

Applications of refractory materials engineering essay



**ASSIGN
BUSTER**

A refractory material is one that retains its strength at high temperatures. ASTM C71 defines refractories as non-metallic materials having those chemical and physical properties that make them applicable for structures or as components of systems that are exposed to environments above 1, 000 °F (811 K; 538 °C)".

Refractory materials must be chemically and physically stable at high temperatures. Depending on the operating environment, they need to be resistant to thermal shock, be chemically inert, and/or have specific ranges of thermal conductivity and of the coefficient of thermal expansion.

The oxides of aluminium (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories. Another oxide usually found in refractories is the oxide of calcium (lime). Fire clays are also widely used in the manufacture of refractories.

Refractories must be chosen according to the conditions they will face. Some applications require special refractory materials. Zirconia is used when the material must withstand extremely high temperatures. Silicon carbide and carbon (graphite) are two other refractory materials used in some very severe temperature conditions, but they cannot be used in contact with oxygen, as they will oxidize and burn.

Binary compounds such as tungsten carbide or boron nitride can be very refractory. Hafnium carbide is the most refractory binary compound known, with a melting point of 3890 °C. The ternary compound tantalum hafnium

carbide has one of the highest melting points of all known compounds (4215 °C).

Classification of refractory materials:

Based on chemical composition

Acidic refractories

They consist of mostly acidic materials like alumina (Al_2O_3) and silica (SiO_2).

They are not attacked or affected by acidic materials, but easily affected by basic materials e. g.: -silica, alumina, fire clay refractories, etc.

Neutral refractories

These are used in areas where slags and atmosphere are either acidic or basic and are chemically stable to both acids and bases. The main raw materials belongs to, but not confined to, R_2O_3 group. The common examples of these materials are alumina (Al_2O_3), chromia (Cr_2O_3) and carbon.

Basic refractories

These are used on areas where slags and atmosphere are basic; they are stable to alkaline materials but react with acids. The main raw materials belong to the RO group to which magnesia (MgO) is a very common example. Other examples include dolomite and chrome-magnesia.

Based on method of manufacture

Dry press process

Fused cast

Hand molded

Formed (normal, fired or chemically bonded)

Un-formed (monolithic-plastic, ramming and gunning mass, castables)

Un-formed Dry Vibratable refractories.

Shaped

These have fixed size and shapes. These may be further divided into standard shapes and special shapes. Standard shapes have dimension that are conformed by most refractory manufacturers and are generally applicable to kilns or furnaces of the same types. Special shapes are specifically made for particular kilns or furnaces.

Unshaped (Monolithic refractories)

These are without definite form and are only given shape upon application.

These types are better known as monolithic refractories. The common examples are plastic masses, Ramming masses, castables, gunning masses, fettling mix, mortars etc.

Dry vibration linings often used in Induction furnace linings are also monolithic, and sold and transported as a dry powder, usually with a magnesia/alumina composition with additions of other chemicals for altering specific properties. They are also finding more applications in blast furnace linings, although this use is still rare.

Applications:

Different applications of refractory materials are given below:

<https://assignbuster.com/applications-of-refractory-materials-engineering-essay/>

Nuclear engines:

