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A New Developmental Design for Parts of Pressure Die Casting

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***Abstract*— In pressure die casting process, dimensioned parts are produced accurately by forcing molten metal under pressure into split metal dies. Later this is opened to allow the casing to be ejected. The objective of this paper is to model aluminum castings and to compare with customer model. The Die Design for "E6 UPPER BODY" is also developed. The necessary modifications are made to rectify the problems identified in the previous design. Ejector pin positions are changed to eliminate the post-casting operations. The component orientation is changed in the assembled die housing so that the forces acting on the side cores are minimized. In this paper, a new design is proposed by modifying the conventional design of spring-supported side-cores.**

***Keywords*—Ejector pin, Air Vent, Hot-tearing**

INTRODUCTION

Aluminium diecasting is a process where molten aluminium alloy is injected into a casting die under high pressure and at a controlled temperature. The mold had two sections, the" cover" half and the "ejector" half. The die may also have additional moveable segments called slides or pulls, which are used to create features such as undercuts or holes which are parallel to the parting line (Fig. No: 1.1)

Aluminium diecasting dies are run in cold chamber diecasting machines. These machines are operated at the required temperatures and pressures to produce a quality part to net-shape or near net-shape specifications. Aluminium diecasting can be readily machined, anodized, painted or powder coated. Some of the more typical application for aluminium die castings are: enclosures for the electronics industry, hand and power tools, hardware, applications, pump parts, plumbing parts, parts for the automotive industries, sports and leisure, home appliances, and communications.

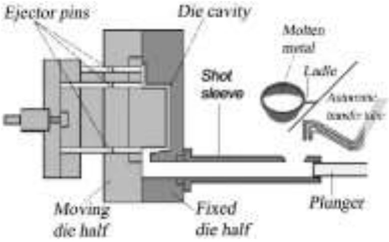


Fig 1.1: COLD CHAMBER

CHARACTERISTICS OF MOLTEN ALUMINIUM

Molten aluminium alloys are extremely reactive and combine readily with other metals, with gases, and sometimes with refractories. Molten aluminium dissolves iron from crucibles. Therefore, aluminum is usually melted and handled in refractory (most often, silicon carbide) containers. High-alumina brick bonded with phosphoric acid is ordinarily used for furnace linings. The surface tension of molten aluminium is high and when augmented by the formation of film of oxide, surface tension is so great that it causes difficulty in casing thin sections. Alloy additions reduce surface tension, but broaden the solidification range, which is likely to cause shrinkage problems. The surface tension of molten aluminium is great enough to keep a charge of fines floating on top of the molten bath. Compositions that are high in alloy content, such as the high-silicon die casting alloys are susceptible to precipitation of the alloying elements, thus forming sludge. Thereafter of sludge formation increases as the temperature of the molten bath decreases.

Aluminium alloys solidify with a maximum of nearly 10% volume contraction, which must be considered in the design of the gating system for a casting. Molten aluminum weighs only 145 to 150 lb per cubic foot, whereas solid aluminum weighs 160 to 165 lb per cubic foot.

II. LITERATURE REVIEW

High Pressure Die Casting (HPDC) is an important process for manufacturing high volume and low cost components. Examples from the automotive industry include automatic transmission housings, piston heads and gearbox components. The geometric complexity of the dies leads to strongly three-dimensional fluid flow with significant free surface fragmentation. Crucial to forming homogeneous cast components with minimal entrapped voids is the order in which the various parts of the die fill and the positioning of the gas exists. This determined by the design of the gating system and the geometry of the die.

- Ejector pin marks are on jigging surface, so that this surface needs post-casting processes.
- The previous design in injection point is offset, so that the length of feeding system is increased.
- The locking forces needed on the side cores are more.
- The conventional design of spring-supported to side-cores is modified, because while die is mounting and dismounting from the machine, the projected screws may chance to touches the tie bars.

A. *Objective Of The Project*

The main objective of this project is to 3D Modeling of pressure die casting parts

- END COVER
- VALVE BODY
- E6 UPPER BODY ((including core &cavity extraction)
- R12 BODY
- Design the die-casting die for the component "E6 UPPER BODY".

Which involves necessary modifications in manufacturing "E6 Upper Body"

  - Elimination of ejector pin marks on jigging surface.
  - Injection position is aligned in along y-axis, so that length of feeding system is minimised and locking force needed on side cavities is reduced.
  - Feeding system redesigned, so that molten metal reaches at all peak points at a time.

