COMPUTER AIDED FEEDING SYSTEM DESIGN FOR PRESSURE DIECASTING

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ABSTRACT

An important factor for obtaining defect free pressure diecast parts is good design of the feeding system. Feeding system is a path of flow of molten alloy during filling of casting. In this project a systematic approach has been developed to design feeding system for pressure diecasting die. This involved studying current design practices in the industry and translating this into a knowledge base of rules for machine selection, design of gate, gaterunner, runner, overflows and airvents. The designed feeding system is evaluated in terms of criteria such as filling, air entrapment, power utilization, yield, and fettling. The entire approach has been implemented in a windows based program using visual C++.

It has been successfully tested on industrial case study. It is perhaps the first attempt of its kind in the area of pressure diecasting die design, and is expected to be of significant interest and value to the industry.

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1 INTRODUCTION

Pressure diecasting is the process in which the molten metal is forced with high pressure into the cavity of a steel mould called die. Pressure diecasting is the fastest and most economical way to produce a net shape component out of raw material.

Pressure diecasting industry has developed enormously during the past two decades owing to the numerous advantages it offers in comparison with other casting processes:

1. Thin wall castings with high tensile strength and less material wastage, resulting in low material cost.
2. Mass production on fast running machines reduces the manufacturing cost.
3. Intricate castings can be produced with high dimensional accuracy that consequently reduces or eliminates machining and assembling time of the components.
4. Pressure diecast parts can be obtained with smooth and clean surface finish which are suitable for painting, plating, anodizing, etc.

Nearly all non ferrous metals can be cast by pressure diecasting, the most commonly used alloys are aluminium and zinc.

Pressure diecasting is however a complex process. It requires careful handling of molten metal, proper handling and maintenance of intricate and expensive dies, operating a very complex machine under extremely high pressures, critical temperature of dies and molten metal and special safety considerations.

For the die casting of light or heavy metal alloy, there are three types of machines:

1. Horizontal cold chamber machines.
2. Vertical cold chamber machines.
3. Hot chamber machines.

Pressure diecasting machines, peripheral equipment and alloys have witnessed considerable developments in the last few years. The ever increasing quality demands on the casting by the customer has forced an increase in die quality.

The Pressure diecasting die has four basic functions as follows :

1. Accommodate the molten metal to form in the shape of desired casting.
2. Provide the means for the molten metal to get into the space where it is to be held in the desired shape.
3. Remove heat from the molten metal to solidify the metal.
4. Provide for the removal of solidified casting.

The most obvious feature of a diecasting die is that it consists of two die blocks that close against each other. All the components and features of the die are machined into those blocks. Die design is discussed in the next section.

1.1 Die design

The die is split into two halves, the fixed die which is mounted on the stationary platen of the diecasting machine, and the moving die which is mounted on the moving platen of the diecasting machine (Fig. 1).

The ejection arrangement is assembled with the moving die, and consist of one ejector housing, in which the ejector plate is moving, which is pushed by ejector rods of machine, during the die opening operation.

The die design helps the tool maker to understand what the die should be like when it is finished. The features of the die must control the metal flow, heat flow, the forces applied by the machine, and the molten metal. The die also has features which facilitate identification, storage, handling, maintenance, manufacture, operation, longevity and its compatibility to the machine.

The die design process can be divided into two stages:

Analysis & Design stage.

1.1.1 Analysis stage

The decisive factors, that dictate the final die concept based on the optimum casting process, quality and die cost are :

1. The component drawing should be considered from the casting point of view for example draft angle and machining allowance.

2. Possible and achievable tolerances should be discussed between the customer and the die maker. Avoid unnecessary close tolerances limits, as it will mean a cost increase and frequently a low production rate.
3. Select the most suitable diecasting alloy for the proposed component, considering the physical properties, cost, and availability.
4. Establish the required monthly or yearly production which will greatly influence the decision of the proposed number of die cavities.
5. Considerations for fast tool loading and unloading on diecasting machine.

It is always advisable to consider the opinion and the requirements of the customer, marketing expert, diecasting engineer, diemaker during the die design phase.

Analysis stage can further be divided into following:

1. Feeding system analysis.
2. Thermal system analysis.
3. Dimensional analysis
4. Force calculations.

1.1.2 Design stage

After the die designer has established all the requirements regarding production quantities, various allowances on casting, required pressure diecasting machine based on analysis stages, the actual die design work can be started. The die designer’s objective is to design dies which will give sound casting, operate at optimum shot rate, and be of reasonably simple construction.

Design stage consists of:

1. Casting to die orientation.
2. Parting line geometry.
3. Feeding system design.
4. Thermal system design.
5. Mechanical constructions within the cavity blocks.
6. Cavity blocks and alignment systems.
7. Material selection for various parts in die.

In the following section pressure diecasting feeding system is discussed.

1.2 Feeding system

The feeding system of a diecasting die consists of a series of passages through which the molten metal can flow into the die and then through the interior of the die to fill the cavity. The molten metal is pushed into the feeding system from outside the die by a plunger.

The cold chamber diecasting machine usually has that plunger mounted horizontally in a thick tube called the shot sleeve. The plunger pushes the molten metal directly into the parting surfaces of the die. Any excess metal remains in the end of shot sleeve between the plunger and the parting surface of the ejector die half is called the biscuit. The biscuit and other parts of the feeding system solidify as integral parts of the casting and are removed from the die with the casting.

Once the molten metal reaches the parting surface of the die it is conducted towards the cavity through channels called runners. The runners are usually trapezoidal in cross section. There may be more than one runner radiating from the biscuit, and any one runner may split into two or more as required to direct the molten metal to various places. As the runner approaches the cavity it blends from trapezoidal shape into a slit like opening into the cavity. The blended portion is called the gaterunner and the slit like opening into the cavity is called the gate. It is usually necessary to allow the gases in the cavity to be pushed out by in rushing molten metal and to allow some of the molten metal to flow through and on out of the cavity. Such a flow through action flushes out the undesirable materials so only proper metal remains in the cavity. To facilitate the flushing action, chambers called overflows are provided outside of the cavity opposite the gate. These features make up the feeding system. In addition to this thin spaces called vents can be provided between the mating die halves that form channels from the overflow or cavity to the outside of the die. These vents allow gases to escape, but are so thin that the metal being cast freezes before reaching the edge of the die (Fig. 2).

The basic function of the feeding system is to provide a system of passageways for the molten metal to flow through to get into the cavity. Once in the cavity, the metal will solidify into the desired casting. Objective of feeding system analysis is to achieve constant cavity fill time. The cavity fill time is influenced in the first place by the optimum setting of the die casting machine’s shot end parameters and by the size, shape and position of various components of the feeding system.

The volume of the casting must be determined before any of the gating calculations are made. The volume must also be known for the cost estimation and the heat flow analysis. But before the volume is computed the first step is to analyze the component and determine where it should be gated, to provide the quality and finish dimensional stability.

The next chapter of literature survey details about study carried out for diecasting die design practices.

2 LITERATURE REVIEW

In this chapter, a detailed study of diecasting die design practices is included, based on both literature and industry sources.

Feed system is a path, through which the molten metal is forced into cavity. The configuration and dimensioning of feed system must be so that the flow is with least resistance and without whirling. There is a wide range of literature and papers about investigation and research work on this subject from various scientists and experts, the mention of which is made in the references. The position, size and shape of the feed system components are the most important factors to obtain a casting of high quality, particularly in respect of surface finish and structural soundness. Since the castings differ widely in size and shape, the feed system design has to be done on case to case basis.

Till now, no equation has been developed successfully, on which basis the size of feed system design can be decided. Years of experience and records of past performance have been the basis in the development of certain rules which are till date generally followed. However, it is quite common that for intricate component designs, more than one of the rules mentioned hereunder might be applicable, which are often contradictory.

Considering this fact, it is essential for the die designer to keep all possible difficulties in mind which may occur, and decide on a design with the possibility to alter later if so required. Following points should be followed for designing feed system [1].

1. Preferably only one gate should be provided. In case of more gates, care should be taken that the individual metal streams entering the cavity do not interfere.
2. The cavity should be filled from one direction to another, to avoid incoming stream getting divides into several jets.
3. It is preferable, specially on large castings, to provide the gating point on casting periphery, which will shorten the distance, the metal has to travel through the cavity.

4. Care should be taken while deciding the place and direction of gates, so that no air pockets can develop during the filling period.
5. On a correct directed gate, the metal entering the cavity should push the air to the air vents.
6. On thin walled castings the best surface finish can be obtained generally with thin gate and high injection speed.
7. On thick walled components, sound and pressure tight castings can be obtained only with thick gate, slow injection speed, but high pressure.
8. The metal stream should fill the cavity with the least possible obstruction, i.e. direct hitting on cores should be avoided as far as possible. The gate location should be so arranged that easy breaking of gate is ensured without breaking corners of casting. At the same time they should be on places where no extra machining will be necessary to remove the marks.

   Theory of cavity filling helps to understand feeding in diecasting die.

2.1 Theory of cavity filling

The filling of the die cavity can be roughly classified in the main groups as free jet filling, mass flow filling and a mixed system of free jet and mass flow. Free jet filling represents the most ideal form of cavity filling, in which the free jet of metal can traverse the entire cavity without resistance. So the cavity is gradually filled from the back (Fig. 3).

Since most die castings have an extremely complicated configuration, it is seldom possible to lead the metal jet so that it can get across to the opposite side unhindered. In most cases it hits an obstruction after a short distance, for instance a slide or core, so that the free jet is totally destroyed. So the die cavity is then filled according to the principle of mass flow. Obviously there is a relation between the gate thickness and the adjoining wall thickness. In order to attain a jet fill, a ratio of 1:2 to 1:3 is necessary between gate thickness and wall thickness. For thin parts this ratio can hardly be kept, so that also here we shall have to do with a mass flow filling.

The jet fill, which is the ideal condition, occurs rather seldom in practice. Very often a mixed system which is a combination of jet fill and mass flow fill takes place. In order to have better control over the mass flow fill most experienced diecasters tend to lead the metal flow into a corner so that the filling of the cavity remains clearly under control [2].

For the fishtail runner the angle of diffusion should not be more than 30 percent since otherwise a flow shadow will be formed in the runner (Fig. 4). The multiple gates was popular for a long time. At the convergence of runner and distributor channel there is a sudden widening, which causes reduction of the flow velocity. This is a reason why now days the multiple gates are not used [3]. Following steps are normally followed for designing feed system for pressure diecasting die –

1. Planning flow path.
2. Computing filling time.
3. Selecting gate velocity.
4. Establishing gate thickness.
5. Determining gate area and its dimensions.
6. Calculating runner dimensions.
7. Finalizing airvents and overflows.

2.2 Planning flow path

The first step in planning a feed system for a diecasting die is to decide how the metal should flow through the cavity. The designer must determine how he wants the metal to flow. Then much of the subsequent design of the gating system is a matter of contriving or inventing geometry's and sizes of the elements in the feed system to cause the desired filling pattern to actually happen.

The planning of the flow paths is the most critical of all the steps since that is where the designer establishes the philosophy of the gating system [4]. The designer must divide the casting into regions. Each region will be filled by a single gate. There is no mathematical equation or procedure for the process of dividing the casting into those regions.

The designer must visualize how each part of the casting would be filled with each type of gaterunner.

Gaterunner are of two types –

1. Fan type.
2. The tangential type.

Both the fan and tangential gate runners match the runner where they connect to it. The fan gate runner becomes thinner and wider as it gets closer to the cavity until it is as wide as the gate is long and as deep as the gate. Usually the depth is changed proportionally with distance, but that is not a requirement. Sometimes it is desirable to have the sides of the fan gate runner be straight lines in the plan view and the depth adjusted to get the cross sectional areas required. Because of the shape of the fan gate runner the molten metal flow is spread out such that the flow streams are diverging as they enter the cavity as indicated by the arrows (Fig. 5). The flow is not in parallel streams and the flow is not perpendicular to the edge of the cavity. Both of these conditions (i.e. parallelism and perpendicularity) were assumed above for ideal flow patterns.

The tangential gate runner carries the flow of molten metal along the edge of the cavity as shown by the arrows (Fig. 6). As the metal travels along the edge of the cavity it passes sideways through the gate into the cavity. The result is the metal can be made to enter the cavity in parallel flow streams, but those flow streams will not be perpendicular to the edge of the cavity. Because the flow of the molten metal entering the cavity is not perpendicular to the edge of the cavity, and in some instances will not even be in parallel flow streams, a gate does not necessarily fill that part of the cavity that is straight across from the gate [5]. There is nothing bad about such behavior, but it must be recognized by the designer and manipulated to his advantage.

The angle between the actual flow direction and a line perpendicular to the edge of the cavity is the flow angle (Fig. 7). In general flow angles between 30 and 40 degrees work out best. Smaller flow angles result in large runners and flow angles over 45 degrees may not even be possible.

If some portion of a casting approximates the shape of a parallelogram it can probably be filled best with a tangential gate runner, and if the region of the casting is shaped more like a trapezoid then a fan gate runner is likely to be best. Usually tangential and fan gate runners are used in combination. A fan gate runner is positioned to feed the center part of the casting and a tangential gate runner is placed along each end. The center of casting is arbitrarily defined as a trapezoid and the two ends as parallelograms.

