ALUMINIUM GDC TECH GREAT DIE CASTING

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Improved Melt Quality for High Integrity Aluminium Castings

Critical melt treatment practice and melt quality analysis for Aluminium foundries

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Introduction

Metal treatment is a critical part of the foundry process, which often has a significant impact on casting **[1]** quality **[2]**, reject rates and costs.

Existing practice often consists of hand fluxing or rotary degassing flux injection, but both have important restrictions or limitations.

Hand fluxing can be unreliable since it is operator dependant. Variations in addition rates, treatment times can cause major differences in efficiency and melt quality when cleaning, grain refining or doing sodium modification. This is especially true in High Pressure Die casting (HPDC) where the number of ladles or furnaces treated can exceed 100 per day.

Rotary degassing flux injection has resolved some of these issues by reducing the variability due to the human operator. It also has increased treatment consistency when performing a larger number of treatments per day. Unfortunately, the injection of flux through a rotating shaft requires a specially formulated and graded flux to prevent blockages. Fine particles smaller than 1 mm can become mushy during injection, whereas those larger than 2 mm can bridge inside the spinning shaft, which in both cases causes the treatment to breakdown. This blockage issue will limit the injection rate of the flux and hence can sometimes increase treatment time.

Furthermore, the application of rotary flux injection is often limited to cleaning fluxes as most other fluxes like sodium (Na) modifiers, Ti-B grain refiners or trace element removal fluxes are more difficult to inject and often lead to shaft blockage which is causing troubles for the users.

As a response to these issues above, Foseco developed the MTS 1500 [3], a robust blockagefree and reliable system to achieve multiple functions in a foundry like:

- Faster degassing using more efficient XSR / FDR rotor design
- Cheaper cleaning & drossing especially in high-pressure die-casting
- Constant and repeatable sodium modification
- Cost efficient Ti-B grain refinement in gravity and wheels
- Cost saving for drossing in Aluminium HPDC
- Oxide removal in Al HPDC, pistons, wheels and chip melting using VMET assessment.

MTS 1500 principles and technology

MTS 1500 (see Fig.1) is an automated Metal Treatment Station based on Foseco's proven FDU Rotary Degassing technology that was sold to more than 2000 units worldwide.

MTS 1500 [3] is an automated system that can perform most metal treatments.

It is a controlled and automatic addition of fluxes that (see Fig.2):

- Performs all metal treatment operations and requirements in a single process.
- Increases productivity & reduces costs
- Eliminates operator involvement
- Reduces risks and emissions
- Improves efficiency of the treatment
- Is blockage free unlike some rotary flux injectors
- can add all grades of fluxes

Fig.1

MTS 1500 allows for the successive or simultaneous addition of a range of newly and proprietary developed COVERAL MTS fluxes.
These granulated fluxes are typically ranging between 0 – 5mm in size.
But the equipment can be adapted to accommodate larger particles as well as metal treatment products other than fluxes.
Typical addition rates are 20g/s and as high as 1, 2 Kg /min.
Upon request the MTS 1500 can be customised to an addition rate of 40g/s which amounts to 2,4 Kg /min.

The MTS 1500 technology comprises 3 major components:

1. The Foundry Degassing Unit (FDU): see Fig.3
Our rotary degassing unit is the basis of the system as it provides a stable platform to which all other components can be attached. Any design of FDU unit can be used to build an MTS 1500.
The primary purpose of the degassing unit is to introduce a rotating shaft into the melt through which Nitrogen or Argon gas is injected.
This produces a fine dispersion of gas bubbles inside the melt, which removes hydrogen as well as oxides and makes for better castings without porosities and inclusions.
Furthermore, degassing is always a part of melt treatment and can eliminate excess moisture that fluxes might have introduced.
The MTS 1500 can have up to 2 hoppers to add 2 different fluxes.
Each hopper has a 20 Kg capacity. The hoppers are designed to protect fluxes from the environment and to prevent moisture pick-up.
The screw-dispensing unit is mounted at the hopper outlet and is capable of dispensing accurate and consistent amounts of flux (+/- 3%) into the vortex.
Adjusting the length of time the screw operates can control the required flux amount.
The end of the dispensing tube is positioned next to the spinning shaft and directly above the vortex to ensure that all the flux will be added to the metal.

2. The movable baffle: see Fig.4
The baffle plate can be moved up and down depending on the cycle phase.
The absence of the baffle helps create the vortex that is needed to efficiently mix the fluxes inside the melt.

Fig.2

Fig.3

Fig.4

The presence of the baffle in the melt eliminates the vortex and creates optimum conditions necessary for cleaning and degassing.
The baffle plate is made of INSURAL, an insulating material non-wetted by molten aluminium. It is durable and resistant to thermal shock.

3. The Foseco patented pumping XSR and FDR Rotors:
Foseco developed and patented the XSR (see Fig.5) and FDR rotors (see Fig.6) designed to efficiently mix the flux into the Aluminium melt while remove unwanted gas and inclusions.
They are highly efficient pumping rotors, which creates a strong mixing action in the melt.
Thanks to their pumping efficiency, it allows for good reaction between the fluxes and the entire aluminium melt.
Both **XSR & FDR** Rotors are a key component of the MTS 1500 system and enable:

- Superior degassing efficiency compared to standard designs
- Time savings during treatment and degassing cycles
- High performance at lower RPM, typically 350 – 450 RPM

Fig.5

Fig.6

MTS 1500 Degassing performance
Hydrogen gas porosity is one of the primary concerns of Aluminium foundries.
The MTS 1500 when used in conjunction with our patented **XSR / FDR** Rotors can efficiently remove gas from the melt.
Figure 7a and 7b show RPT (reduced pressure test) samples @ 80mb of Al-Si7Mg before and after 4 minutes of degassing with MTS 1500.
The measured density before MTS 1500 degassing is 2.34 g/cm3
The measure density after MTS 1500 degassing is 2.68 g/cm3
Average data shows that MTS 1500 is able to degas any foundry alloy within 2-8 minutes at temperatures between 680°C to 780°C.

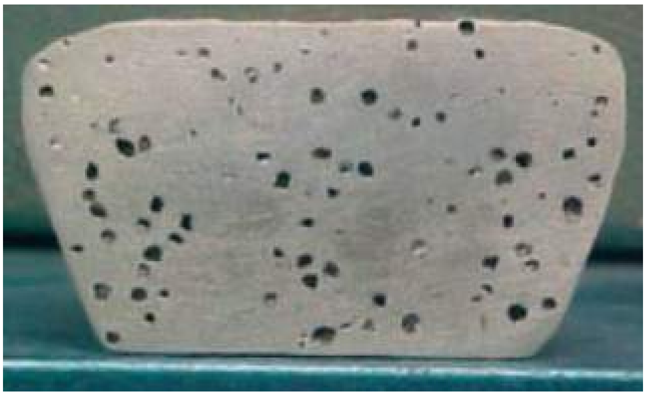


Fig.7a before MTS 1500 degassing

Fig.7b after MTS 1500 degassing

Laboratory scale degassing experiments:

Foseco undertook some comparative degassing measurements (see Fig.8) performed in a 500Kg crucible (BU 500) of AlSi7%Mg alloy using 18l/min of Nitrogen.

A hydrogen measurement device was used to continuously monitor the hydrogen content in the melt.

Within 3 minutes the **MTS 1500 + FDR rotor** system can reach 0.1 ml/100g of hydrogen thus outperforming standard rotors in this demanding application. This performance is especially valuable in un-heated ladle treatments where a shorter degassing time means less temperature loss and hence energy savings.

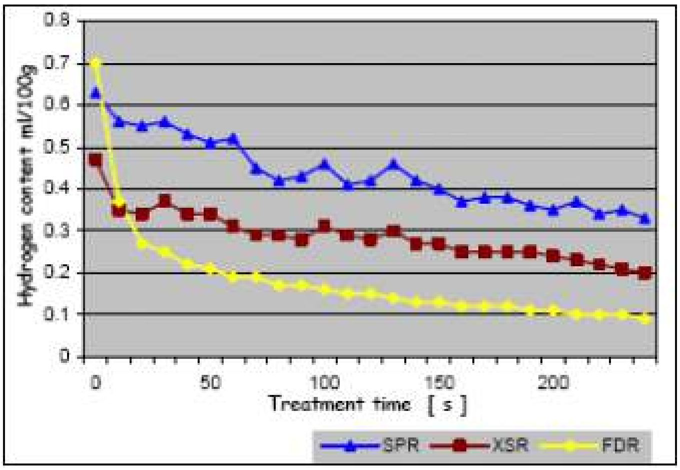


Fig.8

Reliable and consistent Sodium Modification

In the last 10 years, Strontium (Sr) modification has become the most popular modifying agent since it doesn't suffer from the fading issue linked to the use of sodium (Na).

Nonetheless, most people recognise that Sodium is a stronger modifier than Strontium in Aluminium-Silicon alloys. In sand and gravity castings, sodium modification is still used for thicker or difficult castings that are sensitive to shrinkage.

To address this issue, Foseco developed a range of powerful sodium modifiers with a low addition rate (0,1%) that is able to introduce 80 ppm –120 ppm of sodium into Aluminium-Silicon alloys.

Figure 9 presents the benefits of **Coveral MTS 1572** in a gravity die foundry making safety critical components for the automotive industry.

The Al-Si12%-Cu-Ni-Mg alloy is held between 740 – 760°C in a 300 Kg (BU 300) gas fired crucible furnace.

The former practice consisted of a manual-fluxing treatment followed by a 15-minute degassing cycle.

