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Die Design and Development for Ladder Frame

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Abstract: *Pressure die casting is about 150 years old and one of the widely used processes for the mass production of components required in many applications like automobiles, electrical equipment, motors, telecommunications equipment, building hardware, home appliances, etc.*

The design of die casting die requires considerable skill and expertise. Designer purposes designs of dies employed to cast parts from various alloys and perform a variety of other operations. Every new job requires original thought in its design and the solving of individual problems in its manufacture. Each die cast component, currently in production, presents a challenge for the improvement of its output and quality.

The objective here is to design dies to be fit for the purpose, operate at optimum shot rate and is of reasonably simple construction. The main purpose of this report is to present the systematic design procedure for pressure die casting dies. Die casting dies like any other type of tooling can be very simple and very complex. How difficult is to design and build depends entirely on the parts to produce. They can be as simple as a single cavity die with no side cores or they can be complicated dies, which represent split dies along with moving cores actuated by either finger cams or hydraulic cylinders depending on the feasibility.

This project involves design of die casting die for the Cover Cylinder Head-1 for two wheeler. The scope of the project involves,

- Component Study
- Design Calculations
- Designing the tool

Preparation of drawings of assembly and details

Keywords: *High pressure Die casting die, Magma, Drafting and shrinkage allowance, gate design, fill time.*

I. Introduction

Aim of this project is to design a HPDC die for ladder frame, by taking into account of the manufacturing resources and capability of the company within minimum possible time and economic cost of manufacturing.

The project involves design of die casting die for ladder frame. The material of the component is LM24.

The scope of the project involves,

Component Study, Design Calculation, Layout Design, Designing the tool, Preparation of detailed drawings of the parts involved.

II. Methodology

- Check the 3D Model and 2D Drawing given by the customer
- Ensure that 3D Model matches with the 2D drawing and make model inspection report
- Identify critical and major dimensions
- Check for design feasibility and decide parting line
- Get customer approval for the selected parting line
- Add drafts to the model considering tolerances for MMC
- Add shrinkage to the model
- Generate surface as per the decided parting line
- Split core and cavity considering the manufacturing aspects
- Check for draft analysis and clearance analysis
- Optimize feed system as per the filling pattern shown by MAGMA
- Create model base

Die casting is a versatile process for producing engineered metal parts by forcing molten metal under high pressure into reusable steel molds. These molds, called dies, can be designed to produce complex shapes with a high degree of accuracy and repeatability. Parts can be sharply defined, with smooth or textured surfaces, and are suitable for a wide variety of attractive and serviceable finishes. Die cast parts are important components of products ranging from automobiles to toys. Parts can be as simple as a sink faucet or as complex as a connector housing

Core Design

Cores are mold parts used to shape internal holes and cavities. They are also fortification parts of molds where wearing occurs. These parts are made of sand and organic-inorganic bonders such as cereal meals, dextrin, sodium silicate, cement etc. Some properties of cores must have are the followings:

a. High-Temperature Resistivity
b. Metal Erosion Resistivity
c. Easiness of Deformation After Casting
d. Gas Insertion Ability
e. Smooth Surfaces
f. Saving Physical Properties During Storage

Design of Castings

When designing casting the most important consideration is the effect of shrinkage during cooling. Other important factors include metal flow, and porosity.

PROPERTIES	LM2	LM4	LM6	LM24
Tensile Strength (kg/mm^2)	22	24	26	27
BHN	65	75	80	80
Density(gm/cc)	2.7	2.76	2.65	2.75
Melting point(^oC)	595	616	580	585
Solidification Temperature(^oC)	570	520	570	525
Shrinkage (%)	0.6	0.6	0.6	0.6

Some general rules are,

1. Avoid sharp corners - they can lead to hot tearing during cooling.
2. Use fillets cautiously - they lead to stresses as they shrink a radius of1/8" to 1" are acceptable.
3. Avoid large masses - they will cool more slowly, and can lead to pores and cavities in the final part. Cores can be used to hollow out these large volumes.

