Foundry Work

Level-II

Learning Guide-10

Unit of Competence:	**Plan Casting Processes**
Module Title:	**Planning Casting Processes**
LG Code:	**IND FDW2 M04 LO1 LG-10**
TTLM Code:	**IND FDW2TTLM 1019v1**
LO 1:	**Identify work requirements**

Instruction Sheet	Learning Guide #1

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Obtaining, understanding and clarifying instructions and procedures.
- Obtaining, understanding and clarifying relevant specifications.
- Identifying work place Task
  - ✓ Carrying out general requirements.
  - ✓ Dedicating tools and equipment.
  - ✓ Materials and parts.
  - ✓ Working procedures.
  - ✓ Completing time.
  - ✓ Safety measures and equipment.
- Identifying quality measures.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Obtain, understand and where necessary clarification instructions and procedures based on operational standards.
- Obtain, understand and where necessary clarification relevant specifications for work outcomes based on operational standards
- Identify task outcomes following work place procedures.
- Identify task requirements such as completion time and quality measures work place procedures

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks". Each information sheets.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets and LAP Tests if any". However, if your rating is unsatisfactory, ask your teacher for further instructions or go back to Learning Activity.
7. After you accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;
8. Then proceed to the next information sheet.

Information Sheet-1	Obtaining, understanding and clarifying instructions and procedures

1.1 Introduction to Casting processes

Casting processes: Process in which molten metal flows by gravity or other force into a mold where it solidifies in the shape of the mold cavity.

The term casting also applies to the part made in the process.

Obtain the Casting Geometry

The process is referred as the study of the geometry of parts and plans, so as to improve the life and quality of casting.

Casting Steps

Quick route from raw material to finished product

- Melt metals
- Pour / force liquid into hollow cavity (mold)
- Cool / Solidify
- Remove
- Finish

Parts Made by Casting

- Big parts: engine blocks and heads for automotive vehicles, wood burning stoves, machine frames, railway wheels, pipes, church bells, big statues, and pump housings
- Small parts: dental crowns, jewelry, small statues, and frying pans
- All varieties of metals can be cast, ferrous and nonferrous

Importance of Casting

Capabilities and Advantages of Casting

- Can create complex part geometries
- Can create both external and internal shapes
- Some casting processes are net shape; others are near net shape
- Can produce very large parts
- Some casting methods are suited to mass production

Types and various pattern materials

Various casting methods, viz., sand casting investment casting, pressure die casting, centrifugal casting, continuous casting, thin roll casting; Mould design; Casting defects and their remedies. Types of local resourcesMetal casting is one of the oldest industries in human society.

The art of foundry is about 7000 years old. The strength of the foundry industry rests on the fundamental nature of casting as a process for causing metals to take shapes that will serve the needs of man. Practically all metal is initially cast.

Certain advantages are inherent to the metal-casting process. These may form the basis for choosing casting as a process to be preferred over other shaping processes in a particular case [Heine, 1995]. Some of the reasons for the wide use of the casting process are listed below.

1. The most intricate of shapes, both internal and external may be cast.
2. Because of their metallurgical nature, some metals can only be cast to shape since they cannot be hot-worked into bars, rods, plates or other shapes from ingot form as a preliminary to other processing.
3. Objects may be cast in a single piece that would otherwise require construction in several pieces and subsequent assembly.

4. Metal casting is highly adaptable to the requirements of mass production.

5. Extremely large, heavy metal objects may be cast when they would be difficult or economically impossible to produce otherwise.

6. Some engineering properties are obtained more favorably in cast metals, like uniform properties from a decided economic advantage exists as a result of any one or a combination of the above points.

7. A directional standpoint, strength and lightness in certain light metal alloys that can be produced only as castings and good bearing qualities. In general, a wide range of alloy composition and properties is produced in cast form.

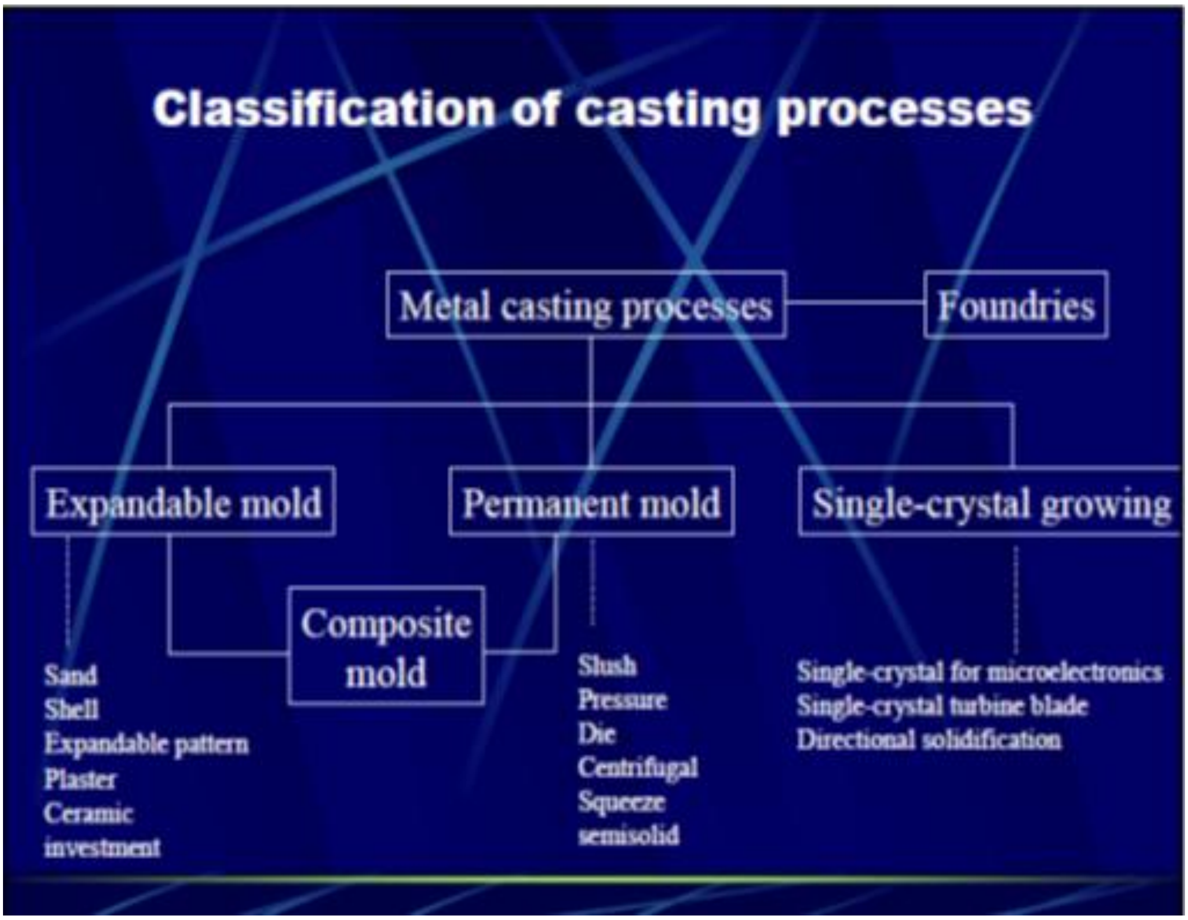


Fig: 1.1 classification of casting processes

Self-Check -1	Written Test

Directions: Choose the correct answer

1. The term ----------------- also applies to the part made in the process.

   A. Metal C. Small parts

   B. Casting D. pattern

2. Which one is Capability and Advantage of Casting?

   A. Can create complex part geometries
   B. Can produce very large parts
   C. Can create both external and internal shapes
   D. All

Information Sheet-2	Obtaining, understanding and clarifying relevant specifications.