Although each casting component has got its own shape, certain characteristic forms can be found on most parts. Some of the most common forms with its best suitable gating are explained as following:

2.2.1 Rectangular casting

Most of the industrial components are more or less classified into rectangular shape [6]. We will analysis eight different shapes and gating layout for same casting (Fig. 8). In the example A and B, the metal flows initially in the runner to one end, from where it fills the cavity. The gating in this case is indirect, but will work satisfactorily. The main disadvantage is, that the metal temperature will have to be increased in order to maintain the required casting temperature by the time it reaches the other end of the cavity. This can be improved to a certain extent if big dimensioned overflows are provided on the opposite gating side, to increase the die temperature on that area.

The example C will have the same problem as A and B with respect of the temperature. One advantage however will be, that the metal enters the cavity parallel to the main axis of the casting and might therefore develop less whirls and turbulence. The examples D and E are likewise A and B gated from one end, but with the filling direction of the cavity. For a casting with thicker section the variation E should be given preference, since the metal will flow more turbulence free and slower, this gives air a better chance to escape.

For thin walled castings where thinner and longer gating and quick filling give better surface finish, the variation D is more desirable. F, G and H show the gating from the middle of the casting. Both F and H are not favorable as on F the metal flows first to both ends and meets last in the center. Trapped air and flow marks cannot be avoided. Overflows as shown are absolutely necessary. The disadvantage of the gating type H is same as that of F. The gating example G will give about the same performance as type E, and is preferably used when the rectangular casting is very long. However the best selection of the gating explained above for castings are D, E or G.

2.2.2 Round casting

Another major class of components generally used in industry are round or circular. Round castings require generally a different gating than rectangular components (Fig. 9). The tangential gating A should be avoided, since the metal injected with high velocity will forcibly fill initially the outside ring and thereby close the airvents on the parting line, before the casting is filled. Similarly, on example B the outside ring will be filled first and therefore the air remains trapped in the center of the casting.

The gating B can work satisfactorily if the component is a flat cover. Gating C and D will work satisfactorily and should be adopted on all round and deep castings. The gating ends, pointing to the center of the casting, will force the metal to flow concentrated to the center, and push the air to the parting surface. Gating C and D are in principle the same, except that in C the metal flowing from the sprue enters the cavity directly. Whereas for D the runner will be filled first and the metal will enter the cavity at the same time on all points of the gating length. This will enable to control the direction of flow better, which is a specific advantage on unsymmetrical components.

(Fig. 10) illustrates how the metal is supposed to flow in a deep casting. The metal. concentrated to the center, is forced to flow along the center core to the deepest point of the cavity and pushes the air from point x to the parting surface, where airvents can be provided.

2.2.3 Pipe shaped castings

Castings like valves, tubes, nozzles, etc. or any other parts with similar shape are mostly gated with ring runner (Fig. 11). The specific advantage is that the metal flows along the core into the cavity instead of hitting the core in right angle. Hence better filling and less soldering. The disadvantage of this gating design is, that it cannot be broken from the casting and requires cutting saw. Further the stroke of the cores increases, consequently the size of the die.

It is a very common about industrial components that wall thickness on castings vary considerably. The decision whether the gating point should be made on the thicker or thinner section, requires lot of experience. Following points should be considered before taking decision.

1. Gating on thin section – The metal flows first through the thinner section and cools down on the die walls. Hence the thick section receives cooler metal and unnecessary overheating can be avoided to a certain extent. The thin section will be filled last with hot metal. Therefore, preferable when more importance is to be given for the thinner section.
2. Gating on thick section – The thick section is filled first, out of which the thin section will be fed. The thin section solidifies first and during that period it will stay under pressure of the liquid alloy in the thick section. Due to metal passing initially through the heavy section of the casting, its velocity drops and results in bad surface finish on thin section. Therefore, preferable if more importance is to be given for the heavy section of the casting.

Deep cavities should not be gated (Fig. 12) as, the metal will hit directly on the core and will disperse. Poor filling and soldering on the core will be the result. Gating as per C and D ensures good filling. Gating should be done as per B and C when machining is done on the bottom, whereas it has to be done as per D when machining is done on the side of the casting, C will improve the metal flow, for its better change of direction.

2.3 Cavity fill time

Computing the cavity fill time is the first step in the gating system design procedure. Filling time is the time from when the molten metal arrives at the gate untill the cavity and overflows are completely filled. Die casting die cavities are typically filled with molten metal in 0.02 to 0.08 seconds. Subsequent packing (feeding shrinkage) is not considered as part of the filling time. The cavity filling time is the critical objective that the gating system geometry and machine operating parameters are designed to meet. Shorter filling times generally require larger gates, larger runners and fast plunger speeds than do longer filling times [4].

The filling time is computed from following equation –

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

where : t = cavity filling time sec

K = empirically derived constant (sec / mm)

T = casting thickness (mm)

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

T_f = Minimum flow temperature (deg C)

T_d = Temperature of die cavity surface (deg C)

S = percent solid fraction allowable in the metal at the end of filling

Z = units conversion factor (C deg. / %)

Typical values for k, T_i, T_f, T_d and Z are given in Table1 refer Appendix 1.

The sizes of the gates and runners will be based on the calculated ideal cavity filling time. The above equation shows that if the die is operated differently, it should have a different filling time. So, once the die is built with gates and runners sized for a specific filling time (and machine power availability), it must be operated at the conditions to which the cavity filling time was calculated. It is critically important that the holding furnace temperature and die temperature assumed for the gating equation be communicated to the operator of the die casting machine. If the die is operated with different conditions for the critical variables, the gating system will not perform correctly. These temperatures and the percent solids factor, S are also critical to the die design. The thermal control features are designed into the die to accommodate the exact resulting heat input.

2.4 Gate

Gate is the opening through which molten metal enters the cavity. It is most important component of feed system design. The dimensions of gate (gate thickness and gate width), gate position and gate velocity are most critical variables from filling point of view of casting. As improper design of any of them can result in failure of die [7].

2.4.1 Gate velocity

The gate velocity is the speed at which the molten metal moves through the gate. It is of crucial essence that the cavity filling takes place with a flow

into the cavity, free of whirling. In order to avoid discontinuity, the flow velocity of the metal in the runners must be constant or slightly accelerated up to gate [8]. The velocity of molten alloy through the gate depends on -

1. The energy of the machine.
2. The pressure losses in the total flow system, including the gate.
3. The type of runner and gate.

Because of the multitude and variety of castings in their form, use and required alloys, the values for gate velocity can be taken only from such tables as have been set up from individual experience or from those that have been published.

Recommendations for gate velocities are given in Table 2 refer Appendix 1.

2.4.2 Gate area

Gate area is always used to mean the cross sectional area through which the molten metal must flow as it passes through the gate. Gate area is calculated based on casting volume to be filled with required fill rate. For calculation of gate area there is a equation, of L.Frommer as given below-

Gate area (Ga) = W / (g x t x Gv)

Where : W = weight of casting inclusive of overflows (gms)
g = specific weight of the alloy
t = cavity fill time (sec)
Gv = gate velocity in cm / sec

2.4.3 Gate thickness

It is always advisable to start on a new die with a thinner gate thickness since it is easy to increase, if require. Reducing thickness of gates requires welding or closing with new insert and rework again. The gating section depends on the volume of the casting. Hence the thin gate are to be made longer than thick gate for castings of same weight and alloy [9].

The high injection pressure provided on the diecasting machines will only serve the purpose if the molten metal remains liquid even in the gate, for a split second after the cavity is completely filled. This fact should be remembered whenever homogeneous and leak proof castings are required. As thicker the gate, as longer and more intensive the high injection pressure will act. A thin gate will act as a jet and will lead the molten metal more concentrated and with higher velocity into the cavity. This is in principle desirable for thin walled castings since they have to be filled quickly and the material entering the cavity should not divide into various paths. Otherwise rapid cooling of the alloy on the die walls will result in distant flow marks [10]. The Table below gives advantageous and disadvantageous of thin and thick gates.

	Advantages	Disadvantages
Thick gate	Sound casting Pressure tight Longer die life	Difficult in breaking More flow marks specially on thin walled castings.
Thin gate	Better surface finish Better control for direction of flow	More shrinkage defects and porosity More soldering Shorter die life

After comparing the advantages and disadvantages of thick and thin gates, it is clear that often compromise is required to be done as per application.

Recommendations for gate thickness for different alloys are given in Table3 refer Appendix 1.

2.4.4 Gate width

Once the gate thickness is decided, calculation of gate width is gate area divided by gate thickness. Care has to be taken as higher gate width will cause fettling problem. Balance is required to be struck between gate thickness and gate width.

2.5 Runner

The runner is channel which leads the metal from the sprue bush to the gate. It is generally machined in one die half. It should have minimum cross-sectional area needed to provide the required metal flow rate [11]. Round, half round and rectangular sections are used, the former is used for small castings. The side walls of runners should be machined in an angle of 3 to 5 degree to facilitate ejection of same (Fig. 13). The runner’s side next to gate has a definite angle, which is called approach.

The approach angle directs the flow of molten metal into the gate. It can also create heat traps or weak die areas, therefore it must be planned properly. The approach of the runner establishes the gate land . Land tend to degrade the quality of the metal flowing over them, so the land should be as small as possible. The land is subjected to die shift variation and must be larger than the amount of shift expected. When starting from the calculated gating the following empirical values apply for obtaining dimensions of runners for horizontal cold chamber machines.

The relation gate area to runner area = 1 : 3 to 1 : 4. The relation gate thickness to runner thickness = 1 : 5 to 1 : 8. For thick wall castings the runner should be taken a little thicker (approx. 20 to 30 %).

The runner should be polished as good as the cavity. Runners should be designed short and straight to the cavity whenever possible. Long runners will result in undesirable loss of metal temperature and overheating of die on the gating area. Abrupt change in direction should be avoided as it tends to develop turbulence. However, there can be instances, where additional local heating in some parts of the die is desirable, and the provision of blind runner improves the performance (Fig. 14).

Whether runners are to be provided in the fix or moving plate of the die depends on the direction of gating. If no particular reason necessitates to machine in either plate, then the side should be selected where water cooling can be provided conveniently.

Runners for multi cavity dies should be properly designed, so that a balanced flow is obtained and all cavities are filled at same time. Same also applies for design of runners for multiple gating on a large casting. Here precaution is to be taken so as to avoid separation or loss in velocity of flow, while metal flowing from main runner into branch runners [12].

2.6 Overflows

Overflows are small pockets cut into dieblocks on opposite ends of gating (Fig. 15). Trapped air and gas in the metal in the form of bubbles can often only escape from the casting through overflow. Excess of lubrication and other impurities are also separated in the same way. The overflows are determined according to empiric values of 1/3 to 1/5 of the cast volume. The depth of overflow should be about 3 times the section of casting and the width about double of the depth. The overflows are machined close to cavity, approximately 3 to 6 mm and their gating thickness between 0.5 to 1.5 mm depending on casting section. A properly placed overflow can improve to join two metal streams, since metal can then flow through the cavity. Further voluminous overflows are often provided to heat up die inserts whenever required.

2.7 Airvents

The importance of airvents is often underestimated [13]. The air in sleeve, runner and cavity has to be pushed out by the molten metal entering the die. The air escapes through specially provided vents on the inserts or cores. The position of airvents should always be on places where the metal fills the cavity last. The dimensioning and the location of vents have a direct relationship with the calculated gate area. For the die venting not only the volume of air from the cavity is deciding, but also that of the runner system and the remaining volume of air of the filling sleeve of horizontal machines after plunger has closed off the filling hole. In addition to this volume of air come the gases from the lubricants of the die and filling sleeve. Calculation of venting system becomes diffcult, since there are so many widely differing factors that play a role.

Since it is often very difficult to predict metal flow, airvents are commonly provided after the first trial when the flow of metal is known. The area of vent channels should be 1/3 to 2/3 of the gate area. In most cases it is sufficient to grind airvents in one of the plates on the parting surface. The depth will be 0.1 to max. 0.15 mm. If airvents proves to be insufficient they should never be increased in depth but in width, or otherwise additional air vents should be provided. Usually the vents are connected with the overflows which are so shaped that the vents remain open for as long as possible. Airvents on parting surface can be easily cleaned after opening of die.

On deep and intricate cavities, air vents on parting surface alone, are often not sufficient. Venting can be provided on fixed cores, between joints of inserts and along moving cores. Even along ejector pins with minimum clearance of 0.02 mm some air can escape. As bigger the volume of the cavity, more venting is to be provided. Only a perfect venting system can ensure a sound and homogeneous casting.

In the next section we will discuss about flow simulation for diecasting process.

2.8 Flow simulation

The application of flow simulation analysis in the die design is gradually gaining popularity. The main idea is to analysis and predict the occurrence of casting defects under a specific design, by systematic evaluation of the design with computer simulation software, it can reduce the number of trials and errors and subsequently shorten the lead time. Moreover the diecasting engineer can gain better understanding of the diecasting process [14].

The analysis of fluid flow phenomena during filling is a very important from point of view of die designer, since diecasting are most troubled by gas entrapment related defects, which are believed to be caused by improper filling. By knowing the flow pattern of the molten metal in the die cavity and in the feeding system, the appropriateness of the of the feed system and the filling operation can be evaluated [15].

To simulate the flow phenomena for the filling of the casting is basically to calculate the flow pattern, the velocity profile, the evolution of the molten metal domain and the filling sequence. Filling simulation is used basically as an appropriate numerical technique for the solution of the differential equations that govern the fluid flow phenomena during die filling process. Therefore the first step is to create the geometry of the casting along with feeding system in the computer. Some simplification or approximation may have to be made. Then created casting geometry is divided into a number of sub domains, called cells. This procedure is commonly known as the preprocessing step, it is done by the computer as per users accuracy requirement. Then the actual calculations are carried out by the software. As the calculations are completed, the computed results such as the flow pattern and the velocity profile can be displayed on the computer. This procedure is commonly known as the post processing step.