Spring support to side cores is modified.

B. *3d Modeling And Component Design*

Advice on designing die-castings is usually based upon desirable practices or situations to avoid. However, like most rules, there are exceptions. These affect costs, appearance and/or quality of final products. Listed below are guides that should be considered when designing and modeling for die-casting:

1. Specify thin sections that can easily be die cast and still provide adequate strength and stiffness. Use ribs wherever possible to attain maximum strength, minimum weight.
2. Keep sections as uniform as possible. Where sections must be varied, make transitions gradual to avoid stress concentration.
3. Keep shapes simple and avoid nonessential projections.
4. A slight crown is more desirable than a large flat surface, especially on plated or highly finished parts.
5. Specify coring for holes or recesses where savings in metal and overall costs outweigh tooling costs.
6. Design cores for easy withdrawal to avoid complicated die construction and operation.
7. Avoid small cores. They can be easily bent or broken necessitating frequent replacement. Drilling or piercing small holes in die-castings is often cheaper than the cost of maintaining small cores.
8. Avoid use of undercuts, which increase die or operating costs unless savings in metal or other advantages fully warrant these extra costs.
9. Provide sufficient draft on sidewalls and cores to permit easy removal of the die casting from the die without distortion.
10. Provide fillets at all inside corners and avoid sharp outside corners. Deviation from this practice may be warranted by special considerations
11. Die casting design must provide for location of ejector pins. Take into consideration the effect of resultant ejector marks on appearance and function. The location of ejector pins is largely determined by the location and magnitude of metal shrinkage on die parts as metal cools in the die.
12. Specify die cast threads over cut threads when a net savings will result.
13. Die-castings which affect the appearance of a finished product may be designed for aesthetics, and to harmonize with mating parts.
14. Inserts should be designed to be held firmly in place with proper anchorage provided to retain them in the die-casting.
15. Design parts to minimize flash removal costs.
16. Never specify dimensional tolerances closer than essential. This increases costs.
17. Design dies castings to minimize machining.

C. *Pressure Die Casting Die Design*

Inputs from the customer can be received in the following ways.

- 3D casting model without 2D drawings and drafts in the model
- 2D drawings only
- 3D machined model
- 3D model in IGES format
- Sample casting /final machined part
- Solid model is made if it is not there.
- Study of component /casting.
- Machine selection
- Identification & selection of the parting line.
- Introduce drafts in the model before giving fillets.
- Perform draft check on the model & rectify if necessary.
- Splitting & extracting the fixed & moving halves of inserts respectively.
- Gating Design
- Optimum Gate, Runner & Overflows are designed.
- Design of other die elements, ejection, guide & cooling system.
- Design review /Design approval
- Complete detailing is done.

Complete die design in 3D (Pro-E) & 2D manufacturing drawings in Pro-e/Auto CAD is released for manufacturing.

D. *Softwares Used For Die Design*

Pro/E:It is a suite of programs that are used in design, analysis & manufacturing of a virtually unlimited range of products.

Pro/E is a *parametric feature based* solid modeling system.
Parametric means that the physical shape of the part /assembly is driven by the values assigned to the attributes of its features & the feature dimensions or other attributes at any time
Solid modeling means the computer model created is able to contain all the information that a real solid object should have.

DiEdifice

DiEdifice provides the designer with an intelligent & powerful Tool for designing PDC dies, thereby reducing the complexity & lead-time of the die design process.

The knowledge base comprises of engineering methods, heuristic rules & other manufacturing & operational considerations.

DiEdifice takes a solid model of the component to be cast & also of the die blocks as the input and through an interactive process with he user, designs the feeding, gating & cooling system.

