

## Properties of Diecasting Alloys and a Comparison of Hot and Cold Chamber Processes for Magnesium Die Casting

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Worldwide consumption of zinc (Zn), aluminium (Al) and magnesium (Mg) alloys have increased in the last several years. Overall, 70 % of aluminium and magnesium light metal castings are used in the automotive industry.

Aluminium (Al) is approximately 50 % heavier than Magnesium (Mg) and Zinc (Zn) is approximately four times heavier than Mg (Table 1). However, certain applications with special mechanical properties are preferred in the automotive industry.

Material	Unit	Zinc	Aluminium	Magnesium
Production process		hot chamber	cold chamber	hot chamber
Density		6.7	2.8	1.8
Specific heat	J/g °C	0.42	0.96	
Coefficient of linear thermal expansion	°C	$2.7 \times 10^{-5}$	$2.3 \times 10^{-5}$	$2.7 \times 10^{-5}$
Heat conductivity	W/mK	109	100	71
Conductivity	% IACS	26	30	10
Tensile strength	N/mm <sup>2</sup> (R <sub>m</sub> )	320	260	220-248
0.2 % Yield strength	N/mm <sup>2</sup> (R <sub>e</sub> )	220	110	160
E-module	N/mm <sup>2</sup>	85000	71000	44000
Elongation	%	8	2	3
Impact strength	J	58	3	3
Hardness	HB	85	85	60

Table 1 - Physical and mechanical properties of the most common diecasting alloys Zn, Al, Mg at a glance



Figure 1 - Casting „Belt-taut“ (Zinc) (source: Foehl, Germany)

Components like this belt-taut (Fig. 1) are made of zinc because of appropriate mechanical requirement.

For that, the correct knowledge of process and the correct equipment is necessary, i.e. machine, spraying unit and die technology.

The really light die casting alloys are, however, aluminium and magnesium.

Whereas aluminium is mainly used in the automotive industry, magnesium is in the growth phase in the automotive segment, where the constant enhancement concerning corrosion protection in the mechanical rework is helpful.

Also, the awareness that solid magnesium is less suspect to fire than originally thought, contributes to magnesium's growth.



Figure 2 – Supporting Frame with wall thickness up to 0.6mm (project Foehl, Germany)

The disadvantage of the specific weight due to the good casting ability should be met with adapted wall thickness. Figure 2 shows that wall thicknesses of up to 0.6 mm can be cast in secure production in the zinc die casting on hot chamber machines.

Although the volumes and quantities come from the automotive sector, die castings can be found everywhere, where very complex geometry is demanded. These can be manufactured on modern die casting cells with high dimensional accuracy, whereby the

quality and economy can be increased by automation of the process.

Figures 3-5 show a little from the spectrum of the high pressure die casting.



Figure 3 - Belt roll (Zinc) (source: Foehl, Germany)



Figure 4 - Mobile phone (Mg)



Figure 5 - Zylinder crank housing (Al) (source: Honsel, Germany)

These figures prove the reasons for design and manufacturing as casting. Some items include:

- Complex part designs can be cast.
- Weight reduction through adequate shape and materials is possible.
- High dimensional accuracy can be reached.
- Shape part rigidity is given.
- Temperature resistance of the material.
- Good mechanical properties.
- Good EMI shielding effect of a casted housing.
- Noise and vibration damping properties of the metals.
- High-quality coating of castings is possible.
- Castings can be recycled completely.

The flow characteristics of magnesium are better than those of the nonferrous metals aluminium and zinc.

This flash-free, net shape component used in an electronic device (Figure 6) is ready-to-use with no extra handling or post-processing costs. Magnesium provides low cost, high performance electronic components requiring light-weight, EMI shielding and close tolerances.



Figure 6 – Electronic Device (Mg), Fishercast, CANADA

## General Comparison - Magnesium Die Casting Process:

### Hot Chamber vs. Cold Chamber

The largest hot chamber die casting machine is the DAM 800 with a locking force of 9300 kN and a theoretical shot weight of 6.5 kg (actual 5.0 kg). The size of the gooseneck of the hot chamber machine is the limiting factor for hot chamber die casting machines. The following survey shows, that for Mg, the hot chamber process has many advantages. In the sizes up to 9,300 kN, the hot chamber process is preferred. Both the hot chamber and cold chamber processes complete one another through the machine size (Table 2).