Alloys And Die Casting

1. Low-melting temperature heavy metal alloys
   Base metals: lead, tin and zinc. (280 ~ 445 c) Hot Chamber
2. High-melting temperature light metal alloys
   Base metals: aluminum and magnesium. (510 ~ 595 c) Cold Chamber
3. High-melting temperature heavy metal alloys
   Base metals: copper and silver. (900 c) Cold Chamber

Aluminium Alloy

Aluminum die casting alloys (Table 1) are lightweight, offer good corrosion resistance, ease of casting, good mechanical Properties and dimensional stability. Although a variety of aluminum alloys can be die cast from primary or recycled metal, most Designers select a standard alloy listed below. Special alloys for special applications are available but their use usually involves

Significant cost premiums:

A360 -- Selected for best corrosion resistance and pressure tightness.
A380 -- The most common and cost effective of all die casting alloys. Provides the best
Combination of utility and cost.

A383 & A384 -- These alloys are a modification of 380. Both provide better die filling but with a moderate sacrifice in mechanical Properties such as toughness.
A390 -- Selected for special applications where high strength, fluidity and wear
Resistance/bearing properties are required.
A413 (A13) -- Used for maximum pressure tightness and fluidity

Pressure & Flow Rate Analysis (PQ2)

The objective of making PQ^2 is to match designed to gating system to the machines hydraulic system. The molten metal flow through an orifice like ingate is function of pressure on molten metal. Higher the pressure, higher will be the flow rate. The Relationship between pressure and flow rate is non-linear.

Bernoulli Equation

Shot System required some pressure to push the molten metal into cavity at a specific gate velocity through gate area. This Pressure can be calculated from Bernoulli's equation

The governing equation for fluid flow through an orifice or ingate is given by Bernoulli Equation,

$$Pm = (\rho/2g) \times [(Vg/Cd)^2]$$

Where,

Pm = metal pressure (kg/cm^2)

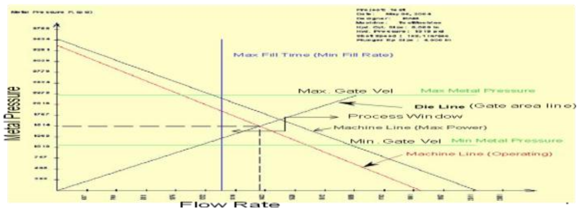
ρ = metal density (gm/cc)

g = gravitational constant (cm/sec^2)

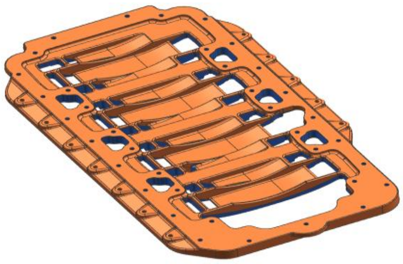
Vg = velocity at gate (cm/sec)

Cd = co-efficient of discharge

From this equation we can observe that



Application	Pressure (kgf/cm2)
Commercial	300 ~ 500
Technical	500 ~ 700
Pressure tight	700 ~ 1000



COMPONENT STUDY

Component name = LADDER FRAME

Material = LM24 (AlSi9Cu3)

Volume of component = 1066.35 cm^3

Density = 2.39 gm/cm^3

Projected area = 921 cm^2

Side Core Projected area = 0 cm^2

Weight of comp = 2540 gm (2.54 kg)

Average Wall Thickness = 4mm

Radius of gyration = 55 mm

Factor of safety = 25 %

Maximum thickness = 18 mm

DESIGN CALCULATIONS

Casting Projected area = 921cm^2

Shot Projected Area

(Casting+Overflow+Runner projected area) = Casting projected area + 30% of Casting Projected Area

= 921 + (30/100) X 921 = 1197.3 cm^2

Taking factor of safety= 25%

Hydraulic slide area= 0 cm^2

Total projected area= 1197.3+0 = 1197.3 cm^2

Casting pressure = 900 Kg/cm^2

Closing Force required = (Total projected area X Casting pressure XFactor of safety) / 1000= 1346.96 Tons

Hence we can select 1400T UBE press can be selected according to obtained calculations and M/C availability.

