

MATERIALS USED FOR THE CONSTRUCTION OF ALUMINUM HIGH PRESSURE DIECASTING MOLDS IN AUTOMOTIVE INDUSTRY.

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Abstract: Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into the wanted shape.

The die casting of the aluminum alloy, requires some very difficult conditions for mold to work in. Large and sudden temperature changes, tool temperature around 200C and the molten alloy 700C, all this factors in a repetitive form. In this context, mold life is limited by the critical thermal fatigue.

1. Introduction

The desire to improve the quality of molds to reduce production costs of cast parts brought the development of "premium quality steel". While the mold cost represents 10-20% of the total cost of the finished piece of aluminum the idea of paying for high quality steel which leads to increased die life is perfectly justified.

The most important factor that decides the mold life is the material of the active parts, treatments and injection process parameters. Cost of active parts material in a mold is between 5-15% and heat treatment between 5 -10%.

The figure below shows the "iceberg type costs" for a mold, showing the relationship between cost and total cost of mold steel.

To ensure a good quality steel, in the last 20 years developed a number of technical specifications for materials used in the making of the molds. Most of them contain information of material chemical composition, microstructure, grain size, hardness, chemical-physical and mechanical properties.

The highest level of qualification standard for steels and heat treatments applied is "Premium Quality Steel H13 Acceptance Criteria for Pressure Die Casting Dies # 207-2003" issued by the NADC (North American Die Casting Association

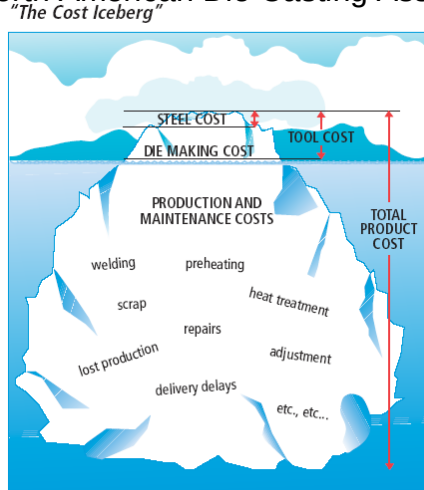


Figure 1.1 The cost Iceberg

2. Mold life limiting factors

2.1 The influence of the material used for the mold cavity's

The main factors that are limiting the life of the mold are: the condition of a high temperature of the mold steel and the need for high speed of the aluminum alloy in the attack. The reality is that the life of the molds is limited.

For the harsh conditions and parameters involved in the cycling process of die casting, thermal fatigue cause remains the main factor for the braking of the molds.

The two main causes of major breakdown of a casting mold are large thermal fatigue cracks and large cracks.

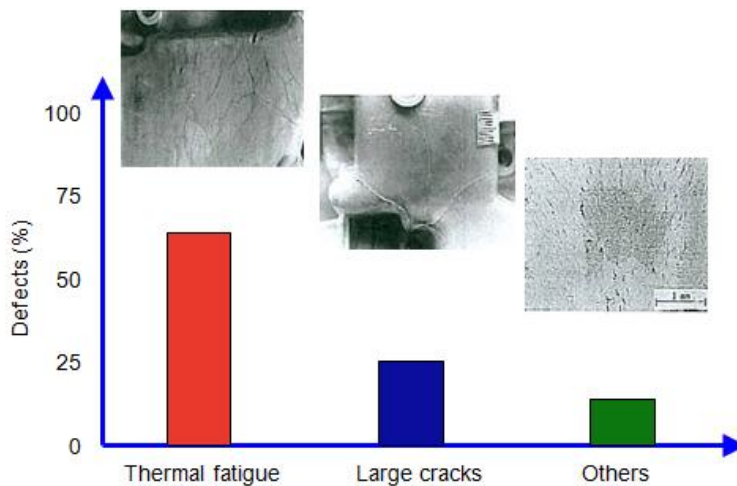


Figure 2.1 Mold defects [3]

Large cracks are caused by stress overload-induced in from different geometric shapes of the mold, or some improper heat treatment, while the initiation and propagation of thermal fatigue processes are depending on the complex processes that the mold is built.

