Early Bronze Age Foundrymen

MME 345

Lecture **A:02**

Chapter A1: Introduction

2. Casting as a metal forming process

Ref: P. Beeley, Foundry Technology, Butterworth-Heinemann, 2001.
Ch 01: Introduction

Topics to discuss today ….

1. Metal forming processes
2. Casting as a metal forming process
3. Introduction to the course MME345

1. Metal forming processes

- Metals and their alloys are the most important of all engineering materials. Important applications of metal and their alloys include:
  - ☐ the use of steels as structural materials
  - ☐ cast irons as pipe fittings
  - ☐ aluminium and titanium alloys in automotive industries

- The size of a metal object may vary from a few ounces (pin) to hundreds of tons (bell) and the shape can be a simple block to the most complicated designs (wrought iron gates or cast iron engine blocks).

- Amongst the manufacturing processes described earlier (Lecture **A:01**) to produce engineering components, only a few of them are used to impart shapes to metals and alloys (**Fig. 2.1**).

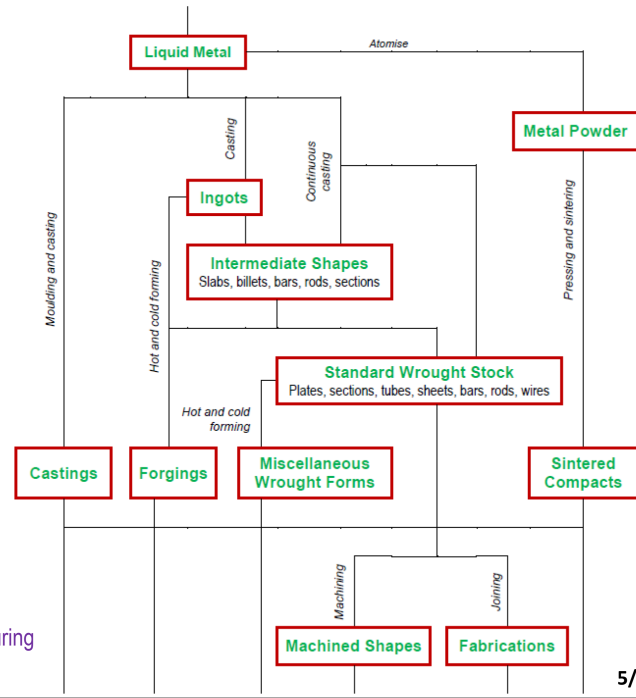


FIGURE 2.1
Major routes in the manufacturing of engineering components.

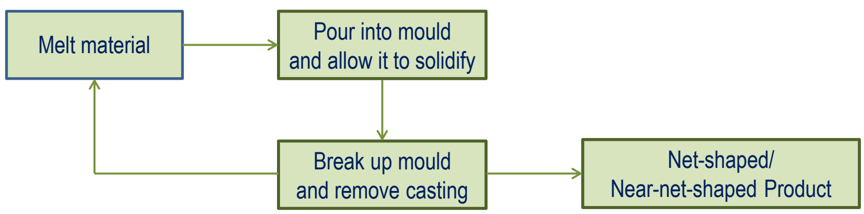
- Most of the methods of shaping finished product shown in **Fig. 2.1** involved several steps.
  - Getting a finished product by **deformation processing**, for example, requires first casting an ingot and then give the final shape by hot/cold working.
  - **Machining** involves chipping away from cast or worked material to get the product shape. Thus machining is a wasteful method of getting final shapes.
  - On the other hand, shaping of product by **powder method** always required production of powders that is a costly process.

- It is clear from the figure that a major share of metals and alloys that are given shape by using many different processes are originated from a common metal forming process, called the **casting**.
  - So the importance of casting as a valuable metal forming process is understood.

2. Casting as a metal forming process

- Casting is a manufacturing process of producing net-shaped or near-net-shaped product by introducing molten metal into a mould, which contains a hollow cavity of the desired shape, and then allowing it to solidify.

