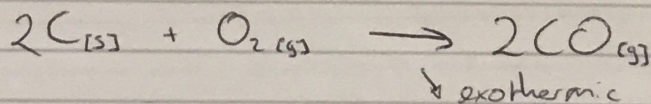


1 a) (i) The chemical process by which iron is made in a blast furnace is known as a redox ~~don~~ reaction REDuction and OXidation

Reduction is a gain of oxygen, a reducing agent is required
Oxidation is a loss of oxygen, an oxidising agent is required

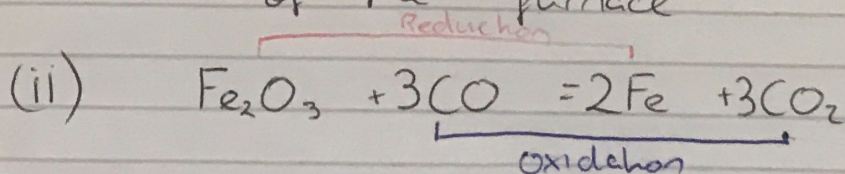
In ironmaking the oxidising agent is the iron ore and the ~~don~~ reducing agent is Carbon monoxide.

The hot air blast at the bottom of the furnace supplies ~~the~~ Oxygen that reacts with Carbon in the coke



The reaction is ~~exothermic~~ exothermic which causes the raceways to heat to a temperature of $\sim 2000^{\circ}\text{C}$, hotter than the input air temperature of $\sim 1000^{\circ}\text{C}$

The Carbon monoxide rises through the charge which reduces the iron ore given by equation (ii)
Fluxes also react with impurities to form slag which floats on top of the iron at the hearth of the furnace

