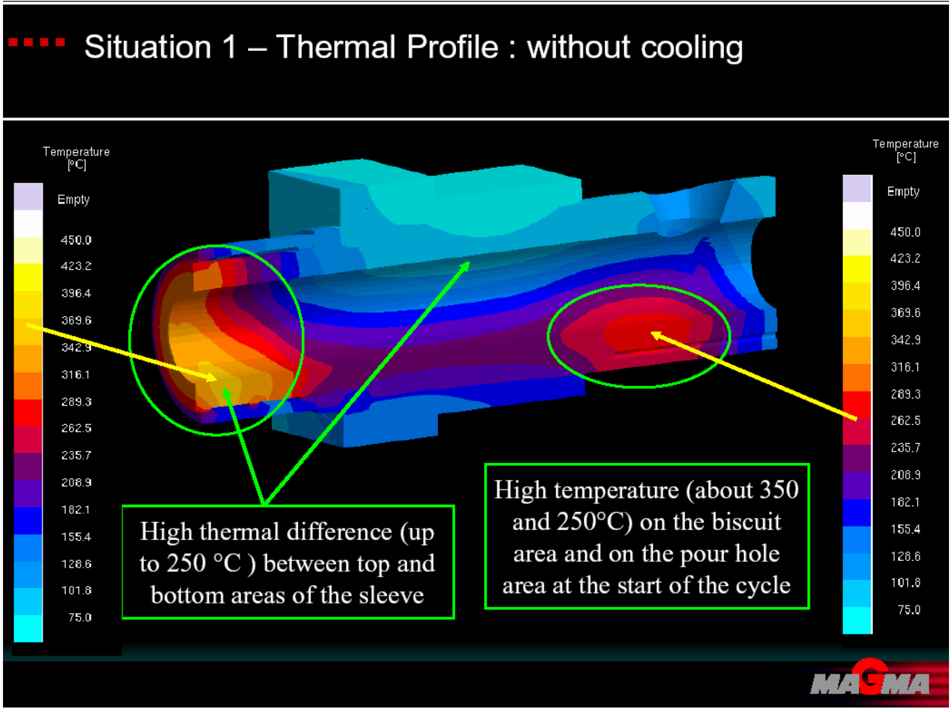


Figure 5. Simulation results showing high heat concentration in the pour hole and biscuit areas as well as high temperature difference between higher and lower areas, without use of cooling.