MACHINE SELECTION

Casting volume = 1066.35 cm^3

Total volume = Volume of component + Volume of over flow and Feed system (excluding biscuit)

= 1066.35 + (30/100) x1066.35

= 1386.255 cm^3

Actual shot volume= 1386255+ $\pi d^2 t/4$

Where "d" is the biscuit diameter and "t" is the biscuit thickness

Stroke length of 1400T machine= 900 mm

Effective stroke length = 900 – 30

= 870mm

Assume fill ratio = 0.35

Volume delivered by machine= πd^2 X (870/4) X 0.35

i.e.1386255+ πd^2 X (30/4) = πd^2 X (870/4) X 0.35

1386255+ 7.5πd^2 = 76.125πd^2

1386255+23.5d^2 = 239.15 d^2

d^2 = 1386255 / 215.58

d = 80.18mm

Available plunger sizes in 1400 T machines is 90,100,110,120,130mm.

Hence we can select 100 mm plunger tip

Actual shot volume= 1386255 + [π X $(100)^2$ X (30/4)]

= 1386255 + 235619.44

= 1621874.44 mm^3 (1621.87 cm^3)

Shot weight = 1621.87 X 2.39

= 3876.26 g (3.87 Kg)

Fill ratio = Metal volume / Shot sleeve volume

= (1386255 + 235619.44) / [π X 100^2 X (870/4)]

= (1621874.44 /6832964.021)x100

= 0.237

Yield (%) = (Casting Weight / Shot Weight) X 100

=(2540 / 3876.26) X 100

= 65.52 %

FILL TIME CALCULATION

Optimum fill time is obtained by increasing the die and metal temperature to the optimum value so that the castings produced have decorative finish.

$$t = \frac{k\,[Ti - Tf + s*z]\,T}{[Tf - Td]}$$

Where,

t = theoretical fill time;

k = empirically derived constant

T_i = temperature of the molten metal as it enters the die

T_f = minimum flow temperature of the metal

T_d = temperature of the die cavity surface just before the metal hits it

S = % solid fraction available in the metal at the end of filling

Z = units conversion factor ^oC / %

T = casting wall thickness

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GATE DESIGN

$$\text{Fill rate (Q)} = \frac{\text{volume of metal through gate}}{\text{Fill time}}$$

Volume of metal through gate = volume of component + volume of over flows
V = volume of component + 15 % volume of component
V = 1066.35 + 159.9525
V = 1226.30 cm^3
Volume of metal through gate (V) = 1226.30 cm^3
Fill rate (Q) = V/t

$$Q = \frac{1226.30}{0.0653}$$

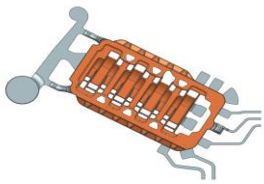
$= 18779.47\ cm^3/sec$
Fill rate(Q) = 18779.47 cm^3/sec
Assuming Gate velocity (Vg) = 40m/sec
Gate area (Ag) = Q/ (Vg X 100)
= 18779.47 /(40 X 100)
= 4.69 cm^2
Gate area (Ag) = 4.69 cm^2

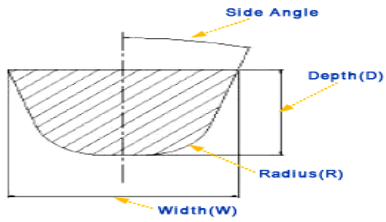
RUNNER DESIGN

Runner area (Ar) = 1.45 Ag
Ar = 1.45 X 4.14
= 6.003 cm^2
Runner area (Ar)= 6.003 cm^2
Runner depth (D) = $(Ar/1.8)^{1/2}$
D= $(1.433/1.8)^{1/2}$
=1.82 cm
Runner depth (D)= 1.82 cm
Runner width (W)= 2 D
W= 2 X 1.82
= 3.65 cm
Runner width (W)= 3.65 cm

GATE AND RUNNER DESIGN

The runner is machined entirely in the ejector half and the cover half forms only the flat side of the runner. the flow chart of runner design. After the cross- sectional area of gate is determined, that of runner can be calculated based on volume constancy point of view. And then the shape of runner is selected from database. The width and depth of runner varies with the volume of metal to be injected into the cavity. Finally, the shape and numerical data are generated. Various shapes of runners are illustrated in Cross-sectional shape of runner is inverted trapezoidal as shown in Generally, the area of runner is 4~5 times of that of gate, the fraction of depth to width 1:1.5~3.0, side angle 10~20 and corner radius longer than 6mm.