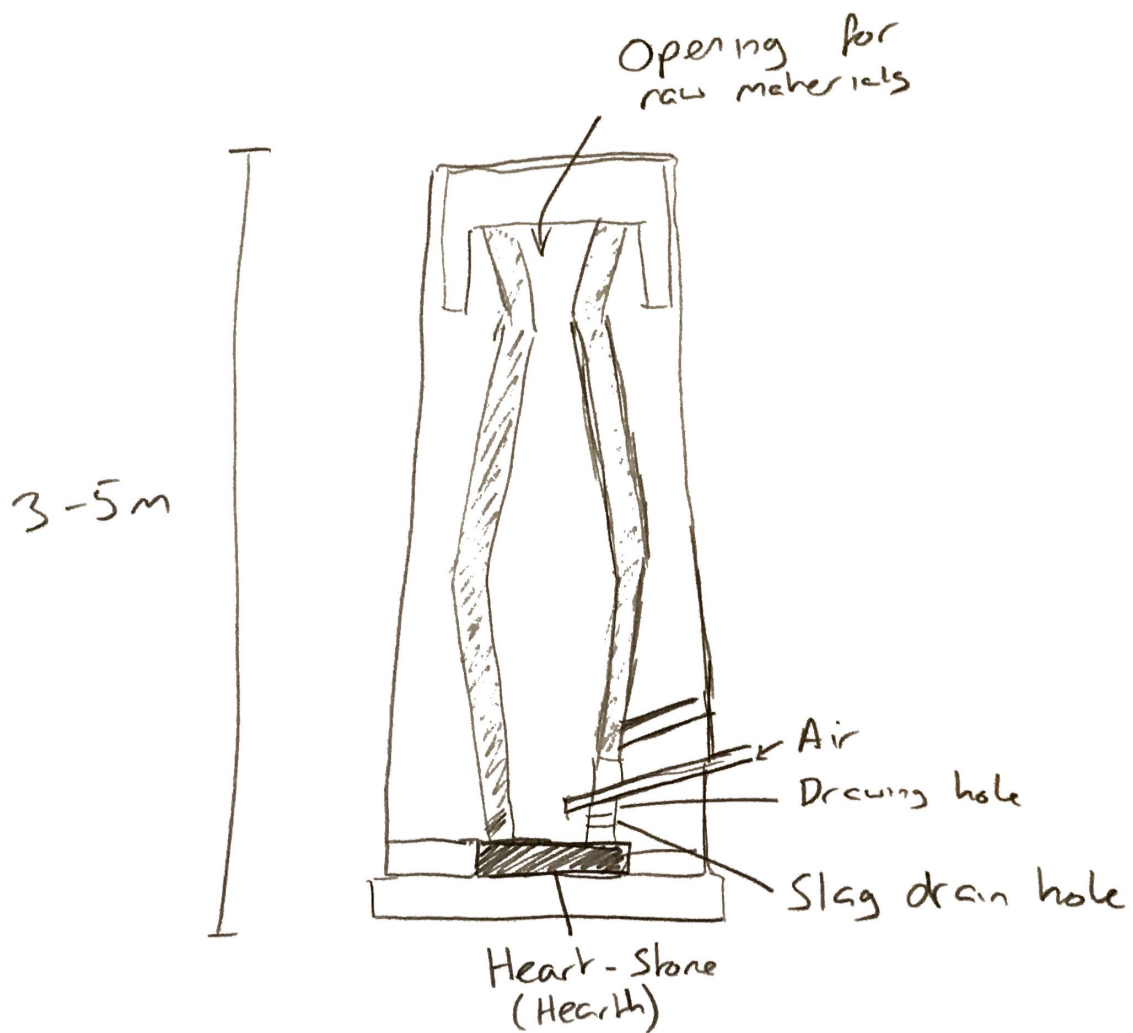


5)(i) A Pit furnace produces 'Bloom' iron, a spongy mass of iron particles intermixed with slag. It is produced by burning charcoal with iron ore and blowing air manually via a pipe. Slag could be removed by heeling and hammering - the result was wrought iron, wrought iron could be made into steel by adding small amounts of carbon. Some methods involved folding and forging charcoal into the iron while others placed a hot ~~steel~~^{bar} in charcoal before quenching.

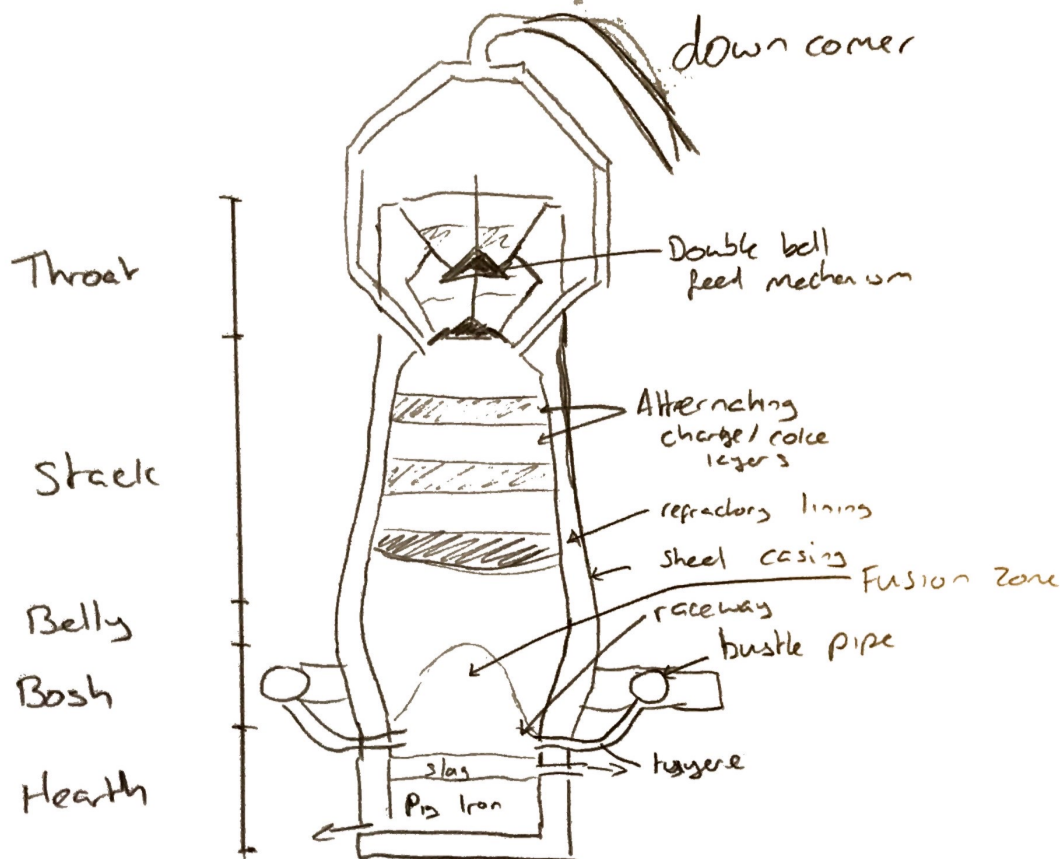
In order to increase yield of bloom iron the pit size and depth would need to be increased. The Struckopen furnace achieved this by building walls up around a hearth stone which could produce blooms large enough that an opening in the wall was required.

