SHOT SLEEVE WITH INTEGRAL THERMAL REGULATION

F. Miglierina  
*BS in Industrial Chemistry, Omnia Press S.r.l.*  
Via Olona  
116 21013 Gallarate-VA-ITALY

B. Vianello  
*BS in Industrial Chemistry, Zanussi Metallurgica S.p.a.-Electrolux Components*  
*Zona Industriale* . loc. Campagna-33085 Maniago-PN-ITALY

**Abstract**

The modern die-casting technique is mainly focused on processing more complex and bigger pieces maintaining a high quality level and very low costs. This aim can be achieved by producing, with the use of faster and faster die forming cycles, aluminum alloy die-cast pieces weighing more than 20 kilos and by improving the life of the press mechanical parts, such as the shot sleeves.

The company Zanussi Metallurgica decided to equip a horizontal die-casting machine featured by a 2000-ton cold room and a 21-kilo aluminum dying capacity with a shot sleeve (length: 980 mm, hole diameter: 140 mm) supplied with an Omnia Press integral thermal regulation circuit made of warm processed steel, hardened in a salt bath and with a surface covered with Nipre® Duplex.

Thanks to the user care and to the special design, the shot sleeve could reach 80,000 injections at the end of the working cycle.

The aim of this report is to introduce those technical solutions which brought to this successful conditions and to suggest shot sleeves with a long life granting a constant casting quality.

**Keywords:** Die-casting technique, injection group, shot sleeve, aluminum;
THE SHOT SLEEVES DURING THE INJECTION PHASE: ANALYSIS OF PROBLEM

Important research have been performed in the development and design of the die-casting molds. The steelworks and the thermal treatment companies introduced several novelties in the production of quality wearproof molds aimed at obtaining aluminum castings featured by higher quality and lower costs.

On the contrary, the shot sleeve and the injection group have never been taken into serious consideration.

The main features of the injection group must be:

- Parallelism and concentricity;
- Hole roundness and roughness;
- Reliability and life;

The reliability and, above all, the life are fundamental factors to obtain quality and cheap die-cast pieces [1]. A shot sleeve can deteriorate because of two main reasons:

- Thermal fatigue;
- Mechanical wear;

Every time the melted material is poured, the shot sleeve is subject to a thermal shock which influences its efficiency: the consequence of this continuous and fast temperature change is the loss of the steel resistance and the creation of cracks on the surface covering with the following corrosion and metalization of the melted aluminum. During the injection phase the shot sleeve is also subject to the continuous abrasion of the piston, of the freely moving silica particles inside the alloy and of the aluminum itself [2].

A shot sleeve becomes normally unusable because of the presence in the material dropping area of a hole which causes a rapid wear of the piston, a bad quality of the produced pieces and possible seizures due to the troubled piston stroke (Fig. 1).

Each injection is featured by events causing the steel wear, the creation of thermal cracks in the material dropping area, the deformation of the "biscuit" area, the presence of superficial cracks and, in extreme cases, the creation of spontaneous fractures [2]
The die-casting shot sleeves must meet several thermal, mechanical, chemical and operative requirements deriving from the specific working environment. Understanding such variables and their influence is very important in the choice of the right material and of the suitable thermal treatment. During the die-casting procedure some mechanical stresses develop in the "biscuit" area with an intensity included between 50 and 150 MPa [3]. Such stress values are usually linked to the thermal stresses developed during the working procedure. The surface erosion and, in particular conditions, the corrosion caused by the liquid metal contribute to the tool damaging above all in the injection area.

Together with the mechanical stresses and the erosion, the shot sleeve life is strongly influenced by thermal factors. It is therefore advisable to analyze each single stress type which the warm steels are subject to.

The liquid metal injected in the shot sleeve overheats the surface reaching temperatures ranging between 550–600°C; in this way a fast reduction of the resistance to the warm yield in the cavity contact area occurs. With a very thin surface layer the thermal stresses can overcome the yield resistance causing a significative plastic deformation. The periodical temperature changes on the mold surface cause a thermal expansion and contraction. These cyclical thermal stresses create thermal fatigue cracks.
Together with the chemical corrosive stresses, the shot sleeve is subject to thermal stresses caused by the temperature difference between the melted aluminum and the shot sleeve steel [4]. With the coefficient of thermal expansion it is possible to evaluate the steel dilatation at different temperatures.