FisherCast Global Corporation opted for the hot chamber die casting process because of the flash-free capabilities it provides. Magnesium components, which are die cast net shape with close tolerance, complex detail, offer a significant advantage to OEMs. The close-looped control system of the Frech equipment provides the ability to adjust parameters on-the-fly. Its pressure adjustment capabilities extend tool life and facilitate ease of operation. While they benefit from reduced weight, production costs are dramatically reduced as no secondary machining operations are required. FisherCast has over 60 years of experience in providing flash-free, net shape small zinc alloy die cast solutions. The company has transferred this expertise in hot chamber die casting to its magnesium casting operation.

A purpose-built magnesium facility was constructed primarily for safety reasons.

Comparing the hot and cold chamber process, there are differences in many fields of the process.

### Specific casting pressure

Because of the low heat content (with regard to Mg characteristics), magnesium solidifies extremely quickly. Especially with thin-wall castings, the filling time is very short. At the end of the filling process, the metal solidifies at the gating. In the cold chamber process, the intensifier often cannot feed any more material through the gating. For thin-wall parts, this is not necessary because no heat sinks will develop due to material accumulations (thick wall-thicknesses). Thin-wall parts are cast in the hot chamber method with an injection pressure of only 160 to 250 bar. This single-step process feeds the clean metal from the gooseneck through a heated nozzle directly into the die. The metal temperature is approximately 640 °C. The cold chamber process is a two-step process. By a separate dosing furnace, the magnesium is fed with a temperature of approximately 680 °C into a basically cold sleeve. The magnesium starts to solidify at the sleeve wall. Now, the piston injects this partly solidified metal with a specific casting pressure of 400 to 500 bars into the die. Because of this partially solidified material in the sleeve, it is necessary to work with a shorter filling time and therefore with a higher injection velocity.

### Machine Size

Because of the low specific injection pressure of 160 to 250 bar in the hot chamber process, a die casting machine with up to 50 % smaller locking force can be chosen.

		Hot Chamber	Cold Chamber
Locking force	[kN]	up to 10000	up to 40000
Casting capacity	[l/s]	up to 30	up to 200
Dry cycle injection velocities	[m/s]	up to 6	up to 11
Cycle times	[s]	from 10 up	from 30 up
Specific casting pressure	[bar]	160 - 250	400 - 1400

Table 2 – Hot Chamber vs. Cold Chamber

## Cycle Time

With the hot chamber method, dosing and injection take less time and smaller die casting machines can operate faster.

## Required Space

The hot chamber machine is smaller and the machine furnace is integrated in the machine base.

## Piston Velocity

As already shown, the cold chamber process works with higher piston velocities. The piston velocity is dependent on the plunger diameter, filling time and thus on the wall-thickness of the casting. In the hot chamber process, the maximum gating velocity of 130 m/s can be achieved at a maximum metal pressure of 250 bar. Cold chamber machines reach a maximum gating velocity of 250 m/s at a maximum metal pressure of 1400 bar. Recommended gating velocities are between 50 to 100 m/s. With cold chamber machines, there is a risk that the die caster works with gating velocities that are too high; thus, erosions will shorten the die life.

## Dosing

In the hot chamber process, the shot weight is constant. The cold chamber process has fluctuations due to the accuracy of the dosing furnace (approx. 3%).

## Air in Casting System

Due to the large diameter of the sleeve and an average filling level of 50 %, more air is forced into the die respectively into the casting with the cold chamber process.