There are many commercial software packages available in market which do the above operations. Table 5 refer Appendix 1 provides a list of such software and their capabilities [16].

2.9 Machine Selection

In designing diecasting die, the first consideration will be determining the required monthly or yearly production numbers, which is a deciding factor in the choice of a single cavity or multi cavity die for producing the casting [17]. It is always desirable to design dies for smallest size machine, with less number of cavities rather than go to large size machines with large number of cavities.

The advantage of making small dies for smaller machines is that the production rate in terms of number of shots per hour is always more in case of smaller size machines, the cost of dies will be less, die mounting will be faster and rejection percentage smaller [18].

Once the number of cavities is decided, following steps are required for selecting the machine size.

1. Definition of specific casting pressure necessary to produce sound casting. Specific casting pressure depends on alloy to be diecasted and application requirements of the casting. The values of specific casting pressure established by the foundry or such as gathered from experience are shown in Table4 refer Appendix 1.
2. Calculation of the projected area for single cavity die and the entire area for multiple cavities die, in order to decide upon the size of the diecasting

machine to be used. The total casting area is calculated from the projected area of all the impressions on the parting line with the addition of 30% for the runner and overflow system.

3. The multiplication of the total projected area (including the area of the runner and overflow system) with the specific casting pressure necessary to produce the part as determined before results in die opening force Fs (Fig. 16).
4. For castings which have mechanically or hydraulically moving cores that form part of the cavity, to be safe the partial force F1 must be subtracted from the locking force F of the machine (Fig. 17). The force Fk is calculated by multiplication of the projected area of the core which forms the part of the cavity area with the specific casting pressure required for the casting. The partial force F1, which must be subtracted from the locking force of the diecasting machine, results from the multiplication of the force Fk acting on the core with the tangential value of the wedge lock. So the die opening force Fs may not exceed the locking force F minus the force F1. Also it is recommendable to include a further reserve in locking force of 10-25%, for high plunger speeds, because of the pressure surges [19] [20].

2.10 Summary of Literature Review

Since the castings differ completely in size and shape, the feeding system has to be exclusively designed for each case. Many factors affect feeding system design. One of the important factor is Planning flow path which is first step and most crucial in designing of feeding system. It is best done with die designer’s experience. Another important factor is deciding cavity filling time which mainly depends on alloy, thickness of casting and percent solid fraction allowable in the metal at the end of filling. As the gate dimensions are calculated other elements are finalized so as to ensure proper filling of casting.

Most of the research focussed on filling simulation. Filling simulation helps to reduce number of trials and errors of feeding system design. Known commercial software for filling and solidification simulation of pressure diecasting do not design feeding system, which is done by die designers experience and his capabilities. It takes lot of iterations for converging to ideal feeding system.

Based on literature survey and experience in industry objectives for the project were laid down. Next chapter deals in problem definition and approach for same.

3 PROBLEM DEFINITION

3.1 Motivation

Feed system design for a pressure diecasting die is most critical calculation in the die design as it is complex and time consuming task. It requires good knowledge of following:

1. Die design
2. Material properties of the diecasting alloy
3. Injection system of the pressure diecasting machine
4. Fluid flow / fluid mechanics
5. Pressure diecasting variables and their interdependability

Various software are available in the market for casting filling and solidification simulation for pressure diecasting, but these software do not do feeding system design as it is part of die design. In that case, feeding system design is done manually, solid model of feeding system is constructed based on manual calculation. Solid model of feeding system is then attached to casting solid model, which then acts as an input for casting filling simulation software.

As feeding system design is based on designers experience and capabilities, it takes lot of iterations for converging to ideal feeding system. This calls for a necessity of a program, which can do automation of feeding system design, and there by reduce number of iterations required for converging to ideal feeding system.

3.2 Objectives & Scope

Objectives is to develop a systematic approach for designing of feeding system for Pressure diecasting, which can then be useful for filling and solidification simulation.

Following objectives are required to be fulfilled –

1. Develop a knowledge based systematic approach for feeding system design for pressure diecasting die.
2. Implement the above approach in a computer program and provide a user interface.

3. Validation of results by testing it on sample industrial castings.

Feeding system design for pressure diecasting mainly depends on type of machine, type of alloy, number of cavities and number of gates. Most of the castings, which require filling simulation are in range of medium to big sizes, which are produced in single cavity die. It has been found that properly designed single gate is sufficient for giving good filling of the medium size.

System will be designed for feeding system of dies working on cold chamber diecasting machine with pressure diecasting of aluminium alloys as 70% of pressure diecasting is done for above. It will be based on feeding system design for single cavity die with single gate.

3.3 Approach

All of the objectives about program were studied and brain storming was done. First list of variables, which affects directly or indirectly pressure diecasting process was made.

List of variables was divided into five basic categories, (Appendix 2) those are as follows:

1. Casting
2. Material
3. Die
4. Diecasting machine
5. Diecasting factor

Based on the literature survey and experience in industry, total procedure for feeding system design was broken into logical steps, where each step was interdependent with previous or next step.

List was made for number of calculations requires to be done for feeding system design. Equations or logic required for each of them was collected and verified. In each step various calculations were clubbed. Flow chart of decided steps was made.

In next chapter we will see in detail about the developed system for program of feeding system design.

4 SYSTEM DESIGN

The objective of the project is to develop a knowledge based systematic approach for feeding system design and implement it in a computer program ***Diecast*** (Fig. 18).

Diecast is designed where total procedure for feeding system design was broken into logical steps, each interdependent with previous or the next step. Equations or logic required for each of them was collected and verified. *Diecast* consist of four modules – Product, Flow design, Feed design and Analysis.

In the product module *Diecast* gets the casting data input either from the user or in the form of text file generated from known 3D CAD system, its flow design module calculates the flow variables for feeding system by help of available material and machine database. Feed design module calculates dimensions for feeding system, where as analysis modules evaluates the calculated feeding system

4.1 Database

It comprises of data required to design feeding system for pressure Diecasting die, which is stored in simple text file format. Database is further subdivided into three subsystems like Product, Material, and Machine.

4.1.1 Product

It holds all the data about the casting required for performing feeding system design. It gets the data either from user through interactive dialog box or through text file generated from known 3D CAD system. It contains all information about casting like name, number, weight, volume, length, width, height, projected area, average thickness, maximum thickness, minimum thickness, surface area, casting alloy, shape and its application. This acts as a primary input for calculation, which can be edited by the user.

4.1.2 Material

It comprises of database which contain all the properties of material which are required for feeding system design. Material properties like name, density, pouring temperature, minimum flow temperature, liquidus temperature, ejection temperature, latent heat, specific heat, coefficient of friction and recommended die temperature are stored (Appendix 3). The material properties are accessed by providing the material name as the input parameter, which is normally selected by the user.

4.1.3 Machine

It comprises of technical specifications about machines which are required for selection of appropriate machine for feeding system design. Specifications for the range of commonly used machines are stored in this database. Typically it has fields like machine tonnage, hydraulic plunger diameter, power, minimum plunger diameter, maximum plunger diameter, plunger diameter steps, stroke, max velocity and offset distances available with machine (Appendix 4). The specified machine is first located in the database and the required specifications are then retrieved.

4.2 Feed system

Feed system consist of different modules which does various calculations required for feeding system design. Following are the different modules present in the feed system – Factors, Flow design, Feed design, Layout, and Analysis.

4.2.1 Factors

It comprises of various empirical factors which are used for calculating different variables of feeding system for Diecasting die. As the factors gets varied from designer to designer and foundry to foundry, they can be edited by the user as per his experience. Typically it holds values of factors for safety, maximum fill ratio, minimum fill ratio, overflow, gate velocity, gate / casting thickness, maximum gate thickness, runner / gate area, runner / gate thickness, venting, solidification.

4.2.2 Flow design

Flow design module is subdivided into two modules machine and filling (Fig. 19). In the machine module, first the opening force required for casting is calculated, then based on the available machine database, machine which will give optimum result is selected. Once machine selection is done plunger diameter required for die is calculated which in turn is checked for its suitability with selected machine. Best plunger location with respect to die center is then decided.

Filling module first calculates filling time for a given casting, then it calculates the fill velocity which will be required for filling the casting in calculated time. Approximate shot weight is calculated for gating calculations.

4.2.3 Feed design

Feed design module calculates all dimensions related to feeding system it also calculates machine settings parameters to get best results. Feed design is subdivided into six modules which are as follows – Gate, Gaterunner, Runner, Venting, Machine settings, and Result.

A) Gate

This module first calculates gate velocity for the feed system. Overflows weight is calculated as per application category of casting. Based on the flow variables, gate area required for feeding system is calculated, correspondingly gate thickness and gate width are calculated.

Plunger velocity for achieving above results is calculated and is checked with machine capability (Fig. 20).

B) Gaterunner

As per the type of gaterunner decided by gate module or from user input, it calculates flow angle and approach angle of metal respect to casting. It then computes dimensions of different cross sections and calculates its relative location with respect to casting (Fig. 20).

C) Runner

Based on the design strategy runner crossection area and its other dimensions like width and thickness are calculated. Velocity of metal in runner is calculated for finding turbulence. Biscuit thickness for feeding system is then decided (Fig. 21).

D) Venting

Venting area is calculated based on application and gate area. Knowing the venting depth venting width is calculated. Venting velocity is calculated which gives some idea about air entrapment (Fig. 21).

E) Machine settings

Based on the dimensions of feeding system and machine selected, process variable settings required to achieve desired results are calculated, for that locking force required, plunger velocity for first and second phase, accumulator pressure, and critical point where first phase to second phase change takes place are calculated (Fig. 22).

F) Result

This module calculates additional variables related to feeding system. It calculates maximum flow path that can be achieved by the designed feed system. It calculates pressure drop in gate, gaterunner and runner elements because of metal flow. It calculates reynolds number in gate, gaterunner and runner cross sections which gives indication about amount of turbulence present. It also calculates rate of heat loss from gate, gaterunner and runner cross sections (Fig. 22).

4.2.4 Layout

This module gives the 2D representation of the designed feeding system based on the dimensions and positional information calculated during feed design module.

4.2.5Analysis

This modules evaluates the designed feeding system and shows performance of same. It evaluates feeding system in terms of filling, air entrapment, yield, machine power utilization and ease of fettling. It gives the final assessment of the designed feeding system as per the weightage provided by the user for above mentioned functions. This gives the user a clear cut picture of the designed feeding system in terms of his requirement (Fig. 23).

4.3 Data Structure

An object oriented data structure is developed for representing the casting and feeding system information. System is grouped into five main groups like Admin, Product, Tooling, Process, Material (Fig. 24). Tooling is subdivided into Machine_data, Die, Feed_system. Feed_system is further subdivided into Machine, Factors, Filling, Gate, Gaterunner, Runner, Overflows, Venting, Results, Analysis. This approach facilitates better abstraction of data and recreation of usable objects. In the next chapter we will see the results obtained from *Diecast*.

5 RESULTS

The *Diecast* is programmed using Visual C++ 5.0 language on Windows NT / 95 operating system. A typical session for *Diecast* is given below.

5.1 Session

1. Click on *Diecast* icon in the windows desktop, the program will display the start-up screen.
2. Click on the database item in the main menu & then on the product, a dialog box appears, where all input data related to casting are to be entered.
3. Click on material & machine to check for valid data, which can be edited to suit user requirements.
4. Click Feed system item in the main menu and then on factors to check for valid values, which user can change from his experience & knowledge.
5. Click on Flow design and then on filling & machine which gives values of flow variables & selected machine data respectively, values in these can be edited by user from his experience.
6. Click on Feed design and then on gate, gaterunner, runner & etc. which gives dimensions & values of various components of feeding system respectively.
7. Click on the layout to get 2D representation of designed feeding system.

   Click on the analysis and then on analysis & weights to study performance of designed feeding system from user requirements.

5.2 Validation

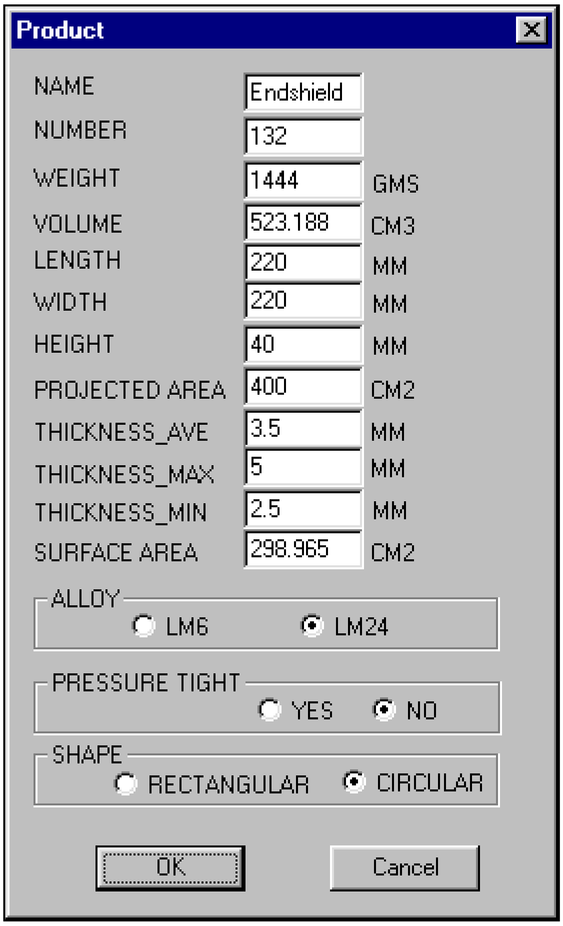
Diecast program developed was checked doing manual calculations for its accuracy. Results of the manual validation carried out are available in Appendix 5.