Cycle sequencing

- 00 .- Beginning of mold filling
- 02 .- Maximum temperature
- 15 .- Solidification
- 23 .- End of solidification
- 30 .- Expulsion of the part
- 35 .- Extraction of the part
- 50 .- Top spray
- 55 .- Close machine

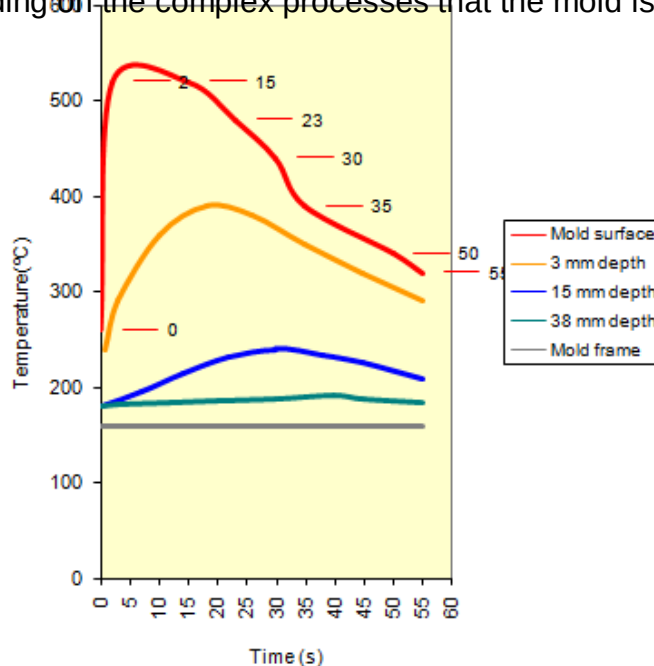


Figure 2.2 Mold temperatures in a casing cycle

Mold thermal fatigue arises from a number of cycles, to appear as late as possible is important to minimize temperature fluctuations using appropriate methods and systems for thermoregulation of the mold.

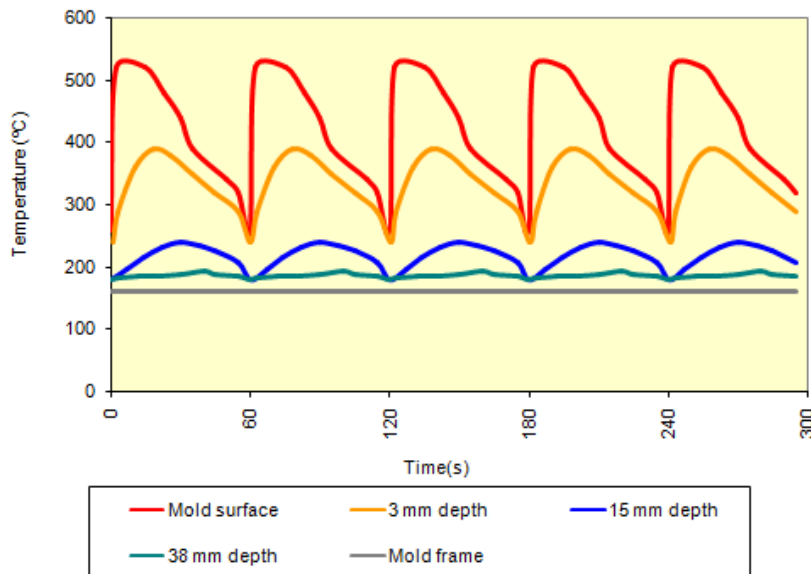


Figure 2.3 Temperature cycles in a mold

2.2- The influence of part geometry

The poor durability or premature aging of a mold, usually is caused in most cases by the complexity of the geometry of the part or by the great demand on quality requirements, sometimes even at the limit of the process of casting itself. When a certain area of the part has a primary requirement of quality and for this reason it will have predisposition to brake, mold design must use inserts within the cavity itself that can be used as spare parts.