3.1.1. Simulation of situation 2 (with water at 30º C in the nose end of the sleeve and on the pour hole) :

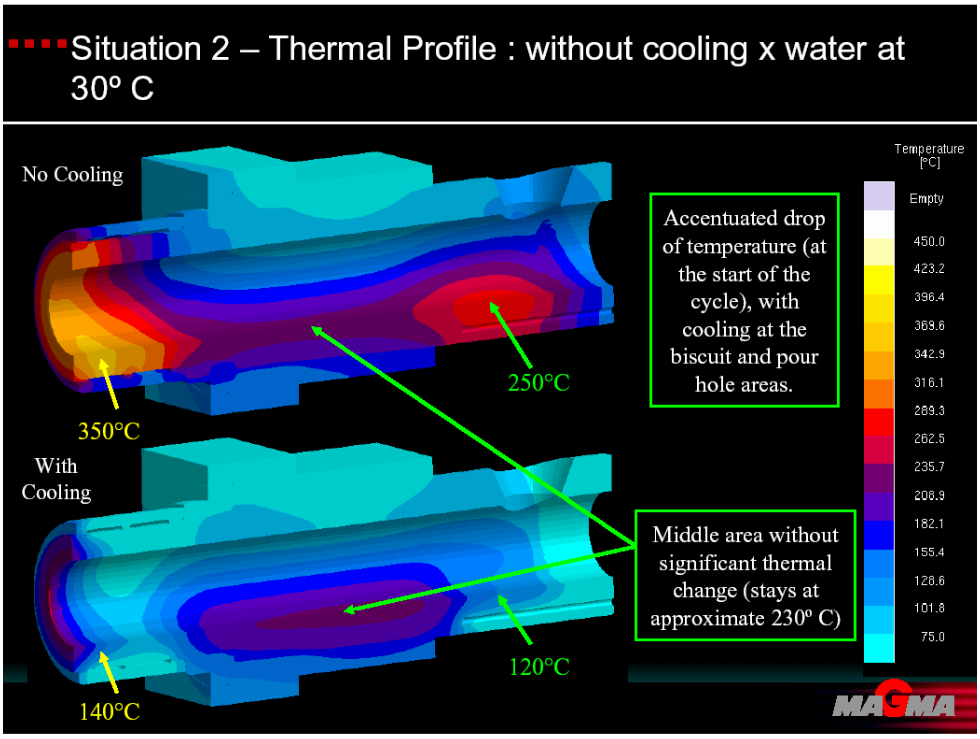


Figure 6. Results of simulation showing high degree of heat removal in the pour hole and in the biscuit area, with the application of cooling in comparision with anterior situation (without cooling).

3.1.3. Simulation of situation 3 (water at 140ºC in the nose end of the sleeve and on the pour hole) :

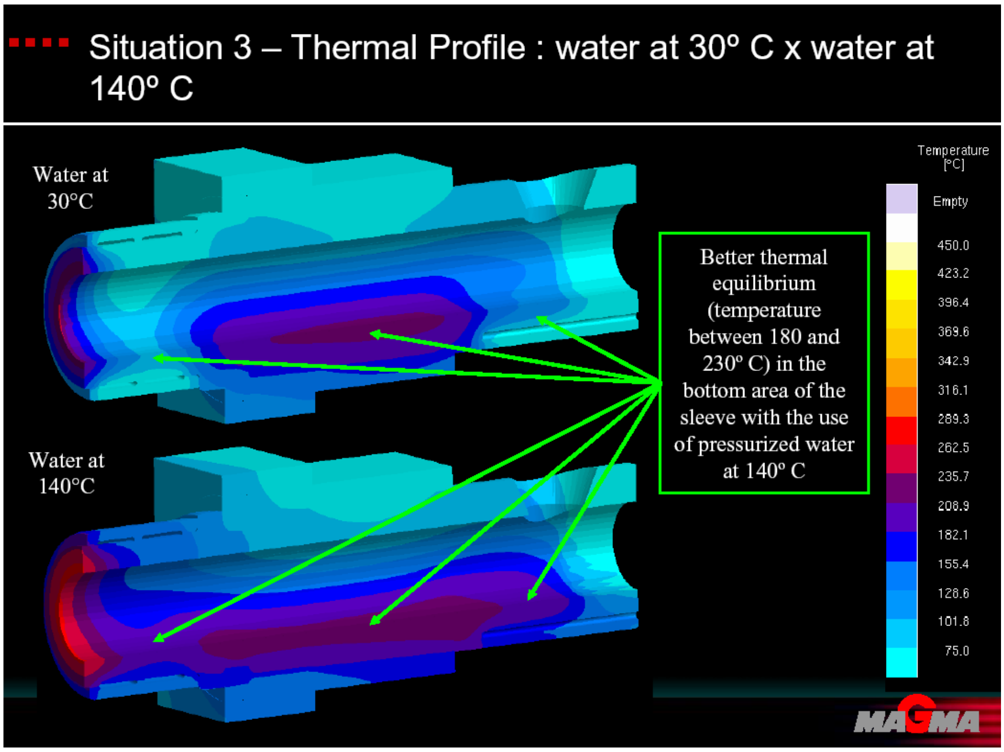


Figure 7. Results of simulation showing better thermal balance in the lower area of the shot sleeve, using water at 140º C in comparison with the anterior situation (water at 30º C).