Unfortunately, this practice is not able to achieve consistent sodium levels after degassing, as there is a +12% variation in sodium content from one treatment to the next.

Using the MTS 1500, the foundry is now able to achieve consistent sodium levels, which result in better consistency of casting properties. Additionally, treatment times and flux addition rates were reduced significantly, which is making an impact on the overall treatment costs.

Gravity Foundry	Degaser + manual flux addition	Automated MTS 1500
Flux used	Proprietary flux	COVERAL MTS 1572
Amount of flux used	890 g ± 8%	270 g ± 3%
Flux Addition rate	**0.3 %**	**0.1 %**
Treatment time	15 minutes	9 minutes
Density achieved after degassing	2.68 g/cm3	2.69 g/cm3
Variation in sodium content	**+ 12.7%**	**+ 5%**
Sodium (Na) content before treatment	< 18 ppm	< 18 ppm
Average sodium (Na) content after treatment	**80 ppm**	**78 ppm**

Fig.9

In order to better understand the savings that MTS 1500 can generate in the case of sodium modification, we undertook some extensive lab testing designed to compare sodium uptake (yield) as a function of flux quantity used both in a manual addition and an MTS 1500.

Results in figure 10 shows that MTS 1500 is 2,5 times more efficient at releasing sodium than the Standard degassing units + manual flux addition.

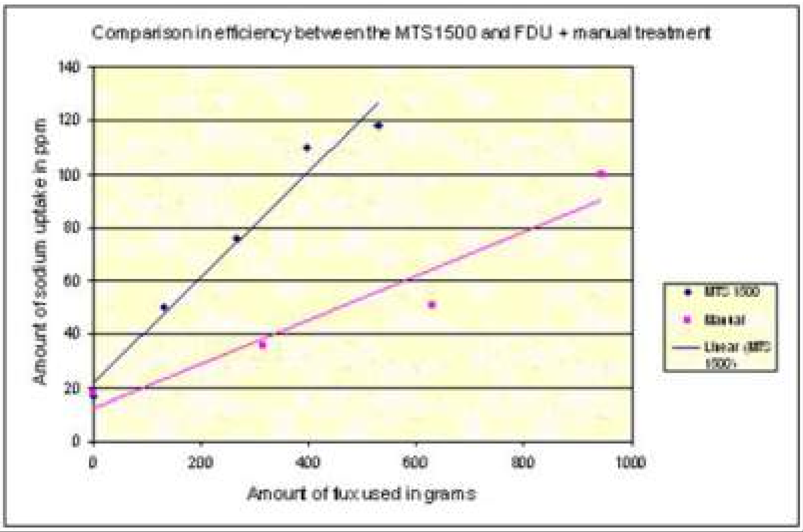
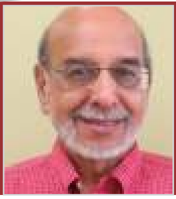


Fig.10

To be continued in next issue...



MANAGE YOUR TIME

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Time is money, but time cannot be retracted. A few simple guidelines may help you.
Remember deadlines, due dates, have a system for them

- **Every day**

Before you begin, organize your work

Decide:

1) What is pending from yesterday's work?
2) What is to be done today ?
   a) High priority
      Must be done 100 % - top priority = because of your commitment to somebody inside the company or outside
   b) Low priority
      May be done after work (a) is completed
3) To complete (a)) what you need ?
   Do not start unless you have all necessary data, documents, material etc

Before end of day

Keep the list ready for tomorrow.

- **Do this**

Any piece of paper

a) destroy it
b) send or give to someone who will work on it
   If it does not concern you do not hold it
c) keep in your folder for working
d) file it

Do not keep anything loose.

- **Solve one issue at one time**

Divide large work into small manageable pieces.
Avoid tension.
Think what can go wrong.
This will help you to plan in advance.

- **Write down everything in diary or notebook**

Never on a loose paper.

- **Follow agreed schedule**
- **Keep your table clean**

- **Use telephone and e mail to get correct information and fast**

Communicate clearly – when you talk or when you listen.
So the instruction need not be repeated.

- **See that meetings start and end on time without wasting time**

Do not avoid meeting
Talk about the issues only
Do not remain silent.
Meeting can waste everybody's time.

- **Keep your colleagues and the person whom you report informed**

With bad news and good news

- **Spend time like money**

- **Do most challenging work when you are freshest in the day**

You decide what is unpleasant, challenging and has to be done

- **Twice in day ask yourself = Am I using my time correctly?**

Change your work sequence if needed.

- **Doing the work again or more than one time wastes time and money**

Do it first time correctly.

- **Finally, Stop thinking what you have to do today**

Do it and enjoy peace !

ALUMINIUM FURNACES

ENERGY SYSTECH

Sklenar-type Melting Furnace

"Bulk Melting solutions"

Salient Features:

- Rugged construction with smooth & jerk-free tilting.
- Efficient combustion system.
- Easy charging of material into the furnace.
  Manual or Skip Hoist type.
- Easy dross cleaning.
- Long refractory life.
- Rapid & economical melting.
- Low melt loss.

Electrical Stationary Furnaces

Electrical Hydraulic Tilting Furnaces

Nitrogen Degassing Machine (auto)

Density Index Unit

Other Products for the Aluminium Industry

- Electrical Furnaces (Crucible)
- Fuel Fired Furnaces
- Electrical & Fuel Fired Tilting Furnaces
- Heat Treatment Furnaces
- Rotary Degassing Unit
- Density Index Unit

ENERGY SYSTECH

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GDCTECH Journal - Celebration of 51st Issue

A function was held to celebrate the publication of 51st Issue of GDCTECH Bi-monthly Journal, on 6th April 2022 at Arkey Hall.

Mr. Vivekananda Lokare, Managing Director, PYROTEK INDIA PVT. LTD., graced the Journal Release Function as the Chief Guest. He felicitated the authors who were present on the occasion. Mr. Anand Joshi was also presented citation, for his distinguished performance who worked as the Editor of the Journal from its inception. Mr. Anand Joshi expressed his gratitude to all the authors, advertisers and Arkey staff whose efforts have greatly contributed to successful and timely publication of the journal over last more than eight years.

Mr. R. T. Kulkarni presented a memento to the Chief Guest and thanked all for their presence.

Releasing Journal 51st issue

Facilitation of Author

Citation to Mr. Anand Joshi

Facilitation of Author

Audience

Coffee Talk

76th GDCTECH Coffee Talk
Systematic Thinking
on 6th April 2022

K. Muralidhar Bhat delivering speech

Facilitation of Speaker

77th GDCTECH Coffee Talk
Solar Energy
Harnessing Power of the Sun
Misconceptions about Solar Energy
Financial models of Solar system
Benefits...
on 4th May 2022

Kiran Bhagat delivering speech

Facilitation of Speaker

Die casting Product design guidelines

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Die casting Product design guidelines

Tool makers and die casters are forced to do re engineering of the part design for a friendly processing . They are forced to discuss and this enhances the time line to achieve the target for the product

Hence this thought of sharing the probable solution based guidelines is furnished in this article

Features and details that are required in a product for process friendliness

Material Selection	Shrinkage	Undercut
Draft	Boss	Slot & Groove design
Moving Die & Fixed Die	Ribs	Ejector design
Parting Line	Hole to Edge Space Design	Sharp Edge
Machining Allowance	Hole and Window	Pressure Tightness
Wall Thickness	Side Cores/Slides	Part Strength
Lightweight Design	Thread Forming	Tiny Features
Fillets & Radii	Insert	Die Casting Lettering

Design Requirement- Using Function

When designing an aluminium die-cast part, you must take into consideration its application, appearance, performance, precision, and most importantly the cost. First, you have to decide what you want to achieve in your parts and balance your requirements to comply with your budget. Here we have highlighted the major things you should be concerned with when designing a part.

When designing a product, you need to consider its possible application. Aluminum die-cast parts can serve both structural function and cosmetic functions. So, it has become a popular alternative to others.

As modern computers are far more powerful than before, the accuracy attainable by die casting has remarkably increased multifold. Along with their superior structural importance, die-cast parts also serves a very good cosmetic function.

You should clearly state the application of your parts to the die caster. He can help you choose the right material and decide proper tolerances for the design parameters based on your requirements. You should also consider properties such as corrosion resistance, strength-to-weight-ratio, conductivity, etc.

But the customers often end up paying for quality and strength that far exceeds their need. So, having a good idea of the using function of your parts will provide you better insight into the die casting process.

Assembly Method

The Assembly of aluminium die casting parts can be relatively simple or highly complicated depending on the complexity of the parts. Conventional die casting equipment had some limitations on what type of parts can be cast. So, casting parts with intricate details was difficult before.

But, complex parts can be divided into suitable segments and then joined together after casting by a suitable assembly method. Some of the common die casting assembly techniques include:

- Fastening
- Threading
- Welding
- Injected Metal Assembly
- Cored Holes, etc.

You must choose a specific assembly technique for your die cast parts before you start designing. Because the assembly method will heavily influence the design. Choose a suitable assembly option that meets your requirement.

Product Structure Design

Properly designing an aluminium die cast part comes with many challenges. Even the smallest features in a design can have a great impact on the casting operation. So, each of the details should be designed with proper care according to the recommended guidelines. We have focused on the major features present in aluminium die casting design. You will find recommended precision for many important features and learn about the design considerations you should be following during product design.

Material Selection

The product design can significantly vary depending upon your material choice. There will be certain limitations imposed for each type of alloy. Optimum integrity and strength of your aluminium die cast parts require careful design and execution.