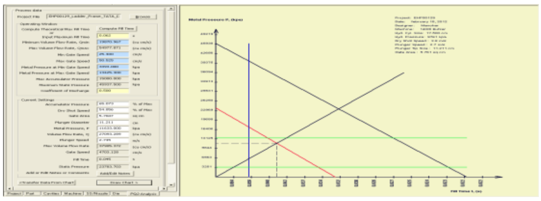




Cross-section of runner
Gate area (Ag) = 4.69cm^2 (Theoretical Circulation)
(Ag) = 5.761 cm^2 (Magma Simulation Result)
Area of runner (Ar)= R_d x R_w

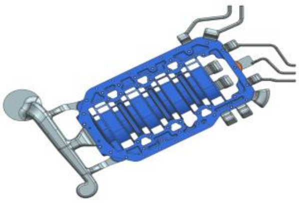
Where, R_d= Depth of gate
R_w= Width of gate

SIMULATION PART (MAGMA ANALYSIS AND FINAL PQ2)
GATE AREA - 5.761 cm^2
FILL TIME - 65.31 ms
GATE VELOCITY - 47.03 m/s
V2 - 2.745 m/s

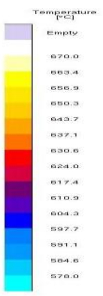


MAGMA5 uses the method of numerical simulation to reach the required aims. The entire casting process from the filling of the melt into the mold up to solidification and subsequent feeding is available as a sound physical calculation model for all supported casting methods and materials. "Cold casting" on the screen allows you to improve your casting system step by step. You can easily change the casting geometry (casting, position of the feeders, cores, etc.) and the casting parameters (pouring temperature, velocity of filling, etc.). MAGMA5 also facilitates the design of permanent mold casting processes

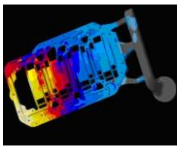
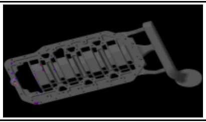
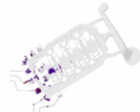
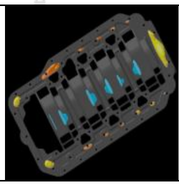
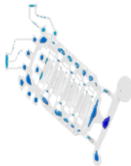
FULL VIEW OF CASTING



MAGMA SIMULATION RESULTS

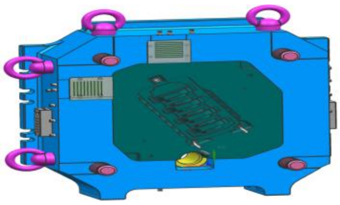


Metal Filling

RUNNER VERSIONS	V01	V08
AIR PRESSURE		
AIR ENTRAPMENT		
POROSITY		
HOTSPOT		

DIE PARTS MODELING:

The individual parts is modeled in 3d using Unigraphics NX 7.5 and assembled in 3d for better visualization. The parts modeled in 3d are detailed using UG NX 7.5 for the detailed dimensions of the individual parts. The 3d models are use for the design reviews, design updating process and the customer interaction. The following are the some of the 3d models of the tool, is shown below



COOLING ARRANGEMENT:

FIX INSERT

Cooling circuits are provided according to the obtained calculations

In the Fix insert, the length of the cooling channel is 2884mm.Position of the cooling channel is placed covering core region of the insert, where accumulation of heat is more.

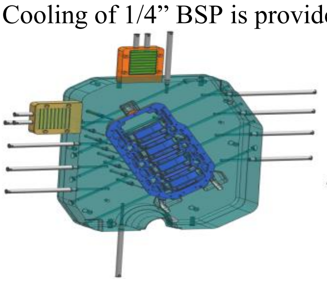
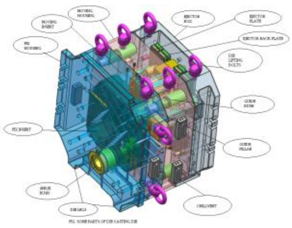
3/8" BSP threading is used for cooling nipples.