They have several uses in a variety of electronic applications, in tubes, condensers, etc., but these will not be discussed in this presentation. Mo and W are being used in propulsion systems even now, particularly in solid fueled rocket nozzle and vector control applications, but the bulk of the applications for these materials is still ahead, some in the rapidly approaching future. The primary uses will be in two major areas, structure and propulsion. A third area of consideration which is just as important, although somewhat farther away in the time cycle, is the generation of power, such as electrical energy, in outer space. In propulsion applications, summarized in figure 2, refractory metals will be used in all major devices, solid and liquid rockets, nuclear propulsion devices and high performance air breathing devices such as ramjet engines. In solid rocket applications, the most interest as far as refractory metals are concerned is centered about W or possibly suitable W alloys which will be an important part of the materials system comprising the nozzle area and vectoring devices. Whether it will be used in the form of thin wrought sheet to minimize weight, or a plasma sprayed product, or a more massive form which will accommodate a cooling technique by infiltrating with copper or a refractory oxide will depend upon the particular system and upon later developments in this area. The primary advantage of W for these applications is its high melting point. Its resistance to erosion and thermal shock is also very good when compared to other available materials. The drawback is its weight, and designs will undoubtedly incorporate only the amount necessary to do the job. Therefore, developments for this application have been to a great extent in the area of fabrication of W in attempts to obtain a suitable geometry. There has been recent interest in small, <https://assignbuster.com/applications-of-refractory-materials-engineering-essay/>

uncooled liquid rockets, primarily for directional control uses. Interest here seems to be in Ta base alloys because of their high melting point and good fabricability. Nuclear propulsion systems such as the nuclear ram-jet (Project Pluto) and the nuclear rocket engine (Project Rover) will have a number of requirements for high temperature materials up to 4000°F such as supporting material for fuel elements. In ion-propulsion units, the work function of W in the temperature range 2000° to 2500°F seems to be well suited for the ionizing surface and other refractory metals, such as Cb or Mo which will be used to contain the liquid and gaseous cesium. Ram-jets will utilize refractory metals for resistance to aerodynamic heating encountered as a result of their high speed in the atmosphere.

Missiles

An improved pneumatic valve and missile with an improved thrust directional valve. In one embodiment, a refractory material lining for a pneumatic valve enables better valve operation and better valve performance. A thin-wall cylindrical sleeve of rhenium or other suitable refractory metal is located inside a cylinder. A valve piston may then travel within the refractory sleeve with greater reliability and better operation. The refractory sleeve cylinder lining can be subject to high temperatures at a rapid rate and remain operational. Under such a hostile environmental, including corrosive/erosive environments created by the passage of hot propellant gasses, the refractory cylinder sleeve has a more reliable operational life and is lighter in weight than conventional valves made entirely of refractory metals.

C: UsersHussainDesktop6895991-0-display. jpg

Furnaces

The unit processes utilized in the metal casting industry are lined with a wide range of refractory compositions (including silica, alumino-silicate, high alumina, zircon, magnesia, spinel, chrome, and magnesia-carbon) and forms (monolithics, precast shapes, and bricks). Most metals casting industry melting and holding furnaces are lined with ceramic refractories which are selected to minimize reaction with the specific metal being processed. Major refractory lined units include reverberatory furnaces, crucible (pot) furnaces, channel induction furnaces, coreless induction furnaces, electric arc furnaces, and pouring ladles. These furnaces are lined with wide ranges of refractory compositions, including silica, alumino-silicate, high alumina, zircon, magnesia, spinel, chrome, and magnesia-carbon.

Substantial problems do still exist with molten material containment and handling. For example, cupola linings for ferrous alloy melting usually require weekly repairs because of corrosion and mechanical damage. An alternative to refractory linings is “skull melting” (in titanium melting, for example) where in a mechanism similar to the slag splashing in the steel industry or the formation of a “frozen ledge” in the aluminum industry, a protective layer of metal is solidified on the containment vessel surface, creating a corrosion-resistant layer but lowering the thermal efficiency of the system.

Iron foundries are the major energy consumer for this sector, representing about 12% of the industry, followed by steel foundries at about 10%. Within each process, approximately 55% of the total energy cost is used for the

melting of the metal, with other processes (core making, mold making, heat treatment, and post-casting processes) accounting for the other 45%.

Although the total energy cost (fuel + electricity) accounts for only about 10% of the total material cost, it can be as high as 20% or more for many foundries depending on efficiency and the materials processed.