Coefficient of thermal expansion for °C AISI H13 = 0.000011

\[ \text{A.D.} = D.T. \times \Delta T \times 0.000011 \]

Where \( \text{A.D.} \) = diameter increase [mm]
\( D.T. \) = diameter with the reference temperature [mm]
\( \Delta T \) = temperature difference [°C]

During an important German die-casting procedure it has been possible to check the diameter increase in a thermal regulated shot sleeve connected to a gearcase with diathermic oil.

The obtained data are perfectly compatible with the theoretical ones.

In a 1200-ton die-casting machine with a 60-second working cycle and an aluminum quantity equal to 4.5 kilos, the temperatures of a standard shot sleeve have been checked both in the lower section (in touch with the melted aluminum) and in the upper section (not in touch with the melted material) [5].
The shot sleeve has a different temperature in the material dropping area and in the mold inserted area; the temperature is also different in the hole upper section and in the hole lower section where the material is poured. It is inevitable that inside a cylinder, when the temperature difference is so high, the hole gets an oval shape and the cylinder bends (bending effect). Figure 2 calculates the ovalization inside a shot sleeve with a 110-mm hole and a 220-mm external diameter.

Figure 3 calculates the bending in the material dropping area inside a shot sleeve. It is clear that a standard shot sleeve, without any thermal control, is
MD: diameter inside the hole
MD = (OD-ID)/2 + ID = (220-110)/2 + 110 = 165 mm
Segment length with an MD diameter
L = MD\pi /4 = 165\pi /4 = 129.5 mm
The theoretical expansion of each segment is:
E1 = 129.5 \cdot 0.000011 \cdot 320\degree C = 0.46 mm
E2-E4 = 129.5 \cdot 0.000011 \cdot 220\degree C = 0.31 mm
E3 = 129.5 \cdot 0.000011 \cdot 160\degree C = 0.23 mm

Length of the shot sleeve exposed section:
250 mm
Window length: 100 mm

Expansion in the shot sleeve lower section:
250 mm \cdot 300\degree C \cdot 0.000011 = 0.825 mm

Expansion in the shot sleeve upper section:
(250 mm - 100 mm) \cdot 140\degree C
\cdot 0.000011 = 0.231 mm

Difference between the lower and the upper section:
0.825 - 0.231 = 0.594 mm

subject to important deformations which can not always be foreseen theoretically. The ideal condition would be keeping the shot sleeve at a temperature included between 100 and 200\degree C, with a difference in the upper and lower section, in the material dropping area and in the "biscuit" area not higher than 50\degree C. In this way the shot sleeve maintains a concentric shape and has a very small bending [6].
APPLIED TECHNICAL SOLUTIONS

The shot sleeve must be manufactured according to the best technological procedures and with new solutions allowing to obtain high quality die-cast pieces at a very low price. In order to achieve this aim, Omnia Press, a company producing shot sleeves and accessories for the injection group, and Zanussi Metallurgica, a company for the aluminum die-casting, have combined their long experience in the sector and researched the best market offer at a reasonable cost. In order to obtain this result we have decided to focus our job on the following choices:

1. Steel choice;
2. Type of hardening and tempering treatment in order to obtain the right hardness level;
3. Type of superficial treatment;
4. Engineering modification;

STEEL

The steels used for the shot sleeve production are tool steels for warm processing linked to Cr-Mo-V; they are particularly suitable also for molds used to die-cast Al and Mg alloys. These steels can be used at high temperatures without changing their mechanical features. In particular, they must be featured by [7]:

- High mechanical resistance
- Bar toughness and ductility both at very high temperatures and at ambient temperature
- High hardenability and resistance to the tempering procedure
- Wear resistance at high temperatures
- Resistance to thermal shocks and to thermal fatigue stresses
- Resistance to corrosion and erosion caused by the metals in their liquid state
- Resistance to oxidation
Easy to be processed by a machine tool