5.3 Case Studies

Diecast was tested using casting data for two different components having different geometry . Two components were selected such that they have different shape, size and require different type of gating. In the following pages are the photographs of castings ,and results obtained from the *Diecast*.

5.3.1

B.



Product

NAME: Endshield
NUMBER: 132
WEIGHT: 1444 GMS
VOLUME: 523.188 CM3
LENGTH: 220 MM
WIDTH: 220 MM
HEIGHT: 40 MM
PROJECTED AREA: 400 CM2
THICKNESS_AVE: 3.5 MM
THICKNESS_MAX: 5 MM
THICKNESS_MIN: 2.5 MM
SURFACE AREA: 298.965 CM2

ALLOY: ○ LM6 ● LM24
PRESSURE TIGHT: ○ YES ● NO
SHAPE: ○ RECTANGULAR ● CIRCULAR

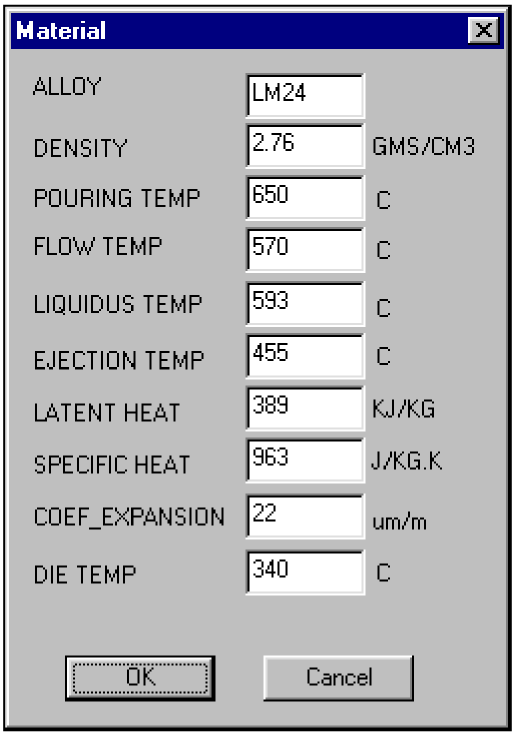
FIGURE 25

ENDSHIELD

25A - PHOTOGRAPH

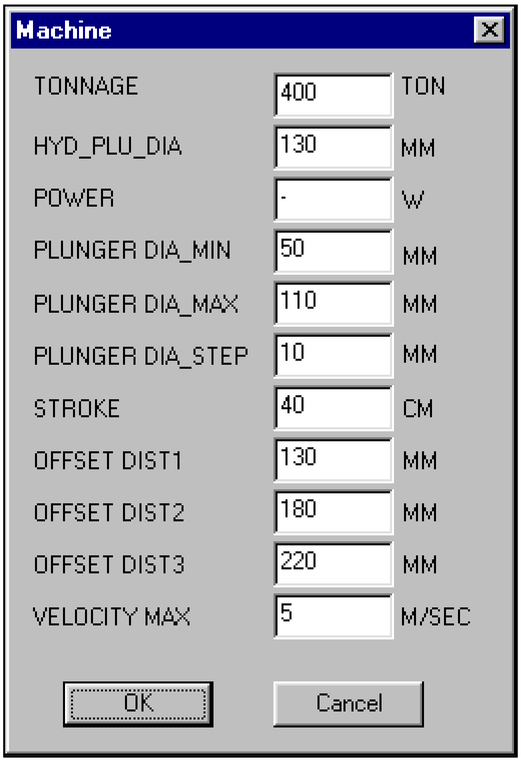
25B - PRODUCT

A.



ALLOY	LM24	
DENSITY	2.76	GMS/CM3
POURING TEMP	650	C
FLOW TEMP	570	C
LIQUIDUS TEMP	593	C
EJECTION TEMP	455	C
LATENT HEAT	389	KJ/KG
SPECIFIC HEAT	963	J/KG.K
COEF_EXPANSION	22	um/m
DIE TEMP	340	C

B.



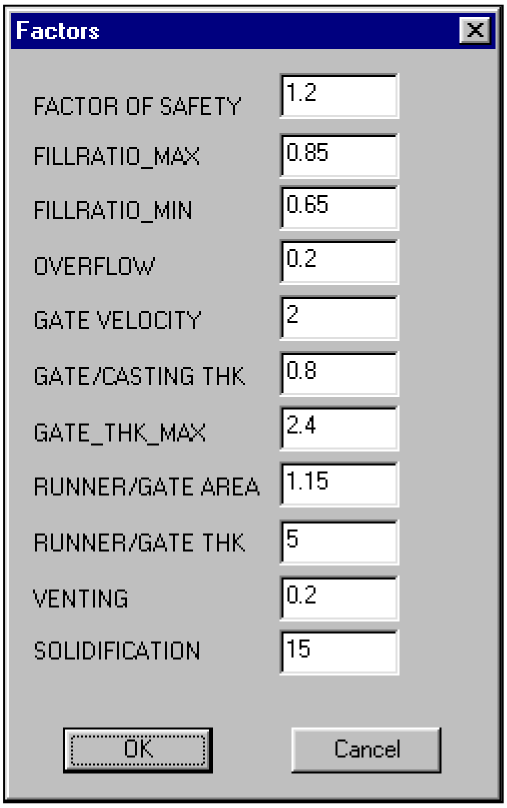
TONNAGE	400	TON
HYD_PLU_DIA	130	MM
POWER	-	W
PLUNGER DIA_MIN	50	MM
PLUNGER DIA_MAX	110	MM
PLUNGER DIA_STEP	10	MM
STROKE	40	CM
OFFSET DIST1	130	MM
OFFSET DIST2	180	MM
OFFSET DIST3	220	MM
VELOCITY MAX	5	M/SEC

FIGURE26

DATABASE FOR ENDSHIELD

26A – MATERIAL
26B - MACHINE

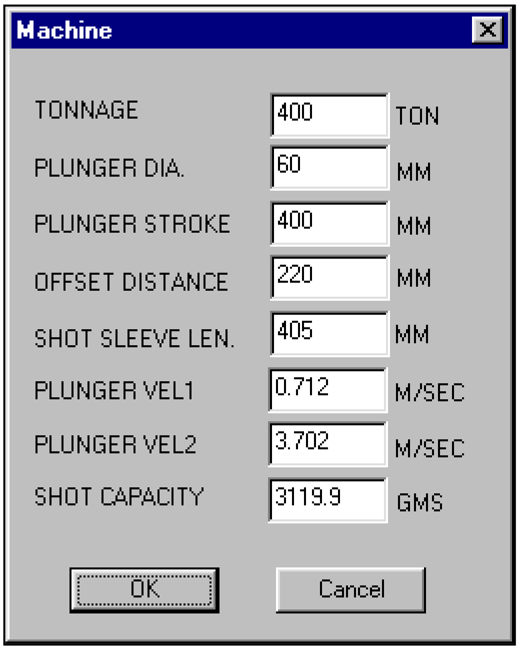
A.



Factors

FACTOR OF SAFETY	1.2
FILLRATIO_MAX	0.85
FILLRATIO_MIN	0.65
OVERFLOW	0.2
GATE VELOCITY	2
GATE/CASTING THK	0.8
GATE_THK_MAX	2.4
RUNNER/GATE AREA	1.15
RUNNER/GATE THK	5
VENTING	0.2
SOLIDIFICATION	15

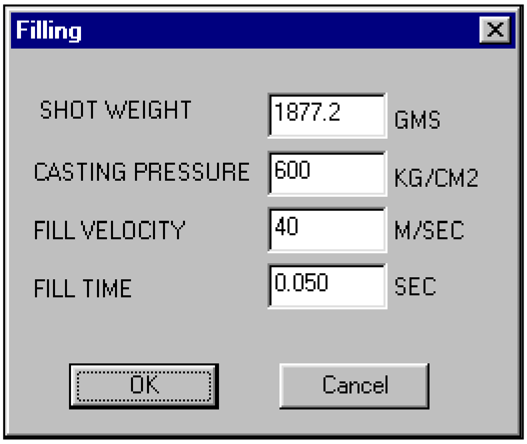
C.



Machine

TONNAGE	400	TON
PLUNGER DIA.	60	MM
PLUNGER STROKE	400	MM
OFFSET DISTANCE	220	MM
SHOT SLEEVE LEN.	405	MM
PLUNGER VEL1	0.712	M/SEC
PLUNGER VEL2	3.702	M/SEC
SHOT CAPACITY	3119.9	GMS

B.



Filling

SHOT WEIGHT	1877.2	GMS
CASTING PRESSURE	600	KG/CM2
FILL VELOCITY	40	M/SEC
FILL TIME	0.050	SEC

FIGURE 27

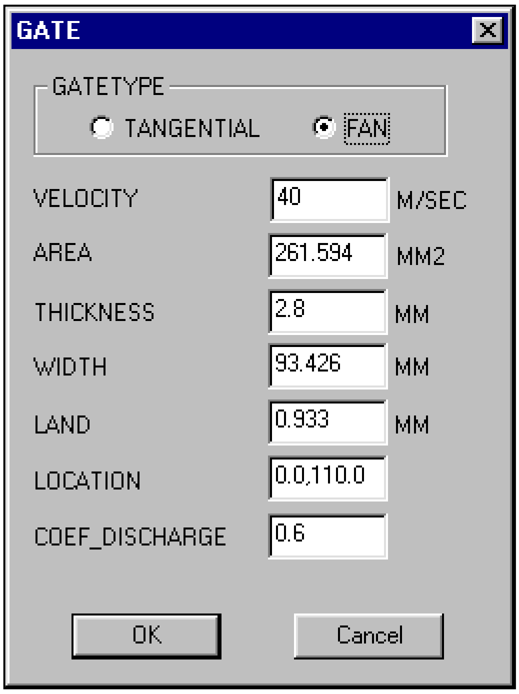
FLOW DESIGN FOR ENDSHIELD

27A - FACTORS

27B - FILLING

27C - MACHINE

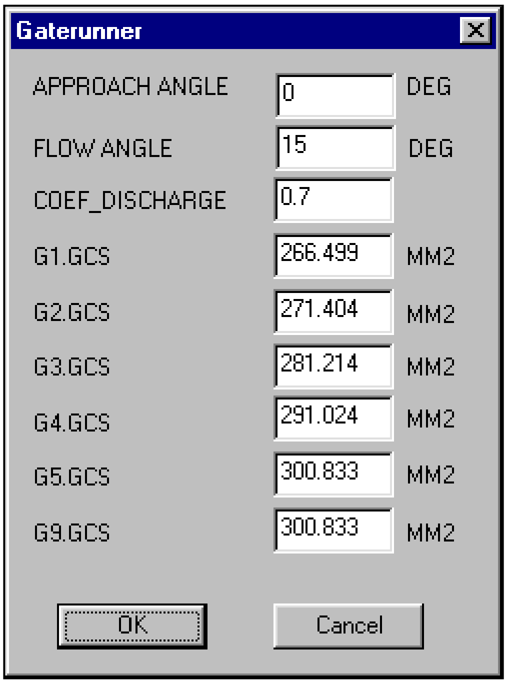
A.


GATE

GATETYPE
○ TANGENTIAL ● FAN

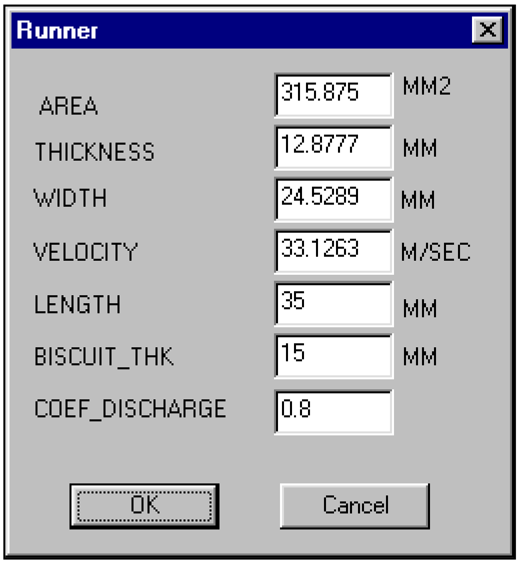
VELOCITY 40 M/SEC
AREA 261.594 MM2
THICKNESS 2.8 MM
WIDTH 93.426 MM
LAND 0.933 MM
LOCATION 0.0,110.0
COEF_DISCHARGE 0.6

B.


Gaterunner

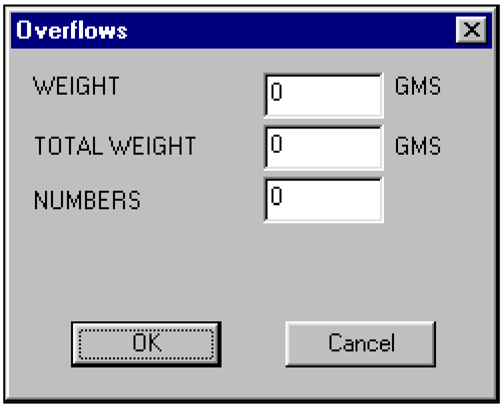
APPROACH ANGLE 0 DEG
FLOW ANGLE 15 DEG
COEF_DISCHARGE 0.7
G1.GCS 266.499 MM2
G2.GCS 271.404 MM2
G3.GCS 281.214 MM2
G4.GCS 291.024 MM2
G5.GCS 300.833 MM2
G9.GCS 300.833 MM2

C.


