中南大學
CENTRAL SOUTH UNIVERSITY

# Unit 13 steelmaking

lecturer: Xiyun Yang

School of Metallurgy and Environment

- molybdenum [mə'lɪbdənəm] 钼
- boron ['bɔ:rɑ:n]硼
- titanium [tɪ'teɪniəm]钛
- Vanadium [və'neɪdiəm]钒
- niobium [naɪ'oʊbiəm]铌
- chromium ['kroʊmiəm]铬
- dislocation [ˌdɪslə'keɪʃn]位错
- crystal lattice晶体点阵
- entrain [ɪn‘treɪn]夹带
- solidification [səˌlɪdɪfɪ'keɪʃn] 固化
- Castability [kɑ:stə'bɪlɪtɪ]可铸性
- manganese ['mæŋgəni:z]锰
- Inclusion内含物 [ɪn’klu:ʒn]
- meniscus [mə'nɪskəs] 弯液面
- appliances [əp'laɪənsɪz]家用电器
- Hot metal 铁水
- Tap to tap cycle 冶炼周期
- tensile strength ['tensl]抗拉强度
- blast furnace （高炉）
- oxygen steelmaking process氧气炼钢

# New words and expressions



- ladle ['leidl]钢水包
- barrel [‘bærəl] 桶
- tapping [‘tæpiŋ] 出料口,出钢
- turnaround ['tɜːrnəraʊnd]回转，转身
- pellets ['pelɪts]球
- decarburization [diː¸kɑːbjərɪ'zeɪʃən]脱碳
- Mold powders 保护渣
- Slag stopper挡渣板
- Trunnion [‘trʌnjən]耳轴
- strand [strænd]钢坯
- heats 炉次，炉
- operating cycle 运行周期
- pig iron pellets 生铁球团
- stroke/ strəuk / n. 冲程，行程
- energy optimizing furnace (EOF) 能量优化炼钢炉
- mushy/ 'mʌʃi / adj.糊状的
- **Event工序**
- a horizontal trunnion /'trʌnjən/ axis耳轴，平衡轴

- BOF： basic oxygen furnace 碱性吹氧转炉
- EAF: electric arc furnace电弧炉
- LF: ladle furnace钢包炉
- VD： vacuum deoxidation ['vækjʊəm]真空脱氧
- VOD: vacuum oxygen decarburization真空吹氧脱碳
- VAD: vacuum arc degassing真空电弧加热去气
- AOD: argon-oxygen decarburization vessel氩-氧脱碳炉子

## ➢What can we learn?

- 1、What is steel?
- 2、What is the flowsheet of steelmaking?
- 3、what is secondary refining?
- 4、what is casting?

# process from iron ore to steel

- Iron ore treatment
- Ironmaking: to make hot iron from blast furnace

- Primary steelmaking /Secondary steelmaking: decarbonization
- Ladle metallurgy/Refining: deoxidation, desulfurization and vacuum degassing
- casting

# outline



- Steel introduction
- Steelmaking process
  - Primary steelmaking process: Oxygen steelmaking process
  - secondary steelmaking process: Electric arc furnace
- casting

- 复合形容词 （compound adj.）
  - The furnace or converter is a barrel-shaped, open-topped, refractory-line vessel.
- 多个目的/工序 描述
  - The overall purpose of this process is to reduce the carbon from about 4% to less than 1% (usually less than 0.1%), to reduce or control the sulfur and phosphorus, and finally, to raise the temperature of the liquid steel made from scrap and liquid hot metal to approximately 1635°C (2975°F).
- A process description

# Steelmaking

- **Steelmaking** is the process for producing steel from iron and ferrous ores and scrap. In steelmaking, impurities such as nitrogen, silicon, phosphorus, sulfur and excess carbon are removed from the raw iron, and alloying elements such as manganese, nickel, chromium and vanadium are added to produce different grades of steel. Limiting dissolved gases such as nitrogen and oxygen, and entrained impurities (termed “inclusions”) in the steel is also important to ensure the quality of the products cast from the liquid steel。

- Steel is an alloy made by combining iron and other elements, and the most common of these is carbon. When carbon is used, its content in the steel is between 0.002% and 2.1% by weight, depending on the grade. Other alloying elements sometimes used are manganese, silicon, chromium, molybdenum, boron, titanium, vanadium and niobium.