The material chosen to manufacture the shot sleeve is UNI 30CrMoV1227KU

<table>
<thead>
<tr>
<th>Code</th>
<th>Chemical composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN</td>
<td>UNI 2013</td>
</tr>
<tr>
<td>AISI</td>
<td>Wnr. 2013</td>
</tr>
<tr>
<td>AFNOR</td>
<td>Cr 2013</td>
</tr>
<tr>
<td>C</td>
<td>Si 2013</td>
</tr>
<tr>
<td>Mo</td>
<td>V 2013</td>
</tr>
<tr>
<td>X32CrMoV33</td>
<td>30CrMoV1227KU</td>
</tr>
<tr>
<td>H10</td>
<td>23 0.30</td>
</tr>
<tr>
<td>2D65</td>
<td>65 0.30</td>
</tr>
<tr>
<td>30DCV28</td>
<td>30 3.00</td>
</tr>
<tr>
<td>2.80</td>
<td>0.60</td>
</tr>
</tbody>
</table>

This kind of steel is suitable to be processed at high temperatures, it has a high resistance to the thermal oscillations, has a very good toughness and a good tempering resistance, it can be cooled with water while working. The higher percentage of Mo as compared those steels containing a 5% chrome allows its use at higher temperatures [8]. The steel for the shot sleeve production is annealed with an hardness of 180 Brinell.

**HARDENING AND TEMPERING TREATMENT**

Starting from a 272.5-mm bar, it has been possible to perform the size cut, the drilling on vertical machines, the processing on numeric controlled lathes and the milling on machine tools; some stock has been left on the piece external side, on the piece itself and inside the hole for the grinding to be performed after the hardening procedure on numeric controlled machines. The piece hardening and tempering treatment has been performed with the following thermal cycles:

1) preheating at 650°C;
2) preheating at 880°C for two hours;
3) vacuum austenization at 1030°C;
4) hardening with cooling in thermal baths at respectively 520°C and 200°C;

The desired hardness (HRC 47–49) has been obtained with three tempering procedures:

1) tempering at 580°C;
2) tempering at 590°C;
Figure 4. Micrographies of annealed steel ($\times 100; \times 500$).

Figure 5. Time-temperature-transformation continuous diagram.
Figure 6. Warm resistance curve.

Figure 7. Tempering diagram.

Figure 8. Creep.
3) tempering at 550°C;

The hardening has been performed in a salt bath, where the heat is dipped into bath tanks with a 1:10 volume ratio; the total cooling homogeneity is therefore granted. The practical consequences are a limitation of the deformations and, above all, thanks to the high thermal exchange coefficient of the melted salts, a cooling speed higher than the one obtained, with the same deformations, using the gas quenching [9].

The possibility to cool the material using several baths of melted salts (the first at 500°C and the second at 200°C) allows to combine the speed and the cooling uniformity to the controlled thermal jump, thus obtaining a cooling speed suitable to grant the desired hardening structure and to prevent possible piece distortions.

Passing through a salt at a high temperature it is possible to use the steel bainitic "window" for the processing at high temperatures; in this way, without any structural change, the temperature difference between the core and the surface is uniformed. Passing through the salt from 500°C to 200°C the starting point of the martensitic transformation is crossed at such an high speed that the bainitic nose can be avoided or touched in its lower part, thus forming a lower bainite and martensite. The result is a suitable structure for its mechanical properties, the most important being the impact strength [10].

The steel, after the hardening and tempering treatment, was tempered martensite with an austenitic grain sized 4–6 ca (ASTM E112).

SUPERFICIAL TREATMENT

According to the principles suggested by the best technologies, the produced shot sleeve has undergone a superficial treatment called Nipre® Duplex in order to reach a double hardening layer (0.20–0.25 mm) obtained via the ionic nitriding and the 4–5 micron magnetite. The superficial covering is patented and called Nipre®.

The ionic nitriding allows to obtain a superficial layer with an hardness equal to 1050 Hv and a thickness variable from 0.2 to 0.3 mm. It is evident the presence of a single-phase white sheet, which is compact, tough, with high anti-seizing properties and a good resistance to the wear caused by the sliding of the silicon particles suspended in the aluminum alloy. Such procedure is performed inside vertical furnaces for a better control of the deformations.
Figure 9. Plant for hardening in salt bath – T.T.N. s.p.a. Nerviano-MI.

Figure 10. Microographies of hardened and tempered steel (100X; 500X).
The nitriding procedure is aimed at increasing the steel superficial hardness and to improve its wear resistance features. This treatment is performed via the nitrogen superficial diffusion; the ionized nitrogen spreads on the steel surface creating some nitrides, which are hard and wear resisting. The consequence is a non metallic superficial layer with a good wear and rubbing resistance. The main advantage is the process extreme delicacy which allows not to damage the surface with too aggressive or fragile hardening [10].