2.1. Sand Casting Process Basic Concept and Procedure

The **sand casting process** also called as sand mold casting. It is a common method for metal casting. Almost 70% of metal castings of product follow by sand casting process. The bonding agent (clay) is mixed with the sand. The mixture is moisturized with water for develop strength and plasticity of clay to make mold.

The pattern prepare for required shape of product. which pattern made of wood or metal. First the mold prepared start of process and molten metal is poured into the mold. After cooling process completed, the mold part removed and cleaned.

The Various sand casting method such as Green sand , Dry sand, Loam Sand, Facing Sand, Backing or floor sand, System Sand, Parting Sand, Core Sand. The Green Sand is most use method.

Basic of terminology of sand casting process

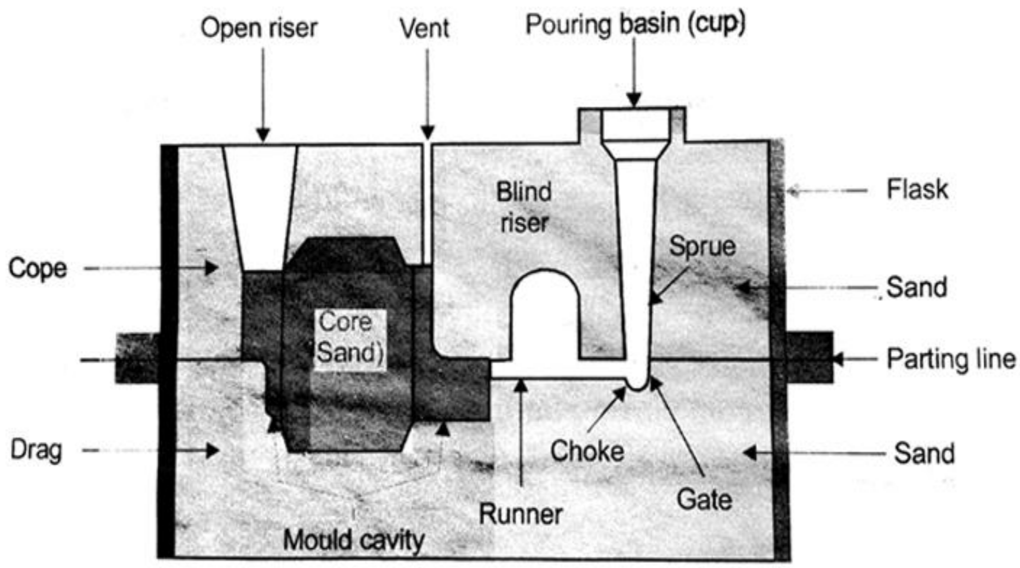


Fig: 2.1 terminology of sand casting process

Sand casting process step by step procedure

- The suitable flask or molding box selected and space allow ramming the sand.
- The drag is placed on molding board with upside down. Now the pattern lower part is placed on the board inside the flask. The space is left for cutting.
- Now sand is filled in the flask and cover the pattern. Then sand firmly packed by means of hammers. The ramming is properly and the excess sand is leveled off with straight strike off bar.
- The vent holes or vent rod are made in drag to full depth of flask because of gases (or) air removed during pouring and solidification process.
- Then the cope half of pattern is placed over the drag by using locating pins. The cope flask is placed on drag. The sprue pin is provided for sprue passage, it located at a small distance from the pattern. The riser pin also located on the pattern.
- The cope is filled with sand and proper ramming force applied.
- The ramming, filling, venting same as perform.
- The excess sand is cut off from mold surface. The riser pin and sprue
- Molding box is opened, then pattern removed from cope and drag. The dry sand core is mounted in position.
- Now molten metal is poured through riser into mold cavity. After pouring and solidification the part removed with require pattern shape.

Need for Process Selection

There is increasing realization in the manufacturing industry that increasing manufacturing efficiency and reducing costs does not only accrue from investment in automation and advanced machine tools.

Selecting the most appropriate manufacturing process in terms of technological feasibility and cost for a component design is one of the most important decisions making tasks [Allen, 1990]. To ensure that most appropriate manufacturing process is selected, the product designer must be aware of the manufacturing route by which a component is produced.

There are many manufacturing processes available and selection of the most appropriate process depends on a large number of factors. This is a complex problem and requires a considerable manufacturing expertise and there is a lack of systematic techniques to assist the designer in this area. The problem becomes more acute in the casting domain, since it offers a very wide variety of routes to make a product.

Process Selection

The need to provide the design activity with information regarding manufacturing process capabilities and costs has been recognized for many years. There is comparatively little published work in this area. Books on design rarely provide any relevant data and the data available in manufacturing volumes is insufficient.

Also the information is inconsistent making the designer's task more difficult [Allen, 1990]. Selection of an appropriate casting method requires a sound understanding of the interactions between casting design constraints, required product properties, technical limitations of individual casting methods, available tooling and overall cost determining factor. Various authors have suggested different approaches for process selection.

Classification of Casting Processes

Metal casting, a 7000-year technology; over the years have evolved a large number of techniques to cast a product. There can be many criteria on the basis of which casting processes can be classified.

The mold is the foundry man's forming tool; good casting cannot be made without good molds. Because of the importance of the mold, casting processes and castings are often described by the materials and methods employed in molding.

They can be broadly classified into the following three groups: expendable mold type, permanent mold type and special processes.

They classified the factors influencing process selection into the following three categories.

- Material factor: which includes Mechanical properties, Physical properties and Alloy specifications
- Geometry factors: which includes Part shape, Part envelop size, Part weight, Dimensional tolerance, Surface finish and Secondary operations.
- Production factors: which includes Lead time, Production volume and Production rate?

In the domain of the casting, the area of study is limited to the following processes only:

1. Green sand casting
2. High pressure sand casting
3. Shell molding
4. No-bake process
5. Gravity die casting
6. Low pressures die casting
7. High pressure die casting
8. Wax investment process
9. Foam investment process

Self-Check -2	Written Test

Directions: Choose the correct answer

1. They classified the factors influencing process selection into the following ----------- categories.

   A .One C. three
   B. Two D. four

2. The mold is the foundry man's forming tool; good casting cannot be made without good_____________.

   A. Permanent mold C. molds
   B. Expandable D. neon

3. The ____________ prepare for required shape of product. which pattern made of wood or metal

   A. Molds C. cope
   B. Pattern D. drag

4. ____________which includes Part shape, Part envelop size, Part weight, Dimensional tolerance, Surface finish and Secondary operations.

   A. Production factors C. Permanent mold
   B. Material factor D. Geometry factors

Information Sheet-3	Identifying work place Task

3.1 Identifying work place Task

The six basic steps in making sand castings are,

(i) Pattern making, (ii) Core making, (iii) Molding, (iv) Melting and pouring, (v) cleaning

Pattern making

- Pattern: Replica of the part to be cast and is used to prepare the mould cavity. It is the physical model of the casting used to make the mould. Made of either wood or metal.
- The mould is made by packing some readily formed aggregate material, such as molding sand, surrounding the pattern. When the pattern is withdrawn, its imprint provides the mould cavity. This cavity is filled with metal to become the casting.
- If the casting is to be hollow, additional patterns called ‘cores’ are used to form these cavities.