Depending upon the composition of alloying elements used with aluminium, the properties such as weight, fluidity, strength, conductivity, melting point, etc. can vary. But not all of them are suitable as a die casting material.

Some of the popular aluminium alloys you can use for die casting include,

• A380
• A383 (ADC12)
• A413

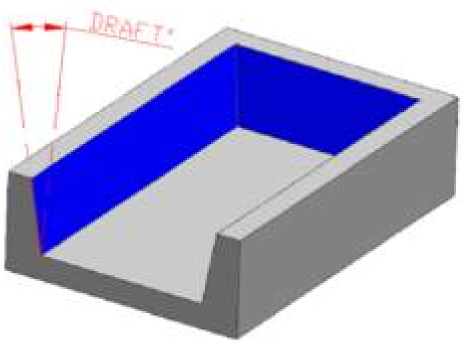
There are numerous other aluminium alloys available as well. You have to choose the right aluminium alloy based on your requirements and budget constraints.

	Aluminum Die Casting Alloys										
Commercial: ANSI/AA	360 360.0	A360 A360.0	380 380.0	A380 A380.0	383 383.0	384 384.0	390* B390.0	13 413.0	A13 A413.0	43 C443.0	218 518.0
Resistance to Hot Cracking A	1	1	2	2	1	2	4	1	1	3	5
Pressure Tightness	2	2	2	2	2	2	4	1	1	3	5
Die-Filling Capacity B	3	3	2	2	1	1	1	1	1	4	5
Anti-Soldering to the Die C	2	2	1	1	2	2	2	1	1	4	5
Corrosion Resistance D	2	2	4	4	3	5	3	2	2	2	1
Machining Ease & Quality E	3	3	3	3	2	3	5	4	4	5	3
Polishing Ease & Quality F	3	3	3	3	3	3	5	5	5	4	1
Electroplating Ease & Quality G	2	2	1	1	1	2	3	3	3	2	5
Anodizing (Appearance) H	3	3	3	3	3	4	5	5	5	2	1
Chemical Oxide Protective Coating I	3	3	4	4	4	5	5	3	3	2	1
Strength at Elevated Temp. J	1	1	3	3	2	2	3	3	3	5	4

Draft

The draft is one of the most important design parameters for aluminum die casting. It is the tapering or inclination provided to the cores and surfaces of a part that are perpendicular to the parting line of the die. We also call it a draft angle.

A designer must provide a sufficient draft wherever it's necessary. Because without an adequate draft, the casting will be hard to eject after solidifying and there remains a possibility to damage the part or even the die itself.



Design Considerations for Draft

Take the following considerations when calculating draft requirements for parts,

- Normally adopt a common draft angle for most of the geometric features.
- Some exception is applicable for internal walls and surfaces. The draft is normally doubled than the outer walls in this case.
- The draft requirement can vary depending on the alloy used for casting as well. You may have to calculate the draft according to your choice of aluminium alloy. The standard tolerances of the draft for an inside surface of an aluminium cast part at different depths show below as an example.

Depth	Draft Distance	Draft Angle
in. (mm)	in. (mm)	Degrees
0.1 (2.50)	0.010 (0.250)	6°
1.0 (25)	0.033 (0.840)	1.9°
5.0 (127)	0.075 (1.890)	0.85°

Aluminum Die Casting Alloys

Commercial: ANSI/AA	360 360.0	A360 A360.0	380 380.0	A380 (E)(F) A380.0	383 (E) 383.0	384 384.0	390* B390.0	13 413.0	A13 A413.0	43 C443.0	218 518.0
Mechanical Properties											
Ultimate Tensile Strength ksi	44	46	46	47	45	48	46	43	42	33	45
(MPa)	(303)	(317)	(317)	(324)	(310)	(330)	(317)	(300)	(290)	(228)	(310)
Yield Strength (A) ksi	25	24	23	23	22	24	36	21	19	14	28
(MPa)	(170)	(170)	(160)	(160)	(150)	(165)	(250)	(140)	(130)	(97)	(193)
Elongation % in 2in. (51mm)	2.5	3.5	3.5	3.5	3.5	2.5	<1	2.5	3.5	9.0	5.0
Hardness (B) BHN	75	75	80	80	75	85	120	80	80	65	80
Shear Strength ksi	28	26	28	27	–	29	–	25	25	19	29
(MPa)	(190)	(180)	(190)	(190)		(200)		(170)	(170)	(130)	(200)
Impact Strength ft-lb	–	–	3	–	3 (D)	–	–	–	–	–	7
(J)			(4)		(4)						(9)
Fatigue Strength (C) ksi	20	18	20	20	21	20	20	19	19	17	20
(MPa)	(140)	(120)	(140)	(140)	(145)	(140)	(140)	(130)	(130)	(120)	(140)
Young's Modulus psi x 10^6	10.3	10.3	10.3	10.3	10.3	–	11.8	10.3	–	10.3	–
(GPa)	(71)	(71)	(71)	(71)	(71)		(81.3)	(71)		(71)	
Physical Properties											
Density lb/in³	0.095	0.095	0.099	0.098	0.099	0.102	0.098	0.096	0.096	0.097	0.093
(g/cm³)	(2.63)	(2.63)	(2.74)	(2.71)	(2.74)	(2.82)	(2.71)	(2.66)	(2.66)	(2.69)	(2.57)
Melting Range °F	1035-1105	1035-1105	1000-1100	1000-1100	960-1080	960-1080	950-1200	1065-1080	1065-1080	1065-1170	995-1150
(°C)	(557-596)	(557-596)	(540-595)	(540-595)	(516-582)	(516-582)	(510-650)	(574-582)	(574-582)	(574-632)	(535-621)
Specific Heat BTU/lb °F	0.230	0.230	0.230	0.230	0.230	–	–	0.230	0.230	0.230	–
(J/kg °C)	(963)	(963)	(963)	(963)	(963)			(963)	(963)	(963)	
Coefficient of Thermal Expansion µ in/in°F	11.6	11.6	12.2	12.1	11.7	11.6	10.0	11.3	11.9	12.2	13.4
(µ m/m°K)	(21.0)	(21.0)	(22.0)	(21.8)	(21.1)	(21.0)	(18.0)	(20.4)	(21.6)	(22.0)	(24.1)
Thermal Conductivity BTU/ft hr°F	65.3	65.3	55.6	55.6	55.6	55.6	77.4	70.1	70.1	82.2	55.6
(W/m °K)	(113)	(113)	(96.2)	(96.2)	(96.2)	(96.2)	(134)	(121)	(121)	(142)	(96.2)
Electrical Conductivity % IACS	30	29	27	23	23	22	27	31	31	37	24
Poisson's Ratio	0.33	0.33	0.33	0.33	0.33	–	–	–	–	0.33	–

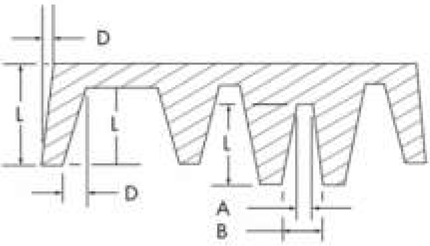
Calculation for Draft Distance

$$D = \frac{\sqrt{L}}{C}$$

Calculation for Draft Angle

$$A = \frac{\left(\frac{D}{L}\right)}{0.01746} \quad \text{or} \quad \frac{57.2738}{C\sqrt{L}}$$

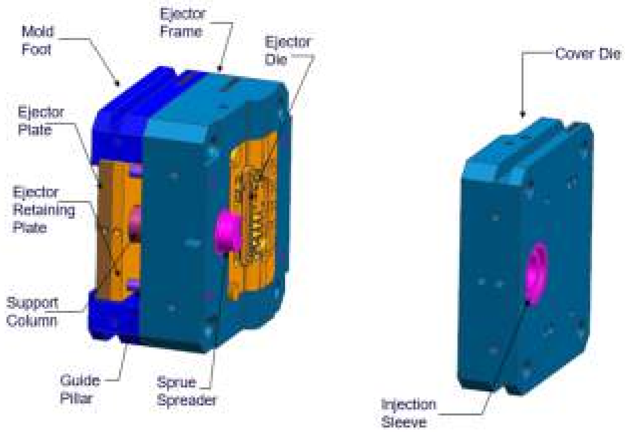
Where: D= Draft in inches
L= Depth or height of feature from the parting line
C= Constant, from table S-4A-7, is based on the type of feature and the die casting alloy
A= Draft angle in degrees Draft



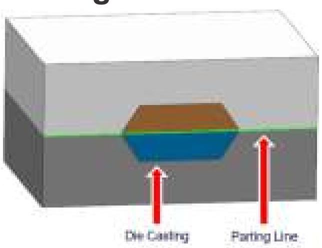
Values of Constant "C" by Features and Depth (Standard Tolerances)

Alloy	Inside Wall For Dim. in inches (mm)	Outside Wall For Dim. in inches (mm)	Hole, Total Draft for Dim. in inches (mm)
Zinc/ZA	**50** (9.90 mm)	**100** (19.80 mm)	**34** (6.75 mm)
Aluminum	**30** (6.00 mm)	**60** (12.00 mm)	**20** (4.68 mm)
Magnesium	**35** (7.00 mm)	**70** (14.00 mm)	**24** (4.76 mm)
Copper	**25** (4.90 mm)	**50** (9.90 mm)	**17** (3.33 mm)

Moving Die & Fixed Die



Parting Line



The parting line is a clear indication to distinguish between the moving half and fixed half of a die. The Parting Line Tolerance refers to the maximum amount of die separation allowed to ensure proper execution of the aluminium die casting process.