Runner

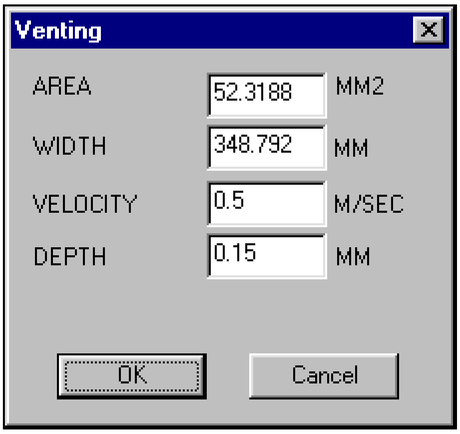
AREA 315.875 MM2
THICKNESS 12.8777 MM
WIDTH 24.5289 MM
VELOCITY 33.1263 M/SEC
LENGTH 35 MM
BISCUIT_THK 15 MM
COEF_DISCHARGE 0.8

D.


Overflows

WEIGHT 0 GMS
TOTAL WEIGHT 0 GMS
NUMBERS 0

E.


Venting

AREA 52.3188 MM2
WIDTH 348.792 MM
VELOCITY 0.5 M/SEC
DEPTH 0.15 MM

FIGURE 28

FEED DESIGN FOR ENDSHIELD

28A – GATE

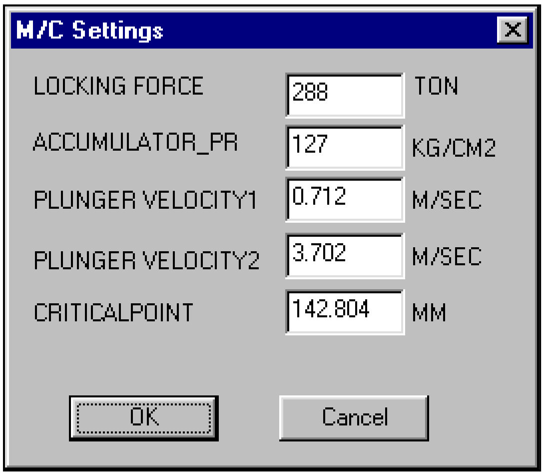
28B - GATERUNNER

28C - RUNNER

28D - OVERFLOWS

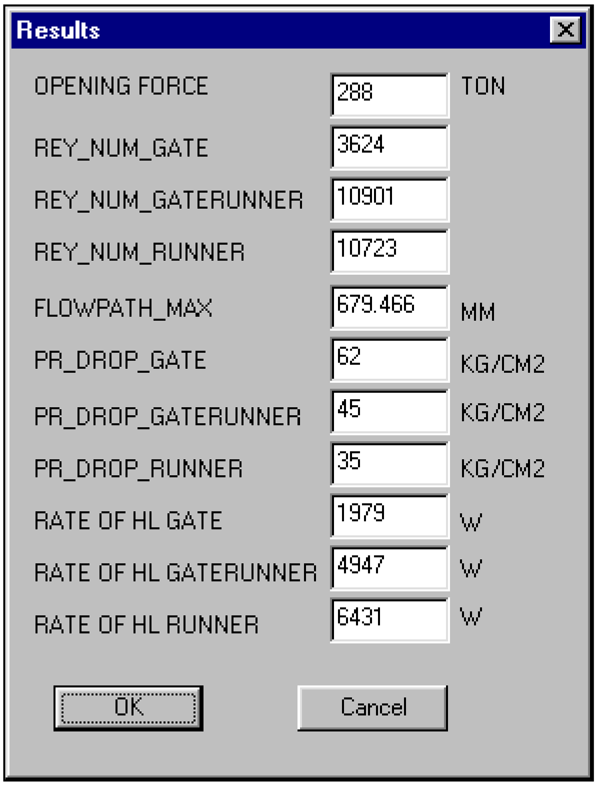
28E - VENTING

F.



LOCKING FORCE 288 TON
ACCUMULATOR_PR 127 KG/CM2
PLUNGER VELOCITY1 0.712 M/SEC
PLUNGER VELOCITY2 3.702 M/SEC
CRITICALPOINT 142.804 MM

G.



OPENING FORCE 288 TON
REY_NUM_GATE 3624
REY_NUM_GATERUNNER 10901
REY_NUM_RUNNER 10723
FLOWPATH_MAX 679.466 MM
PR_DROP_GATE 62 KG/CM2
PR_DROP_GATERUNNER 45 KG/CM2
PR_DROP_RUNNER 35 KG/CM2
RATE OF HL GATE 1979 W
RATE OF HL GATERUNNER 4947 W
RATE OF HL RUNNER 6431 W

FIGURE 28F – M/C SETTINGS
28G– RESULTS

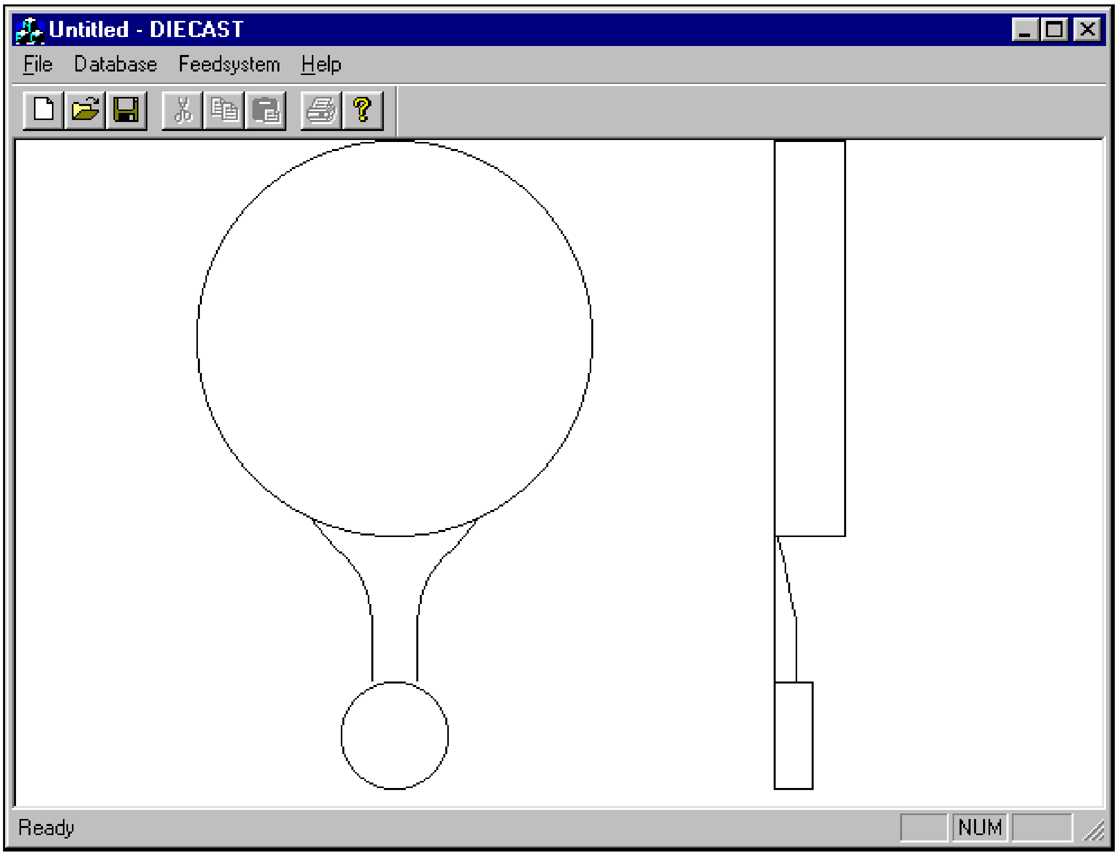
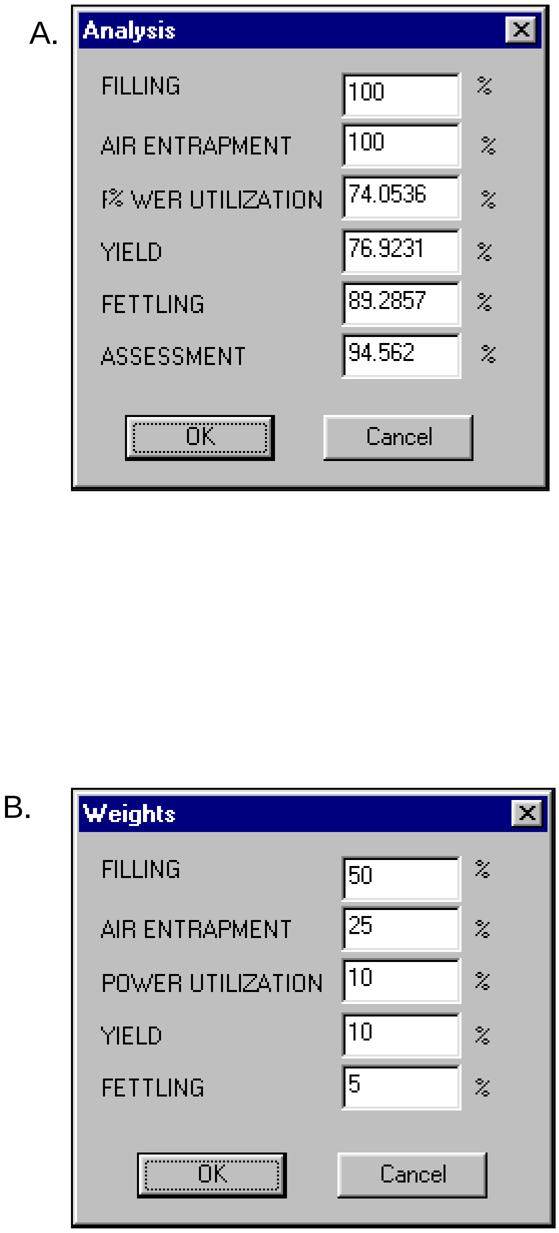


FIGURE 29

LAYOUT FOR ENDSHIELD


A.

Analysis

FILLING	100	%
AIR ENTRAPMENT	100	%
P% WER UTILIZATION	74.0536	%
YIELD	76.9231	%
FETTLING	89.2857	%
ASSESSMENT	94.562	%

B.

Weights

FILLING	50	%
AIR ENTRAPMENT	25	%
POWER UTILIZATION	10	%
YIELD	10	%
FETTLING	5	%

FIGURE 30

ANALYSIS FOR ENDSHIELD

30A – ANALYSIS
30B - WEIGHTS

Comparison Table
For Endshield Component

INPUT

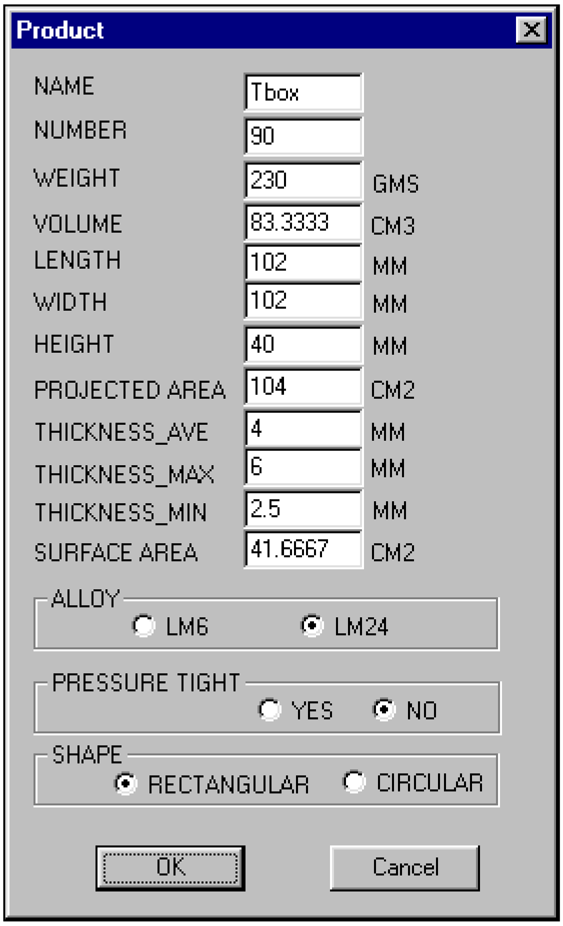
Variables	Calculated	Actual
Casting Weight	1444 gms.	1444 gms.
Casting average thk.	3.5 mm	3.5 mm
Casting projected area	400 cm2	400 cm2
Application	Non pressure tight	Non pressure tight

OUTPUT

Machine tonnage	400 Tons	400 Tons
Shot weight	1877 gms	1850 gms
Plunger diameter	60 mm	60 mm
Plunger velocity 1	0.712 m/s	0.75 m/s
Plunger velocity 2	3.701 m/s	-
Gate area	261.49 mm2	260 mm2
Gate thickness	2.8 mm	2.6 mm
Gate width	93.39 mm	100 mm
Runner area	315.75 mm2	338 mm2
Runner thickness	12.87 mm	13 mm
Runner width	24.52 mm	26 mm
Venting area	52.29 mm2	52 mm2
Critical point	142.80 mm	140 mm

5.3.2

B.



