High Temperature Materials.

High temperature science is critical to many processes and applications in heat engines, combustion, chemical plant process, high temperature fuel cells, nuclear power generation and many geological / geochemical processes.

High temperature materials can be defined depending on whether it is unstressed or stressed at ~~ax~~ elevated service temperature.

The properties required in high temperature alloy are

* Good Oxidation resistance
* Adequate Creep strength
* Microstructural stability
* Corrosion resistance, fatigue strength
* Impact toughness.
* The alloy must be capable of easy fabrication and should not undergo large property changes on heating and cooling.

<u>Super Alloy</u>: A super alloy or high performance alloy is an alloy that exhibits excellent mechanical strength, Creep resistance, good surface stability and resistance to corrosion or oxidation.

Examples: Hastealloy, Inconel, Waspaloy etc.

Superalloys are led to the development of Vaccum melting and forging technology, powder metallurgy.

Development of superalloys with improved Creep resistance lowered the oxidation resistance.

Oxidation resistance could be enhanced by using chromium as alloying element.

Super alloys are group of materials that are used in high temperature applications.

Examples:
* Aircraft gas turbines
* Steam turbine power plants
* Metal processing
* Nuclear power systems
* chemical and petrochemical Industries
* Pollution control equipment.

The nickel, iron, Cobalt based superalloys and high temperature stainless steel alloys are the most important super alloys or high temperature alloys.

Nickel based Super alloys:

* Nickel base superalloys are the most Complex, the most widely used for the hottest parts. They currently constitute over 50% of the weight of advanced aircrafts Engines.
* They have high phase stability.
* The surface stability of nickel is improved by alloying with chromium or aluminium. (formation of Cr_2O_3 and Al_2O_3)

Composition: 10 - 20% Cr
8% Al+Ti
5 to 15% Co

Properties: High strength
High toughness & ductility
excellent corrosion resistance
excellent cryogenic temp. properties
good creep resistance.

small amount of boron, Zirconium, Magnesium and Carbon.

Molybdynum, niobium and Tungsten play dual roles in strengthing and carbide formation.

Microstructure: The major phases that may be present in nickel based Superalloys are

1) Gamma matrix (γ) [FCC non magnetic phase Consist of Co, Fe, Cr, Mo, W]
2) Gamma prime (γ') [Al & Ti are added to γ. High Temp strength, creep resistance] [FCC γ']
3) Gamma double prime (γ'') [Ni_4Nb Combine in the presence of Fe, to Form BCT] [It is unstable at temp. >650°C]
4) Topologically closed-packed (TCP) type phases. [These are plate like or needle like phases, lowered ruptured strength & Ductility.

Examples: Nimonic, Hastelloy and Inconel.

Applications:

Ni superalloys are used in Jet engine Components, Corrosion resistant chemical process equipment (Valves, piping and pumps), magnets, electrical resistance alloys and heating elements.

Ni based Super alloys are widely used in aircraft engine Components, mainly in turbine disks and high pressure Compressor.

Cobalt based Super Alloys:

Cobalt based alloys are non ferrous magnetic alloys with high strength and toughness, excellent corrosion and oxidation resistance & high temperature strength.

The Creep resistance of Co based superalloys are lies between the nickel base & nickel-iron base Superalloys.

Co based Superalloys have better fabricability, weldability and thermal fatigue resistance than nickel based alloys.

When compared to nickel or iron based alloys, Cobalt based alloys Can be melted in air or Argon atmosphere. whereas nickel or iron required Vaccum melting.

Co alloys are having higher melting point than nickel or iron alloys. This gives them the ability to absorb stress to a higher temperature.

Composition: 25% Cr

10% Ni

8% W

0.5% C and balance cobolt.

Here the major strengthing comes from tungsten and chromium Carbide precipitates.

Microstructure: At 417°C the Cobalt Crystalizes in HCP (Hexagonal close-packed] structure. At higher temperatures it transforms to FCC [Face centered Cubic] structure.

Applications: Cobalt based Super alloys are widely used in surgical implants.

Since 1930's Vitallium an alloy under Cobalt based Superalloy has been used for artificial hips and Knees.

They have also used in turbine Vanes due to their higher temperature Creep resistance.

Co based super alloys are used in exhaust Case and Burner liners.

Examples: Vitallium

Iron based Super alloys :

The iron (Fe) based super alloys are less expensive than cobalt or nickel based Super alloys.

Iron based Super alloys characterised by high temperature as well as room temperature strength.

They are good Creep, Oxidation, wear and Corrosion resistant materials.

Examples: Discaloy and incoloy

Composition : 15% Cr

20-40% Ni

Smaller concentrations of molybdenum, titanium, aluminium and balance iron.

The Fe-based alloys are of three types

1) Martensitic alloys
2) Austenitic alloys
3) Caustenitic alloys.

The alloys that can be strengthened by a martensitic type of transformation they are called 'Martensitic alloys'.

The austenitic alloys are strengthened by a sequence of hot and cold working.

The Caustenitic alloys are strengthened by precipitation hardening.

Applications: They have been used in

aircraft bearings

steam turbine blades

tool making and

specialized medical devices.

Oxide Dispersion strengthened Materials:

Oxide Dispersion strengthened alloys (ODS alloys) typically consist of a high temperature metal matrix such as iron aluminide, iron chromium, iron - chromium - alumium, nickel - chromium or nickel aluminide with small (5-50 nm) oxide particles of alumina (Al_2O_3) or yttria (Y_2O_3) dispersed within it.

High temperature metal matrix (Iron chromium) + Dispersion of small oxide particles (Al_2O_3 or Y_2O_3) $\longrightarrow$ ODS alloys.

Iron based and nickel based ODS alloys exhibit good corrosion resistance and mechanical properties of elevated temperatures.

These alloys also show excellent creep resistance.

Inconel MA754 & INCOLOY MA 956 are the two commercially available ODS alloys. Their composition and physical properties are as follows.

Name	Ni	Fe	Cr	Al	Ti	C	Y_2O_3
INCONEL MA754	78	1.0	20	0.3	0.5	0.05	0.6
INCOLOY MA 956	–	74	20	4.5	0.5	0.05	0.5

Property	MA754		MA956	
Melting point (°c)	1400		1482	
density (g/cm^3)	8.3		7.2	
Thermal Conductivity (W/m.K)	14.3 @ room temp	32.6 @ 1000°c	10.9 @ room temp	25.5 @ 1000°c
Electrical resistivity ($\mu\Omega m$)	1.08 @ room temp	1.16 @ 1000°c	1.31 @ room temp	1.45 @ 1000°c

ODS alloys are produced by the mechanical alloying of powders. The powder constituents can be in the elemental, inter metallic or pre alloyed state.

The metal Oxide powders (Al_2O_3 or Y_2O_3) are blended and mechanically alloyed using a ball mill. The process produces a fine mixture of the metal and oxides.

This powder is then packaged into sealed Containers ~~and~~ that are hot worked into simple primary shapes either by extrusion or hot isostatic Pressing (HIP).

The resultant Product is dense and fine grained (less than 1 μm) but has highly developed directional residual strain.

Advantages:

1) It can be machined, formed, cut with available processes.
2) It develops a protective oxide layer
3) It requires low maintenance cost & low material cost

Applications:

ODS are used in space crafts

glass production

high temperature turbine blades

heat exchanger tubing and

in nuclear applications.