The placement of small inserts in these areas can minimize the problem, but it has to be carefully with any burrs that can produce these fake joints.

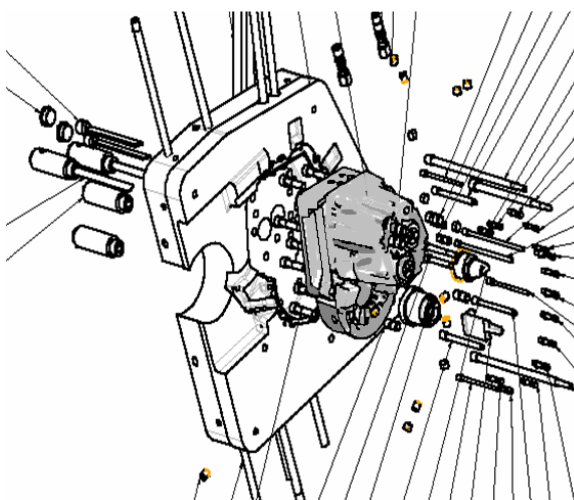


Figure 2.4 Using inserts in molds

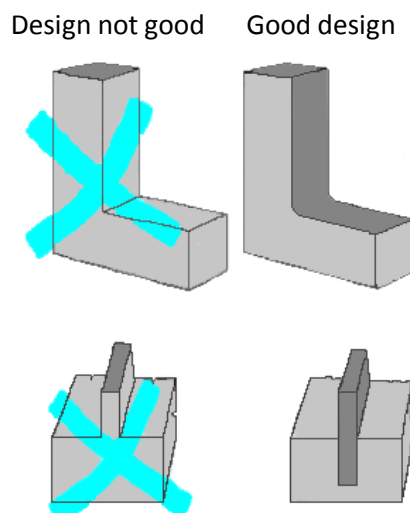


Figure 2.5 Geometry of the part [3]

To extend the life of the molds is necessary to:

Apply large radiuses, where possible, R 1.75 mm at least in all the edges, increases impact resistance.

Find a balance in the thickness of the part. The great thickness increases the thermal fatigue of steel, but allow for easier mold filling.

Use inserts and pins.

Use a large enough distance between the cooling and cavity surface.

Avoid sharp corners and notch effects.

2.3- The influence of mold making

In the process of making a mold must be taken into account also a minimum of details that contribute in improving the durability, such as:

- The direction of the fiber of the mold steel
- Heat treatments
- The use of EDM (electro erosion)
- Surface treatment
- Polish of the active parts

Having the direction of the steel fiber of the inserts or cavities in the same direction as the main filling flow, is good for the life of the mold.

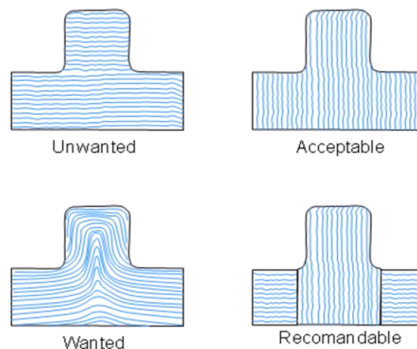


Figure 2.5 Orientation of the steel fiber [3]

During the EDM (electro erosion) occurs a new tempering of the surface layer of steel and the resulting weakness can lead to fatigue cracking and reduced mold life. For best results in the EDM of the cavity must be taken into account the following factors:

- Finishing operations with fine EDM, it means low-intensity, high frequency.
- Remove the surface layer affected, by polishing or grinding.

The cavities and all parts in contact with aluminum must be quenched and tempered to improve the mechanical properties of steels, and thus increasing mold life. Applying a surface treatment on a new mold, like oxidation with a specific product, is to coat the surface of the steel with thin protective layer, very tough and hard removable for an easier sliding of the mobile components of the mold.