When the material pressure is trying to force the die halves apart, the material will flow out from separation created along the parting line. This is the flash defect of die casting. The cast parts require an additional trimming process to remove the flash, runner, gate, and overflow.

The parting line tolerance can vary depending on the alloy, size, and depth of the parts. The recommended standard and precision tolerance values for die casting parting lines show below.

Table S-4A-2 Parting Line Tolerances (Standard) – Added to Linear Tolerances

Projected Area of Die Casting inches^2 (cm^2)	Casting Alloys (Tolerances shown are "plus" values only)			
	Zinc	Aluminum	Magnesium	Copper
up to 10 in^2 (64.5 cm^2)	+0.0043 (+0.114 mm)	+0.0055 (+0.14 mm)	+0.0055 (+0.14 mm)	+0.008 (+0.20 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.005 (+0.13 mm)	+0.0065 (+0.165 mm)	+0.0065 (+0.165 mm)	+0.009 (+0.23 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.006 (+0.15 mm)	+0.0075 (+0.19 mm)	+0.0075 (+0.19 mm)	+0.010 (+0.25 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.009 (+0.23 mm)	+0.012 (+0.30 mm)	+0.012 (+0.30 mm)	—
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.012 (+0.30 mm)	+0.018 (+0.46 mm)	+0.018 (+0.46 mm)	—
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0.018 (+0.46 mm)	+0.024 (+0.61 mm)	+0.024 (+0.61 mm)	—

However, consult with your die caster if the projected area of die casting is over 300 in2 (1935.5 cm2).

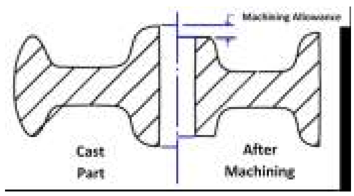
Table P-4A-2 Parting Line Tolerances (Precision) – Added to Linear Tolerances

Projected Area of Die Casting inches^2 (cm^2)	Die Casting Alloys (Tolerances shown are "plus" values only)			
	Zinc	Aluminum	Magnesium	Copper
up to 10 in^2 (64.5 cm^2)	+0.003 (A) (+0.076 mm)	+0.0035 (+0.089 mm)	+0.0035 (+0.089 mm)	+0.008 (+0.20 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.0035 (+0.089 mm)	+0.004 (+0.102 mm)	+0.004 (+0.102 mm)	+0.009 (+0.23 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.004 (+0.102 mm)	+0.005 (+0.153 mm)	+0.005 (+0.153 mm)	+0.010 (+0.25 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.006 (+0.153 mm)	+0.008 (+0.203 mm)	+0.008 (+0.203 mm)	—
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.008 (+0.203 mm)	+0.012 (+0.305 mm)	+0.012 (+0.305 mm)	—
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0.012 (+0.305 mm)	+0.016 (+0.406 mm)	+0.016 (+0.406 mm)	—

Machining Allowance

Machining Allowance is the extent of stock material that can be removed from a finished aluminium die cast part. A cast part may have surface roughness and geometric deviations from the actual design to some extent.

So, secondary machining is necessary after the die casting process to correct these errors.



Usually, make the minimum machining allowance as 0.010 in. (0.25 mm) to reduce tool wearing and minimize porosity in casting. The maximum allowance is the sum of this minimum and the casting deformation.

Here is a comparative example of the machining allowance for two different datum point locations.

Machining Stock Allowance Comparative Example: Precision Tolerances

	Example A Datum Points In Same Die Half	Example B Datum Points In Opposite Die Half
Minimum Machine Stock Allowance inches (mm)	0.010 (0.25 mm)	0.010 (0.25 mm)
Machining Allowances (± 0.001 in. or ± 0.026 mm)	0.002 (0.05 mm)	0.002 (0.05 mm)
Linear Casting Allowance on 5.000 in. (127 mm) Dimension Precision Tolerance A	0.012 (0.356 mm)	0.012 (0.356 mm)
Across Parting Line Precision Tolerances B	–	0.008 (0.020 mm)
Maximum Stock	0.026 (0.56 mm)	0.034 (0.86 mm)
Casting Dimension C	5.017 ± 0.006 (127.45 ± 0.18 mm)	5.026 +0.014/-0.006 (127.66 +0.38/-0.18 mm)

A ±0.007 (±0.18 mm) P-4A-1-03 Precision Tolerance
B ±0.008 (±0.20 mm) P-4A-2 Precision Tolerance
C Casting dimension would not be needed if drawing was a combined drawing, only finish dimension of 5.00 ± 0.001 in. (127 ± 0.025 mm) would be needed.

Wall Thickness

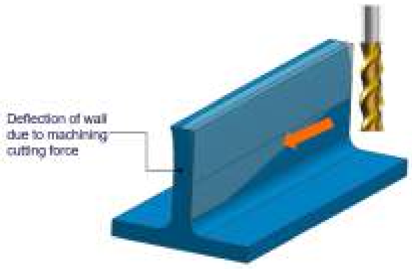
Always try to keep a uniform wall thickness throughout the part. Because uniform thickness allows better metal flow and solidification. So, casting quality and integrity are much better. However, if you must provide a variable wall thickness to your design, you should introduce a gradual transition in the form of a fillet/radii instead of abruptly changing the thickness. Otherwise, you will leave sharp edges in your design.

It is not desirable to have any sharp edges in product design. Because it will affect the metal flow and cause difficulty in ejection after casting. However, you can leave the edges as it is if the walls meet at the parting line.

Recommended Wall Thickness

While there are no absolute values for how thick or thin you should make the walls, it is wise to keep it within a limit. The typical wall thicknesses for aluminium die casting design can range from 0.787 in. (2.0mm) to 0.1737 in. (3.5mm). It also depends on the part's size and structure.

But this is subject to change depending on the alloy, part configuration, part size, and application of your die casting parts. For instance, if the part size is smaller then you can cast wall sections as thin as 0.020 in. (0.50 mm).

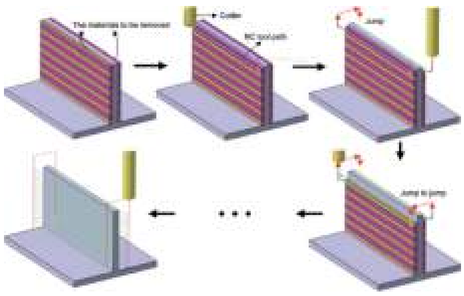


Avoid Too Thick and Thin Wall

Thicker walls will increase the stiffness of your parts. But making them too thick will delay the cooling thus hampering the solidification process. So, this can result in poor casting quality unless taking proper measures.

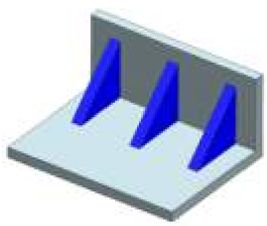
Thick walls also add extra weight to your product. So, product designers with a focus on making the parts lighter will prefer thin walls. But, if making the walls thinner beyond a certain limit, the stiffness will be too low and it will be prone to warping when subjected to further machining. The warping issue can be dealt with by machining step by step. But thin walls in a cast part lack stiffness and strength. Providing ribs will substantially improve the thin wall's stiffness and make it more stable.

However, modern die casting technologies are advanced enough to deal with most of the critical design parameters. But you should only consider them if it will ensure better performance or economy for your parts.



Design Recommendation for Metal Savers

- Avoid sharp edges along with the metal saver, use fillets/radii with a radius as large as possible. Consider a minimum radius of 0.06 inch (1.524mm)
- Keep a uniform wall thickness around the metal saver. Try to keep the thickness close to the typically recommended value.
- Provide a draft angle as larger as possible.



Pockets can Considerably Reduce the Weight

Pockets are another weight reduction technique. Thicker sections with holes can be replaced with thin-walled sections to reduce the amount of material needed for production. However, pockets can sometimes cause irregular shrinkage.

Tips to Reduce Shrinkage in Castings

The designer should abide by the following design considerations to reduce shrinkage in aluminium die cast parts.

- Avoid large/thick sections in your design. Redesign them with thinner sections and metal saving cores if possible.
- Add flat or vertical ribs to the walls can improve the feeding characteristics and reduce the tendency to shrink.
- Add squeeze pins can reduce the shrinkage porosity in the localized area.

Ribs

Ribs are incorporated in a design to increase the stiffness thus add strength to aluminum die casting.

So, ribs can assist in producing sound castings. They are mostly paired along with other weaker sections such as thin walls, to impart additional strength to them.

It can often provide more strength than a thicker solid section, as thicker sections tend to have more porosity in them which reduces their structural capacity. However, overusing ribs can cause stress concentration at the edge of the ribs.

Ribs are often designed with hollow sections known as metal savers. They are a method to reduce the material usage in ribs and reduce the weight of the part.

The recommended rib dimensions for some common scenarios show in the following diagrams along with some conditions where ribs should not be used.

Ideal Tolerances for Threads

Threads can be easily formed with aluminium die casting equipment.

Cast threads are usually limited to external threads where precision class fits are not required. If you must have a precision class fit for your parts, you can always consult with your die caster.

Secondary machining may be required for achieving better precision.

Also, the major diameter should be following the specified thread form definition as agreed upon by both parties.