Core making

Cores are placed into a mould cavity to form the interior surfaces of castings. Thus the void space is filled with molten metal and eventually becomes the casting.

Moulding

Moulding is nothing but the mould preparation activities for receiving molten metal. Moulding usually involves:

- ✓ preparing the consolidated sand mould around a pattern held within a supporting metal frame,

- ✓ Removing the pattern to leave the mould cavity with cores.Mould cavity is the primary cavity.
- ✓ The mould cavity contains the liquid metal and it acts as a negative of the desired product.

The mould also contains secondary cavities for pouring and channeling the liquid material in to the primary cavity and will act a reservoir, if required.

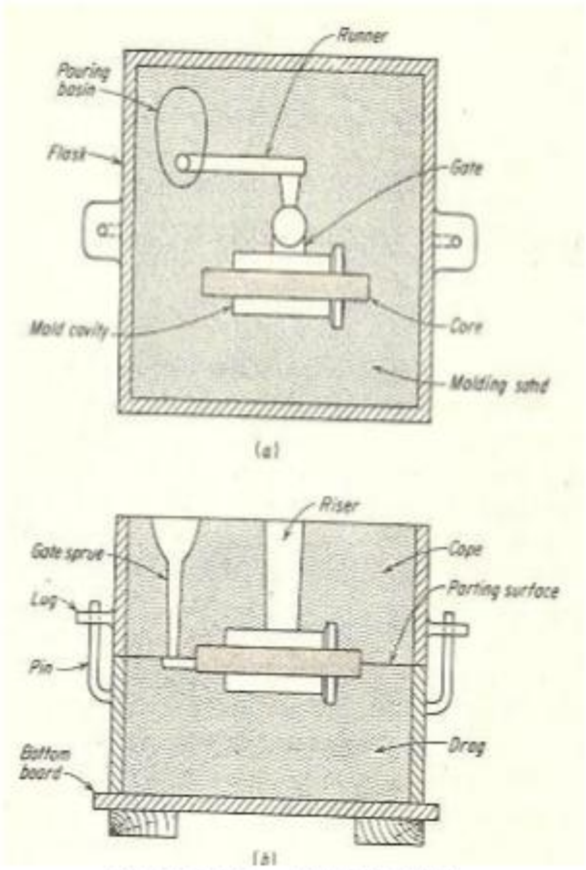
Melting and pouring

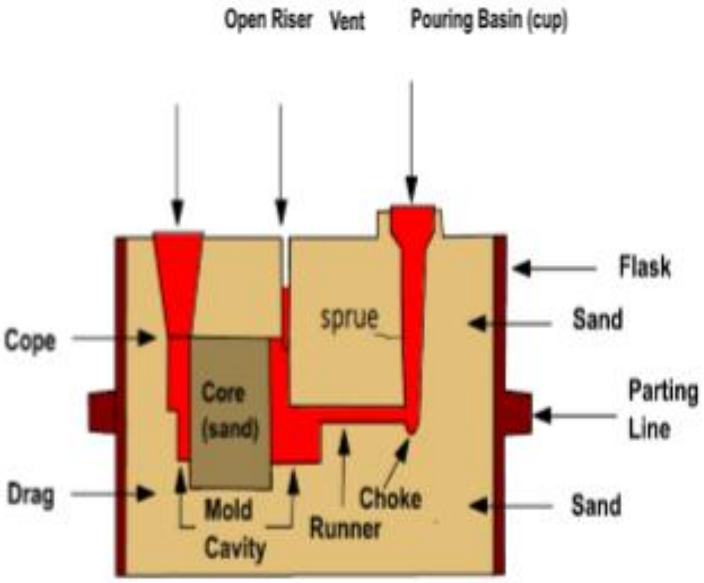
The preparation of molten metal for casting is referred to simply as melting. The molten metal is transferred to the pouring area where the moulds are filled.

Cleaning

Cleaning involves removal of sand, scale, and excess metal from the casting. Burned-on sand and scale are removed to improve the surface appearance of the casting. Excess metal, in the form of fins, wires, parting line fins, and gates, is removed. Inspection of the casting for defects and general quality is performed.

1.3.3 Important casting terms





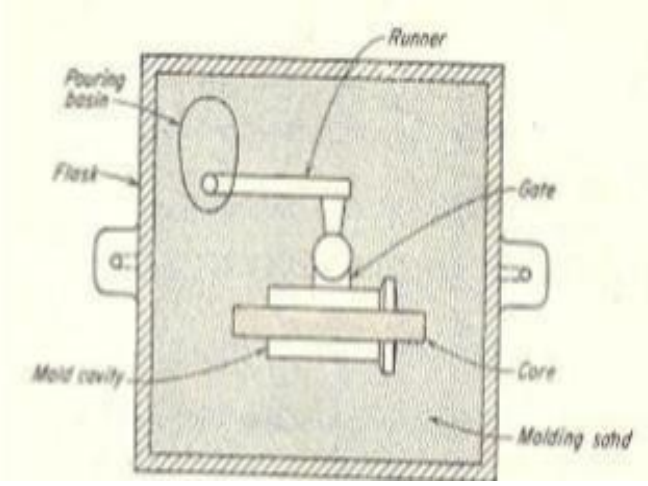
Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as

drag – lower moulding flask, cope – upper moulding flask, cheek – intermediate moulding flask used in three piece moulding.

Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

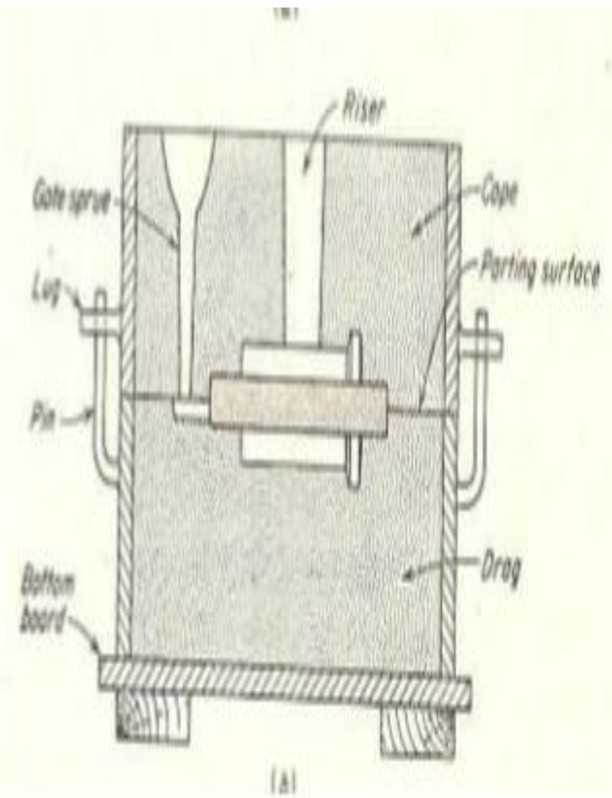
Parting line: This is the dividing line between the two moulding flasks that makes up the mould.

Moulding sand:
Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions



Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings.

Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in tcastings.