NAME	Tbox	
NUMBER	90	
WEIGHT	230	GMS
VOLUME	83.3333	CM3
LENGTH	102	MM
WIDTH	102	MM
HEIGHT	40	MM
PROJECTED AREA	104	CM2
THICKNESS_AVE	4	MM
THICKNESS_MAX	6	MM
THICKNESS_MIN	2.5	MM
SURFACE AREA	41.6667	CM2

ALLOY ○ LM6 ● LM24

PRESSURE TIGHT ○ YES ● NO

SHAPE ● RECTANGULAR ○ CIRCULAR

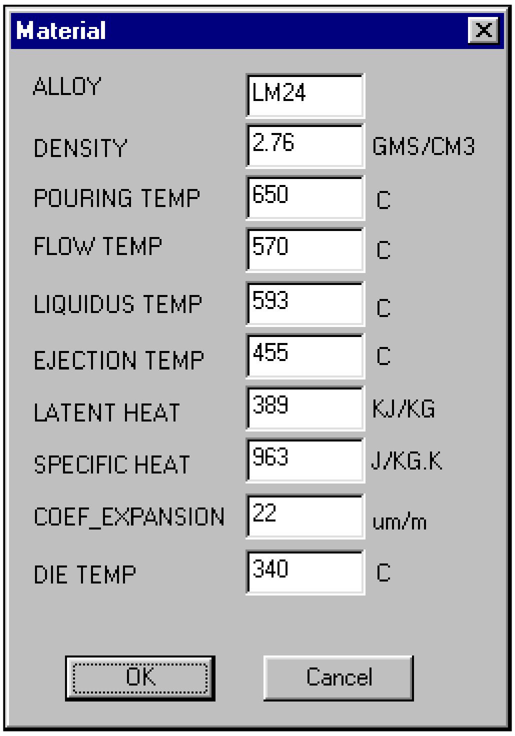
FIGURE 31

TERMINAL BOX

31A - PHOTOGRAPH

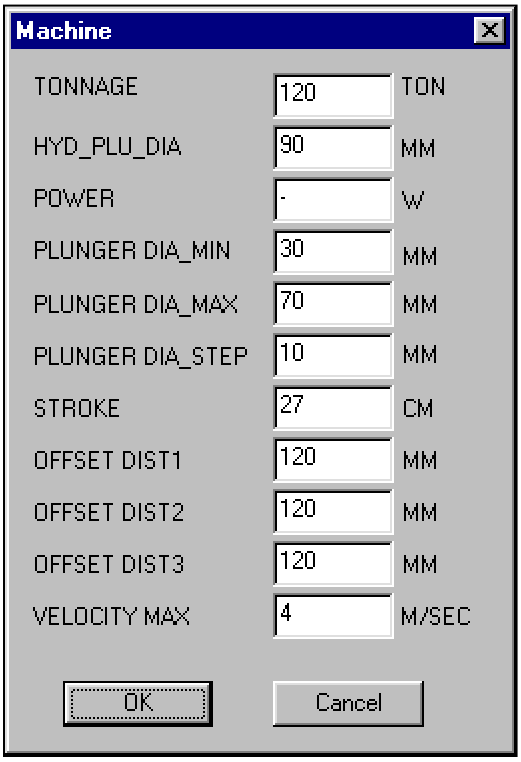
31B - PRODUCT

A.



ALLOY	LM24	
DENSITY	2.76	GMS/CM3
POURING TEMP	650	C
FLOW TEMP	570	C
LIQUIDUS TEMP	593	C
EJECTION TEMP	455	C
LATENT HEAT	389	KJ/KG
SPECIFIC HEAT	963	J/KG.K
COEF_EXPANSION	22	um/m
DIE TEMP	340	C

B.



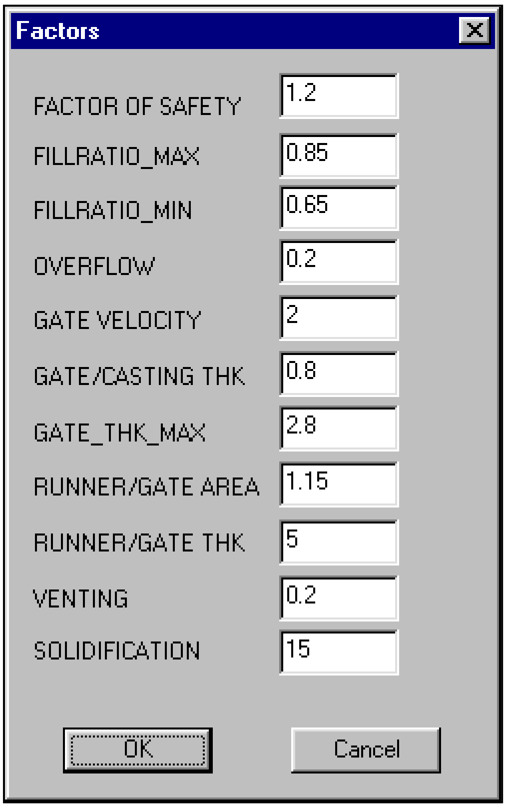
TONNAGE	120	TON
HYD_PLU_DIA	90	MM
POWER	-	W
PLUNGER DIA_MIN	30	MM
PLUNGER DIA_MAX	70	MM
PLUNGER DIA_STEP	10	MM
STROKE	27	CM
OFFSET DIST1	120	MM
OFFSET DIST2	120	MM
OFFSET DIST3	120	MM
VELOCITY MAX	4	M/SEC

FIGURE 32

DATABASE FOR TERMINAL BOX

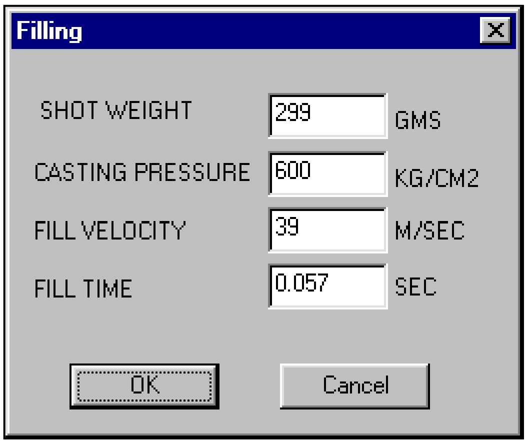
26A – MATERIAL
26B - MACHINE

A.



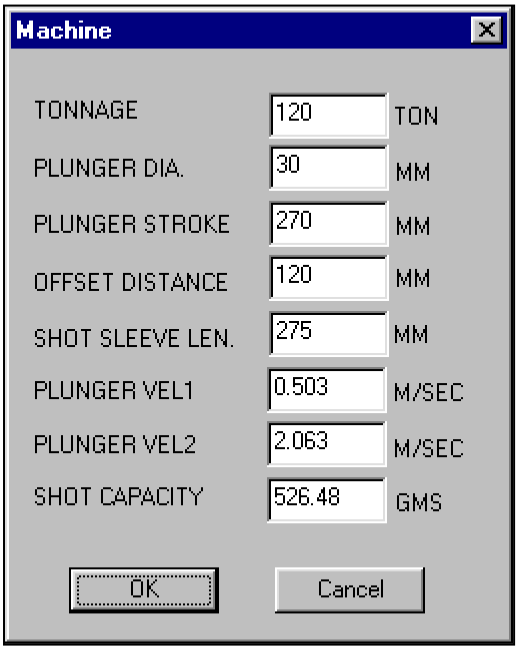
FACTOR OF SAFETY	1.2
FILLRATIO_MAX	0.85
FILLRATIO_MIN	0.65
OVERFLOW	0.2
GATE VELOCITY	2
GATE/CASTING THK	0.8
GATE_THK_MAX	2.8
RUNNER/GATE AREA	1.15
RUNNER/GATE THK	5
VENTING	0.2
SOLIDIFICATION	15

B.



SHOT WEIGHT	299	GMS
CASTING PRESSURE	600	KG/CM2
FILL VELOCITY	39	M/SEC
FILL TIME	0.057	SEC

C.



TONNAGE	120	TON
PLUNGER DIA.	30	MM
PLUNGER STROKE	270	MM
OFFSET DISTANCE	120	MM
SHOT SLEEVE LEN.	275	MM
PLUNGER VEL1	0.503	M/SEC
PLUNGER VEL2	2.063	M/SEC
SHOT CAPACITY	526.48	GMS

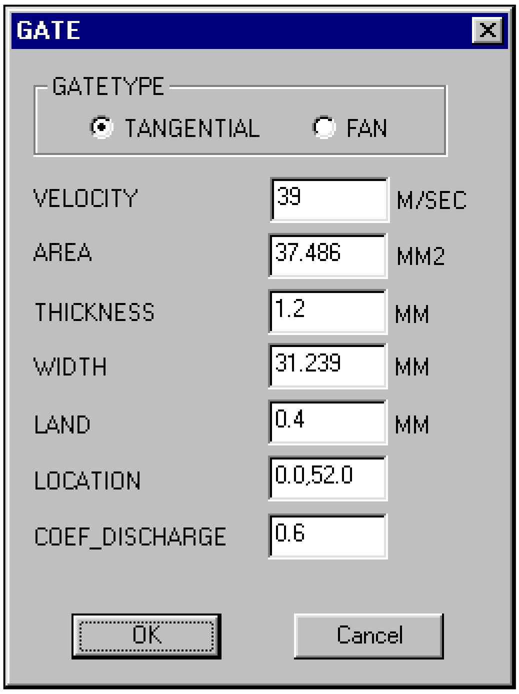
FIGURE 33

FLOW DESIGN FOR TERMINAL BOX

33A - FACTORS

33B - FILLING
33C - MACHINE

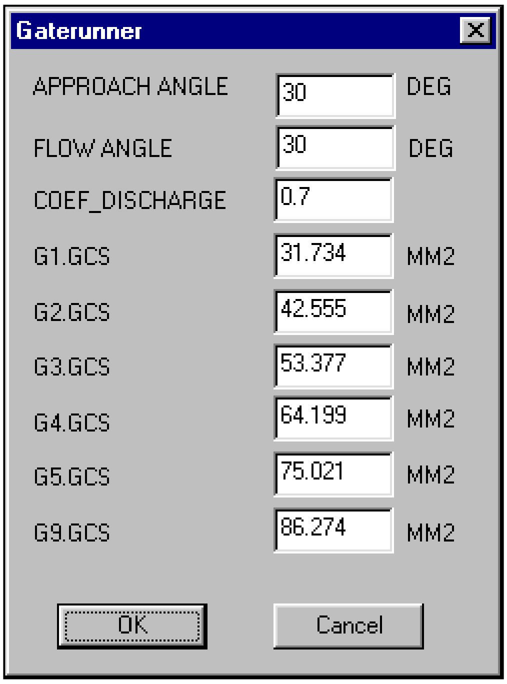
A.


GATE

GATETYPE
● TANGENTIAL ○ FAN

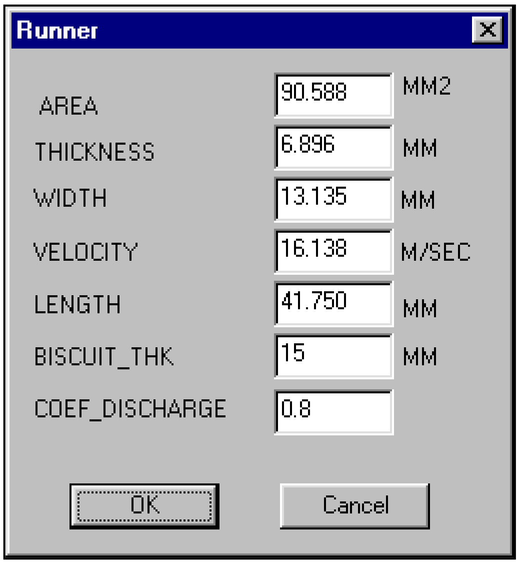
VELOCITY 39 M/SEC
AREA 37.486 MM2
THICKNESS 1.2 MM
WIDTH 31.239 MM
LAND 0.4 MM
LOCATION 0.0,52.0
COEF_DISCHARGE 0.6

B.


Gaterunner

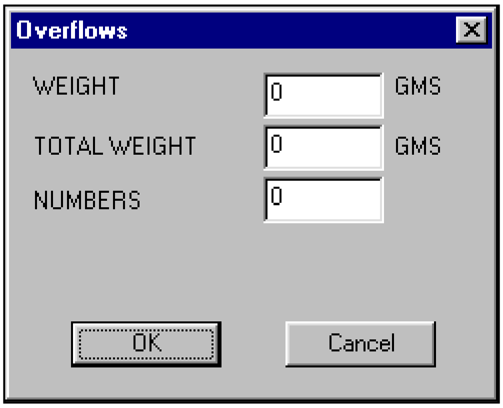
APPROACH ANGLE 30 DEG
FLOW ANGLE 30 DEG
COEF_DISCHARGE 0.7
G1.GCS 31.734 MM2
G2.GCS 42.555 MM2
G3.GCS 53.377 MM2
G4.GCS 64.199 MM2
G5.GCS 75.021 MM2
G9.GCS 86.274 MM2

C.


Runner

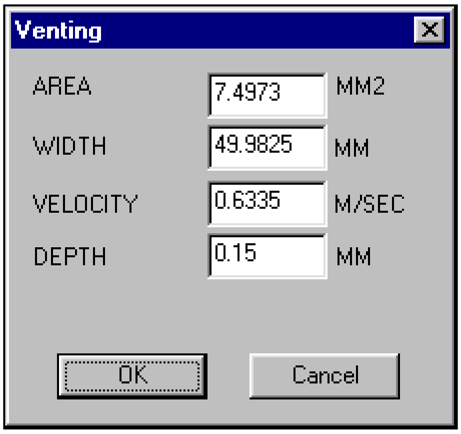
AREA 90.588 MM2
THICKNESS 6.896 MM
WIDTH 13.135 MM
VELOCITY 16.138 M/SEC
LENGTH 41.750 MM
BISCUIT_THK 15 MM
COEF_DISCHARGE 0.8

D.