- The solidified product, also known as a casting, is ejected or broken out of the mould to complete the process.



- Two categories of metal casting processes:

① **Expendable mould processes** - mould is sacrificed to remove part

Advantage: more complex shapes possible

Disadvantage: production rates often limited by time to make mould rather than casting itself

② **Permanent mould processes** - mould is made of metal and can be used to make many castings

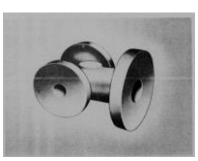
Advantage: higher production rates

Disadvantage: geometries limited by need to open mould

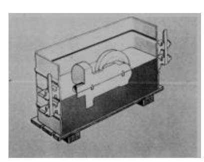
- **Sand casting**, one of the most widely used expendable moulding process, accounts for a significant majority of total tonnage of metal cast.
  - ☐ **A pattern**, an exact replica of the casting, is required to prepared the mould cavity in a sand mould.
  - ☐ The liquid metal is then poured into the mould cavity and allowed it to solidify to make the casting.
- The method of casting used today is no different from the casting process used by the primitive people.
- The modern day casting, however, becomes much more complex.

FIGURE 2.2 Steps in casting an arrowhead (used by the primitive people).

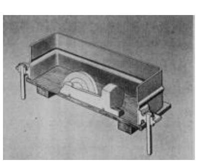
2.1 A typical modern casting process



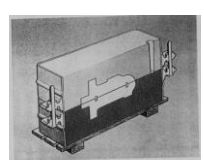
1
The iron casting to be produced in the subsequent illustrations of moulding



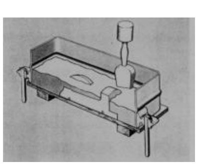
4
After the bottom half of the mould is filled, it is rolled upright and the top half of the pattern and flask are put in place to complete the mould



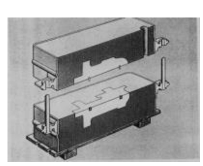
2
Cross section of the first step in making a greensand mould. Bottom half of the pattern is on the mould board and surrounded by the bottom or drag half of the flask



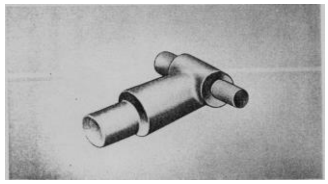
5
Section through the completed mould with pattern still in place and the sprue hole formed for entrance of molten metal



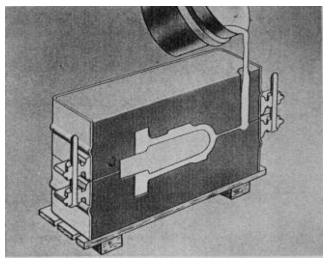
3
Moulding sand is rammed around the pattern in multiple steps to provide uniform density



6
Cope and drag halves of the mould are separated to remove the pattern. The gate channel is then cut from the sprue to the mould cavity.



7
The core is made separately to form the internal passages of the casting



8
After placing core in the mould, the mould is closed and clamped to resist the pressure exerted by the molten metal when it is poured in the mould

2.2 Basic steps involved in making a casting

1. Pattern making
   - Required to make mould cavities
   - An approximate replica of the exterior of a casting
   - Designed and prepared as per the drawing of the casting received from the planning section and according to the moulding process to be employed
   - If the casting is to be hollow, additional patterns, referred to as core boxes, are prepared to make the core

2. Mould making and core making

- The cavity in the sand mould is formed by packing sand around the **pattern**, then separating the mould into two halves and removing the pattern
- Adequate **gating system** and **feeding system** are required in the mould to direct the liquid metal into the mould cavity and to feed the solidification shrinkage
- If casting is to have internal surfaces, a **core** must be included in the mould