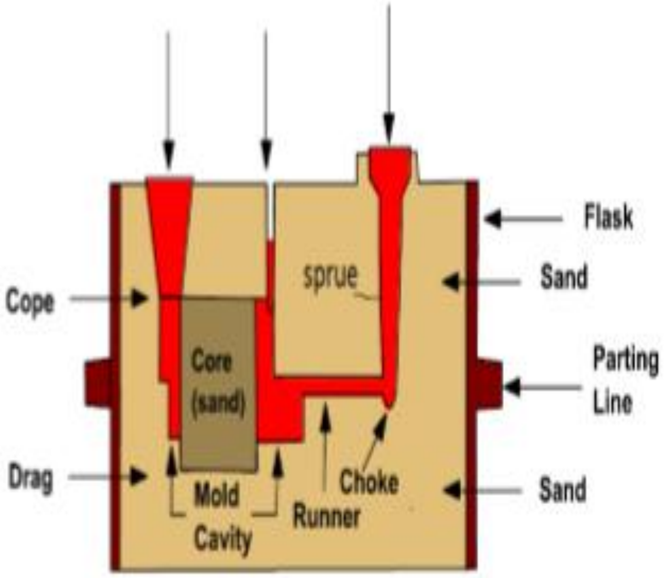
Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould.

Runner: The channel through which the molten metal is carried from the sprue to the gate.

Gate: A channel through which the molten metal enters the mould cavity.

Chaplets: Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metal lostatic force.



Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as "feed head".

Vent: Small opening in the mould to facilitate escape of air and gases.

3.1 Important casting term

Self-Check -3	Written Test

Directions: Match column **A** with column **B**

A	B
____ 1. Pattern	A. Small opening in the mould to facilitate escape of air and gases.
____ 2. Gate	B . The channel through which the molten metal is carried from the sprue to the gate.
____ 3. Runner	C . A channel through which the molten metal enters the mould cavity.
____ 4. Vent	D. It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

Information Sheet-4	Identifying quality measures.

4.1. Identifying quality measures.

There are numerous opportunities for things to go wrong in a casting operation, resulting in quality defects in the cast product. In this section, we compile a list of the common defects that occur in casting, and we indicate the inspection procedures to detect them.

Casting Defects

Some defects are common to any and all casting processes. These defects are illustrated in Figure 4.1 and briefly described in the following

a) Misruns, which are castings that solidify before completely filling the mold cavity. Typical causes include
   - ✓ fluidity of the molten metal is insufficient,
   - ✓ pouring temperature is too low
   - ✓ pouring is done too slowly, and/or
   - ✓ cross-section of the
   - ✓ mold cavity is too thin.

b) Cold Shuts, which occur when two portions of the metal flow together but there is a lack of fusion between them due to premature freezing. Its causes are similar to those of a misrun.

C) Cold shots, which result from splattering during pouring, causing the formation of solid globules of metal that become entrapped in the casting. Pouring procedures and gating system designs that avoid splattering can prevent this defect.

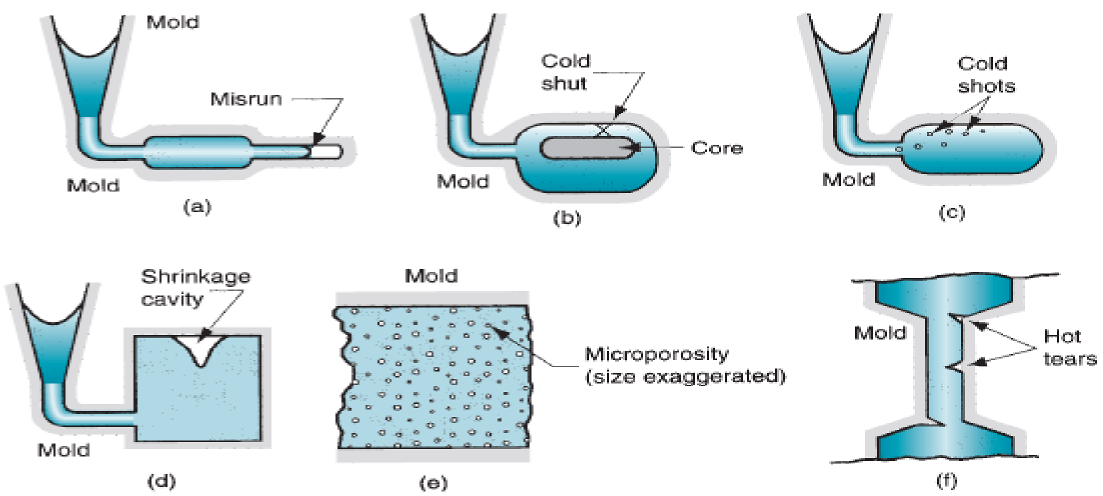


Figure 4.1 Some common defects in castings:

(a) misrun, (b) cold shut, (c) cold shot, (d) shrinkage cavity, (e) microporosity, and (f) hot tearing.

d) Shrinkage cavity is a depression in the surface or an internal void in the casting, caused by solidification shrinkage that restricts the amount of molten metal available in the last region to freeze. It often occurs near the top of the casting, in which case it is referred to as a ''pipe.''
e) Microporosity consists of a network of small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal in the dendritic structure. The defect is usually associated with alloys, because of the protracted manner in which freezing occurs in these metals.
f) Hot tearing, also called hot cracking, occurs when the casting is restrained from contraction by an unyielding mold during the final stages of solidification or early stages of cooing after solidification.
    - ✓ The defect is manifested as a separation of the metal (hence, the terms tearing and cracking) at a point of high tensile stress caused by the metal's inability to shrink naturally.
    - ✓ In sand casting and other expendable-mold processes, it is prevented by compounding the mold to be collapsible.
    - ✓ In permanent-mold processes, hot tearing is reduced by removing the part from the mold immediately after solidification.

- The casting which we make is, of course, never quite perfect in terms of size and shape.
- To allow for this, tolerances are quoted on engineering drawings.
- So long as the casting is within tolerance, it will be acceptable. Some reasons for the casting being out of tolerance include elementary mistakes like the patternmaker planting the boss in the wrong place.
- This leads to an obvious systematic error in the casting, and is easily recognized and dealt with by correcting the pattern.
- It is an example of those errors which can be put right after the first sample batch of castings is made and checked. (Even in this simple case, care may be needed if great accuracy is required, as is explained a little later below.)

- Another common systematic error in castings is the wrong choice of patternmaker's contraction allowance.
- The contraction of the casting during cooling in the mold is often of the order of 1 or 2%. However, it depends on a number of factors, particularly strongly on the strength of the mold and the cores.
- For instance, in an extreme case, a perfectly rigid mold will fix the casting size; in such a situation the casting simply would have to stretch during cooling since it would be prevented from taking its natural course of contracting. Such a situation is common for thin wall castings made in steel molds.
- However, there is often uncertainty. The choice of contraction allowance prior to the making of the first casting sometimes has to be decided in the absence of previous similar castings that would have provided a guide.
- Thus the chosen value for contraction is often not exactly right.
- This point is taken up at length in Section 18.1, with recommendations on how to live with the problem. Other errors are less easily dealt with.
- These are random errors. No two castings are precisely alike. The same is true for any product, including precision-machined parts.
- The ISO (International Standards Organization) Standard (1984) for casting tolerances indicates that although different casting processes have different capabilities for precision, in general the inaccuracies of castings grow with increasing casting size, and the standard therefore specifies increasing linear tolerances as linear dimensions increase.
- (Nevertheless it is worth pointing out that the corresponding percentage tolerance actually falls as casting size increases.)
- Although other work on the tolerancing of castings suggests that the ISO standard has considerable potential for further improvement (Reddy et al. 1988), it is the only European standard at this time.
- This also has to be lived with. Because of the effects of random errors being superimposed on systematic errors, where great precision is required, it is of course

risky to move the boss into an apparently correct location simply after the production of the first trial casting.