The maximum and minimum tolerances for some ideal thread forming operation are shown in the next slide

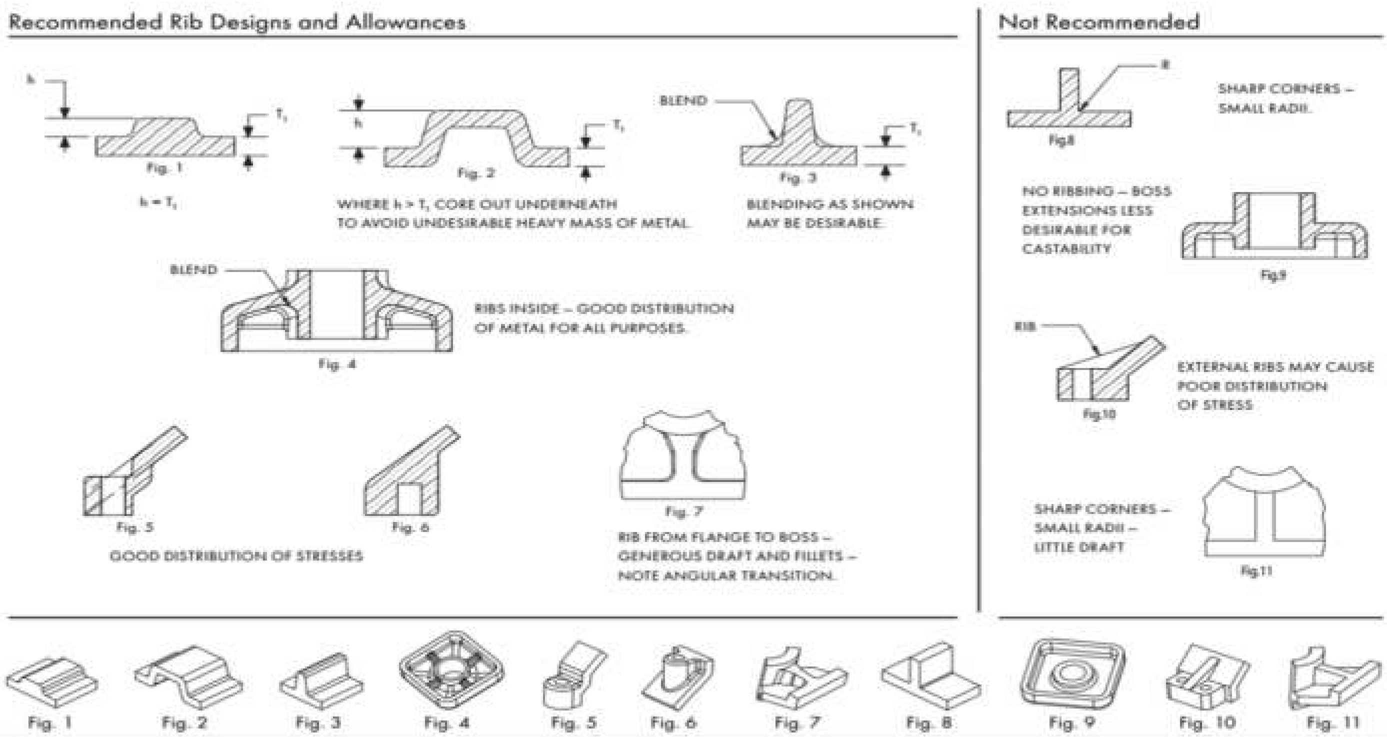
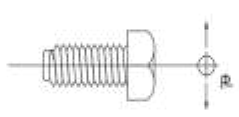
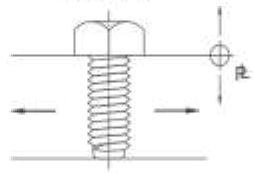
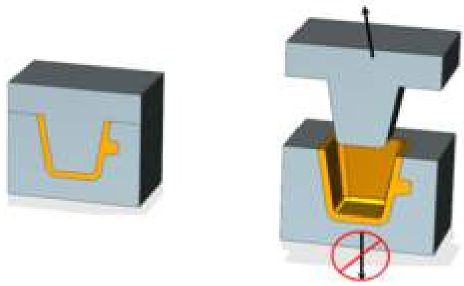


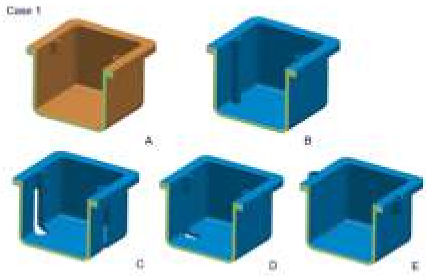
Table S-4A-12: Die Cast Threads Tolerances

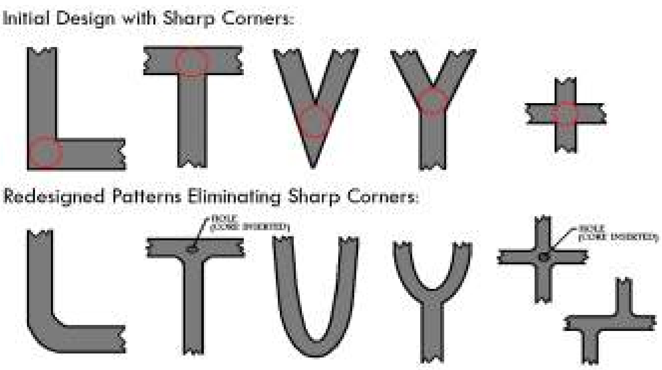
Method of Forming Threads	Figure 1 		Figure 2 	
Tolerances	Zinc	Aluminum/ Magnesium	Zinc	Aluminum/ Magnesium
Minimum pitch or maximum number of threads per inch	32	24	32	24
Minimum O.D.	0.187" (4.763 mm)	0.250" (6.350 mm)	0.187" (4.763 mm)	0.250" (6.350 mm)
Tolerance on thread lead per inch of length	±.005" (±.127 mm)	±.006" (±.152 mm)	±.005" (±.127 mm)	±.006" (±.152 mm)
Minimum Pitch Diameter Tolerance	±.004" (±.102 mm)	±.005" (±.127 mm)	±.005" (±.127 mm)	±.006" (±.152 mm)

Undercut

Undercut usually refers to a recessed geometric feature or surface of a part that is not accessible with a straight cutting tool. In the case of die casting, undercuts are features that restrict ejecting the casting with a single pull mechanism.







Additional guidelines

- The face (line thickness) of any letters or symbols should be at least 0.010 in. (0.254 mm) or greater.
- The height of cast lines or symbols should be equal or less than its line thickness.
- If any lettering or ornamentation includes complex details or fine serifs may not be clear when cast. So, try to simplify them if possible.
- The draft angle should not be less than 10°.

Following these guidelines should be helpful for most of the cases.

Company News

Lakshmi Venu has taken over as the Managing Director of Sundaram-Clayton, one of India's leading auto components manufacturers.

She managed the turnaround of Sundaram Clayton to make it a competitive foundry in the world, and has built deep customer relationships with Cummins, Hyundai, Volvo, Paccar and Daimler. Her decision to set up a foundry in the US three years ago in 2019 in Dorchester, South Carolina was almost prescient, as most US-based customers were looking for on-shore foundry units to reduce supply chain risks and curtail carbon footprint.

R Gopalan, Chairman, Sunaram-Clayton said, "She has successfully chartered a strategy to have a global footprint to build competitive advantage. "

Venu Srinivasan, Chairman Emeritus, Sundaram-Clayton said, "She has spearheaded the establishment of our US operations which has commenced activities recently. We are confident that under her leadership, Sundaram-Clayton will see its rise globally."

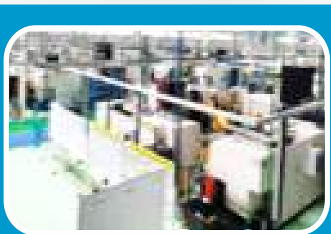
Source:- by Autocar Pro News Desk , 06 May 2022

MINDA INDUSTRIES LTD.

(Alloy Wheel 2W Division)

- FIFO at all stages of production cycle.
- Single piece flow
- Unidirectional flow
- Minimised Material Handling.
- Raw material to finished product in one shed
- Casting movements only through conveyers or AGVs.
- Flexible production set-up for variety of models
- Training room / DOJO room for operators Training
- Implementation of Industry 4.0

- Minda Industries Ltd has set up fully integrated manufacturing facility for Alloy wheel 2 wheeler.
- Facilities include state of art infrastructure for Foundry, Machining and Painting (Powder Coating & Liquid Painting) providing one stop solution
- Flexibility to manufacture a variety of sizes (range 10-19 Inches) & surface coats
- Location: Supa Industrial Area- 86 KM from Pune Airport
- Land: 20 acres
- Built-up: 24000 sq. mtr.
- Capacity: 4 Million Wheels p.a. , expandable up to 6 Mn


Robotic CNC Cells


Smart Conveyers


Auto Storage System


Product Portfolio


AGVs


CNC Robot


Pouring Robot

Comparison of Gravity, Low Pressure and High Pressure Die Casting Techniques for Aluminium Alloys

Madhav Athavale - Consultant, Email : athavalemadhav@gmail.com

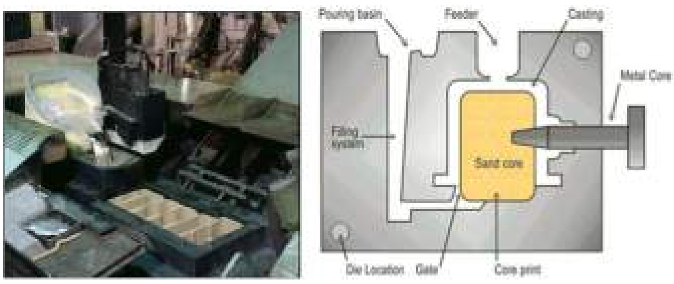
I Introduction

Aluminium and its alloys, as the materials of construction for engineering application, started in a big way during the period of 1940s and has grown rapidly thereafter. Aluminium has a unique combination of light weight and ability to form many alloys with different elements that offers a range of mechanical, thermal and electrical properties. It is amenable to shaping by techniques like casting, forging, rolling, extrusion, fabrication methods like welding & riveting and now additive manufacturing. It is used very extensively in wide variety of sectors such as automotive, public transportation, domestic appliances, aerospace, packaging, housing, construction, energy etc.