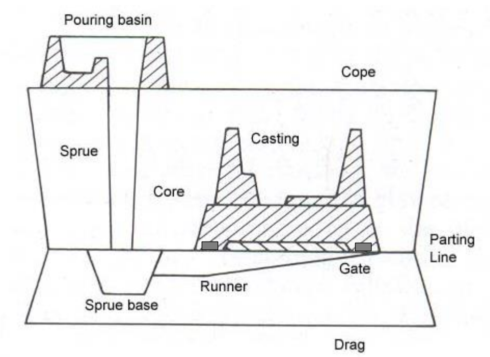


FIGURE 2.4 Schematic view of cross section of a sand mould

3. Melting and pouring

- Preparation of molten metal of correct composition in a suitable furnace is referred to as **melting**
- When molten, the liquid metal is taken into a ladle and poured into the mould
- The mould is then allowed to cool down so that the liquid metal solidifies
- The castings are finally extracted by breaking the mould. This operation is known as **shake out**.

4. Fettling and finishing

- **Fettling** refers to all operations necessary to the removal of sand and oxide scale (adhered to the casting surface), core and excess metal (fins and other projections, gating system, feeder) from the casting.
- **Finishing** of casting is the final stage of cleaning of casting. Typical finishing operations include **polishing** and other operations (shot blasting, etc.) used to improve surface finish and appearance of castings and different **surface treatments** (painting, electroplating, galvanising, heat treatment, etc.) given to impart special properties to castings.

5. Inspection and quality control

- Finally, before the casting is dispatched from the foundry, **inspection and testing** of the casting is carried out to ensure that it is flawless and conforms to the desired specifications.
- In case any defects or shortcomings are observed, **salvage and rectification** of castings are carried out to save the casting.
- Proper and thorough **quality control** scheme is followed to analyse and determine the causes of these defects, so as to prevent their reoccurrence. The production process then has to be corrected accordingly.

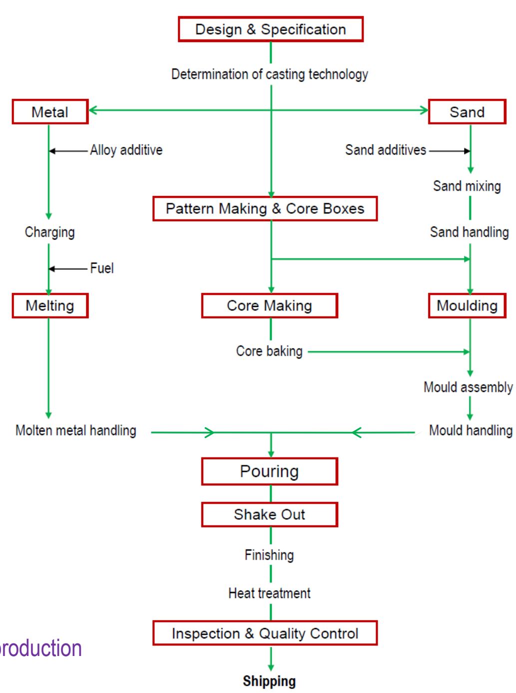


FIGURE 2.3 Steps in the production sequence in sand casting.

2.3 Advantages of casting process

- Casting is a versatile process capable of being used in mass production items in very large shaped pieces, with intricate designs and having properties unobtainable by any other methods.

- The full exploitation of the casting process requires careful study not only of its advantages but of potential difficulties and limitations.

- Three classes of advantages of casting process and castings:
  ① Advantages of casting process
  ② Design advantages of castings
  ③ Metallurgical advantages of castings

Advantages of casting process

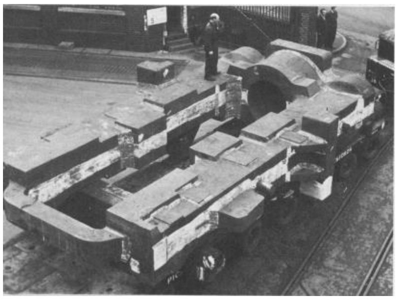
① Versatile (jobbing/mass production)
② Dimensional accuracy (tolerance up to ~0.1 mm, surface finish ~ 5-50 micron)
③ One step process (minimizing/eliminating forging, joining, etc. processes)
④ Low cost (the cheapest method of metal shaping)