- A sample of at least two or three castings is really needed, and preferably ten or a hundred. The mean boss location and its standard deviation from the mean position can then be known accurately and the appropriate actions taken.

Self-Check -4	Written Test

Directions: Choose the correct answer

1. The casting which we make is, of course, never quite perfect in terms of ------- and------.

A. size and shape C. cast and mould

B. steel and brass D. none

2. -----------, which occur when two portions of the metal flow together but there is a lack of fusion between them due to premature freezing. Its causes are similar to those of a misrun.

A. Cold shots C. Cold Shuts

B. Misruns D. Hot tearing

List of Reference Materials

1. J S Campbell, Principles Of Manufacturing Materials And Processes, Tata McGraw Hill, 1995 pdf.
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Foundry Work

Level II

Learning Guide-11

Unit of Competence:	**Plan Casting Processes**
Module Title:	**Planning Casting Processes**
LG Code:	**IND FDW2 M04LO2-LG-11**
TTLM Code:	**IND FDW2 TTLM 1019v1**
LO 2:	**Plan steps required to complete task**

Instruction Sheet	Learning Guide #11

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Determining plan and sequence of activities.
  - ✓ Preparing plan
  - ✓ Sequencing activities
  - ✓ Comparing planned steps and task requirements.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Determined plan and sequence of activities according to instructions and specifications provided

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
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6. If you earned a satisfactory evaluation proceed to "Operation sheets and LAP Tests if any". However, if your rating is unsatisfactory, ask your teacher for further instructions or go back to Learning Activity.
7. After you accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;
8. Then proceed to the next information sheet.

Information Sheet-1	Determining plan and sequence of activities.

1.1 Determining plan and sequence of activities.

1.1.1 Process Planning

Process planning can be defined as the systematic determination of the detailed methods (process and parameters) by which work pieces or parts can be manufactured economically and competitively from initial stage (raw material form) to finished stage (desired form), subject to constraints of part specifications and available resources [Alting, 1994]. Following is the basic information essential for process planning:

Design and Quality requirement data,

- Production type data,
- Raw material data,
- Resources and capability data.

Since process planning activity acts as an effective bridge between design and manufacturing, it dictates cost, quality and production rate in a manufacturing organization

1.1.2 Process Selection Methodology

The casting process selection methodology involves screening the casting process database to get a set of feasible alternative for the given product requirements. User gives the casting product requirements in terms of design, production and quality parameters as an input to the system through the user interface screen.

These parameters includes weight, casting size, metal, preferred casting process, minimum wall thickness, minimum core hole size, dimensional tolerance, surface finish, order size, delivery quantity, delivery frequency, production rate, latitude and longitude. The screening process involves comparing these casting product design requirement values with the respective value of an alternative to discard those, which do not satisfy the requirements.

The following criteria are used to screen the feasible processes from the various alternatives available.

- Casting weight.
- Maximum size.
- Minimum core hole diameter.
- Minimum section thickness.
- Delivery quantity.
- Foundry production capacity.

This screening process results into a set of alternatives that are feasible for the given casting product requirements. The product design can further be modified to test the cast ability of the product for the selected processes.

For example, if the minimum wall thickness value given was is 3 mm and A, B and C processes are screened by the system. Now if the minimum value of the wall thickness is reduced to 2.6 mm and after the screening if it is found that process B is now not listed.

This means the cast ability of the product by the process B is not very good and close process control is required to achieve the desired results. The Figure 1.1 shows the simplified flow chat for the process selection.

Plan and Schedule Development – Create a Work Breakdown Structure

Overview of WBS Creation

The WBS is the first step in developing a detailed work plan for the project. It bridges from the early Scope definition to creation of a detailed project schedule.

1. Start with the Scope

Defines at the highest level what must be created and delivered to the project's customers to satisfy the objectives of the project.

⇩

2. Create the Work Breakdown Structure (WBS)

A top-down hierarchical description of the work required to produce what is called for in the Project Scope and achieve the mission, satisfy stakeholders

- Provides approach for 'decomposing' the work into measurable units, which allows easier and more accurate estimates of duration, needed resources, and time required.
- Helps ensure that the scope is completely defined and the team has not forgotten any work.
- Allows breakdown of work to deliverables and activities that can be assigned to an owner.

⇩

3. Based on the WBS, develop the Project Schedule

- Created by adding resource assignments, identifying dependencies among activities