This paper focuses on, the comparison of, three widely used permanent mould casting processes namely Gravity Die Casting (GDC), Low Pressure Die Casting (LPDC) and High Pressure Die Casting (HPDC). It compares capabilities & limitations of these processes to meet the dimensions & mechanical property specifications and cost of a component.

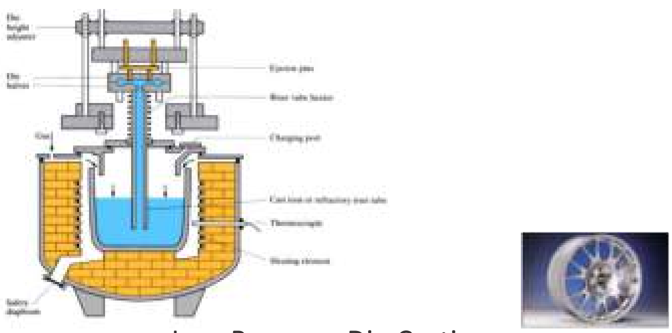
II Principles of GDC, LPDC & HPDC casting processes

Diagrams below show the schematics of the three processes.



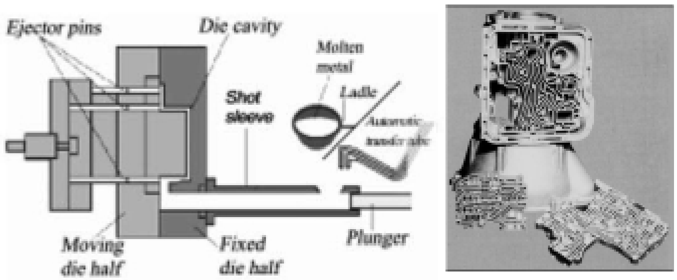
Gravity Die Casting

Metal fills & freezes in the die under gravity



Low Pressure Die Casting

Metal fills & Freezes in the die under counter pressure to gravity



High Pressure Die Casting

Metal injected at high velocity in the dies held together by locking force and freezes under high pressure

III Points of Comparison

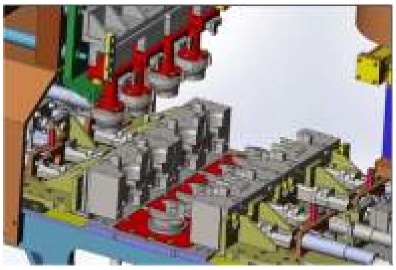
<u>1 Material of construction of dies</u>

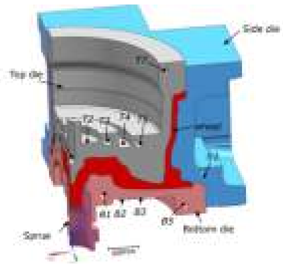
GDC & LPDC: Dies are mostly made of pearlitic grey cast iron or low alloy steel.

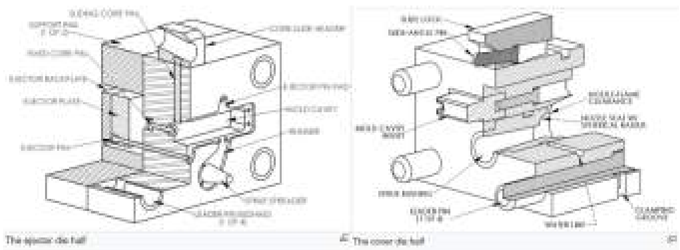
HPDC: Dies are made from hot die tool steel like H13.

<u>2 Typical Design Features of Dies for GDC, LPDC & HPDC</u>

Images below show GDC multi cavity tool for Piston (Top Left) LPDC wheel die section (Top Right) & Bottom - HPDC die schematic and a Die with casting. The level of automation increases for all the three processes as complexity and number of casting cavities per die and numbers required to be produced become higher.







GDC dies are relatively simple compared to LPDC which is more mechanised plus has cooling channels and HPDC dies are the most complex with cooling and heating channels and the process is inherently most mechanised

3 Types of cores

GDC and LPDC processes are more flexible since liquid metal enters cavity at low speeds under gravity or low counter pressure as compared to HPDC. Depending on the shape and size of casting metallic cores or sand cores bonded by binders (PU Cold Box, Hot Box, Shell etc.) and salt cores (in case of some pistons) are used in these processes giving them more flexibility in terms of complex shape of cavities.

Source: M. Röhrle, Mahle GmbH

HPDC process uses mostly metallic cores only as of now.

4 Types of Alloys Suitable for the Process

(I) For GDC and LPDC: They are versatile processes. All the Aluminium Casting Alloys can be cast using these techniques

(ii) For HPDC: Due to working principle of the process with high cooling rates, one needs to use alloys with low melting and casting temperatures as they will also have good fluidity at casting temperature. Metal chemistry close to Al Si eutectic composition is commonly used though with increasing equipment capabilities and development of new alloys hypoeutectic compositions with appropriate alloying elements as some hyper eutectic compositions are now regularly used.

(iii) Annexure I & II give tables of the casting alloy specifications and suitable casting method and end uses.

5 Metal Filling Time, Fill Pressure & Freezing Time:

(I) In GDC, metal fills the die and freezes in it under gravitational force. Filling time is few seconds. Elaborate running/gating system design is needed to ensure smooth, quiet filling of the die with minimum turbulence. Depending on the geometry, the freezing time will be in minutes. Die may or may not be water or air cooled. Typically cycle ~9 cycles/hr are done for cylinder head casting.

(ii) In LPDC metal is pressurised in a sealed holding furnace and rises slowly through a tube (1), against the gravity, and fills the die cavity (2,3). There is no elaborate gating system required. Filling time is few seconds. The casting freezes under the counter pressure (4) and freezing time depends on the casting geometry and can be in minutes (5). Typical pressure fill curve is shown below. Around ~ 9 cycles/hr are done. Die is water cooled.

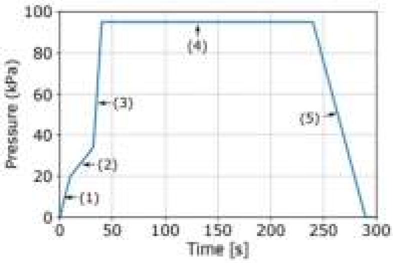


Figure 3. Pressure fill-curve.

(iii) In HPDC, the metal is poured in a shot sleeve and it is injected in the die cavity using a plunger at high velocity and high pressure is applied when metal is freezing in the die after injection. Filling time will be fraction of a second and freezing time will be in seconds but less than a minutes. Around ~ 40 cycles/hr are achieved. Typical shot cycle is shown below. Thermal management of the die temperature is done by combination of water and oil. Water is for cooling and oil is for heating. Die face coating, when water dilutable, will also help cool the die.

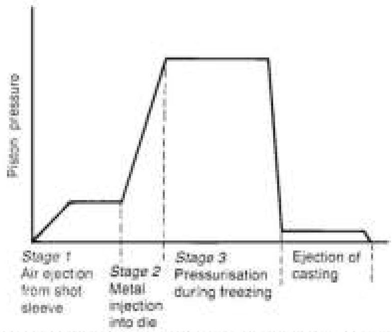
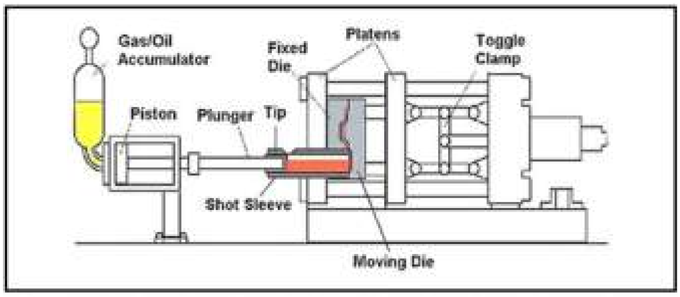


Figure 9.3 *Typical injection-control stages during pressure diecasting. (From Campbell, J. (1991) Castings. Butterworth-Heinemann, reproduced by permission of the publishers.)*



Schematic drawing of a typical cold-chamber diecasting machine

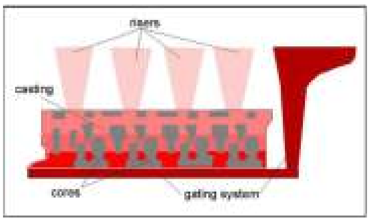
This is the only HPDC-type used with aluminium

Table 9.1 Guidance values for casting pressures (courtesy of Buhler Ltd)

	Casting pressure (bars)		
	Al and Mg	*Zn*	*Brass*
Standard parts	up to 400	100–200	300–400
Technical parts	400–600	200–300	400–500
Pressure-tight parts	800–1000	250–400	800–1000
Chromium plating parts		220–250	

6 Method for feeding of solidification shrinkage in hot spot areas

(I) In GDC, risers/feeders of the right size and geometry must be provided to feed the hot spot areas of the casting along with right coating practice for the given die.