The cooling circuit is placed 25 mm below the casting surface.

Water is used as cooling medium

A Dia 10mm pipe is used throughout the circuit.

Spot Cooling of 1/4" BSP is provided at the Punch region in Fix Insert.

Endurance Technologies Ltd

Bill Of Material

Format No	F/CPDC/ 25					
Format Rev. No.	01					
Effective From	3/5/2011					
Die Assembly Name	LADDER FRAME	Date	20/03/12	BOM Prepared By	MANOHAR	Revised By
Project Number	EHP00129	Die No.	1	BOM Approved By	D MANDAL	Revision Approved

Item Code	Description	Material Type	Rev.	Qty (Nos)	Material	Finish Size in mm L	W	T	DIA	L (ROUND BAR)	Weight(kg	HT	Remarks	BOM RE
40A089L000 (MOULD BASE)														
40A089L010	FIX HOUSING	ZROH	B	1	EN8 CAST	1285	1210	310			2203	175-195BHN	N.A	B
40A089L020	MOVING HOUSING	ZROH	A	1	EN8 CAST	1225	1070	290			2045	175-195BHN	N.A	A
40A089L030	EJECTOR BOX	ZROH	A	1	EN8 CAST	1225	1070	270			1291	175-195BHN	N.A	A
40A089L040	EJECTOR PLATE	ZROH	A	1	EN8	875	675	35			107	NA	N.A	A
40A089L050	EJECTOR BACK PLATE	ZROH	A	1	EN8	875	675	40			126	NA	N.A	A
40A089L060	GUIDE PILLAR	ZROH	A	4	EN 353				D80	210	8	58 - 60HRC	C'HDN	A
40A089L070	GUIDE BUSH	ZROH	A	4	EN 353				D105	120	2.11	58 - 60HRC	C'HDN	A
40A089L080	EJECTOR GUIDE PILLAR	ZROH	A	4	EN 353				D60	245	5.36	58 - 60HRC	C'HDN	A
40A089L090	EJECTOR GUIDE BUSH	ZROH	A	4	EN 353				D85	73	0.99	58 - 60HRC	C'HDN	A
40A089L100	FRONT STOPPER	ZROH	A	6	EN 353				D40	55	0.44	58 - 60HRC	C'HDN	A
40A089L110	BACK STOPPER	ZROH	A	6	EN 353				D30	15	0.07	58 - 60HRC	C'HDN	A
40A089L120	RETURN PIN	ZROH	A	4	HDS (H13)				D40	440	2.5	44 - 46HRC	HDN&TEMP	A
40A089L130	EJECTOR BOX DOWEL	ZROH	A	2	HDS (H13)				D50	100	0.7	44 - 46HRC	N.A	A
40A089L140	SPRUE BUSH LOCK PIECE	ZROH	A	1	EN8	40	40	20			0.2	NA	N.A	A
40A089L150	WATER JACKET (FIX & MOVING)	ZROH	A	6	EN8	200	80	50			5.38	NA	N.A	A
40A089L160	GUIDE BUSH SPACER	ZROH	A	4	EN 353				D105	170	4.45	58 - 60HRC	C'HDN	A
40A089L170	SUPPORT PILLAR-RECTANGULAR_TOP	ZROH	A	1	EN8	210	115	90			14.4	NA	N.A	A
40A089L180	SUPPORT PILLAR-RECTANGULAR_BOTTOM	ZROH	A	1	EN8	210	170	90			19.6	NA	N.A	A
40A089L190	MOVING CORE PIN SPACER LOCK PLATE-1	ZROH	A	1	EN8	60	40	15			0.23	NA	N.A	A
40A089L200	MOVING CORE PIN SPACER LOCK PLATE-2	ZROH	A	1	EN8	70	60	15			0.4	NA	N.A	A
40A089L210	SUPPORT PILLAR	ZROH	A	2	EN8				D80	210	7.62	NA	N.A	A
40A089J000 (FIX SIDE)														
40A089J010	FIX INSERT	ZMFG	B	1	HDS (H13)	730	670	180			578.33	44 - 46HRC	HDN&TEMP	B
40A089J020	SPRUE BUSH	ZMFG	A	1	HDS (H13)				D220	230	23	46 - 48HRC	HDN&TEMP	A
40A089J030	COOLING RING	ZROH	A	1	M.S				D192	134	13.11	NA	N.A	A
40A089J040	FIX CORE PIN-FC1 TO FC12	ZROH	A	12	HDS (H13)				D12	163	0.05	46 - 48HRC	NITRIDING	A