Features

- Calculation of filling parameters.
- Gating System Design
- Overflow design
- Gate & Gate Runner design
- Runner design
- Venting calculations
- Gating Systems Analysis (Health Checks)
- Air Entrapment
- Dynamic injection pressure
- Fettling Factor, Yield, Reynolds Number
- Cooling System Calculations
- Total cooling load required
- Total effective cooling length required
- Ejection System Calculations
- Total ejection load required
- Number of ejector pins required
- Standard Parts library
- DiEdifice comes with a inbuilt in DME Catalog
- Provision for creating a customized library of parts

III. PQ^2 CALCULATIONS

- Objective is to make a design that will have the die & machine operates within the range of developed operating window.
- PQ^2 predicts whether a given die will operate when mounted on a machine with known performance.
- Inputs Required
- Dry shot speed
- Shot pressure used for dry shot
- Shot cylinder bore diameter
- Shot stroke
- Total shot weight
- Safety factor for machine
- Estimated gate area
- Desired gate thickness
- Weight of metal through gate
- Liquid density for this alloy
- Projected area
- Coefficient of Discharge - C_d est. Machine speed setting (Cold Chamber, Al. 0.35)
- Establish plunger diameter
- Establish operating pressure
- Maximum fill time
- Maximum gate velocity
- Minimum gate velocity

A. *Moving Core Mechanisms*

Cores with axis not parallel to the die movement are called movable cores. These cores must be withdrawn by a separate mechanism before the casting is ejected from the die by mechanical slides, by hydraulic actuated mechanism, by Dog Leg cam and by Rack And Pinion. (Fig. No: 6.1)

The movable die elements needed to build up die surfaces. These are used when it becomes impossible to avoid under cuts in the casting. These slides must be retraced before the casting ejection.

The core must be shaped, so it is loose and free to move once the die has opened.

The core must not be shaped so that it can get pinched between other parts of the die as those parts and core wrap and change size due to their thermal gradients.

B. *Mechanical Core Slider*

The locking wedge locates the core and retains its position against the force of the molten metal pressure. The actuating mechanism must strip the core from the casting. The actual moving of the core should require little force, although the simple lifting of big cores can require a substantial mechanism.

The angle pin is fixed cover die and extends through a hole in the core block. The hole in the core block is larger than the angle pin. As the die opens, the angle pi moves through the clearance until at some point it contacts the core block. Also, as the die opens, the locking wedge withdraws from the core. The amount of die opening at the time, the angled pin contacts the core block is known as the dwell. Once contact is made, the angle of the pin will force the core to move away from the casting. The distance the core will move (i. e travel) determined by the length of the core pin and its angle. (Fig. No: 6.2)

C. Force Calculation

The angle of the angle pin, and the angle of the wedge, also determines the amount of machine locking force that must be allocated to „hold‟ the core.

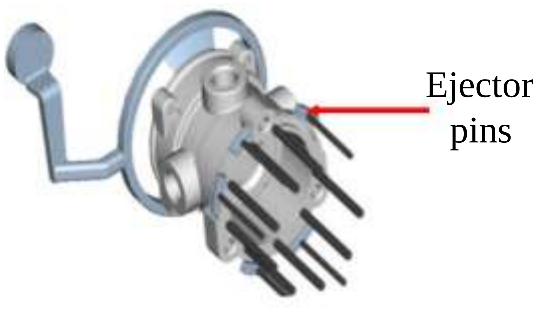
The projected area must be selected in the plane that is normal (i.e. 90^o) to he direction of core travel, the forces applied by the injected metal should be computed and recorded for all moving cores.

Finger cam angle of inclination $\Phi = 18^o$-22^o

Angel of wedge= $\Phi + 2^o$ Force FY= FX

TanΦ Φ=angle of finger cam inclination

Proposed Design



Existing design

Machinability

Castings made in lm20 are rather difficult to machine. This is due to their tendency to drag and rapid tool wear caused by the high silicon content. The higher copper content does reduce the problem of drag compared to lm6. Carbide-tipped tools with large rake angles and relatively low cutting speeds give comparatively good results. A cutting lubricant and coolant should be employed.

Corrosion Resistance

LM20 exhibits high resistance to corrosion under both ordinary atmospheric and marine conditions. For the severest conditions this property can be further enhanced by anodic treatment. LM20 is only marginally worse than LM6 with respect to corrosion resistance.

Anodising:

LM20 can be anodized by any of the common processes. The resulting protective film ranging in color from grey to dark brown. The surfaces of diecasting are generally not suitable for decorative anodizing.

Casting Characteristics:

Fluidity - Can be cast into thinner and more intricate sections than many other types of casting types.

Pressure Tightness - Especially suitable for teak-tight castings.

Hot-tearing - Castings tend to exhibit complete freedom from hot-tearing.