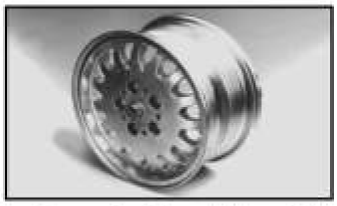
(ii) In LPDC, entire holder is connected to the casting till the solidification takes place. Separate risers/feeders are rarely needed.

(iii) In HPDC, design of the runner bar has to take in to account the feeding needs of the hot spots. In some case the squeeze pins are provided to physically force the liquid metal in isolated hot spot areas at the right time during the casting cycle.

7 Casting yield

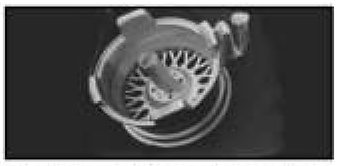
(I) GDC: This process has a yield of around 45-50% since there is lot of weight taken in running system and risers/feeder

(ii) LPDC: This process has a yield of 90 – 95 % and more since there is hardly any gating/running system as well as feeders.



LPDC wheel as cast, note small riser at hub center

Source: VAW



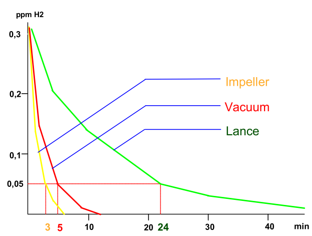
Gravity Die Cast wheel, note large risers at rim and center hub

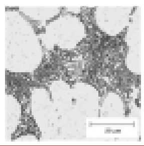
Source: VAW

(iii) HPDC: This process gives a yield of >50% since there are no risers required due to very quick solidification and runner design and squeezers help feeding

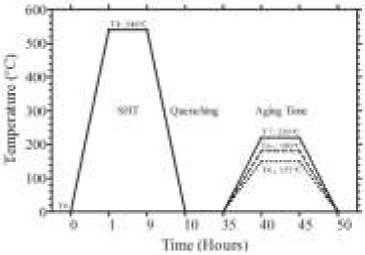
8 Melt Treatment and Heat treatment:

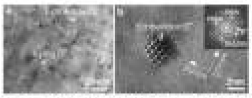
(I) Melt treatment such as degassing to control dissolved Hydrogen, grain refinement and modification for getting desired microstructure and fluxing for oxide removal are commonly used for GDC and LPDC components. Picture below shows a typical equipment where all the treatments are carried out at a single station.





(ii) Depending of casting specifications castings are heat treated to modify the as cast microstructure to further enhance the mechanical properties. Annexure IV gives Heat Treatment Types/Tempers. Typical T6 Heat treatment Cycles is shown below that results in precipitation hardening of the casting. (SHT stands for Solution Heat Treatment)

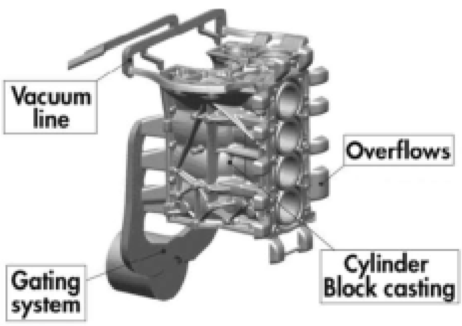




TEM images showing the precipitates in the α–Al matrix of the T6 heat-treated Al9Si0.5MgCu alloys

(iii) HPDC castings were not heat treated earlier. Most of HPDC applications are castings with low wall thickness 2mm to 6mm and metal freezes very quickly. Entrapped air and dissolved hydrogen remain in the matrix. If castings are subjected to heat treatment air and hydrogen cause blisters.

(iv) Now with use of "vacuum" during HPDC process and melt quality improvement by treatments like degassing, grain refinement and modification, thicker wall structural components that are heat treated are being regularly produced. Given below are examples of engine block and strut dome for suspension



Strut Dome Die casting430 x 330 x340 mm, weight: 4.4 kg

9 Types of Die Face Coatings used for the process

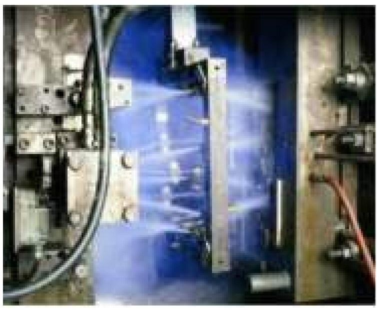
(i) GDC and LPDC:

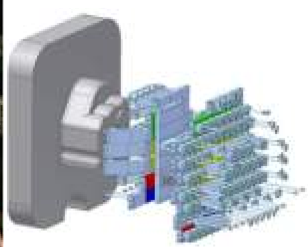
All the coatings provide protection to the die face from the attack of the molten aluminium. A range of water dilutable coatings is used, to give different levels of insulation (High, medium and low), in different areas of the die to ensure proper filling of the casting as wells proper feeding of the shrinkage prone hot spot areas. Sometimes a base layer of coating is topped with a working layer for meeting specific surface finish or thermal properties for the die face.

Annexure III gives a table of details for die coatings. With modern coatings, elaborate procedure for die surface preparation, application and curing of the coating are used.

This ensures long service life and consistent performance.

(ii) HPDC:

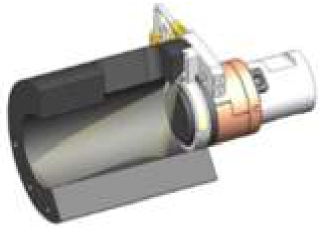




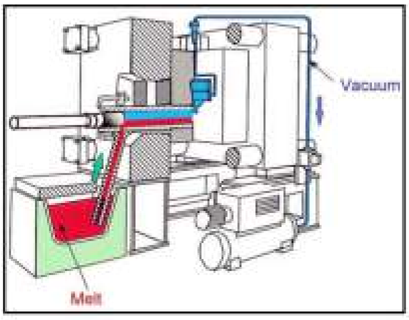
These coatings are also called as die face lubricants. Water based emulsion of formulations containing synthetic waxes, high temperature lubricants etc are sprayed on the surface of the hot die at the beginning of each production cycle as shown above.

Modern die casting cells also used programmable spray head and use of robots. It provides protection from attack of aluminium on the die as well as provides lubrication for easy release of the casting from the die. It also plays role in thermal management of die face temperature.

Shot sleeve where liquid metal is poured and plunger that is used for injecting the liquid metal in to die cavity also needs to be properly lubricated for smooth working of the HPDC machine. Heavy lubricating oils and wax granules are used as lubricants. Pictures below depict the application of plunger lubricants

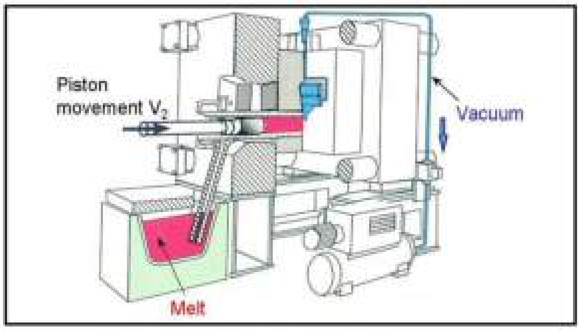


With emphasis on light weighting of the components there is continuous development in alloys as well processing techniques. HPDC with Vacuum application is regularly used for structural applications.



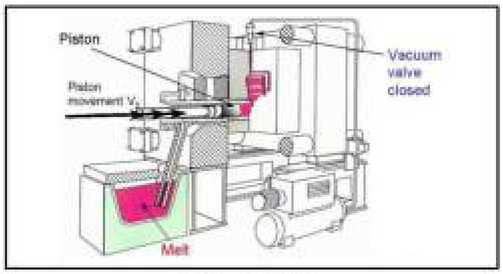
1. Step: Dosage, suction of metal into the feeding chamber

Source: Müller-Weingarten



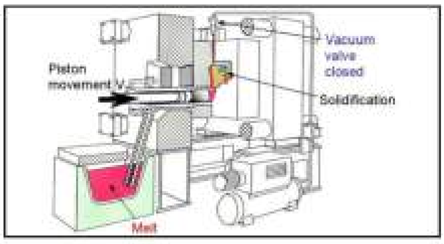
2. Step: Transport of metal to the gate

Source: Müller-Weingarten



3. Step: Injection

Source: Müller-Weingarten



4. Step: Post Injection Pressure, important to prevent blisters in heat treatment & guarantee weldability

Source: Müller-Weingarten

Annexure I

To be continued in next issue...