Design advantages of castings

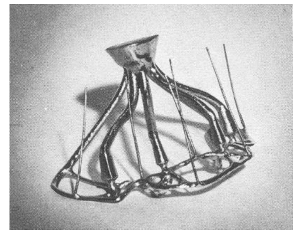
① Size
② Complexity
③ Weight saving
④ Production of prototypes
⑤ Wide range of properties
⑥ Versatility in casting alloys

Metallurgical advantages in castings

① Uniform/isotropic properties
② Grain size
③ Density



cast steel mill house, 198 tonnes



dental implant, 9 gram

cast steel paper mill stockbreaker

cast iron gate assembly

2.4 Disadvantages of casting process

① Bad surface finish and dimensional accuracy

② Lack of directional properties

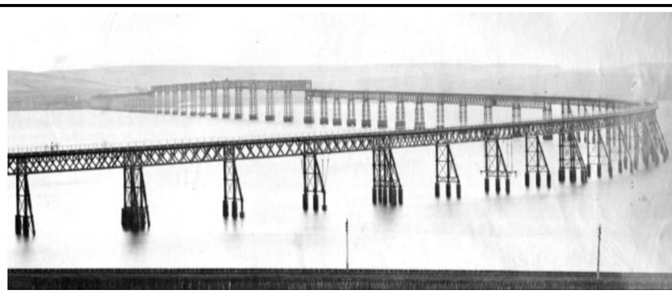
③ Unable to produce complex structures

④ Unable to use refractory materials

⑤ Presence of casting defects

2.5 History and development of metal casting

5000-3000 BC	• Metal casting is a technology, which reaches back almost 5000 years. • The oldest casting in existence is believed to be a copper frog cast in Mesopotamia (roughly modern Iraq) probably around 3200 BC.
2250 BC	Life size portrait head of cast bronze from Mesopotamia
2000	Discovery of iron
1766-1122	The first foundry centre in China (during Shang dynasty)
600	First iron casting in China
500 AD	Cast crucible steel in India
1200	Use of metal bells and ornaments in Greeks and Romans temples
1480-1539	**Vannoccio Biringguccio**, the father of foundry, wrote a detailed account of metal founding
1683-1757	Extensive works on cast iron by **Reaumur;** development of malleable cast iron
1709	Smelting of iron ore in coke blast furnace by **Abraham Darby**
1879	**The collapse of Tay Bridge**
Middle of twentieth century	• Invention of chemical bonded and other new moulding techniques • Better understanding of the casting phenomenon • Start of teaching metal casting in engineering institutes as an independent subject



Original Tay Rail Bridge

Date	28 December 1879
Time	7:16 pm
Location	Dundee
Country	Scotland
Rail line	Edinburgh to Aberdeen Line
Operator	North British Railway
Cause	Structural failure

https://en.wikipedia.org/wiki/Tay_Bridge_disaster

2.6 Foundry establishment

- A foundry is a commercial establishment for founding, or producing castings.
- The modern foundry is **a well-organised business**, efficiently operated to maintain quality as well as quantity production of castings at a low cost.

Classes based on type and capacity of production

① **Jobbing foundries**
② **Production foundries**
③ **Captive foundries**

Classes according to the type of materials melted

① **Ferrous foundries**

(a) Steel foundries
(b) Grey iron foundries
(c) Malleable iron foundries
(d) Ductile iron foundries

② **Non-ferrous foundries**

(a) Light metal foundries (for Al and Mg)
(b) Copper, brass and bronze foundries
(c) Lead, tin and zinc-base foundries