Typical Pouring Temperature - Pouring temperatures for diecasting depend very largely on the particular casting and the machine and vary too widely for a typical temperature to provide useful guidance. The melt should not, however, be allowed to stand at temperatures only a little above the freezing range or the bottom of the melt may become enriched in such elements as iron and manganese

Patternmakers' Shrinkage: 1.3% or 1/75.

Applications And General Notes

Suitable for marine 'on deck' castings. Water-cooled manifolds and jackets, motor-car and road transport fittings; thin sections and intricate castings such as motor housings, meter cases and switch-boxes; for very large castings, e.g., cast doors and panels where ease of casting is essential; for chemical and dye industry castings, e.g. pump parts: for paint industry and-food and domestic castings. In general use where marine atmospheres or service conditions make corrosion resistance a matter of major importance. LM20 is generally only preferred to LM2 or LM24 when the castings are used in aggressive media, requiring the higher resistance LM20 offers. Where the very highest resistance is required, then LM6 may be found superior to LM20. LM20 has slightly better castability than LM6. [5]

Design Calculations And Results

Component volume=135100
mm^3 Density=0.00278g/ mm^3
No. Of cavities=1
Projected area of component=5814.58 mm^2 (In pull direction) Surface area of =53370 mm^2
Mass= 375.578 gm

Machine Tonnage Calculations

Specific injection pressure for pressure tight casting=800 bar= 8 kgf/ mm^2
Projected area of shot (projected area including overflows and feed system)=
=Projected area of component X1.3
=6194.31X1.3=8052.603 mm^2
Locking force required for the die=projected area of shot X sp.injection pressure
=8052.603x8=64,421.04 kgf/ mm^2 =64.04
T Projected area of side core 1=4185.00 mm^2
Projected area of side core 2=3525.00 mm^2
Force acting on side core1= projected area of core X sp.inj.pressureXtan 20^0
=4185 X8X tan 20^0=12183.37 kg/mm ^{2}=12.183T
Force acting on side core2=3525X8X tan 20^0=10261.98 kg/mm^2=10.261T
Total locking force required=82.97
T Taking factor of safety 1.2
Total tonnage required for locking =99.50T
Hence we can select 250T machine according to the tonnage.

C. Shot capacity calculation

Shot volume=volume of component + overflow and feed system, excluding
biscuit
=Component volume X 1.3
=135100 X1.3=175630 mm^3
Shot weight= 375.578 X1.3=488.25 g

Machine Tonnage Calculations

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Force acting on side core1= projected area of core X sp.inj.pressureXtan 20^0

=4185 X8X tan 20^0=12183.37

kg/mm^2=12.183T

Force acting on side core2=3525X8X tan 20^0=10261.98 kg/mm^2=10.261T

Total locking force required=82.97

T Taking factor of safety 1.2

Total tonnage required for locking =99.50T

Hence we can select 250T machine according to the tonnage.

Shot Capacity Calculation

Shot volume=volume of component + overflow and feed system, excluding biscuit

=Component volume X 1.3

=135100 X1.3=175630 mm^3

Shot weight= 375.578 X1.3=488.25 g

Table 1: *Machine Specifications*

Locking force	Tonnes	250
Hydraulic ejection force	Tonnes	15
Die mounting plates HX V	mm Xmm	800X 850
Space bar between tie bars HXV	mm Xmm	500X 550
Tie bar diameter	mm	100
Max. die height	mm	750
Min. die height	mm	225
Die opening stroke	mm	500
Injection plunger stroke	mm	350
Ejection stroke adjustable	mm	100
Machine area	m^2	5.9 X1.6
Capacity of oil tank	lts	550
Plunger diameter	mm	40~85
Shot capacity for aluminium	Kg	0.8~3.6

Plunger Diameter Calculation

Volume of shot = volume of shot sleeve

Total volume of casting and feed system= total volume in the shot sleeve

$175630+(\prod d^2/4)= (\prod d^2/4) X (370) X 0.5$

Where h is the biscuit height, 0.5 the fill ratio, 370 is effective stroke

d=36.26, Considering plunger diameter 60 mm

Plot The M/C Power Line.