## carbon

- Carbon and other elements act as a hardening agent, preventing dislocations in the iron atom crystal lattice from sliding past one another. Varying the amount of alloying elements and the form of their presence in the steel (solute elements, precipitated phase) controls qualities such as the hardness, ductility, and tensile strength of the resulting steel.
- Steel with increased carbon content can be made harder and stronger than iron, but such steel is also less ductile （韧性、可延伸性） than iron. Alloys with a higher than 2.1% carbon content are known as cast iron because of their lower melting point and good castability.

- Today, steel is one of the most common materials in the world, with more than 1.4 billion tons produced annually. It is a major component in buildings, infrastructure, tools, ships, automobiles, machines, appliances, and weapons.

- Steelmaking can be roughly defined as the refining or removal of unwanted elements or other impurities from hot metal produced in a blast furnace （高炉） or similar process or the melting and refining of scrap （废铁，废料）and other forms of iron in a melting furnace, usually an electric arc furnace (EAF，电弧炉或电炉).
- When iron is smelted from its ore by commercial processes; it contains more carbon than desirable.

- To become steel, it must be melted and reprocessed to reduce the carbon to the correct amount, at which point other elements can be added.
- Steelmaking is the second step in producing steel from iron ore. In this stage, impurities such as sulfur, phosphorus, and excess carbon are removed from the raw iron, and alloying elements such as manganese, nickel, chromium, and vanadium are added to produce the exact steel required.

steelmaking

Remove : carbon, sulfur, phosphorus

Add: manganese, nickel, chromium, and vanadium

# Flowchart of steelmaking



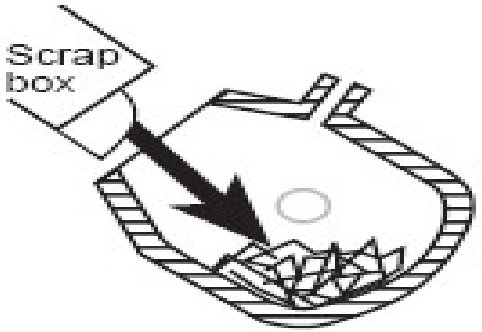
- Currently most all of the hot metal (铁水) produced in the world is refined in an oxygen steelmaking process (OSM). A small amount of hot metal is refined in open hearths, cast into pigs for use in an EAF or refined in other processes.
- Generally, modern steelmaking processes are broken into two categories: primary and secondary steelmaking.

# Primary and secondary steelmaking

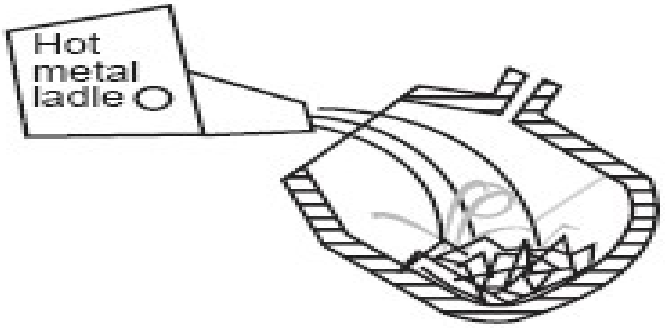
- Primary steelmaking uses mostly new iron as the feedstock, usually from a blast furnace. Secondary steelmaking uses scrap steel as the primary raw material. Gases generated during the production of steel can be used as a source of power. Oxygen steelmaking process is a method of primary steelmaking and Secondary steelmaking is most commonly performed in an electric arc furnace.
- The major element removed in OSM is carbon which is removed by oxidation to carbon monoxide (CO). Other elements such as silicon, phosphorous, sulfur and manganese are transferred to a slag phase.
- In the EAF steelmaking process the chemical reactions are similar but generally less extensive.