The blast furnace was developed as a method of casting iron from a molten source. The furnace produces molten pig iron which before the advent of modern steelmaking was sent to a puddling furnace for refining.

Stuckofen Furnace



Blast Furnace



(ii) Both furnaces are charged from the top of the throat, however the blast furnace uses a system called a double bell to feed raw materials while keeping the system sealed and under pressure. This allows waste gases to be captured and preheat incoming feed air.

Both furnaces are cylindrical, though square versions have existed in history.

In a Stuckofer air is fed mechanically into the hearth. In a blast furnace preheated air is fed around the entire circumference by pipes called tuyeres which are fed by a main distribution pipe known as a bustle pipe.

In a Stuckofer the bloom is removed as a solid mass through an opening. A blast furnace produces molten pig iron which is tapped from the hearth separately to the slag.

The shape of the blast furnace tapers out to the belly to increase surface area for gases to react and in towards the hearth to account for the reduction in volume as the charge melts.

2 a) Additive manufacturing is the term given to processes where material is added to a component / part. Commonly called 3D printing examples include SLA - stereolithography and SLS selective laser Sintering.

Subtractive manufacturing is a retronym given to describe the traditional method of creating a component by starting with a large billet of feedstock and 'subtracting' material by machining and turning and non-traditional processes such as abrasive water jet cutting.

b) Traditional machining, for example milling and turning removes material by shear deformation with sharp cutting tools and high forces.

Abrasive water jet cutting is an example of a ~~not~~ non-traditional machine tool that uses the mechanical abrasive action of a stream of suspended particulates in a high pressure jet of water.

Even though the water pressure can be in excess of 4000 bar the forces exerted on a part are low unlike milling where workpieces must be securely clamped. This improves the accuracy and repeatability of water jet cutting as the workpiece is not deformed by the clamp itself or the lateral forces imposed by cutting.

Both Abrasive water jet cutters and milling machines can be mounted into 5-axis machines allowing complex shapes to be manufactured.

(c) Electron Beam Machining (EBM) is a non traditional subtractive method of manufacture

It works by accelerating electrons across an anode-cathode grid, before focusing the electrons using magnets into a narrow beam that can be used to cut material held in a vacuum chamber

The electrons are accelerated to 80% of the speed of light (0.8c) which upon striking the workpiece causes intense localised heating which removes material by evaporation. The vacuum must be maintained as air & vaporised material can interfere and diffuse the electron beam.