40A089J050	FIX_CHILLVENT DUMMY BLOCK	ZROH	A	2	EN8	170	150	60			9.71	NA	HDN&TEMP	A
40A089J060	COOLANT EXTENSION PIPE FIX INSERT	ZROH	A	6	S.S				D20	256	0.5	NA	N.A	A
40A089J070	COOLANT EXTENSION PIPE FIX INSERT	ZROH	A	2	S.S				D20	225	0.44	NA	N.A	A
40A089J080	COOLANT EXTENSION PIPE FIX INSERT	ZROH	A	1	S.S				D20	270	0.53	NA	N.A	A
40A089J090	COOLANT EXTENSION PIPE FIX INSERT	ZROH	A	1	S.S				D20	325	0.64	NA	N.A	A
40A089J100	COOLANT EXTENSION PIPE FIX CHILLVENT	ZROH	A	4	S.S				D20	85	0.15	NA	N.A	A
40A089J110	COOLANT EXTENSION PIPE SPRUE BUSH	ZROH	A	2	S.S				D20	78	0.14	NA	N.A	A
40A089J120	FIX CORE PIN SPACER	ZROH	A	12	EN8				D12	95	0.08	NA	N.A	A
40A089J130	FIX CHILL VENT	ZERS	A	2	HDS (H13)	170	150	59				46 - 48HRC	HDN&TEMP	B
40A089J140	FIX CORE PIN-FC1 3 & FC14	ZROH	A	2	HDS (H13)				D14	170		46 - 48HRC	NITRIDING	B
40A089J150	FIX CORE PIN SPACER	ZROH	A	2	EN8				D14	95		NA	N.A	B
40A089K000 (MOVING SIDE)														
40A089K010	MOVING INSERT	ZMFG	B	1	HDS (H13)	730	670	150			440.4	44 - 46HRC	HDN&TEMP	B
40A089K020	DIFFUSER	ZMFG	A	1	HDS (H13)	150	140	210			29.68	46 - 48HRC	HDN&TEMP	A
40A089K030	MOVING_CHILLVENT DUMMY BLOCK	ZROH	A	2	EN8	170	150	62			11.13	NA	N.A	A
40A089K040	MOVING CORE PIN1-----(MC3,MC4)	ZROH	A	2	HDS (H13)				D12	143	0.053	46 - 48HRC	NITRIDING	A
40A089K050	MOVING CORE PIN2-----(MC2,MC5)	ZROH	A	2	HDS (H13)				D18	149	0.16	46 - 48HRC	NITRIDING	A
40A089K060	MOVING CORE PIN3-----(MC8,MC13,MC14,MC18,MC20,MC32,MC34,MC37,MC40,MC44,MC45,MC50)	ZROH	A	12	HDS (H13)				D12	138	0.054	46 - 48HRC	NITRIDING	A
40A089K070	9,MC21,MC22,MC23,MC24,MC25,MC27,MC28,MC29,MC30,M	ZROH	A	33	HDS (H13)				D12	149	0.059	46 - 48HRC	NITRIDING	B

III. Conclusion:

In this project the following learning's were made:

- Systematic approach leads to better understanding and yields a better result.
- Able to reach the customer expectations within the limit
- Design reviews will help in identifying the problems and solving the same with team work
- Usage of technology helped in achieving the targets
- Team work yields the best result
- Launched the product at the least rejection levels

Component "LADDER FRAME" was given as my project to design and to develop the tool. The die design was completed successfully and sent for manufacturing. Apart from the above mentioned project, I have done the assembly, detailing and product designing for other castings.

References

[1]. www.efunda.com/processes/metal_processing/die_casting.cfm

[2]. www.dynacast.com/index.php?l1=home2&language=en

[3]. www.diecasting.asn.au/pubs.php

[4]. www.en.wikipedia.org/wiki/Casting_(metlworking).