1.3 CASTING PROCES PLANNING SYSTEM

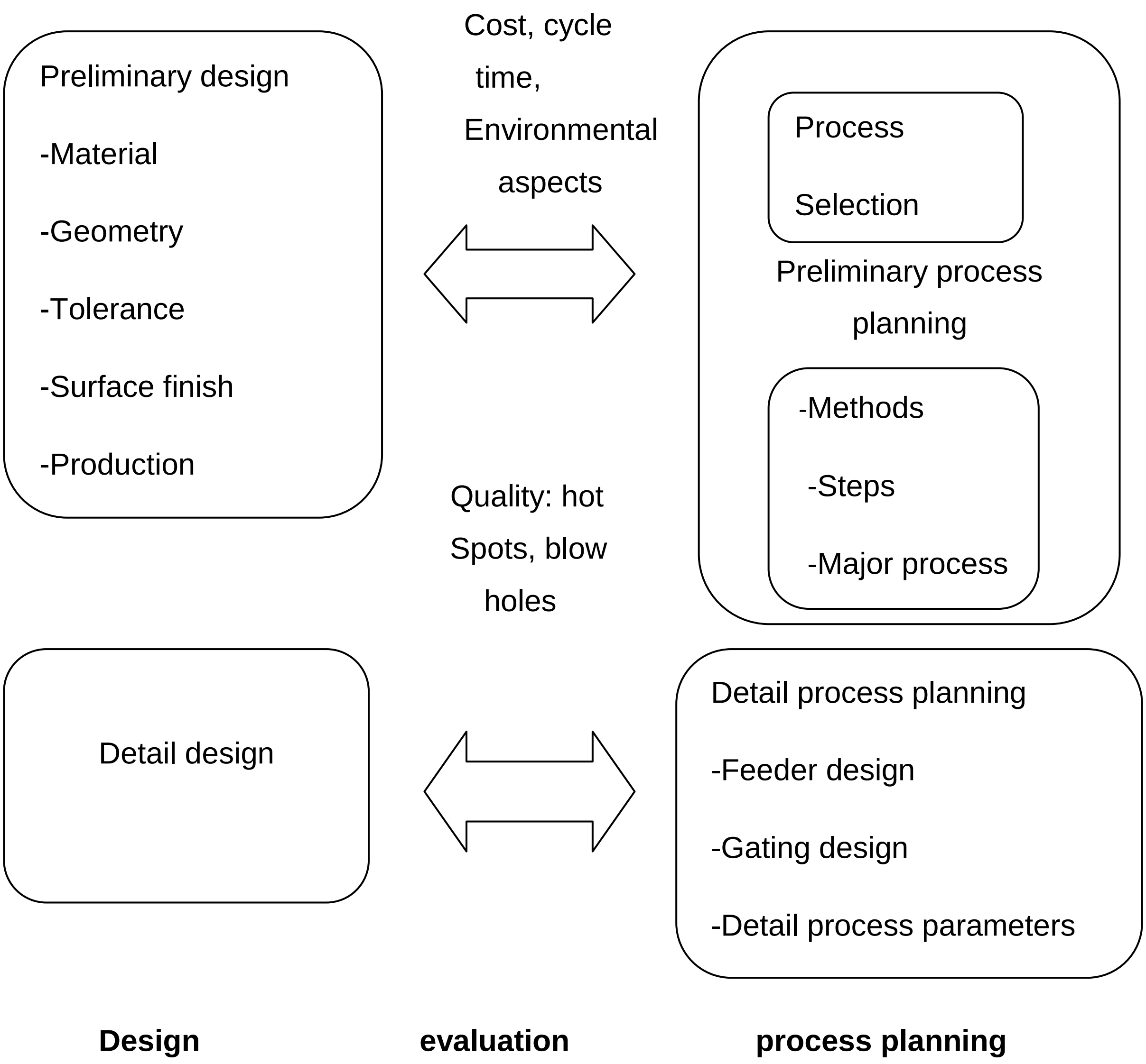

Fig. 1.3 casting process planning

Product design is considered as an iterative process divided into preliminary design and the detailed design. At the preliminary stage, designers finalize different attributes like material, weight, overall size and a little bit tentative about surface finish, tolerances and dimensional parameters.

While at the detailed design stage designer freezes all dimensional and quality parameters of the product. Similar to design, casting process planning can be divided into three levels viz: process selection, preliminary process planning and detailed process planning (also referred as methoding in foundry).

The preliminary process planning is mainly concerned with decisions regarding the methods, steps and major process parameters (type of mold or core sand, pouring temperature, etc.).

The detailed process planning involves determining all necessary process parameters, including detailed design of feeding and gating systems as shown in the fig 1. The work reported in this paper is focused on the preliminary process planning of the cast components.

For preliminary casting process planning, both generative and variant process-planning approaches have been developed.

The generative process planning approach involves automatically generating the process plan from the standard process plans stored in the libraries while variant process planning approach involves generating the process plan automatically.

Self-Check -1	Written Test

Directions: Choose the correct answer

1. Process planning activity acts as an effective bridge between _______ and _______

   A. Needs and gaps C. Local and resources

   B. Local and maps D. Design and Manufacturing

2. Which one of the following criteria are used to screen the feasible processes from the various alternatives available.

   A. Casting weight. C. Minimum core hole diameter.

   B. Maximum size. D. All

List of Reference Materials

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2. R.G. Chougule Indian Institute of Technology, Bombay, India.
3. Ravi Indian Institute of Technology, Bombay, India.
4. Submitted in the partial fulfillment of the requirements for the award of the degree of MASTER OF TECHNOLOGYBy
   BORADE NIKET P. (Roll No. 00310405)
   Under the guidance of DEPARTMENT OF MECHANICAL ENGINEERING INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY JANUARY 2002 Dissertation Approval sheet Dissertation entitled "Web-based casting process selection and preliminary process planning" by Borade Niket P. (Roll No. 00310405) is approved for the degree of Master of Technology.

Foundry work

Level II

Learning Guide-12

Unit of Competence:	**Plan Casting Processes**
Module Title:	**Planning Casting Processes**
LG Code:	**IND FDW2 M04 LO3-LG-12**
TTLM Code:	**IND FDW2 TTLM 1019v1**
LO 3:	**Review & assure work plan**

Instruction Sheet	Learning Guide #12

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Reviewing effectiveness of plan
- Revising of plan

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Review effectiveness of plan against specifications and task requirements.
- Revise plan, if necessary, to better meet specifications and task requirements

Learning Instructions:

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2. Follow the instructions described below
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks". Each information sheets.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets and LAP Tests if any". However, if your rating is unsatisfactory, ask your teacher for further instructions or go back to Learning Activity.
7. After you accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;
8. Then proceed to the next information sheet.

1.1. INTRODUCTION

A casting defect is an undesired irregularity in a metal casting process. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated. A properly designed casting, a properly prepared mould and correctly melted metal should result in a sound casting. However, if proper control is not exercised a variety of defects may result in a casting. These defects may be because of following reasons

1. Improper pattern/tool design or lack of allowances,
2. Improper mould and core constituents,
3. Improper melting practice,
4. Improper pouring practice
5. Because of molding and core making materials.
6. Improper gating - rise ring system along with lack of feed aids.
7. Improper metal composition
8. Inadequate melting temp and rate of pouring.
9. Unskilled post melting treatment like shakeout, fettling etc.

Casting Defects

Defects can be as simple as broken or loose sand, or more complicated like gas bubbles. In any case, it doesn't look good, and it may make the casting part useless. Seven types of casting defects, which are developed and recognized by The International Committee of Foundry Technical Associations, are illustrated in the following; typical examples of them are shown in figure 1.1

Metallic Projections

Metallic projections consist of joint flash or fins. They are very common defects in casting. It is caused by the mould somehow separated to allow metal filled between the halves, along the parting line. But it can be broken off with a hammer or pliers since the thickness of flash usually less than 3mm.

Cavities

Cavities consist of rounded or rough internal or exposed cavities such as blowholes and pinholes. They are produced because of gas entrapped in the metal during the course of solidification. This defect can appear in all regions of the casting.

Discontinuities

A discontinuities defect such as cracks often scarcely visible because the casting in general has not separated into fragments. The fracture surfaces may be discolored because of oxidation. The design of the casting is such that the crack would not be expected to result from constraints during cooling.

Defective Surface

Defective surface such as flow marks. It appears as lines which trace the flow of the streams of liquid metal.

Incomplete Casting

Incomplete casting is usually caused by the metal solidifying before it fills the cavity. It could also be a restriction: too small a sprue, gate, or not enough venting keeping the metal from going in.

Incorrect Dimensions or Shape

It is due to factors such as improper shrinkage allowance, pattern mounting error, irregular contraction, deformed pattern or warped casting. And the mould shift may be caused by the mismatch of mould halves at the parting line, not aligning the mould correctly. Most flasks have alignment pins to prevent this defect.

Inclusions

Inclusions forms during melting, solidification, and moulding, generally nonmetallic are considered harmful because they are stress raisers. These defects most often appear after machining.

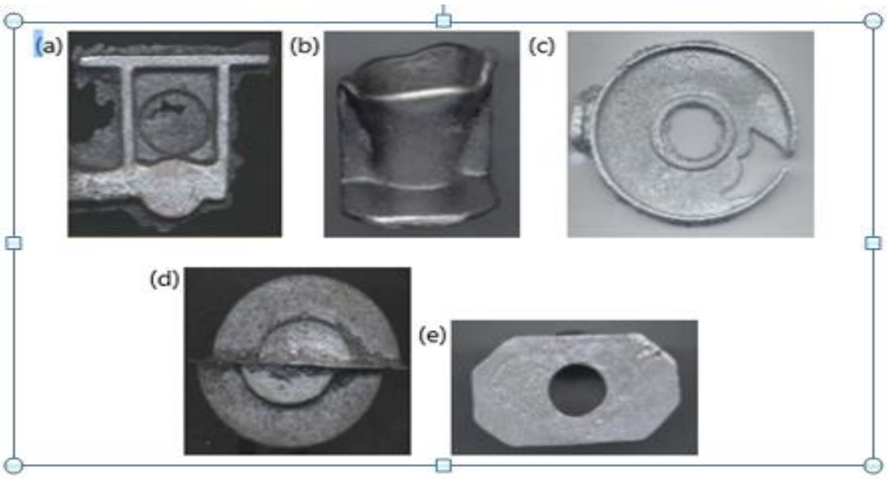


Fig. 1.1 Examples of common defects in castings – (a) flash, (b) porosity, (c) short casting, (d) mould shift, (e) inclusions

Cause and effect diagrams were developed by Kauro Ishikawa of Tokyo University in 1943 and thus are often called Ishikawa Diagrams. They are also known as fishbone diagrams because of their appearance (in the plotted form).