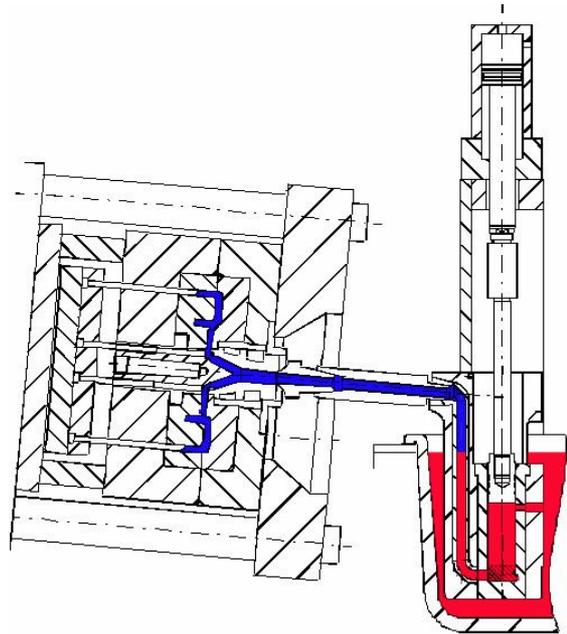


Figure 7 - Ventilation of die in hot chamber process

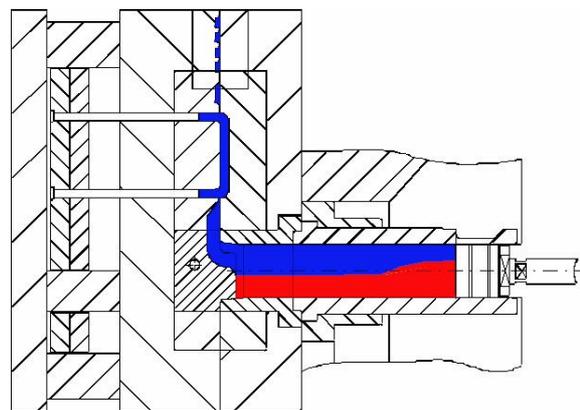


Figure 8 - Ventilation of die in cold chamber process

## Metal Bath Temperature in Furnace

With a melting temperature of more than 700 °C, the effect of the protective gas is reduced considerably. The oxidation (dross) is increased immensely.

Alloy	Hot Chamber [°C]	Cold Chamber [°C]
AZ91 HP	630	660
AM60 HP	640	670
AM50 HP	650	680
AM20 HP	not possible	680

Table 3 – Metal bath temperature in furnace

## Metal Temperature Variations

In the hot chamber process, there is a constant metal temperature from the metal bath to the nozzle. In the cold chamber process, the metal temperature varies in the dosing time and especially in the long sleeve.

## Clean Metal

In the cold chamber process, considerable oxidation develops in the sleeve. Furthermore, the piston of cold chamber machines must be lubricated. This leads to an increased absorption of hydrogen in the melt.

## Costs of Wear Parts

The gooseneck of a hot chamber machine is made of an expensive hot-working steel. After approximately 100,000 to 200,000 shots, the gooseneck must be dismantled and the sleeve hole needs reworking.

## Consumption Protective Gas

The cold chamber process operates with a higher metal temperature. Furthermore, during the dosing process, protective gas is deliberately given into the sleeve and therefore also into the atmosphere.

## Heated Cold Chamber Sleeve

To reduce fast solidification in the sleeve of cold chamber machines, the heating of the sleeve is recommended to cast thin-wall parts with large surfaces. Furthermore, there is less deformation of the sleeve due to smaller temperature differences.

## Oxide Formation

Due to the large metal surface in the sleeve of a cold chamber machine and the higher metal temperature, more oxides develop.

## Casting Parameters

The process parameters discussed in the single points are better in the hot chamber process than in the cold chamber process.

## Efficiency

To be able to compare both processes, the dosing furnace of cold chamber machines must also be included. The changing of wear parts, such as gooseneck, piston and piston rings of hot chamber machines, needs more time than changing the piston and the dosing pump at cold chamber machines.

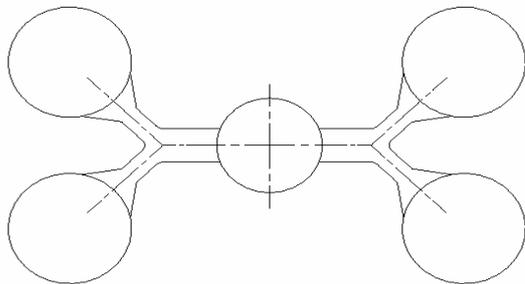
## Die Casting Die

### 1. Life of die

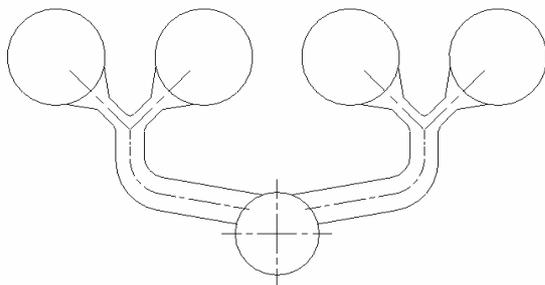
The beneficial casting parameters of the hot chamber process do not stress the die thermal and mechanically.