Overflows

WEIGHT 0 GMS
TOTAL WEIGHT 0 GMS
NUMBERS 0

E.


Venting

AREA 7.4973 MM2
WIDTH 49.9825 MM
VELOCITY 0.6335 M/SEC
DEPTH 0.15 MM

FIGURE 34

FEED DESIGN FOR TERMINAL BOX

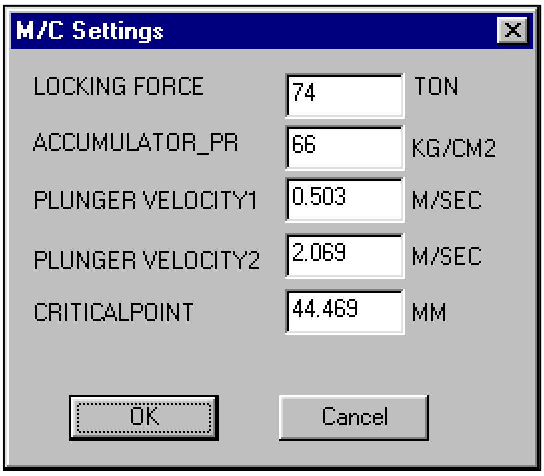
34A – GATE

34B - GATERUNNER
34C - RUNNER

34B - OVERFLOWS

34C - VENTING

F.



LOCKING FORCE 74 TON

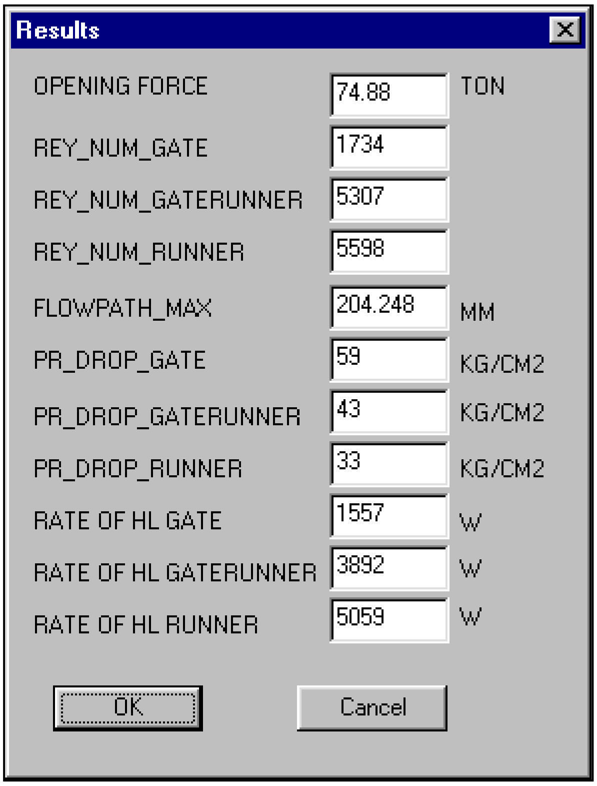
ACCUMULATOR_PR 66 KG/CM2

PLUNGER VELOCITY1 0.503 M/SEC

PLUNGER VELOCITY2 2.069 M/SEC

CRITICALPOINT 44.469 MM

G.



OPENING FORCE 74.88 TON

REY_NUM_GATE 1734

REY_NUM_GATERUNNER 5307

REY_NUM_RUNNER 5598

FLOWPATH_MAX 204.248 MM

PR_DROP_GATE 59 KG/CM2

PR_DROP_GATERUNNER 43 KG/CM2

PR_DROP_RUNNER 33 KG/CM2

RATE OF HL GATE 1557 W

RATE OF HL GATERUNNER 3892 W

RATE OF HL RUNNER 5059 W

FIGURE 34F – M/C SETTINGS

34G– RESULTS

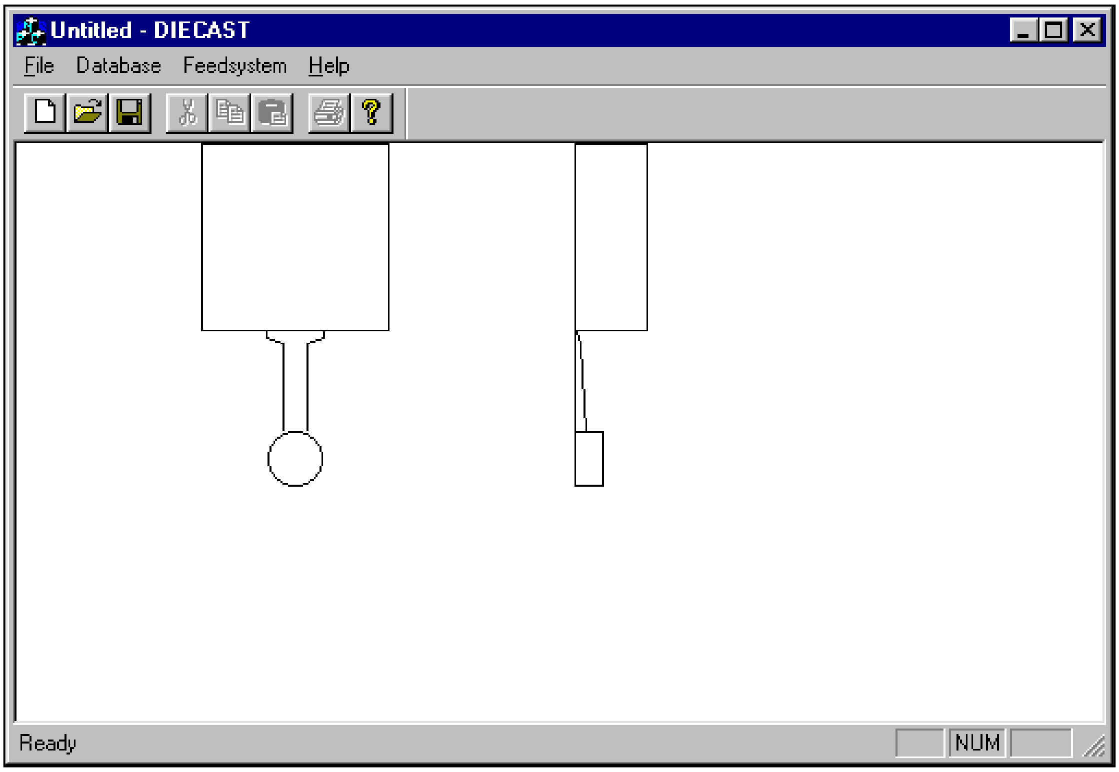
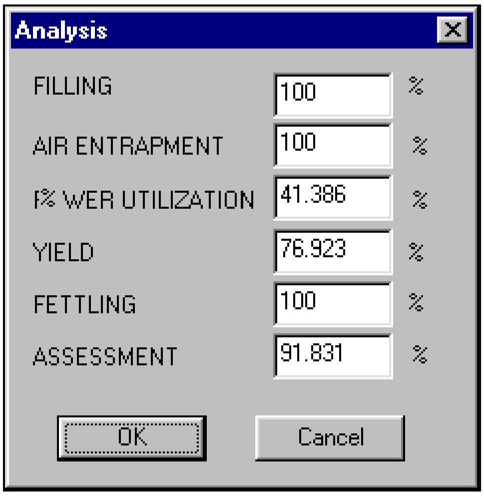


FIGURE 35

LAYOUT FOR TERMINAL BOX

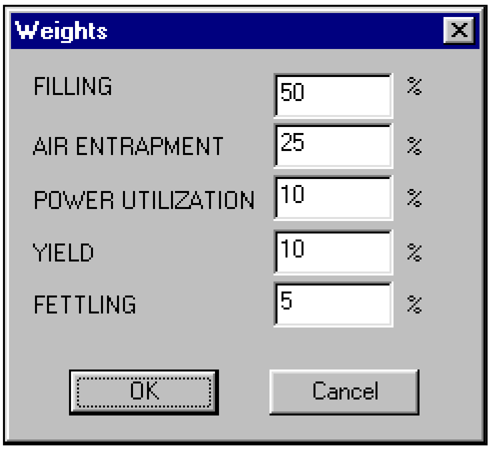
A.



Analysis

FILLING	100	%
AIR ENTRAPMENT	100	%
P% WER UTILIZATION	41.386	%
YIELD	76.923	%
FETTLING	100	%
ASSESSMENT	91.831	%

B.



Weights

FILLING	50	%
AIR ENTRAPMENT	25	%
POWER UTILIZATION	10	%
YIELD	10	%
FETTLING	5	%

FIGURE 36

ANALYSIS FOR TERMINAL BOX

36A – ANALYSIS
36B - WEIGHTS

COMPARISON TABLE
For Terminal Box Component

INPUT		
Variables	Calculated	Actual
Casting Weight	230 gms.	230 gms.
Casting average thickness	4 mm	4 mm
Casting projected area	104 cm2	104 cm2
Application	Non pressure tight	Non pressure tight
OUTPUT		
Machine tonnage	120 Tons	120 Tons
Shot weight	299 gms	310 gms
Plunger diameter	30 mm	30 mm
Plunger velocity 1	0.503 m/s	0.5 m/s
Plunger velocity 2	2.06 m/s	-
Gate area	37.378 mm2	35 mm2
Gate thickness	1.2 mm	1.25 mm
Gate width	31.14 mm	28 mm
Runner area	90.32 mm2	87.5 mm2
Runner thickness	6.88 mm	7 mm
Runner width	13.11 mm	12.5 mm
Venting area	7.47 mm2	7 mm2
Critical point	44.46 mm	50 mm

6 CONCLUSIONS

6.1 Conclusions

This work “ Computer aided feeding system design for pressure Diecasting” started with the objective of developing a PC based program, uses most of the available knowledge on design rules, to assist a designer in the design of feeding system.

It involved an extensive study of literature on feeding system design to identify the knowledge base of the design rules. The *Diecast* has been developed and implemented using object oriented programming methodology and requires a personal computer for its execution. Considerable efforts has been taken for verifying equations and logic used in the program.

Program is developed that takes into account technical requirements of the product and selects machine based on its technical specifications. Program for feeding system design calculates the required dimensions for various elements, it provides figures showing the impact of design on casting filling, air entrapment, machine power utilization, yield & fettling.

The *Diecast* has been tested on industrial casting samples and results are included in the form of case studies in the present report.

The main achievements of this work are –

1. A systematic, logical presentation of the design rules for selection of machine, design of gate, gaterunner, runner, overflows and venting for single cavity single gating feeding system.
2. Successful development of the PC based software which can help in designing feeding system of Diecasting die with greatly reduce time.
3. A number of case studies were carried out, illustrating the use of this work.

The program is designed to be a useful tool in hands of a die designer, assisting in faster completion of jobs, & providing insight in the design process.

6.3 Future Work

The *Diecast* uses input in form of text file which is generated from known 3D CAD system where as 3D CAD system can be integrated in the program for getting casting data input as well as for representation of designed feeding system. The program can be extended for multiple gating with inclusion of hot chamber Diecasting process.

The program can be incorporated with filling simulation for the designed feeding system, so that less numbers of iterations are required and it gives more accurate results.

7 REFERENCES

1 Moorman J H , "Gating & Metal flow patterns in Pressure diecasting", AFS Transactions, vol 71, 1963, pp 929 – 940

2 Belopukhov A K , "Critical rates for spray filling in Pressure diecasting", Russian Casting Production, May 1974, pp 208 – 209

3 Wallace J F , "Gating of diecasting", AFS Transcations, vol 73, 1965, pp 569 – 580

4 Russ Van Ress, "Gating Diecasting Dies", North American Diecasting Association, 1996

5 Davis A J , "Tapered runners feeding thin gates", Transcations Society Diecasting Casting Engineers, 1979, Paper G-T79-052

6 Makelskii M F , "Gating systems for Pressure diecasting", Russian Casting Production, September 1967, pp 413 – 416

7 Rodionov E M , "Influence of gating systems on quality of Pressure diecasting", Russian Casting Production, September 1974, pp No 397

8 Davis A J , "Some consequences of the relationship between the flow of molten metal in feed systems and the concurrent flow of hydraulic fluid in diecasting machines", Transcations Society Diecasting Casting Engineers , 1975, Paper G-T75-124

9 Draper A B , "Effect of vent and gate areas on the porosity of diecastings", AFS Transactions, vol 75, 1967, pp 727 – 734

10 Sheptak N , "Water analogy study of fluid flow in the cold chamber", AFS Transactions, vol 71, 1963, pp 349 – 357

11 Keil E , "The development of die", Druckguss – Technical information Nr 6, Gebruder Bhuler AG, Uzwil, 1985.

12 Prokhorov I I , "Nomographs for calculating Pressure diecasting conditions", Russian Casting Production, May1976, pp 198 – 199

13 Shvetsov V D , "Factors influencing the effectiveness of venting arrangement in PDC dies", Russian Casting Production, May 1975, pp 206 – 207

14 Chen C W , "Numerical simulation of filling pattern for an industrial diecasting & its comparison with the defects distribution of an actual casting", AFS Transactions, vol 102, 1994, pp 139 – 146