The purpose of applying nitriding to mold inserts is to increase the hardness of the steel surface and improve wear properties.

Nitriding is a thermo-chemical treatment, since it changes the composition of the steel incorporating nitrogen in a heat treatment process.

The hard surface coating is the application of titanium nitride or titanium carbide. The high hardness and low friction provide a hardwearing surface, minimizing the risk of adhesion.

The most common methods of coating are:

- PVD (Physical Vapor Deposition), which is between 200 and 500 ° C

- Coating CVD (Chemical Vapor Deposition), which is performed about 1,000 °C

2.4- The influence of operating mode

Mold heating, aims to establish a thermal equilibrium of the mold by preheating. We can say without any doubt that much of the next behavior of the mold, and even the durability of the mold, will depend on the success of this operation. No one can begin to work with a cold mold, under these conditions would obviously produce big thermal shocks that will short the mold life.

2.5- The influence of process parameters

On the good design of the geometry of the part and on the mold design will depend the strength or capacity of the casting process and therefore the adjustment range of the parameters. The parameters with the biggest influence on the life of the mold are:

- Material temperature
- Mould lubrication
- Mold Temperature
- The filling speed and pressure

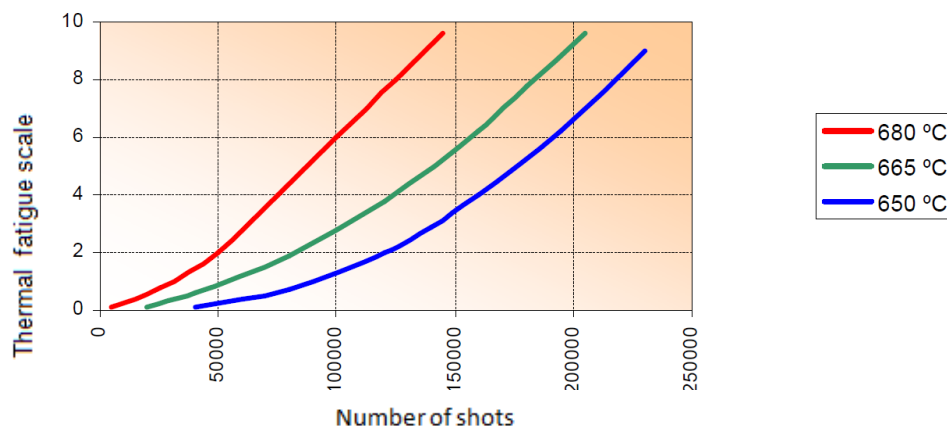


Figure 2.6 Temperature of the aluminum alloy influencing the life of the mold [3]

A mold temperature too low, not only affects the quality of the cast part, but affects the mold life.