## Oxygen Steelmaking Process

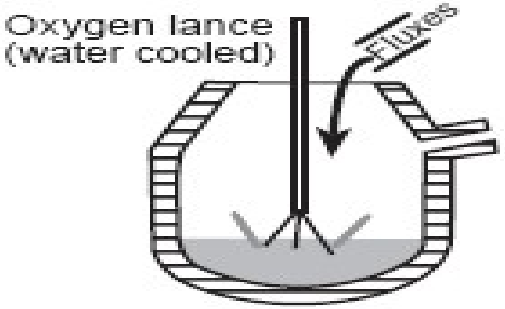
- The oxygen steelmaking process rapidly refines a charge of molten pig iron and ambient scrap into steel of a desired carbon using high purity oxygen.
- Steel is made in discrete batches called heats （炉次，炉）. The furnace or converter is a barrel-shaped, open-topped, refractory-line vessel that can rotate on a horizontal trunnion （耳轴，平衡轴） axis. The basic operational steps of the process (BOF) are shown schematically in Fig.1.



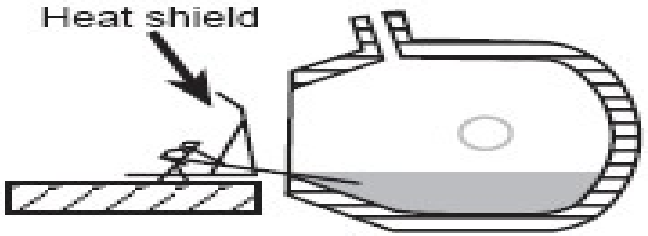

Charging scrap



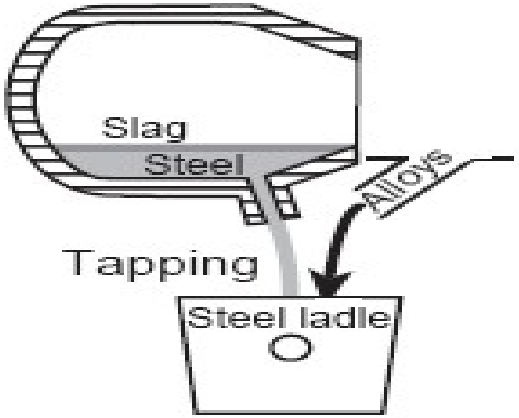

Charging
hot metal




Main blow




Sampling




Tapping


Slag off

# Flowchart of steelmaking



- The overall purpose of this process is to reduce the carbon from about 4% to less than 1%, to reduce or control the sulfur and phosphorus, and finally, to raise the temperature of the liquid steel made from scrap and liquid hot metal to approximately 1635°C (2975°F).
- A typical configuration is to produce a 250 t (220 metric ton) heat about every 45 min, the range is approximately 30 to 65 min. The major event times for the process are summarized below in Table.1.