### 2. Central gating

A good quality of the castings is reached when the die can be filled from the inside to the outside. For specific parts with a larger hole, the hot chamber process allows to work with a central gating.



Figures 9 - Gating for the hot chamber process



Figures 9 - Gating for the cold chamber processes

### 3. Gate thickness

Due to the stronger solidification in the cold chamber process, a shorter filling time and therefore a larger gating thickness and gating area are required.

### 4. Die temperature

To achieve a shorter filling-time in cold chamber, the die temperature must be approximately 20 °C higher. The flow performance of the molten metal in the die improves.

### 5. Air Vents

The air volume is lower in the case of the hot chamber, in comparison to the cold chamber, because the sleeve is always filled up to 100%! The air volume is greater in the case of the cold chamber, as opposed to the hot chamber, because the filling chamber can only be filled up to a maximum of 2/3!

Air must escape or be compressed.

## Parts Properties

### 1. Minimum wall-thickness

As previously shown in the comparison, it is possible to cast thinner walls in the hot chamber process. Magnesium alloy properties and FisherCast's hot chamber magnesium die casting process allows casting of wall thickness to as little as 0.5 mm for short distances.

### 2. Strength and elongation

Higher strength and elongation values can be reached in the cold chamber process and with parts with a wall-thickness > 2 mm. The latest surveys show that the tensile strength and the elongation of thin-walled hot chamber castings increase considerably in comparison to the cold chamber process. These latest perceptions can be incorporated in the design of thin-wall magnesium castings. This means that the wall-thickness on components can be reduced with the hot chamber method.

If a higher elongation is needed for thick-wall castings, an increase of approximately 20 % is possible by using vacuum with the die.

### 3. Gas porosity

Because of the large sleeve, there is considerably more air in the casting system of the cold chamber.

### 4. Shrinkage holes

Shrinkage occurs on parts with large wall-thickness or with material accumulations at thin walls to thick walls.

Gating should be designed so that material accumulation is close to the runner system.

This will allow longer intensification and more material can be fed to compensate for the shrinkage porosity.

### 5. Hardness of surface

The surface hardness at parts with equal wall-thickness depends on the speed of cooling. A lower die temperature results in a higher hardness of the surface. This, on the other hand, can negatively influence the filling process. Therefore temperature control of the die is very important for the surface hardness.

### 6. Clean surface

In the cold chamber process, the melt is in contact with the atmosphere and is filled into the sleeve, which is coated with lubricant. Remnants of oxides and lubricant pollute the surface of the casting to some extent.

### 7. Tolerances of holes

The higher injection pressures of the cold chamber process during the cavity fill and the intensification of 400 to 1400 bars cause an elastic deformation of the inserts and the die frame (deflection) proportional to the pressure and, thus, a deformation of cores.

### 8. Magnesium alloy

The casting unit of the hot chamber machine (gooseneck, piston and piston rings) is located in the metal bath. Despite the special hot working steel, the metal bath temperature is the limit for the hot chamber process. Temperatures greater than 650°C cause more leakages between piston rings and sleeve.

The injection pressure does not build up sufficiently, and the life of the wear parts is reduced considerably.

All Mg. die casting alloys can be cast on cold chamber machines, however with respect to above mentioned reasons in hot chamber process AZ91 and AM 60 are the preferred alloys.

## CONCLUSION

The presented results and empirical values show that it is better to cast thin-wall parts (< 1,2 mm) on hot chamber machines.

This is more economical and the castings have a better quality. If distinct mechanical properties are requested for thick-wall parts or a casting quality with fewer porosity is demanded, it is better to cast such parts on a cold chamber machine. The comparison of the hot and cold chamber process should help the die caster to choose the right process according to the requested casting properties.