3.1.4. Simulation of situation 4 (with oil at 140º C in the nose end of the sleeve and on the pour hole) :

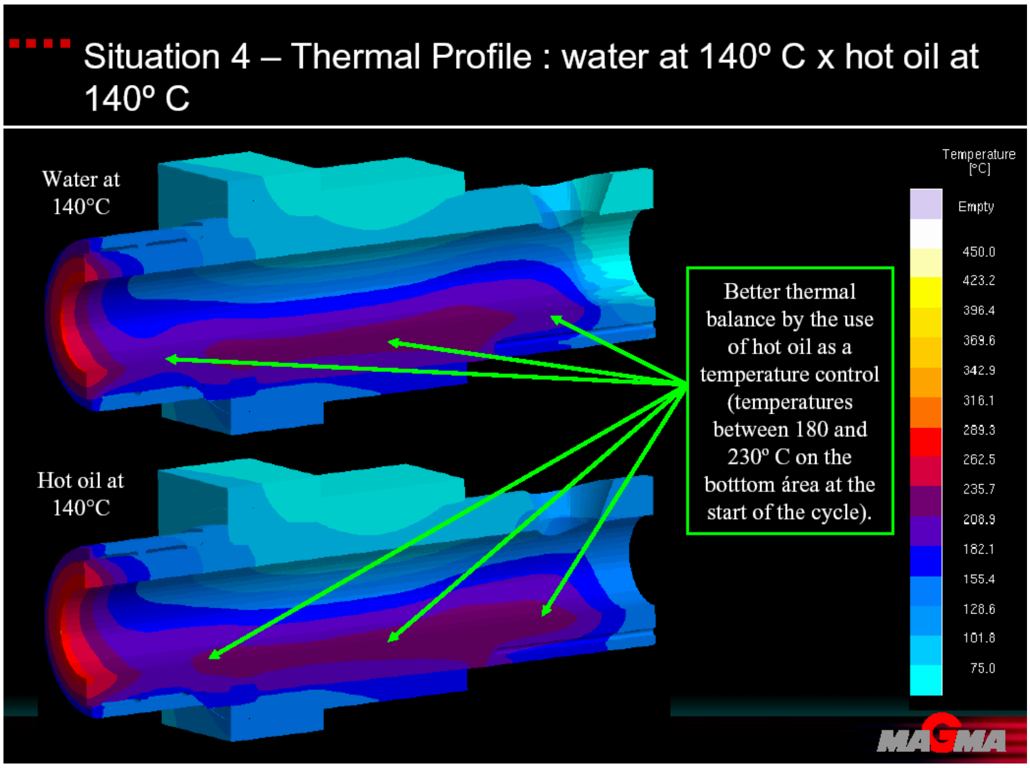


Figure 8. Results of simulation showing better thermal balance in the lower area of the shot sleeve, using oil at 140º C in comparison with the anterior situation (water at 140º C).