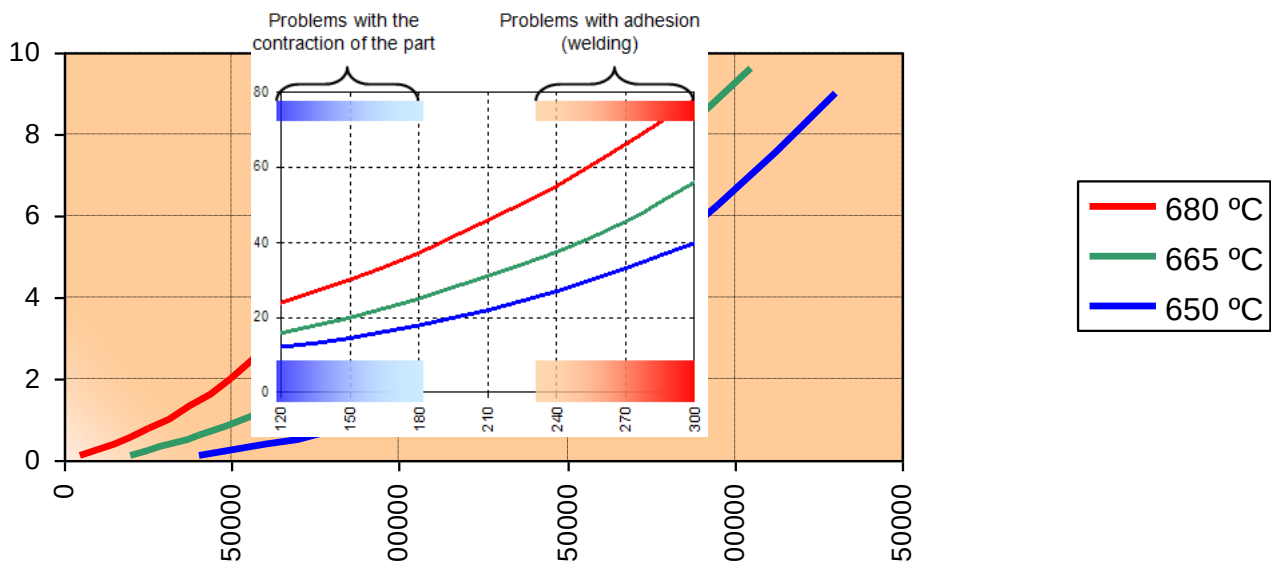


Figure 2.6 Interval of temperature for a mold to work proper [3]

Keys to improve the performance of the molds:

- Preheat the mold to minimize the thermal shock
- Minimize temperature fluctuations of the mold using proper thermoregulation
- Lubricate the surfaces of the cavity to reduce the contact of hot metal and to facilitate the separation of the parts.

3. Materials used in mold construction

The next table presents the different materials used in CIE Matricon for the construction of the elements of a mold (Figure 3.2).

ID.	Element	Material ISO 4957:1999	Commercial	Heat treatment	Surface treatment
1	<u>Die casting inserts</u> (fixed, movable and slides). Use in dies for medium and big sized parts	Nr.-1.2343 (X37CrMoV5-1)	I*.- Vidar Supreme	Tempered and letdown	Nitridation
			II*.- ADC3 III*.- Thyrotherm E38K V*.- Dominal USN o HP1	HB 401 / 429 (HRc 42 / 45)	Capa = 0,1 mm $\pm$ 0,02 HV 900
2	<u>Die casting inserts</u> (fixed and movable) Use in dies for medium sized and small parts	Nr.-1.2367 (X38CrMoV5-3)	I.- Dievar	Tempered and letdown	Nitridation
			IV*.- W403 VMR III.-Thyrotherm 2367 Supra	HB 415 / 444 (HRc 44 / 46)	Capa = 0,1 mm $\pm$ 0,02 HV 900
3	<u>Die casting inserts</u> (Fixed, movable and slides.) Use in dies for small parts	Nr.-1.2344 (X40CrMoV5-1)	IV.-W302 Isobloc	Tempered and letdown	Nitridation
			I.-Orvar Supreme III.-Thyrotherm 2344 Supra V*.-Dominal USD	HB 415 / 444 (HRc 44 / 46)	Capa = 0,1 mm $\pm$ 0,02 HV 900
4	<u>Slide carriers</u>	Nr.-1.2343 (X37CrMoV5-1) Laminated		Tempered and letdown	
				HB 388 / 415 (HRc 41 / 44)	

Figure 3.1 Table with materials used in mold construction [1]