2.7 Foundry layout

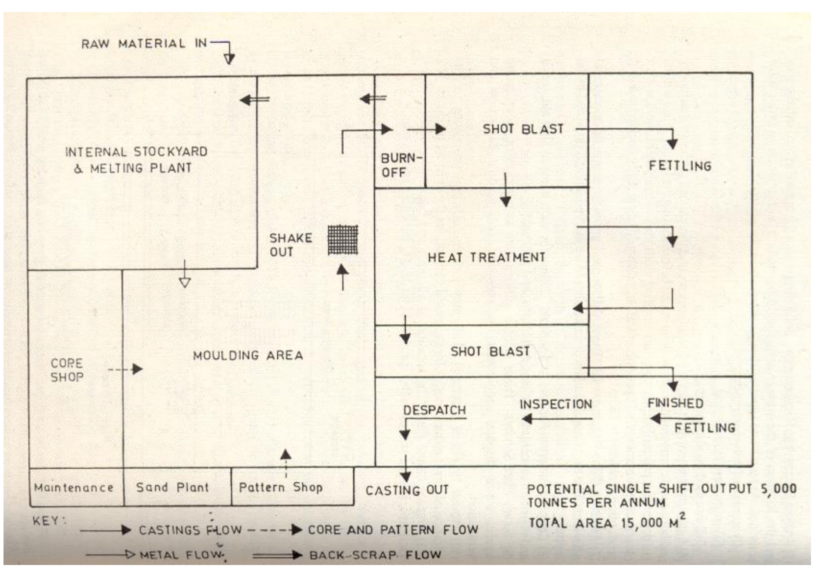


FIGURE 2.5 Typical layout of a grey iron foundry

2.8 Influence of casting to other industrial sectors

- Foundry is a basic industry
  Its product, castings, enters into every field in which metals serve man
- Castings are produced almost everywhere that manufacturing occurs
  Transportation, communication, construction, agriculture, power generation, in aerospace, atomic energy applications
- Modern civilisation would not be so far advanced as it is today
  if it were not for the foundry and its products

3. Introduction to the course MME345

Course Description

- This course is designed for students of MME to acquire knowledge in the area of design and production of net-shaped and near-net-shaped objects using metals and their alloys.
- The course is nourished with practical problems and solutions that will enhance the skill of the students especially those that are willing to be self reliant in future.
- The course is also an entrepreneurship course that avail the student the opportunity of becoming self employed after they might have graduated from the University.

Course Objective (CO)

The principal objective of this course is to provide the students with knowledge on the principles that guide production of sound engineering castings.

Course Learning Outcome (CLO)

Upon successful completion of this course, the student will be able to:

1. identify basic steps of making net-shaped and near-net-shaped castings,
2. differentiate between different moulding and casting processes and their end products,
3. explain solidification processes for different metals and alloys, and analyze effects of foundry variables affecting cast structures,
4. understand the methods of calculating gating and feeding systems, and then be able to design a complete gating and feeding system for a casting,
5. describe different casting defects and methods of their removal and examine the effects of defects on casting properties, and
6. evaluate design features of casting to obtain sound product.

MME 345: Syllabus

Part A: Technology Aspects

1 – 2	Introduction
3 – 10	Moulding and casting methods
11 – 12	Patternmaking and core making
13 – 20	Ferrous foundry practices
21 – 23	Nonferrous foundry practices
24	Finishing, inspection and quality control
25	Review class 1

Part B: Science and Engineering Aspects

1	Creating quality casting
2 – 6	Solidification
7 – 11	Feeding design
12 – 18	Gating design
19 – 22	Casting defects
23 – 24	Casting design
25	Review Class 2

Reference Books

1. J. Campbell, Castings, 2nd Edition, Butterworth-Heinemann, 2003.
2. A. Ohno, The Solidification of Metals, Chjin Shokan Co. Ltd., Japan, 1976.
3. M. C. Flemmings, Solidification Processing, McGraw-Hill, Inc., 1974.
4. P. Beeley, Foundry Technology, 2nd Edition, Butterworth-Heinemann, 2001.
5. Heine, Loper and Rosenthal, Principles of Metal Casting, Tata McGraw-Hill, 1976

Course Website

http://teacher.buet.ac.bd/bazlurrashid

Next Class

MME **345**, Lecture **A:03**

Chapter A2: Moulding and Casting

1 Introduction to moulding and casting methods