15 Hwang W S , “Computer simulations for the filling of castings”, AFS Transactions, vol 95 , 1987, pp 425 – 431

16 Estrin Len, “A deeper look at casting solidification software”, Modern casting, July 1994, pp 20 – 23

17 Sloane David J , “Relationship between machine clamp and casting area in aluminium diecasting”, AFS Transactions, vol 70, 1963, pp 442 – 448

18 Mostovshchk G , “Determining the injection & locking speeds in Pressure diecasting machines”, Russian Casting Production, May 1975, pp 207 – 208

19 Rearwin Earle W , “Controlling variables in a diecast shop”, AFS Transactions, vol 72, 1965, pp 865 – 871

20 Barton H K , “Controlling operational variables in diecasting”, AFS Transactions, vol 70, 1963, pp 306 – 315

21 Akivis, “Plunger speeds in horizontal cold chamber PDC”, Russian Casting Production, Feb 1968, pp 67

22 Arthur C Street, “The diecasting book”, Portcullis press, 2nd edition, 1986

23 Ben Takach, “Die design, The weakest link in the chain”, Arkey Conference Service Cell, Alucast, vol 4, 1998, pp 2 – 6

24 Kiselenko L E , “Influence of entry velocity on loss of lubrication & breakdown of oxide dross in the PDC”, Russian Casting Production – March 1969 – pg No 123 – 124

Appendix 1

Table 1 Variables for cavity filling time calculations

Alloy	Emprical constsnt, k			Metal injection temp. T_i	Min. Flow temp. T_f	Die cavity temp. T_d	Solids Factor Z
	P20	H13	Tungsten				
	Sec/ mm	Sec/ mm	Sec/ mm	C	C	C	C / %
Al 360	-	0.0346	0.0124	650	570	340	3.8
Al 380	-	0.0346	0.0124	650	570	340	3.8
Al 390	-	0.0346	0.0124	720	595	355	3.8
Zn 12,27	0.0312	0.0346	0.0124	565	445	260	3.2
Zn 3,5,7	0.0312	0.0346	0.0124	405	382	230	2.5
Mg	-	0.0346	0.0124	650	510	340	2.5
Fe	-	0.0346	0.0124	1540	1370	980	6.0
Cu 60/40	-	0.0346	0.0124	955	900	510	4.7

Table 2 Recommended values for gate velocity

Alloy	Typical gate velocity m/sec	J factor
Al 360	38.7	525
Al 380	38.7	525
Al 390	38.7	525
Zn 12,27	29.0	624
Zn 3,5,7	25.0	624
Mg	42.0	360
Fe	25.0	1314
Cu 60/40	22.5	985

Table 3 Recommended values for gate thickness.

Alloy	Castings upto 100 gms.	Castings from 100 to 1000 gms.	Castings from 1000 to 5000 gms.
Zn alloy	0.3 – 0.6	0.5 – 1.2	0.8 – 1.5
Al alloy	0.5 – 1.0	0.8 – 1.8	1.5 – 3.5
Cu alloy	1.0 – 1.5	1.5 – 3.0	2.5 & more

Table 4 Recommended values of specific casting pressure.

Application	Al & Mg alloys	Zn alloys	Cu alloys
	Kg / cm2	Kg / cm2	Kg / cm2
Standard parts	Upto 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	-	200 – 250	-

Table 5 List of softwares and their capabilities

Name	Platforms	Strengths and Capabilities
Cap ,Amesh	PC , SGI worksations	Short time required for analysis execution, efficient use of memory, FEM allows accurate representation of geometry, AMESH mesh generator tailored specifically to casting applications. A post-processor is also available.
Magma soft	Unix based systems	It features modules dedicated to – project management, pre-processing, fluid dynamics, and heat flow processing, post-processing, thermophysical data collection. Its capabilities include a powerful flow solver for fluid flow problems, such as misruns and cold-shuts, direct visualization of problem areas, ability to run multiple cycles, ability to quickly model complex castings such as cylinder heads etc.
Procast	Unix based systems	Using FEM Procast solves fully coupled thermal-fluid-stress-electromagnetic problems. Nonlinear stress can be modeled along with thermal mechanical contact at material interfaces. Micromodeling is also included for providing detailed information about microstructure and mechanical properties. The user-friendly motif based interface contains databases, automatic mesh generation capabilities and sophisticated visulization tools.

Appendix 2

Variables affecting diecasting process along with abbreviations used in program.

Casting related

1. Casting volume (cv).
2. Casting weight (cwt).
3. Casting average thickness (cat).
4. Casting minimum thickness (cmt).
5. Casting projected area (cpa).
6. Casting length max. (cl).
7. Casting width max. (cw).
8. Casting surface area (csa).
9. Casting height max. (ch).
10. Casting alloy (ca).
11. Casting application (cap).
12. Casting number (cn).
13. Casting name (can).

Material related

1. Density (md).
2. Pouring temperature (mpt).
3. Minimum flow temperature (mft).
4. Liquidous temperature (mlt).
5. Specific heat (msh).
6. Latent heat (mlh).
7. Coefficient of friction (mf).

Die related

1. Shot weight (dsw).
2. Opening force (dof).
3. Plunger diameter (dpd).
4. Specific cavity pressure (dcp).

5. Fill ratio (dfr).
6. Die temperature (dt).
7. Ejection temperature (det).
8. Number of cavities (dnc).
9. Cavity fill time (dct).
10. Gate location (dgl).
11. Number of gates (dng).
12. Number of overflows (dno).
13. Weight of overflows (dwo).
14. Venting area (dva).
15. Venting width (dvw).
16. Gate velocity (dgv).
17. Gate thickness (dgt).
18. Gate area (dga).
19. Gate land (dgl).
20. Gate width (dgw).
21. Approach angle (daa).
22. Runner thickness (drt).
23. Runner area (dra).
24. Runner width (drw).
25. Runner length (drl).
26. Runner velocity (drv).
27. Biscuit thickness (dbt).
28. Percent solid fraction allowable (dsf).

Diecasting machine related

1. Locking force i.e tonnage (dmlf).
2. Plunger offset distance (dmpod).
3. Shot sleeve length (dmsl).
4. Shot sleeve diameter (dmsd).
5. Shot capacity (dmsc).
6. Plunger velocity 2nd phase (dmpv2).

7. Plunger velocity 1st phase (dmpv1).
8. Plunger diameter (dmpd).
9. Plunger stroke (dmps).
10. Horizontal distance between tie bar (dmhd).
11. Vertical distance between tie bar (dmvd).

Diecasting factors

1. Factor of safety for machine selection (dffos).
2. Shot capacity factor (dfsc).
3. Fill ratio factor (dffr).
4. Overflow factor (dfo).
5. Gate velocity factor (dfgv).
6. Gate thickness factor (dfgt).
7. Gate area to runner area (dfgara).
8. Gate thickness to runner thickness (dfgtrt).
9. Venting factor (dfv).
10. Machine to plunger stroke (dfmps).
11. Pressure drop (dfpd).
12. Heat loss (dfhl).

APPENDIX 3

Material database

ALLOY	LM24	LM6	A390
DENSITY (gms/cm3)	2.76	2.76	2.76
POURING TEMP. (C)	650	650	720
MIN. FLOW TEMP (C)	570	570	595
LIQUIDUS TEMP. (C)	593	593	663
EJECTION TEMP. (C)	455	455	455
LATENT HEAT(kJ/kg)	389	389	389
SPECIFIC HEAT(J/kg.K)	963	963	963
COEF. EXPAN. (um/m)	22	22	25
DIE TEMP. (C)	340	340	355

APPENDIX 4

Machine database

Tonnage (Ton)	60	120	160	250	400	660	1000
Hyd_Plunger Dia.(mm)	75	90	90	130	130	145	160
Power (kg/cm.sec)	-	-	-	-	-	-	-
Min. Plunger Dia. (mm)	30	30	40	40	50	50	50
Max. Plunger Dia. (mm)	50	70	80	90	110	120	130
Plunger Dia. Step (mm)	10	10	10	10	10	10	10
Stroke (mm)	250	27.5	300	350	400	600	700
Offset Dist. 1 (mm)	80	120	150	150	130	140	150
Offset Dist. 2 (mm)	80	120	150	150	180	190	210
Offset Dist. 3 (mm)	80	120	150	150	220	330	300
Max. Plunger vel.(m/sec)	3	3.5	3.5	4	4	5	5

APPENDIX 5

Key calculations for endshield component –

1. Shot weight = dfsc x cwt = 1877 gms.
2. Casting pressure = 600 kg / cm2 (non pressure tight castings).
3. Opening force = dcp x cpa /1000 = 288 Tons.
4. Machine selected = 400 Tons.
5. Plunger area = dsw / (md x dffr x dgv) = 24.28 cm2.
6. Plunger diameter = 56.61 mm.
7. Plunger diameter selected = 60 mm.
8. Fill time = k x cat x (mpt – mft + SZ) / (mft – dt) = 0.050.
9. Gate velocity selected = 40 m/s.
10. Gate area = (cwt + dwo) / (dgv x md x dct) = 261.59 mm2.
11. Gate thickness = dfgt x cat = 2.8.
12. Gate length = dga / dgl = 93.39.
13. Gate runner cross section = dfgara x dga = 300.82.
14. Venting area = dfv x dga = 52.31 mm2.
15. Hyd. Dia at gate = 4 x area / perimeter = 5.43 mm.
16. Reynolds number at gate = dgv x hyd . dia / (10 x viscocity) = 3620.
17. Heat loss at gate = dfhl x (dgw + dgt) = 1978.7 W.
18. Pressure drop at gate = dfpd x dgv x dgv = 62.5 bar.

APPENDIX 6

Output file for endshield component -

```
BEGIN                MACHINE
MACHINE_REQD         400(tons)
PLUNGER_DIA          60(mm)
PLUNGER_STROKE       400(mm)
PLUNGER_OFFSET       220(mm)
SHOT_SLEEVE_LEN      405(mm)
PLUNGER_VELOCITY1    0.712061(m/sec)
PLUNGER_VELOCITY2    3.70268(m/sec)
SHOT_CAPACITY        3119.9(gms)

BEGIN                FILLING
SHOT_WEIGHT          1877.2(gms)
CASTING_PRESSURE     600(kg/cm2)
FILL_VELOCITY        40(m/sec)
FILL_TIME             0.05(sec)

BEGIN                GATE
GATE_AREA            261.594(mm2)
GATE_WIDTH           93.4265(mm)
GATE_THICKNESS       2.8(mm)
GATE_VELOCITY        40(m/sec)
GATE_LAND            0.933333(mm)

BEGIN                GATERUNNER
GATERUNNER_AREA1     266.499(mm2)
GATERUNNER_WIDTH1     66.9082(mm)
GATERUNNER_THK1      3.98306(mm)
GATERUNNER_AREA2     271.404(mm2)
GATERUNNER_WIDTH2     52.5354(mm)
```

GATERUNNER_THK2	5.16611(mm)
GATERUNNER_AREA3	281.214(mm2)
GATERUNNER_WIDTH3	37.3348(mm)
GATERUNNER_THK3	7.53222(mm)
GATERUNNER_AREA4	291.024(mm2)
GATERUNNER_WIDTH4	29.4013(mm)
GATERUNNER_THK4	9.89834(mm)
GATERUNNER_AREA5	300.833(mm2)
GATERUNNER_WIDTH5	24.5289(mm)
GATERUNNER_THK5	12.2644(mm)
GATERUNNER_AREA6	300.833(mm2)
GATERUNNER_WIDTH6	24.5289(mm)
GATERUNNER_THK6	12.2644(mm)
GATERUNNER_AREA7	300.833(mm2)
GATERUNNER_WIDTH7	24.5289(mm)
GATERUNNER_THK7	12.2644(mm)
GATERUNNER_AREA8	300.833(mm2)
GATERUNNER_WIDTH8	24.5289(mm)
GATERUNNER_THK8	12.2644(mm)
GATERUNNER_AREA9	300.833(mm2)
GATERUNNER_WIDTH9	24.5289(mm)
GATERUNNER_THK9	12.2644(mm)

BEGIN	RUNNER
RUNNER_AREA	315.875(mm2)
RUNNER_WIDTH	24.5289(mm)
RUNNER_THICKNESS	12.8777(mm)
RUNNER_LENGTH	35(mm)
RUNNER_VELOCITY	33.1263(m/sec)

BEGIN	OVERFLOWS
OVERFLOWS_WEIGHT	0(gms)

```
BEGIN               VENTING
VENTING_AREA        52.3188(mm2)
VENTING_WIDTH       348.792(mm)
VENTING_VELOCITY    0.5(m/sec)

BEGIN               SETTINGS
LOCKING_FORCE       288(tons)
ACCUMLATOR_PRESSURE 127(kg/cm2)
CRITICAL_POINT      142.804(mm)

BEGIN               RESULTS
OPENING_FORCE       288(tons)
REYNOLDS_GATE       3624()
REYNOLDS_GATERUNNER 10901()
REYNOLDS_RUNNER     10723()
FLOWPATH_MAX        679.466(mm)
PRESSUREDROP_GATE  62(kg/cm2)
PRESSUREDROP_GATER  45(kg/cm2)
PRESSUREDROP_RUNNER 35(kg/cm2)
HEATLOSS_GATE       1979(W)
HEATLOSS_GATERUNNER 4947(W)
HEATLOSS_RUNNER     6431(W)

BEGIN               ANALYSIS
FILLING             100()
AIR_ENTRAPMENT      100()
POWER_UTILIZATION   74.0536()
YIELD               76.9231()
FETTLING            100()
ASSESSMENT          95.0977()
END                 BLOCK
```

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