With the plasma nitriding, the piece to be nitrided is placed into a "process chamber" filled with gas, mainly nitrogen; the nitrogen acts as a cathode while the chamber as an anode.

When the electric circuit is closed, the gases, which are also heating and nitriding means, are ionized and the piece to be treated is subject to a N$_2$ + H$_2$ ion bombardment [11].

The main advantages of the ionic nitriding are the low required temperature, the hardness and the toughness of the obtained superficial layer.

A fundamental further feature of the ionic treatment applied to the shot sleeve is the use of furnaces with a warming wall; it means that contrary to old plants, where the plasma supplied the energy required both for the process and for the heating, in the warm wall plants the heating is obtained in a convective way and the plasma is used only for the nitriding procedure with a power 10–15 times lower than the original one. The result is a very good homogeneity of temperature and process and an important reduction of the edge or tip effect present in an electric field, which means overtemperature and a fragile condition [12].

The Nipre® superficial treatment is used to obtain a layer of iron oxide with an hardness of 850–900 Hv, with a high chemical inertia and a strong buffer action against the aluminum alloys. It prevents those destroying processes such as the wear, the thermal fatigue and the following pyrocracking, the metalization and the Al corrosion. The Nipre® is derived from a theoretical approach to the problem trying to evaluate and find the best barrier against the entrance of the Fe in the liquid Al which is in contact with the steel: first cause of the metalization and of the stuck weld. [12].

The micrography in Fig. 11 shows the nitride double layer and the magnetite layer.
ENGINEERING MODIFICATION

It has been demonstrated that the aluminum introduction in the shot sleeve and the continuous working cycles cause some steel distortions which can only be partly foreseen. The shot sleeve, furthermore, is overheated thus compromising the mechanical features of the steel and of the superficial covering [13, 14].

Without changing the drawing of the mechanical piece and without compromising the quality of the aluminum casting, the market suggests that the shot sleeve life can be improved by using cooling or thermal regulation circuits.

There are three main methods to be used to control the shot sleeve temperature: external earth plates or jackets with water circuits, creation of a water cooled 4-hole circuit in the material dropping area, creation of an oil thermal regulated circuit with 4/6 holes in the shot sleeve lower section and in the "biscuit" area [5].

1. The use of copper earth plates or of external "jackets" in the material dropping area can decrease the temperature up to 50°C. This method is used when the temperatures are not too much severe and the aluminum quantity is not excessive (Fig. 12);

2. The creation of a 4-hole circuit in the material dropping area is widely used in the die-casting procedures. This system is reliable because it removes the excessive heat present in the pouring area. The use of water allows to improve the shot sleeve life delaying the creation of the troublesome hole. This system, anyway, does not allow to control the deformations;
the temperature in the "biscuit" area is very high and some cracks could arise due to a thermal shock

3. The creation of an oil thermal regulated circuit with 4/6 holes in the shot sleeve lower section connected to a jacket in the "biscuit" area is used to remove the excessive heat both in the material dropping area and the mold inserted area; the life of a shot sleeve supplied with this circuit is longer than a standard one; the hole is anyway oval and not perfectly cylindrical (bending effect) because of the temperature difference between the lower and the upper section (Fig. 14).

SHOT SLEEVES WITH AN INTEGRAL THERMOREGULATION

With the idea of creating a shot sleeve with the best technology, Omnia Press has improved the oil thermal regulation concept, suggesting a shot sleeve with an integral thermal regulation on the whole hole and on the whole length. This technology, together with the advantages offered by a circuit located only in the material dropping area – "biscuit" area, is used to maintain the cylindrical shape of the injection hole, to control the steel working temperature and to obtain a constant injection with a specific speed and pressure.
Figure 13. Drawing of the cooling system with water in the material dropping area.

Figure 14. Drawing of the oil thermal regulated circuit in the material dropping area and in the "biscuit" area.
The bending and ovalization effect are practically removed. Only with this system the injection piston has a longer life because it slides into a cylindrical and not into an oval-shaped hole. All shot sleeves with an integral thermal regulation have:

- sector divided supporting diameters for a better protection against any external influence (machine fixed shoulder and mold fixed section), for an easy assembling procedure and for a more homogenous dilatation above all in the mold inserted area;

- an input and an output for the oil flow into the circuit according to the specific needs;

The shot sleeve of Zanussi Metallurgica, hole diameter: 140 mm, length: 980 mm, has been developed with a 12-hole circuit and with a 900-mm length. Its total development is 10.8 meters.