Table.1 Basic Oxygen Steelmaking Event Times

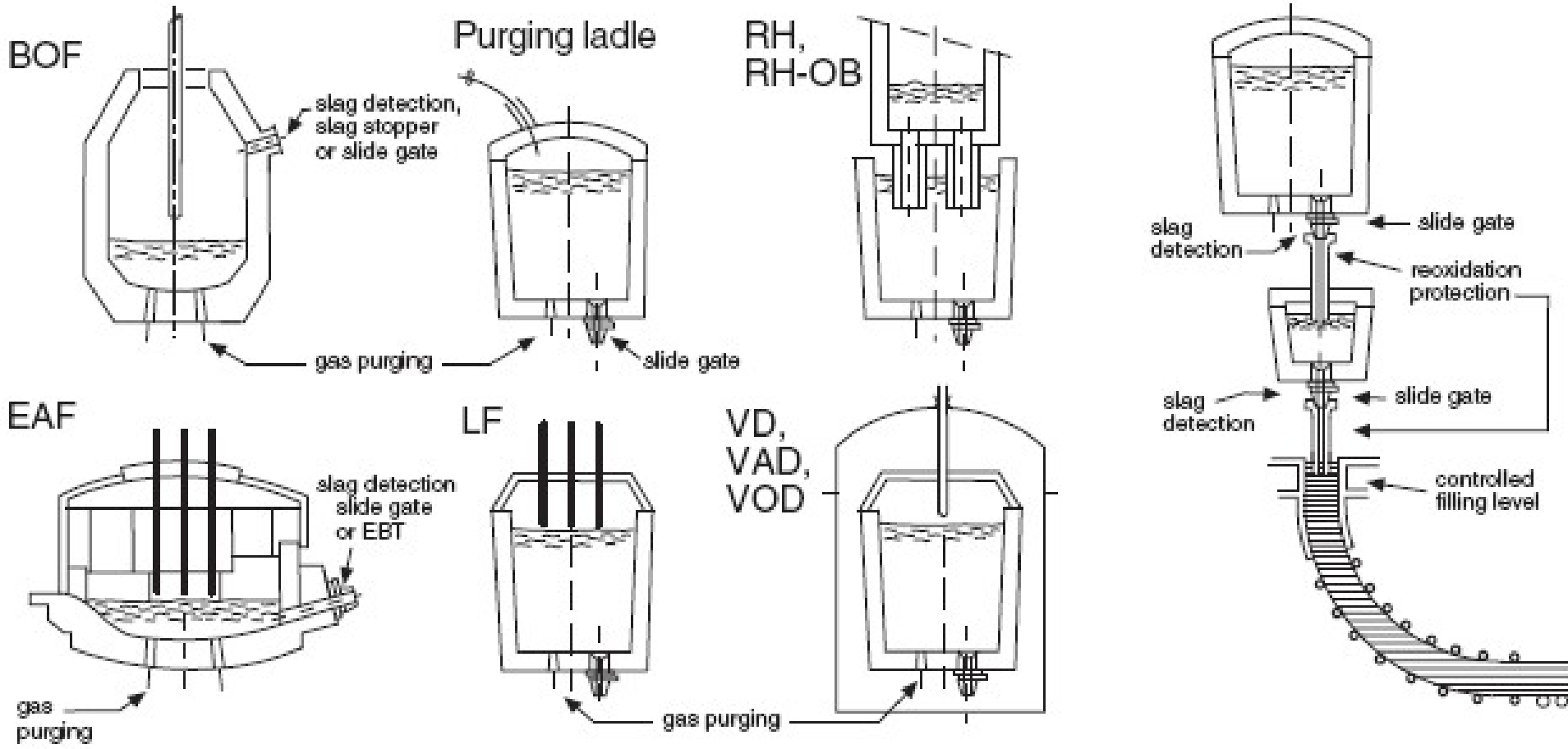
| Event | Min | Comments |
|---|---|---|
| Charging scrap and hot metal | 5-10 | Scrap at ambient temperature, hot metal at 1340°C(2450°F) |
| Refining-blowing oxygen | 14-23 | Oxygen reacts with elements, Si, C, Fe, Mn, P in scrap and hot metal |
| Sampling-chemical testing | 4-15 | Steel at 1650°C (3000°F), chemistry and temperature |
| Tapping | 4-8 | Steel is poured from furnace into a ladle, typical size 250 tons |
| Pouring slag off at furnace | 3-9 | Most slag is removed from furnace, in some shops slag is used to coat furnace walls |

# EAF steelmaking process

- The electric arc furnace operates as a batch process. Each batch of steel that is produced is known as a heat. The electric arc furnace operating cycle is known as the tap-to-tap cycle冶炼周期. The tap-to-tap cycle is made up of the following operations: furnace charging, melting, refining, de-slagging, tapping and furnace turnaround. Modern operations aim for a tap-to-tap cycle of less than 60 min.