3.1.5. Simulation of situation 5 (oil at 140º C and tungsten sleeve) :

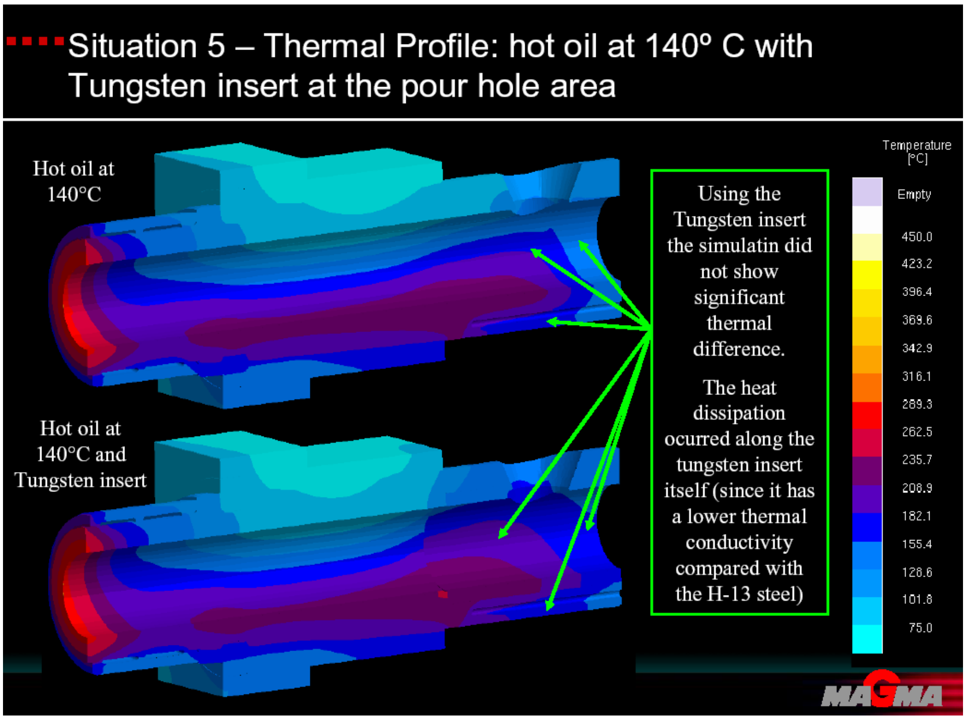


Figure 9. Results of simulation showing no significant thermal difference in the lower are of the shot sleeve, with oil at 140º C and tungsten sleeve in comparison with anterior situation (oil at 140º C without tungsten sleeve).

3.1.6. Comparison of the 5 simulated situations :

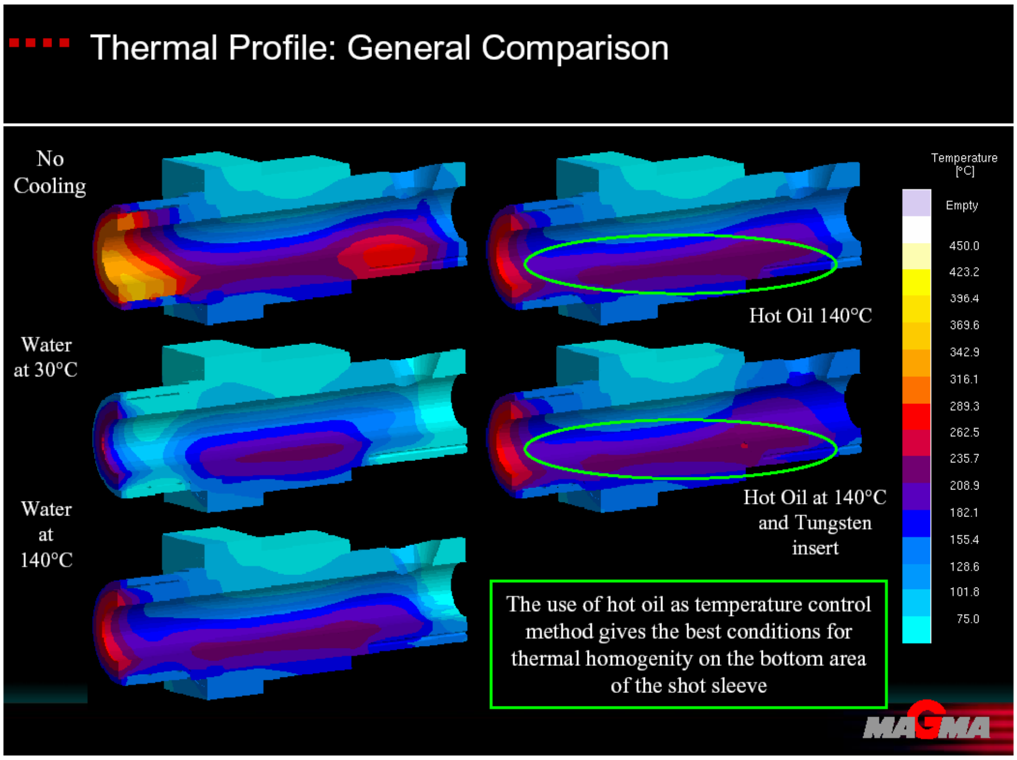


Figura 10. Comparision of all 5 situations of simulation, showing the advantage of the use of the hot oil for the thermal balance of the lower area of the shot sleeve.