Cause and effect diagrams are used to list systematically the different causes that can be attributed to a problem (Effect-Y). By carrying out systematic analysis of casting rejection using Parato charts 82-20 principle a definite cause of defect can be known. A cause-and-effect diagram can aid in identifying the reasons why a process goes out of control and once its cause is identified then it can be overcome by various remedies.

Aspiration effect: entering of gases from baking of organic compounds present in the mould into the molten metal stream. This will produce porous castings. Pressure anywhere in the liquid stream should not become negative.

Free falling liquid

Metal flow with aspiration effect

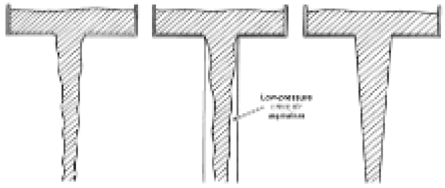
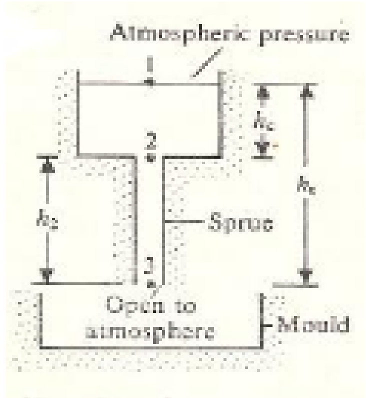


Fig 1.2 A tapered sprue without aspiration effect

Case 1 straight Vs tapered sprue



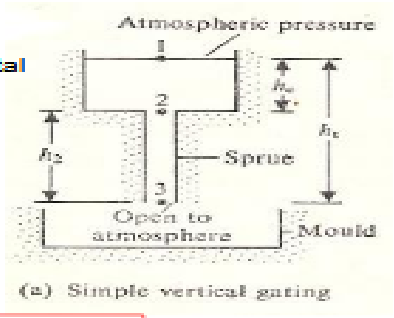
Pressure anywhere in the liquid stream should not become negative.

a) simple vertical gating

Points 2 & 3

$$gh_2 + \frac{p_2}{\rho_m} + \frac{v_2^2}{2} = \frac{p_3}{\rho_m} + \frac{v_3^2}{2}$$

ρ_m = density of molten metal



Let in the limiting case, $\rho_2 = p_3$, then from above equation

$$\frac{v_3^2}{2} = gh_2 + \frac{v_2^2}{2}$$

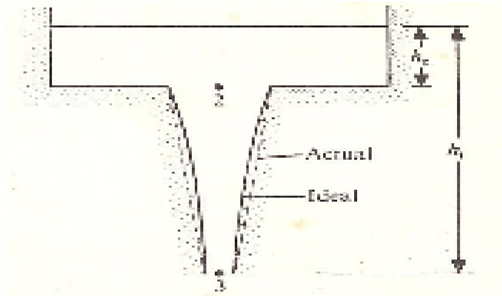
We know that, $v_2 = \frac{A_3}{A_2} v_3 = Rv_3$

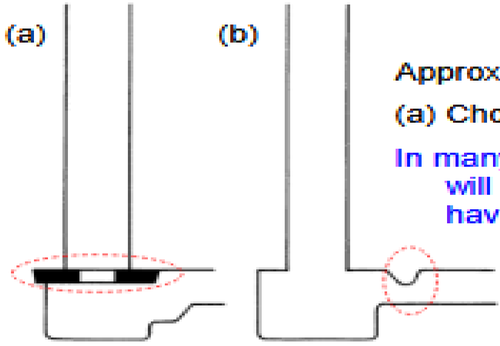
Combining above two eqns., $\frac{v_3^2}{2g} = h_2 + \frac{R^2 v_3^2}{2g}$ $\quad R^2 = 1 - \frac{2gh_2}{v_3^2}$

We know that between points 1 and 3, $gh_t = v_3^2 / 2$

Put this in R^2 eqn, we get, $R^2 = 1 - \frac{h_2}{h_t} = \frac{h_c}{h_t}$ $\quad R = \frac{A_3}{A_2} = \sqrt{\frac{h_c}{h_t}}$

Ideal and actual profiles of sprue



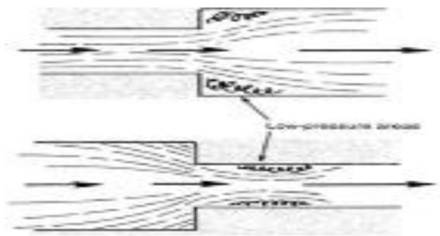


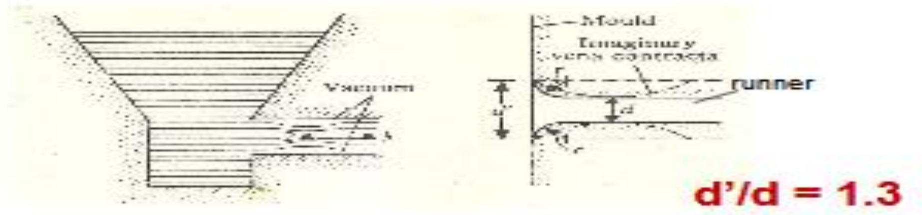
Approximating tapered spure using choke mechanism

(a) Choke core, (b) Runner choke

In many high production casting systems, tapered sprue will not be provided. Instead it is compensated by having chokes at the end of sprue or runner.

Case 2: sudden change in flow direction   fig: 1.3 flow direction





A sharp change in flow direction is avoided by designing the mould to fit vena contracta.

Effect of friction and velocity distribution

The velocity of the liquid metal in the sprue and gate are assumed constant. This depends on the nature of flow and shape of the channel.

Moreover no frictional losses are considered. In real cases, friction losses are always present, specifically when there is sudden contraction and expansion in cross-sections.

The non-uniform velocity distribution is accounted for by modifying the KE term in the energy balance equation by replacing $(v)^2$ by $\frac{\bar{v}^2}{\beta}$ where β where β is a constant and is the average velocity.

For circular conduit, β is equal to 0.5 for laminar flow and 1 for turbulent flow.

The energy loss due to friction in a circular channel (per unit mass) is given by, $E_{f1} = \frac{4fl\bar{v}^2}{2d}$

Here l and d are length and diameter of channel. The value of f(friction factor) depends on the nature of flow and channel smoothness. This Ef1should be added to energy at point 2 (say there are two points 1 and 2 discussed earlier).For smooth channel: where Re< 2000 for laminar flow

$$\frac{1}{\sqrt{f}} = 4\log_{10}(R_e\sqrt{f}) - 0.4 \quad \text{for turbulent flow } (R_e > 2000)$$

$$f = 0.079(R_e)^{-0.25} \quad \text{for the range } 2100 < Re < 10^5 \text{ (simplified from above eqn.)}$$

Frictional losses also occur due to sudden change in flow direction like in 90°bends. In such cases, proper (l/d) ratio should be considered in Ef1equation.The energy loss due to sudden contraction and enlargement of flow area (per unit mass), $E_{f2} = \frac{\bar{v}^2}{2} e_f$. Here is the average velocity of the fluid in smaller CS region and efis the friction loss factor and it depends on the ratio of flow area and Re.In this ef depends on sudden expansion or sudden contraction.