- After treating the metal in an OSM converter or an EAF, it is further refined in the ladle (钢包). This is commonly called secondary refining or ladle metallurgy, as shown in Fig.2. And the processes include deoxidation, desulfurization and vacuum degassing.
- For stainless steelmaking the liquid iron-chromium-nickel metal is refined in an argon-oxygen decarburization vessel (AOD), a vacuum oxygen decarburization vessel (VOD) or a similar type process
- VOD炉子：真空吹氧脱碳，AOD：氩-氧脱碳炉子

Steelmaking → Secondary metallurgy → Continuous casting




Melting
Refining
Homogenization
Slag-free tapping

Homogenization
Desulfurization
Alloying
Reheating

Deoxidation
Alloying, reheating
Vacuum treatment
Deep decarburization

Slag-free continuous
Casting
Controlled filling level
Hot charging, direct rollin

# Continuous casting



- Continuous casting (CC) of steel, as an industrialized method of solidification processing, has a relatively short history of only about 50 years- not much longer than oxygen steelmaking.(作为一项工业化的固化成型工艺，钢的连续浇铸历史相对较短，只有仅仅50年的历史并不比氧化炼钢更长)
- Continuous casting has emerged as one of the great technological developments of the twentieth century, replacing ingot casting and slabbing / blooming operations for the production of semi-finished shapes: slabs,（板坯） blooms （大方坯） and billets （小钢坯、小方坯）连续浇铸作为20世纪的伟大的技术发展之一，取代了铸锭浇铸、切割/开坯处理半成品成形：板坯、大方坯、小钢坯、小方坯。

- The process has been adopted worldwide by the steel industry in the latter half of the twentieth century owing to its inherent advantages of low cost, high yield, flexibility of operation, and the ability to achieve a high quality cast product. （在二十世纪的后半段，由于连续浇铸的低成本、高产量、操作灵活、能够实现浇铸高品质的产品的诸多内在优势而被世界钢铁企业所广泛采用）
- In fact, the CC ratio for the world steel industry, now approaching 96% of crude steel output, attained a mere 4% in 1970.

# 复合形容词的几种形式

- 数词+名词（单数）
  - one –child (独生子的) two- hour （两小时的）
- 数词+名词（单容词）+形容词
  - three -year -old三周岁的 six–inch- tall 六英尺高的
- 数词+名词+ed
- one-eyed (独眼的) four-storeyed (四层的)
- 形容词+普通名词
  - full-time (全日制的；全职的) second-hand（经营旧货的）
  - mid-term(期中的)
- 形容词+名词+ed
  - kind-hearted (好心的)

# 复合形容词的几种形式

- 形容词（副词）+现在分词
- good-looking （好看的）tired-looking（面带倦容的）
- 形容词（副词）+过去分词
  - well-informed（消息灵通的）
- 形容词（副词）+形容词
  - dark-blue（深蓝色的）light-green（浅绿色的） all-round （全面的）
- 名词+现在分词
  - English-speaking（讲英语的） life-saving （求生的)
- 名词+过去分词
  - hand-made（手工制的）heart-broken （令人心碎的)
- 名词+形容词
  - ice –cold（冰冷的）life-long （终生的）
  - world- famous （全国的）

# 复合形容词的几种形式

- 名词+（普通）名词
  - X-ray(X光的) English –language(英语)
- （13）动词 + 副词：
  - takeaway（外卖的；可带走的）
- (14) 名词+介词
  - child-like(像小孩子的)

THANKS

# End

lecturer: Juan Yang

School of Metallurgy and Environment