3.2. Deformation Analysis (simulation of extreme conditions)

3.2.1 Simulation of situation 1 (without cooling) :

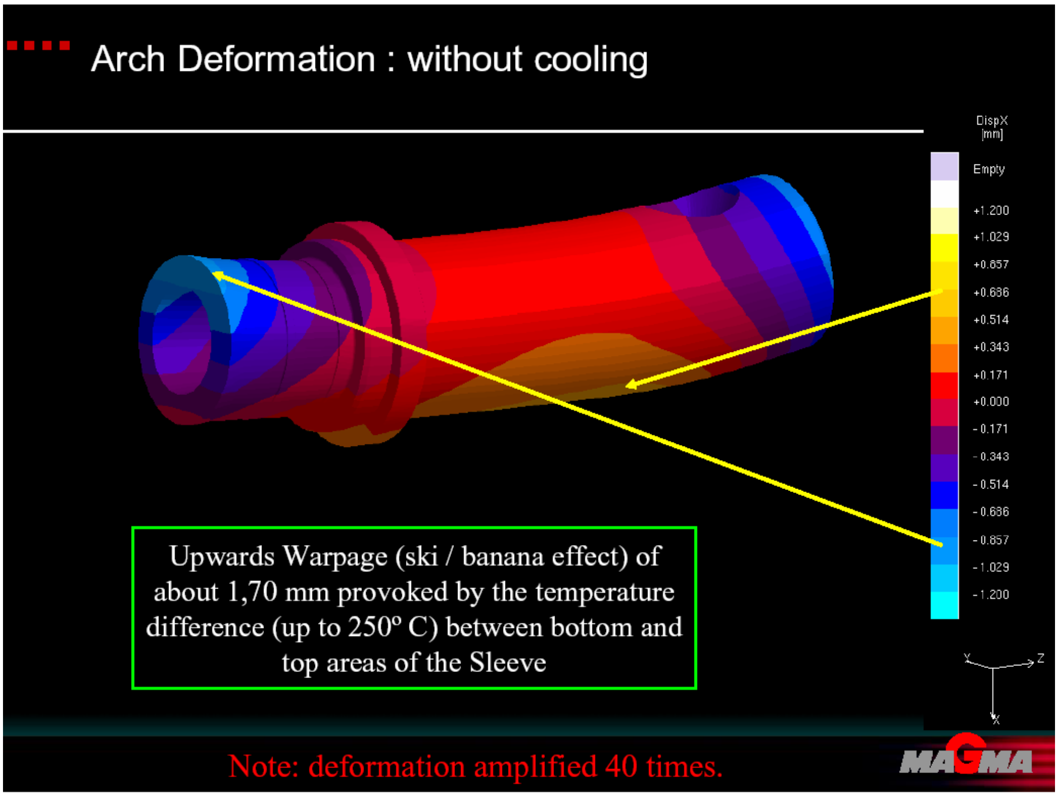


Figure 11. Result of simulation showing upwards arch deformation (in X axis with 40 x amplification) caused by high temperature difference between superior and inferior are of the shot sleeve.