In this way we can be sure that the diathermic oil keeps the shot sleeve at an uniform temperature both in the overheated areas ("biscuit" area and material dropping area) and in the areas with a lower temperature (upper section) (see Figs. 15, 16)

Figure 15. Photo showing the section of the thermal regulated circuit.

Figure 16. Photo showing the material dropping area with thermal regulation holes.

The shot sleeve with integral thermal regulation is used also for the Magnesium die-casting, where the temperature of the diathermic oil can reach 300°C. In this way the Magnesium is injected into the mold at a very high temperature, thus obtaining high quality die-cast pieces.
CORROSION AND WEARING IN USE

We can consider the productive start of a not thermal shot sleeve for die-cast. We can suppose that its starting temperature is the ambient one, while the one of the metal to be injected is about 700°C. At the first contact between the metal and the shot sleeve, the inner surface of the latter (material fall area) will be violently heated, immediately reaching a temperature of ca. 400°C. This phenomenon known as thermal shock creates in steel very strong compression tensions on the surface and of traction in below layers [4]. This is caused by previous possible pre-existent tensions, such as the ones coming from mechanical machining, phenomenon existing in new shot sleeves.

The strong tensions coming from the thermal wave are emitted when the steel yield stress is overcome generating plastic small deformations in the stressed areas [4]. After the injection, the surface temperature of the material fall area will tend to decrease reaching approximately 350°C and then will increase again to 400°C in the next cycle [5]. The shot sleeve surface will be subject to an alternation of heating and cooling processes according to the productive cycle phase. The alternation of each compression and traction tensions will generate prematurely cracks due to thermal fatigue (web cracks) (Fig. 17), or in the case of violent thermal shocks to passing cracks (Fig. 18). The cracks due to thermal fatigue propagate in depth orthogonally to the interested area, making some deviations when they meet the grains edges [4].

These deviations, above all the sudden ones, cause their widening. The cracks phenomena are exalted by the corrosive action of aluminum alloys.

As a matter of fact, aluminium and other alloying elements present in the alloy, such as Si, tend to make with the shot sleeve’s steel intermetallic compounds such as Al₁₂Fe₃Si₂, Al₅FeSi, Al₄FeSi₂, α-AlFeSi, etc. [4].

The combined action of the phenomenon of thermal fatigue and corrosion determine a fast degradation of the shot sleeve definitely compromising its functionality, as clearly stated in the following photos:
THERMOREGULATED SHOT SLEEVE, PRODUCT AND PRODUCTIVE PROCESS

The shot sleeve has been used for a casting of 21 kg. The casting has been produced with a horizontal cold room press of 2,000 tons, using EN AC-46000 alloy.

Hereunder you can find the operative parameters of main interest:
- weight of injected alloy [kg]: 21;
- temperature of injected alloy [°C]: 700±10°C;
- stay time of the alloy in the shot sleeve [s]: 8;
- cycle time [s]: 150.

**USE MODALITY**

We applied the following operative precautions:

- first start-up with new shot sleeve: gradual pre-heating with ramps
- next start-ups during productive cycle: pre-heating at steady temperature
- productive cycle: keeping of steady temperature of shot sleeve.

**HEATING EQUIPMENT AND MEASUREMENT DEVICES**

Heating and keeping of temperature has been reached through an oiled temperature control unit with a heating power of 18 kW and a highest reachable temperature of 250°C.

Temperatures have been measured using a infrared thermometer with laser laying and/or with a contact electronic thermometer with thermocouple of K type.

**FIRST START-UP WITH NEW SHOT SLEEVE: GRADUAL PRE-HEATING WITH RAMPS**

We made a gradual pre-heating with more ramps. The run of calculated and measured temperatures is reported in Fig. 20. The reported temperatures have always been measured in the same point within the shot sleeve and exactly in the metal fall area. The initial temperature of the shot sleeve was of 20°C. The achievement and keeping of pre-heating temperatures have been reached increasing of 20% the corresponding oil’s temperature of the temperature control unit.