Table 2.5 Chemical composition (weight per cent) of BS 1490:1988 alloys

Alloy	*Cu*	*Mg*	*Si*	*Fe*	*Mn*	*Ni*	*Zn*	*Pb*	*Sn*	*Ti*	*Additional elements*	*Others Each*	*Others Total*
LM0	0.03	0.03	0.30	0.40	0.03	0.03	0.07	0.03	0.03	—	Al 99.50 min	—	—
LM2	0.7–2.5	0.30	9.0–11.5	1.0	0.5	0.5	2.0	0.3	0.2	0.2	—	—	0.50
LM4	2.0–4.0	0.20	4.0–6.0	0.8	0.2–0.6	0.3	0.5	0.1	0.1	0.2	—	0.05	0.15
LM5	0.1	3.0–6.0	0.3	0.6	0.3–0.7	0.1	0.1	0.05	0.05	0.2	—	0.05	0.15
LM6	0.1	0.10	10.0–13.0	0.6	0.5	0.1	0.1	0.1	0.05	0.2	—	0.05	0.15
LM9	0.20	0.2–0.6	10.0–13.0	0.6	0.3–0.7	0.1	0.1	0.1	0.05	0.2	—	0.05	0.15
LM12	9.0–11.0	0.2–0.4	2.5	1.0	0.6	0.5	0.8	0.1	0.1	0.2	—	0.05	0.15
LM13	0.7–1.5	0.8–1.5	10.0–13.0	1.0	0.5	1.5	0.5	0.1	0.1	0.2	—	0.05	0.15
LM16	1.0–1.5	0.4–0.6	4.5–5.5	0.6	0.5	0.25	0.1	0.1	0.05	0.2[1]	—	0.05	0.15
LM20	0.4	0.2	10.0–13.0	1.0	0.5	0.1	0.2	0.1	0.1	0.2	—	0.05	0.20
LM21	3.0–5.0	0.1–0.3	5.0–7.0	1.0	0.2–0.6	0.3	2.0	0.2	0.1	0.2	—	0.05	0.15
LM22	2.8–3.8	0.05	4.0–6.0	0.6	0.2–0.6	0.15	0.15	0.1	0.05	0.2	—	0.05	0.15
LM24	3.0–4.0	0.30	7.5–9.5	1.3	0.5	0.5	3.0	0.3	0.2	0.2	—	—	0.50
LM25	0.20	0.20–0.6	6.5–7.5	0.5	0.3	0.1	0.1	0.1	0.05	0.2[1]	—	0.05	0.15
LM26	2.0–4.0	0.5–1.5	8.5–10.5	1.2	0.5	1.0	1.0	0.2	0.1	0.2	—	0.05	0.15
LM27	1.5–2.5	0.35	6.0–8.0	0.8	0.2–0.6	0.3	1.0	0.2	0.1	0.2	—	0.05	0.15
LM28[2]	1.3–1.8	0.8–1.5	17–20	0.7	0.6	0.8–1.5	0.2	0.1	0.1	0.2	Cr 0.6 Co 0.5	0.10	0.30
LM29[2]	0.8–1.3	0.8–1.3	22–25	0.7	0.6	0.8–1.3	0.2	0.1	0.1	0.2	Cr 0.6 Co 0.5	0.10	0.30
LM30	4.0–5.0	0.4–0.7	16–18	1.1	0.3	0.1	0.2	0.1	0.1	0.2	—	0.10	0.30
LM31[3]	0.1	0.5–0.75	0.25	0.5	0.1	0.1	4.8–5.7	0.05	0.05	0.25[1]	Cr 0.4–0.6	0.05	0.15

Notes: Single figures in the table are maxima.
In cases where alloys are required in the modified condition, the level of any modifying element is not limited by the specified maximum value for "other elements".
1. 0.05% minimum if Ti alone is used for grain refining.
2. LM28 and LM29 castings are also subject to metallographic structure requirements.
3. LM31 castings in the M condition have to be naturally aged for 3 weeks before use or determination of mechanical properties.
BS1490:1988 should be referred to for details.

Table 2.4 BS 1490:1988 alloys and approximate equivalents

UK	*ISO*	*EN AC-*	*France*	*Germany*	*Italy UNI*	*USA AA/ASTM*	*USA SAE*	*Japan*	*End uses*
LM0	Al 99.5	–	A5	–	3950	150	–	–	Electrical, food, chemical plant
LM2	Al-Si10Cu2Fe	46 100	A-S9U3-Y4	–	5076	384	383	ADC 12	Pressure diecasting
LM4	Al-Si5Cu3	45 200	A-S5U3	G-AlSi6Cu4 (225)	3052	319	326	AC 2A	Sand, gravity diecast manifolds, gear boxes etc.
LM5	Al-Mg5Si1 Al-Mg6	51 300	AG6	G-AlMg5 (244)	3058	514	320	AC 7A	Sand, gravity; corrosion resistant, for marine use Food plant, chemical plant
LM6	Al-Si12 Al-Si12Fe	44 100	AS13	G-AlSi12 (230)	4514	A413	–	AC 3A	Sand, gravity; thin sections, manifolds etc.
LM9	Al-Si10Mg	43 100	A-S10G	G-AlSi10Mg (233)	3049	A360	309	AC 4A	Low pressure etc., motor housings, cover plates etc. High strength when heat treated
LM12	Al-Cu10Si2Mg	–	A-U10G	–	3041	222	34	–	Gravity, sand cast; machines well, hydraulic equipment
LM13	Al-Si12Cu Al-Si12CuFe	48 000	A-S12UN	–	3050	336	321	AC 8A	Sand, chill; used for pistons
LM16	Al-Si5Cu1Mg	45 300	A-S4UG	–	3600	355	322	AC 4D	Sand, chill; cylinder heads valve bodies, good pressure tightness
LM20	Al-Si12Cu Al-Si12CuFe	47 000	A-S12-Y4	G-AlSi12(Cu) (231)	5079	A413	305	–	Pressure diecasting corrosion resistant, marine castings, water pumps, meter cases
LM21	Al-Si6Cu4	45 000	A-S5U2	G-AlSi6Cu4 (225)	7369/4	308	326	AC 2A	Sand, gravity; similar to LM4, crankcases, gear boxes etc.
LM22	Al-Si5Cu3	45 400	A-S5U	G-AlSi6Cu4 (225)	3052	319	326	AC 2A	Chill casting; solution treated, good shock resistance, automotive heavy duty parts
LM24	Al-Si8Cu3Fe	46 500	A-S9U3A-Y4	G-AlSi8Cu3 (226)	5075 3601	A380	306	AC 4B ADC10	Pressure diecasting; engineering diecastings
LM25	Al-Si7Mg	42 000	A-S7G	G-AlSi7Mg	3599	A356	323	AC 4C	Sand, chill; general purpose high strength alloy with good castability; wheels, cylinder blocks, heads
LM26	Al-Si9Cu3Mg	–	A-S7U3G	–	3050	332	332	–	Chill; used for pistons
LM27	Al-Si7Cu2Mn0.5	46 600	–	–	7369	–	–	AC 2B	Sand, chill; versatile alloy, good castability, general engineering parts
LM28	Al-Si19CuMgNi	–	–	–	6251	–	–	–	Chill; high performance pistons
LM29	Al-Si23CuMgNi	–	–	–	6251	–	–	–	Chill; high performance pistons
LM30	Al-Si17Cu4Mg	–	–	–	–	390	–	–	Pressure diecast; unlined cylinder blocks
LM31	Al-Zn5Mg	71 000	A-Z5G	–	3602	712	310	–	Sand; large castings, good shock resistance, good strength at elevated temp.

Annexure II

Table 2.8 Casting characteristics, etc.

Alloy	*Sand cast*	*Gravity die*	*L.P. die*	*H.P. die*	*Fluidity*	*Hot tear resist.*	*Pressure tightness*	*Machinability*	*Corrosion resistance*	*Density* (g/cm^3)	*Coeff. of expansion per* $°C \times 10^{-6}$	*Thermal conduct. at 25°C* (W/m K)	*Electrical conduct. at 20°C* (% IACS)
LM0	F	F	F	F	F	F	F	F	E	2.70	24	209	57
LM2	G*	G	G	E	G	E	E	F	F	2.74	20	100	26
LM4	E	E	G	G*	G	G	E	G	F	2.75	21	121	32
LM5	F	F	F*	F	F	F	P	E	E	2.65	23	138	31
LM6	E	E	E	G	E	E	E	P	E	2.65	20	142	37
LM9	G	G	E	*	G	E	G	F	G	2.68	22	147	38
LM12	F	G	P*	*	F	G	G	E	P	2.94	22	130	33
LM13	G	G	G	*	G	E	F	F	G	2.70	19	117	29
LM16	G	G	G	*	G	G	G	G	G	2.70	23	142	36
LM20	E*	E	E	E	E	E	E	P	G	2.68	20	155	37
LM21	G	G	G	*	G	G	G	G	F	2.81	21	121	32
LM22	G*	G	G	*	G	G	G	G	F	2.77	21	121	32
LM24	F*	F	F	E	G	E	E	G	F	2.79	21	96	24
LM25	E	E	E	G*	G	E	E	G	E	2.68	22	151	39
LM26	G	G	G*	*	G	E	F	G	F	2.76	21	105	26
LM27	E	E	G*	G*	G	E	E	G	G	2.75	21	155	27
LM28	P	F	P	*	F	G	F	P	G	2.68	18	134	—
LM29	P	F	P	*	F	G	F	P	G	2.65	16	126	—
LM30	*	F	F	G	G	F	F	P	F	2.73	18	134	20
LM31	G	F	F	F	F	F	F	G	E	2.81	24	147	35

Notes: * Not normally used in this form.
E = excellent G = good F = fair P = poor.

L.P. die = Low-pressure diecast.
H.P. die = High-pressure diecast.
Coeff. of linear expansion relates to temperatures in the range 20–100°C.
Thermal conductivity will vary with the condition of the casting.
Electrical conductivity is quoted in percentage of IACS (International Annealed Copper Standard Units).

Training Programme

7 & 8 April 2022

Two days training programme on HPDC Die Design, Defect Analysis & Remedial Measures at Arkey Conference Hall, Pune 04

Faculty - Rajesh R Aggarwal

16 & 17 May 2022

Two days training programme on HPDC/GDC Machine Maintenance at L. K. MACHINERY INDIA PVT. LTD., Chakan

Faculty - Avinash H. Patil

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