$P_m = P_h *(d_h^2/d_p^2)$

Where

P_m = metal pressure (kg/cm^2) (704.17kg/cm^2)

P_h =hydraulic pressure (kg/ cm^2) (150kg/cm^2)

d_h =effective hydraulic cylinder diameter (cm) (130 mm)

d_p =plunger diameter (60 mm)

Metal Pressure is plotted on the Y-Axis of the Graph

Q_{max} =V_pX d_h^2/ d_p^2

Where

V_p = maximum dry shot speed (cm/sec) (4.5 m/s)

d_p =plunger diameter (cm) (60 mm)

Q_{max} = maximum fill rate (cm^3/s) (12717 cc/sec)

Q_{max} is plotted on the X-Axis

Join the P_m on Y-axis & Q_{max} on the X-axis

So the process can run anywhere under the line.

This is the first process boundary

Calculate The Theoretical Fill Rate (Q_{th})

$Q_{th} = V_{cav}/t$

Also $V_{cav} = W/p$

Where

V_{cav} = Volume of metal through the gate

W = Weight of metal passing through the gates (kg)

p = Molten alloy density (kg/cm^3) (2.78 g/cm^3)

Q_{th} = Theoretical fill rate (1804.94 g/cm^3)

$t = k*T*(T_i-T_f+SZ)/(T_f-T_d)$ Where

t = ideal filling time (sec) (0.08 sec)

k = Empirically derived constant (sec/cm) (0.0346 sec/cm)

T_i = temperature of the molten metal as it enters the die (°C) (650 °C)

T_f = minimum flow temperature of the metal (°C) (570 °C)

T_d = temp. of the die cavity surface just before the metal enters. (°C)

(200 °C)

S = % of solid filling allowable in the metal at the end of filling. (%) (30%)

Z = unit conversion factor (°C/%) (4.8°C/%)

T = Average casting thickness (mm) (4 mm)

From this acceptable process can run to the right of the fill rate as long it is below the M/C performance line.

Metal Pressure (P)

$P =(p/2g)*(V_g/C_d)$

^{2} Where

P = metal pressure

V_g = Gate velocity (40 m/s)

p =Aluminum Density (2.78 g/cm ^{3})

C_d = coefficient of discharge (0.35)

g = acceleration due to gravity 9.8 m/s^2

Corresponding to two gate velocities (Max. & Min.) we get two Pressure values

Process point will be in the center of the process window due to normal variation within the die cast process.

Once the process point is decided, total gate area (A_g) can be determined by

$P =(\rho/2g)*(V_g/C_d)^2$

$A_g V_g = Q/A_g$

$A_g = Q/V_g$ ($45.1mm^2$)

Result

Gate Depth = 1.5 mm
Gate length=30.1 mm
Type of gate =Ring Gate

Total ring gate area is divided in to equal 2 segments according to the each segmented weight of casting, so that metal will reach the metal in all peak points at a time. Ring gating is not advisable for multiple cavities.

Runner Design Considerations

- Width of the runner should not exceed twice the depth
- Runner area should be equal to 1.2 times total area of all the gates.
- Side of the runner away from the gate is slightly angled to provide draft for ejection.
- The side next to the gate has a definite angle A, approach angle, which directs the metal in to the gate.
- Bottom is flat but the corner is radiused
- The runner as approaches the sprue/ biscuit it will become progressively larger, reason being cross-section must equal all the gate cross-section down the stream.
- It is desirable to have additional enlargement of about of about 10% at the sprue / biscuit. [2] [4]

Calculations

W= width of the runner
d = depth of the runner
And w<= 2d
Runner area = 1.2*Total Gate Area 1.5 *d*d = 45.1*1.2 d = 6.02mm
w = 12.12 mm

Slow Shot Sleeve Velocity (V_1)

V_{ss}= (V_1)=slow shot sleeve velocity= $C_{cc}(100\%-f_i/100\%)X(d_p)^{0.5}$

V_{ss}= slow shot velocity (m/s)

f_i=Volume fraction of shot sleeve initiating filled with molten metal(%)

d_p=plunger diameter(mm)

C_{cc}=curve fitted constant (0.579 m/s)

$f_i=(V_t/(A_p*l_s))*100$

V_t= volume of metal ladled in to shot sleeve (cm^3).

l_s= length of the shot sleeve between the face of the plunger and face of the Ejector die (cm)

A_p=shot plunger area (cm^2)

Plunger Velocity, (V_p)