ID.	Element	Material ISO 4957:1999	Commercial	Heat treatment	Surface treatment
5	<u>Slide guides and holding tool</u>	Nr.-1.2343 (X37CrMoV5-1) Laminated		Tempered and letdown	Nitridation
				HB 429 / 477 (HRc 45 / 49)	Capa = 0,2 mm $\pm$ 0,05 HV 950
6	<u>Slide wedges</u>	Nr.-1.2343 (X37CrMoV5-1) Laminated		Tempered and letdown	Nitridation
				HB 429 / 477 (HRc 45 / 49)	Capa = 0,2 mm $\pm$ 0,05 HV 950
7	<u>Movable cavity cores</u> Use in dies .- Steering houses	Nr.-1.2344 (X40CrMoV5-1)		Tempered and letdown	Nitridation
				HB 415 / 444 (HRc 45 / 47)	- Capa = 0,1 mm $\pm$ 0,02 HV 900 - PVD Balinit Futura
8	<u>Moveable cores</u> To use with sleeves.	Nr.-1.2344 (X40CrMoV5-1)		Tempered and letdown	Nitridation
				HV ₆₀ 390 / 450 Desliz. HV ₆₀ 390 / 450 Body HV ₆₀ 400 / 500 Cavity.	Capa = 0,1 mm $\pm$ 0,02 HV 900
9	<u>Fixed cores</u> (starting from normalized in commerce)	Nr.-1.2344 (X40CrMoV5-1)		Tempered and letdown	
				HV ₆₀ 390 / 450 Body HV ₆₀ 400 / 500 Cavity.	
10	<u>Fixed cores with coating</u> (starting from normalized in commerce)	Nr.-1.2344 (X40CrMoV5-1)		Tempered and letdown	PVD Balinit Futura
				HV ₆₀ 390 / 450 Body HV ₆₀ 400 / 500 cavity.	> 3000 HV

	<u>Cto. Prismatic guiding ejection</u>		<u>Tempered and letdown</u>	<u>Nitridation</u>
17	Use in big sized dies (Coupled to machines of >1000 Tn).	Nr.- 1.2738 (21MnCr5)	44 / 46 HRc	coat = 0,1 mm ±0,02 HV 900

Figure 3.1 Table with materials used in mold construction [1]

	<u>Cto. Cylindric guiding ejection (F y M)</u>		<u>Tempered and letdown</u>
18	Rest of dies	Nr.-1.7264 (20CrMo5)	62 / 64 HRc

(*):See table of manufacturers (attachment3).

Figure 3.1 Table with materials used in mold construction [1]

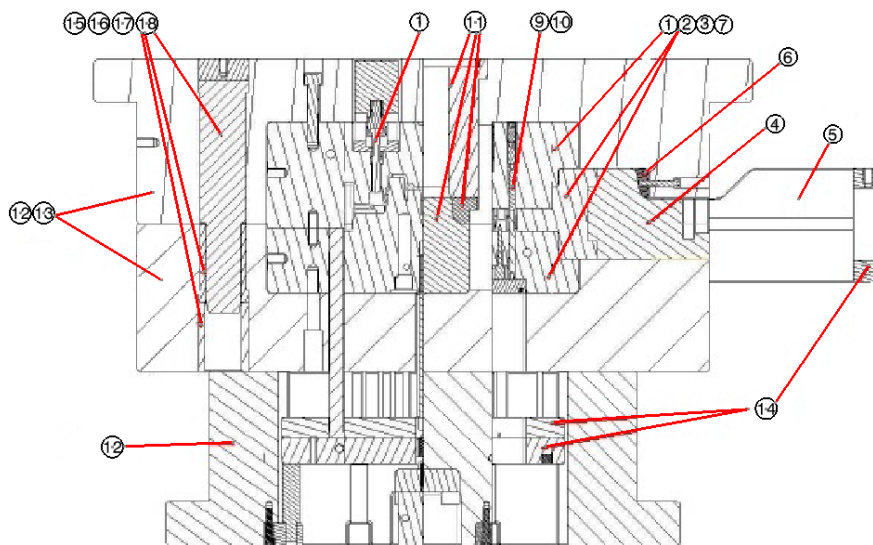


Figure 3.2 Mold assembly [1]

4. Conclusions

As in the first rows of the paper if the cost of a mold represents 10-20% of the total cost of the finished part the idea of paying for high quality steel which leads to increased die life is perfectly justified.

The final idea is to have a mold that runs for a bigger number of shots to produce more and more parts with one set of cavities, for this reason die makers must take the best decisions when are choosing the materials for the mold construction.

5. References

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