- First heating ramp: achievement of temperature of 50°C with an increase of 4°C/ min and keeping for two hours. The surveyed increase was of 1°C/min.
Second heating ramp: achievement of 100°C with a temperature increase of 7°C/min and keeping for two hours. The surveyed increase was of 1.6°C/min.

Third heating ramp: achievement of 150°C with a temperature increase of 7°C/min and keeping for two hours. The surveyed increase was of 1.3°C/min.

Fourth heating ramp: achievement of 200°C with a temperature increase of 7°C/min and keeping for twelve hours. The surveyed increase was of 1.3°C/min.

The difference between the theoretical and the surveyed temperatures is caused by thermal dispersions. In Fig. 21 is reported the thermal profile of shot sleeve surveyed before the start-up. The measured values state a homogeneous distribution of temperature all over the shot sleeve’s surface.

**Figure 20.** Pre-heating temperature trend.  
**Figure 21.** Thermal profile at the end of pre-heating.
EXERCISE PHASE

After having completed the fourth heating ramp production has been started.

After the first five injections, oil’s temperature has been reduced up to 180°C. This value has been used as exercise temperature for production cycles. The thermal profile reached during the exercise phase is reported in Fig. 22 where it is also compared with the thermal profile of an integral shot sleeve without thermoregulation [5].

From the comparison between the two thermal profiles it is noticed not only a more regular distribution of temperatures in thermoregulated shot sleeve but also the presence of temperatures relatively lower. The theoretical bending of the two shot sleeves is shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Theoretical bending calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the shot sleeve exposed section: 640 mm</td>
</tr>
<tr>
<td>Window length: 100 mm</td>
</tr>
<tr>
<td>Average temperature in low part: 272.5°C</td>
</tr>
<tr>
<td>Average temperature in high part: 223.5°C</td>
</tr>
<tr>
<td>Expansion in the shot sleeve lower section: 640 · 272.5 · 0.000011 = 1.94 mm</td>
</tr>
<tr>
<td>Expansion in the shot sleeve upper section: 540 · 223.5 · 0.000011 = 1.32 mm</td>
</tr>
<tr>
<td>Difference between the lower and the upper section: 1.94 − 1.32 = 0.62 mm</td>
</tr>
</tbody>
</table>

Figure 22. Thermal profile of the thermoregulated and no thermoregulated shot sleeves.
FOLLOWING START-UPS: PRE-HEATING AND EXERCISE TEMPERATURES

The reported temperatures have been referred to diathermic oil of temperature control unit.

- Start-up after productive stop in the week-end: pre-heating for 10 h at 210°C; after having made the first five injections, setting of temperature at 180°C.
- Start-up after stops longer than 1h: immediate pre-heating at 210°C; after the start-up (about five injections) setting of temperature at 180°C.

ACHIEVED RESULTS

During all the period of shot sleeve use it has been checked constantly the integrity of the surfaces in order to find possible wear signs. The first wear signs have appeared around the 9500 injections with the presence of a light pitting phenomena in the material fall area, as documented in Fig. 23. The presence of cracks due to thermal fatigue has been noticed after 21000 injections, whose evolution, as well as pitting phenomena, was gradual. This shot sleeve came out of commission after 77530 injections not to wear phenomenon degeneracy, but due to a passing crack caused by a sharp edge of the collar. The evolution of wear phenomena is documented in Fig. 23.

We made a microstructure analysis of a sample taken in the material fall area (Fig. 24). We have shown the presence of martensite with drawn bainite, some globular carbides and a no homogeneous austenitic grain. The nitried zone had a thickness of 0.4 mm, and there was some cracks; magnetite layer was not found.

The wear phenomena due to erosion appeared in the shot sleeves without thermoregulation just after 1500 injections. This phenomena after having been started increased very quickly so that the shot sleeve could not be used after 5000 injections.

CONCLUSIONS

The use of thermoregulated shot sleeve has allowed to:

- drastically reduce the costs due to frequent use of shot sleeves,
- improve the casting quality,
reduce the costs due to frequent wear of injection plungers,

made an interesting study and a standardization about the integral thermoregulated big shot sleeve.
REFERENCES


[14] ROBBINS, SINGH "Bigger casting, Bigger problem" Die casting technology for the new century NADCA publication.