$(V_p)= (V_p)= (Q_{th}X\ 4)/(\prod X$
$d_p^2X0.01)/100 = 0.64$ m/s

OVERFLOWS:
Design Considerations

- Depth of overflow must not be great, as the solidification will take time leading to increase cycle time.
- Overflow should be so provided that heat will enter the appropriate area of the die.
- Shape should be such that it can be easily cut into the steel.
- Generous radii to be provided at the bottom / corners of the overflow.
- Each overflow should have one ejector pin & the pin is cut short so a cylindrical lug is cast over it. This lug ensures that the overflow will be ejected straight for the first 6 mm. (Fig. No: 8.3.2)
- Better to have series of small overflow than one long overflow.
- If the metal flow a long distance, the overflow size should be enlarged.
- Overflow should be sized according to the vol. of cavity from which the overflow receives the molten metal.
- Thickness of segment Cavity Fill Time Overflow

IV. AIR VENTS:

Vents /Air passages lead out of overflows in certain castings or directly from the edge of the castings.

Design Considerations

- Metal flow paths should be such that die vents should be the last area to be filled with molten metal during the fill time.
- Total vent cross section should be minimum 50% of the gate area.
- Depth of vents at die inserts should be 0.25- 0.3 mm.
- Ejector Pins are used for venting by grinding flats on sides
- It should be between (0.05-0.15) at the end of die half or after a distance of (1.5 – 0.2) from the cavity edge.

Venting analysis using *Die Edifice* Software provides information regarding the total volume of air that needs to be vented from the die based on casting, material properties & no. of casting present. Depending on this volume and the parameters (% of vents open, depth of vents, temperature in the cavity, factor of venting, initial pressure of air& max. pressure permissible) established in the settings.

it calculates the dimensions of the vents & the velocity of air being vented.

V. EJECTION SYSTEM DESIGN

Casting contract on solidification. It results in forces of shrinkage & contraction, which must be overcome when the casting is ejected

To avoid damage of surface & to decrease the ejection forces the die-casting must be designed with some tapers/drafts.

Design Considerations

- Ejection Force = *f* (alloy, core size, draft on core, center distance between cores, chill time, gate velocity, injection pressure)
- Ejection Force is directly proportional to chill time, Injection pressure& gate velocity
- Ejection Force is inversely proportional to Iron content.
- Amount of draft depends on the arrangements of die cast part in the die.

Other factors are

- Shape
- Die Casting Alloy
- Area of contracting surface
- Wall thickness
- Depth (T) of the core surface. (Most important)
- Taper (N) is expressed as percentage of depth of the core surface

$N = (K_t/100)*T + (Kb/100)*B$
B = width of the core
For Aluminum
Draft for outer surfaces in % of T (Kt) = 0.2-0.5
Draft for inner surfaces in % of T (Kt) = 0.5
Draft widthwise (Kb)= 0.2

Oil based release agents decrease the compared to water based lubricants because

- Wet ability of oil to water is better.
- Cooling capacity of oil is less than water base lubricants.

Design Considerations

- An ejector pin is provided directly behind all limited draft areas.
- Uniform pattern of ejection points is provided.
- Provide at least one ejector for each overflow.
- Avoid ejector pins over moving cores.
- Avoid ejector pin in line with cover die cavity / features that are fragile or that will form hardware quality surface finishes on the casting.
- Ejector Pins mark (protrusion/ depression) <=0.4 mm & should be given where acceptable. (Fig. No: 8.31)
- Sometimes holes formed in the casting by circular core pins have min. draft & create ejection problems. In this Sleeve ejector provides a uniform ejection around the core pin. [6]

VI. EJECTOR PLATE TRAVEL DESIGN CONSIDERATIONS

- Stops should be used to establish proper spacing. Without it entire surface contact will be there which may stick due to grease /oil. Also foreign material would prevent the die from seating properly.
- Flat parts require 6 mm. (Twice to it is very common)
- Deep / min. drafted castings require more.
- 25-38 mm on dies for manual casting removal.
- Extra travel carries the cast shot out from the various contours.
- Dies built for automatic casting removal will require more ejector pin travel.
- Travel of ejector plate is limited by positive stops.
- Backstops located behind the Ejector Plate in direct line with the Return pins will ensure plate stops in correct position.
- There should be a backstop for each Return Pin.
- Diameter of Back Stop similar to Return Pin & height sufficient to provide clearance to the cap screws.
- Forward position of the Ejector Plate is limited by Forward Stops. Forward stops should be placed in line with the Bumper Pins & its diameter. Height of forward stops must be in accordance with he desired plate travel. [5](Fig. No: 8.3.1, 8.3.2,8.3.3)