3.2.2. Simulation of situation 2 (with water at 30º C in both ends):

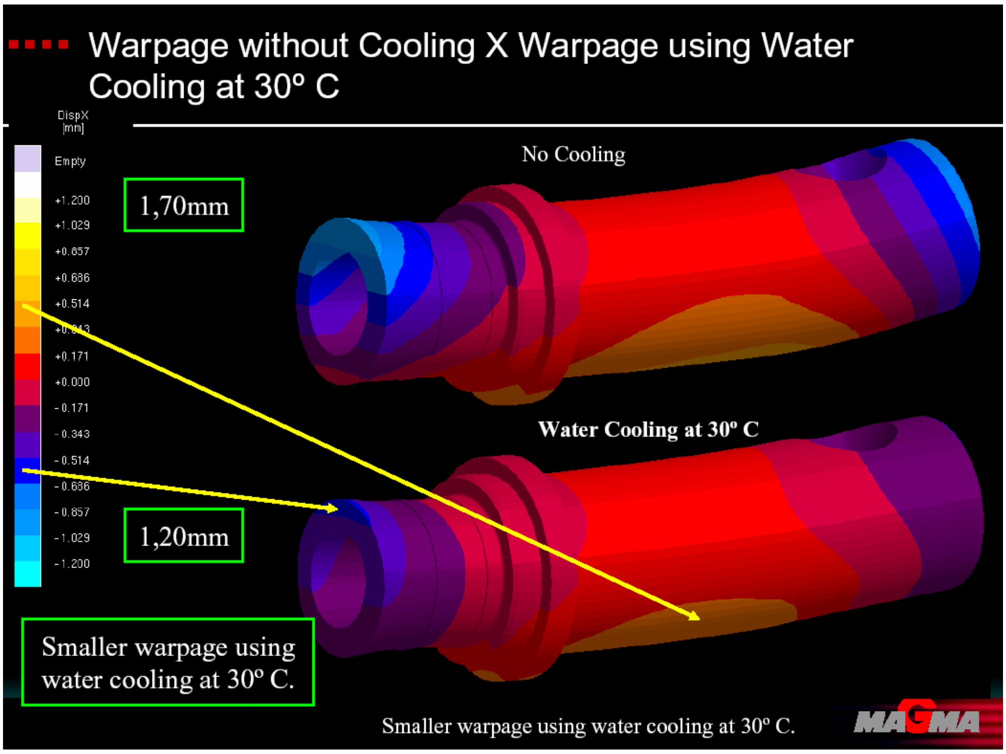


Figura 12. Result of simulation showing reduction on upwards arch (on X axis, 40 x amplification) with water cooling in the ends of the shot sleeve in comparison with anterior situation (without water).

4. CONCLUSION

- ✓ The use of hot oil as control method generates better conditions for thermal balance of inferior area of the shot sleeve (180 to 230º C at the start of the cycle) what results in less thermal loss for the molten alumium (mainly in the situations where the filling is below 40%) and also less thermal shock for the steel.
- ✓ It is suggested to use a temperature control unit (with pressurized water or hot oil) in two circuits for independent control of the temperature of the pouring hole and biscuit area, since there are thermal difference between them considering the contact time with the molten metal.

- ✓ The arch deformation effect occurs even with the water cooling at 30º C at the critical areas (pouring and biscuit). The problem is aggravated with the increase in the shot weight (volume of poured aluminum).To solve this problem we suggest the articulated system for the plunger tip (figure 13) what also reduces the problem with speed loss due warpage of the sleeve and misalignment between sleeve and shot rod.

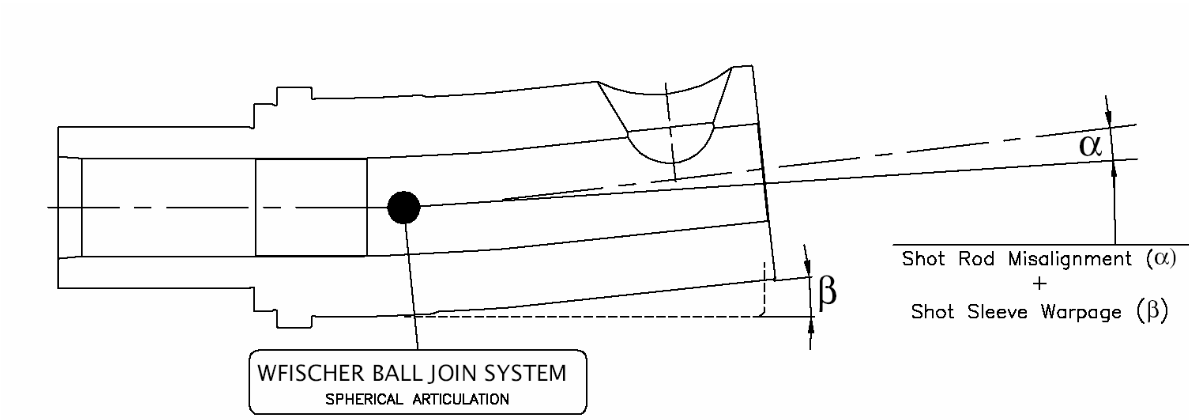


Figure 13. Demonstration of compensation of the upwards arch deformation and misalignment between shot rod and sleeve by the use of the plunger tip with articulating system.

- ✓ The tungsten alloy (used in the inserted of the situation 5) proposed has thermal conductivity that is 4 x compared with the H-13 steel but does not reduced the temperature of the pouring hole area, because it is positioned around the H-13 steel. This alloy is a very good one to reduce the speed of the premature erosion, increasing the lifetime of the shot sleeve because it shows a lower thermal expansion coefficient (3 x less) compared with the H-13 steel and its hardness is constant (it is not tempered).