Self-Check -1	Written Test

Directions:

PART: I choose the correct answer

1. A casting defect is an undesired ___________ in a metal casting process

    A. Irregularity C. circle

    B. Squire D. shape

2. The velocity of the liquid metal in the sprue and gate are assumed constant. This depends on the nature of _________ and _________ of the channel.

    A. Squire and circle C. Aspiration and effect

    B. Flow and shape D. molten and metal

Part: II say true or false

1. Identifying needs and Wants: Before exploring the options for service providers, he/she should think about what client's want and need.
2. Making options/Choices: Take time to review the answers that received when the social practitioner interviewed service providers.
3. Defects can't be as simple as broken or loose sand, or more complicated like gas bubbles.

Information Sheet-2	Revising of plan

2.1. Introduction to Revising of plan

Metal casting is one of the most ancient techniques used for manufacturing metal parts. It is the process of forming metallic objects by melting metal, pouring it into the shaped cavity of a mould and allowing it to solidify. Heat is absorbed by and transferred through the mould wall during pouring of molten metal in mould cavity

- The solidification process for pure metals and eutectics start layer by-layer from the mould wall and proceed to the center. This essentially moving solidification front, contracts in volume, and draws molten metal from the adjacent (inner) liquid layer. When the solidification front reaches the center region or the hot spot, there is no more liquid metal left and a void called shrinkage cavity, is formed (as shown in Fig. 1). Shrinkage defects appear frequently in foundry
- This is avoided by attaching a feeder designed to solidify later than the hot spot. This facilitates shifting of the shrinkage cavity to the feeder. Thus, understanding the solidification phenomenon will help us in predicting the type and location of shrinkage defects.

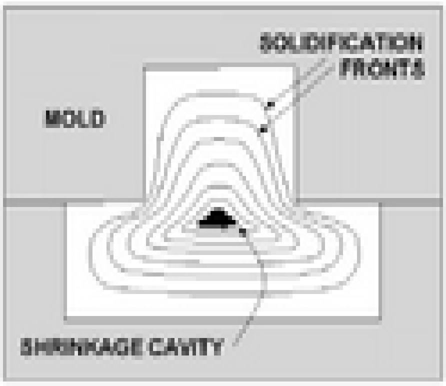


Fig: 1:1 Shrinkage defects

- These defects can be minimized by an intelligent methoding and simulation using casting software. The software simulates the way casting engineers decides the casting process, parting line, cores, mould box, feeders, gating system and mould layout, and analyzes each decision to suggest how the design could be modified to improve quality as well as reduce tooling and manufacturing costs. Hence casting solidification simulation enables predicting and preventing potential problems before freezing the product design, determining 'goodfirst' methoding solutions to achieve high yield at the desired quality level, and evolving optimal process plans compatible with both product requirements and foundry capability. The methoding involves four major decisions:
    - ✓ orientation and parting line,
    - ✓ core print design,
    - ✓ feeder design, and
    - ✓ gating design.

  The objective of this research work is to carryout numerical simulation of casting solidification with experimental trials to minimize above mentioned defects. Casting simulation and analysis has been studied by many researchers and their achievement and limitations are taken into account while solving the case study. The solidification phenomena in sand mould for thermal stress using finite element analysis has been carried out and author has discussed about the effect of solidification on stress formation in casting where the experimental data was available
- The defects formation during solidification of Al alloy using ABAQUS has been studied and showed that most of the defects formed where the metal solidified last
- Thermal history of the sand casting process for mould filling time using FORTRAN has been investigated. This study has shown that the lastly solidifying area is near the junction
- Optimum riser design and its location will ensure removal of hot spot from the casting. Here, riser having higher value of the modulus has been designed so that it should have higher solidification time compared to casting
- Computer-aided casting design and simulation provides much better and faster insight for optimizing the feeder design of castings,[8]. The application of computer aided

methoding, and casting simulation in foundries can minimize the bottlenecks and non-value added time in casting development, as it reduces the number of trial casting required on the shop floor.

Problem Definition

The objectives of this study is to represents stepped plate casting design and its numerical simulation using Auto CAST-X software of square shaped (at top) plate having three perforations with diminishing height (at bottom) followed by experimental validation. It has thick 208 x 208 mm square shape with a thickness of 21mm and then the perforations of diminishing height begins from left to right as 24mm (thickest section), 19 mm (thicker section), and 14 mm (thick section), respectively for the entire width of square shape.

The present component was subjected to high amount of shrinkage defects which was the major cause for the rejection in the foundry. It also was having very low yield as 45 % as per the foundry information. So the objective was to redesign and develop a defect free casting with the improvement in the feed ability index which represents yield of feeders and quality of casting (percentage volume free from shrinkage porosity).

Based on literature survey, feeder location was identified where the formation of hotspot was expected by simple analysis; that was at the thickest section of the casting. Therefore, this was the first location for the placement of the feeder to solve the problem. Auto CAST-X has inbuilt feature to check the hot spot in the component. It has also shown larger hot spot at thicker section as compared to other two. Hence a strategy has been decided to place the feeder, during the experimental trial, at thicker section (at middle).

This has not only fed the molten metal to the thicker section but also to the other two sections. Proper feeding aids have helped in getting the hot spot completely shifted inside the feeder. Flow process chart of function of simulation.

Casting Design Calculations

Casting design mainly consists of pattern design, gating system design and finally the feeder design. Casting is carried out with the LM 6 material by sand casting process. To compensate for any dimensional and structural inadequacies which will happen during the casting or patterning process, allowance are usually provided to the pattern. Various allowances considered are shrinkage allowance, draft allowance, machining allowance etc.

The design of the gating system act as a passage ways for the flow of molten metal from the ladle to various portions of the mould cavity, influencing the casting quality and economy. Nearly 40 % of casting defects are attributed to faulty design of gating systems and poor pouring practices.

The solidification is essentially a phase transformation of metals from liquid to solid state in a pre shaped cavity. This phase transformation is accompanied by volumetric shrinkage in most of the cast metals. In order to produce a sound casting it is necessary to provide means for compensating volumetric shrinkage.

Feeder or riser is the reservoirs of liquid metal provided in the mould to compensate for the volumetric shrinkage of the casting over the total solidification period. The feeder should be thermally and volumetrically adequate with sufficient feeding range. Based on design calculations wooden pattern for component, gating system and feeder has been prepared pattern. Various allowances considered are shrinkage allowance, draft allowance, machining allowance etc.

Self-Check -2	Written Test

Directions: Choose the correct answer

1. These defects can be minimized by an intelligent _______and ______using casting software.
   - A. methoding and simulation
   - B. design and shape
   - C. mould and allowing
   - D. thermally and volumetrically
2. The present component was subjected to high amount of ___________defects which was the major cause for the rejection in the foundry.
   - A. Inclusions
   - B. shrinkage
   - C. flash
   - D. cracks

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