Advantages

- No limits on material hardness, ductility or surface requirements
- No mechanical distortion as process is non-contact
- Can machine holes with length to diameter ratios of 100:1

Disadvantages

- High capital equipment cost
- Vacuum integrity difficult to maintain for large parts
- Very small heat affected zone

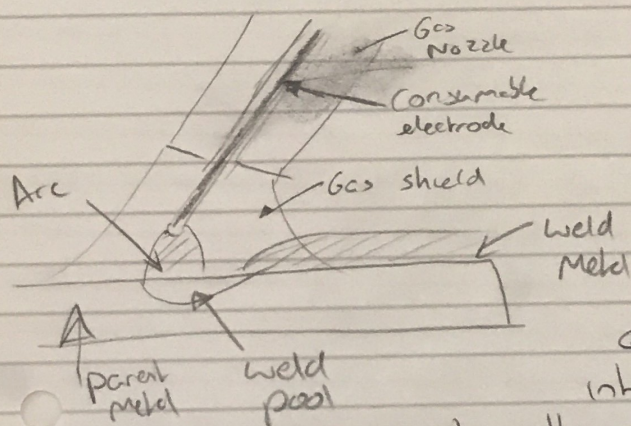
Applications

- Drilling incredibly fine & deep holes
- Semiconductor & micromachining
- Engraving delicate components

		Example Components	Dimensional Accuracy	Surface Finish	Mechanical Properties
Casting	Sand	Engine Blocks, Ship Propellers, Brake Calipers, CNC machine beds	Poor, reliant on accuracy of mould creating and particle size of sand	Poor, reliant on sand quality	Generally the mechanical properties are limited to the material in as cast state. Some heat treatment can be applied to increase surface hardness. Porosity affects all casting processes.
	Die	Toys, locks, crank cases. Generally small parts	Good, moulds are machined to high tolerances	Dependant on mould quality, generally very good	Porosity affects all casting processes. Speed is dependant on pressure and chamber temperature, High pressure die casting is faster (hot chamber is fastest)
	Investment	Turbine blades, Surgical implants	Good dimensional accuracy in mould, more complicated shapes allowed for as lost mould part supports structure as it is removed	Dependant on mould quality, generally very good	Generally the mechanical properties are limited to the material in as cast state. Some heat treatment can be applied to increase surface hardness. Porosity affects all casting processes.
Mechanical Deformation	Forging	Pressure vessels, chains, crankshafts, spanners.	Lowest dimensional accuracy	Poor from process, generally uses a secondary finishing operation	Can produce components of very high strength if process is utilised to manage grain flow and structure within the part. Failing to do this can cause catastrophic failure
	Extrusion	Window frames, tubes, machine channel, bottle openers, pasta.	Complex shapes can be made accurately as long as the shape is a continuous cross section.	Good smooth surface on extruded faces, can be improved by secondary finishing	Complex tooling and part cut off considerations required.
	Deep Drawing	Cans	Shapes must be round or oval as sharp edges cannot be drawn	Surface finish is dependant on die quality but in general is suitable for coating immediately	High elongation can work harden the material
	Pressing	Railway wheels, clutch plates	High but limited shapes available	Poor by comparison	Good properties can be achieved if grain direction is considered. Very tough components can be manufactured.

- 35 Fusion welding relies on raising the temperature of a material above its melting point in order to join it together. The intense heat required to cause this phase transition can create a large heat affected zone.

Solid state welding also relies on heat but the material remains below its melting point relying instead on plastic deformation to join the material together. This can allow for dissimilar materials to be joined.



The diagram shows Metal Arc Gas Shielded welding, commonly called MIG. The consumable electrode acts as the filler material and the source of the arc. The arc causes intense heating, melting the weld pool allowing the filler to join the material.

The gas shielding is an inert gas such as argon to prevent corrosion.

Friction welding is an example of solid state welding. Components can be spun in a double spindle lathe and brought gently together. This initial friction heats the material before the pieces are forced together, plastically deforming and bonding them. Once cool the burr produced by the deformation can be removed.