Thermal Work Determination

Liquid metal loses its heat & metal shrinks during solidification. Heat loss occurs through the die features & though the evaporating waters which is applied as medium for the die coat. If the rate of heat flow is too fast it will result in cold shuts & chill marks. If it is too slow it will extend the cycle time of the die reducing productivity. Long cycle times if operate early may also cause

- Ejection problems
- Hot cracking
- Ejection pin may push through the liquid metal & the casting may explode
- Cause the metal to stick to the surface of the die

Relative rates of heat transfer is very important

During this stage metal having more heat content behave as riser feeding the metal of the shrunk portion, leading to porosity. Pressure is applied to the molten metal with Machine Injection Plunger to force liquid metal from the biscuit/runner area into such voids as they develop. But if the area of rapid solidification is between the plunger & the liquid metal it results in blockage leading to void & porosity.

- Shape of uniform thickness casting can influence the solidification pattern due to the restricted/unrestricted areas of heat flow.
- Core in heavy sections will cause large voids adjacent to the cores.
- Die should be designed to remove heat from the heavy section at faster rates than from thin section surroundings.

- It is required to balance these influence of various heat inputs & heat flow restrictions.

Basic Heat Content Of Sections

Qj = R*Vj*[(Ti-Te) (Cp)+L]
Qj = rate at which the basic heat content of thermal section j is put into the die (watts)
Vj = volume of thermal section (mm^3)
Ti = injection temperature of the casting. (^oC)
Te = ejection temperature of the casting. (^oC)
Cp = specific heat of the alloy being cast
L = Latent heat of the alloy being cast (Joules/mm^3)

R = casting rate (cycles/sec)
Again

Q = Qj - (R*Aj*Aw)
Q = rate of thermal work to be processed by internal features of the die
Aj = cavity surface area of section j (mm^2)

Aw = heat removed by water spray (Joules/(shot*mm^2)
An expected heat loss to evaporation is subtracted from basic heat content of the die.
Only after this die cooling mechanism is worked out. Cooling the die, or part of it with surface water evaporation can shorten the effective die life of the material.
Heat loss by water to evaporation amount of water is determined.
If water is more, it will bounce without much heat. The water that leaves as steam carries 2475 KJ/Liter. Approximately water supply will remove 4.9 J/mm^2 per shot

Procedure

- The runners, casting, overflows must be divided into thermal sections.
- Then the basic heat content is computed for each section.
- Heat to be removed by the water spray is deducted from the total thermal work to determine the heat that will be processed through the die. Diagram

is prepared showing how the water is applied

VII. THERMAL CONTROL FEATURES

Input of heat to the die is intermittent. Each time a shot is made a load of heat is transferred to the die .Die must process that load of heat before the next load arrives.
Waterlines are the drilled hole through which cooling water is pumped is the primary thermal control feature in the die. It is dynamic control as the flow rate can be adjusted.

Waterline Location

Amount of heat that must enter any particular section can be computed.
Heat moves from higher temp. to lower temp.
$(T_c - T_d)/d = Q_j/(k*A)$
where
T_c = average cavity surface temp (^oC)
T_d = Interior die temperature (^oC)
D = distance from cavity surface to Td (mm)
Q_j = rate at which the heat must flow through the j zone of the die (watts)
K = thermal conductivity
A = cavity surface area of j zone (mm^2)
Also
$Qj = hc*A*(T_d-T_w)$
A = area of water line
Td = temperature of die around waterline
Tw = temperature of water flowing through the waterline. hc = heat transfer coefficient W/(m^2* C)
Minimum distance between water lines & other features of the die
All dimensions are in mm

VIII. CONCLUSIONS

- 3D Modeling of Aluminium castings and verified of model with customer model by Inspection report.
- General approach through out the work was to take up a system its element, its purpose; design considerations followed by design calculations& recommended values for the E6 UPPER BODY.
- The use o PQ^2 Graph allows us to calculate the various parameters with in the process limit.
- Die design of E6 UPPER BODY involves changing the orientation of component in die, so that forces acting on side cores are distributed.

IX. REFERENCES

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