Gas Turbines

Driven by the increased firing temperatures of the gas turbines and the need for improved emission control, significant development efforts have been made to advance the combustion hardware, by way of adopting sophisticated materials and processes. The primary basis for the material changes that have been made is improvement of high temperature creep rupture strength without sacrificing the oxidation / corrosion resistance.

Traditionally combustor components have been fabricated out of sheet nickel-base superalloys. Hastelloy X, a material with higher creep strength was used from 1960s to 1980s. Nimonic 263 was subsequently introduced and has still higher creep strength (Schilke, 2004). As firing temperatures further increased in the newer gas turbine models, HA-188, a cobalt base superalloy has been recently adopted for some combustion system components for improved creep rupture strength (Schilke, 2004).

Coutsouradis et al. reviewed the applications of cobalt-base superalloys for combustor and other components in gas turbines (Coutsouradis et al., 1987).

Nickel base superalloys 617 and 230 find wide application for combustor components (Wright & Gibbons, 2007). Table 3 gives the chemical composition of combustor materials.

Grade

<https://assignbuster.com/applications-of-refractory-materials-engineering-essay/>

Chemical Composition

Remarks

Hastelloy X

Ni₂₂Cr_{1.5}Co_{1.9}Fe_{0.7}W₉Mo_{0.07}C_{0.005}B

Nickel-base superalloy

Nimonic 263

Ni₂₀Cr₂₀Co_{0.4}Fe₆Mo_{2.1}Ti_{0.4}Al_{0.06}C

Nickel-base superalloy

HA188

Co₂₂Cr₂₂Ni_{1.5}Fe₁₄W_{0.05}C_{0.01}B

Cobalt-base superalloy

617

54Ni₂₂Cr_{12.5}Co_{8.5}Mo_{1.2}Al

Nickel-base superalloy

In addition to designing with improved materials, combustion liners and transition pieces of advanced and uprated machines involving higher firing temperatures are given a thermal barrier coating (TBC). The coating serves

to provide an insulating layer and reduces the underlying base metal temperature.

Jet Engines

Wherever an industrial process involves heat in excess of 700 to 800 degrees Fahrenheit (roughly), one will find refractory material in place, either as a lining or forming the process vessel itself. Some common process vessels using refractories are; boiler combustion chambers, furnaces like the one in the foundry, incinerators, many emission control scrubbers, rotary kilns and so on. The list is by now means exhaustive. For example, Launch Pads 39A and 39B at the Kennedy Space Center are refractory lined. The shuttles themselves are lined with ceramic tiles to protect them from the heat of re-entry into earth's atmosphere, these tiles are! unique to the shuttle, but are non-metallic and heat resistant.

Cast alloy IN-713 was among the early grades established as the materials for the airfoils in the most demanding gas turbine application. Efforts to increase the ϵ^2 volume fraction to realize higher creep strength led to the availability of alloys like IN 100 and Rene 100 for airfoils in gas turbine engines. Increased amount of refractory solid solution strengtheners such as W and Mo were added to some of the grades developed later and this led to the availability of grades like MAR-M200, MAR-M246, IN 792 and M22.

Addition of 2 wt% Hf improved ductility and a new series of alloys became available with Hf addition such as MAR-M200+Hf, MAR-M246+Hf, Rene 125+Hf. General Electric pursued own alloy development with Rene 41, Rene 77, Rene 80 and Rene 80+Hf having relatively high chromium content for

improved corrosion resistance at the cost of some high temperature

<https://assignbuster.com/applications-of-refractory-materials-engineering-essay/>

strength. Other similar alloys with high chromium content are IN738C, IN738LC, Udimet 700, Udimet 710.

Grade designation Chemical composition

IN 713 74. 2Ni12. 5Cr4. 2Mo2Nb0. 8Ti6. 1Al0. 1Zr0. 12C0. 01B

IN 100 60. 5Ni10Cr15Co3Mo4. 7Ti5. 5Al0. 06Zr0. 18C0. 014B

Rene 100 62. 6Ni9. 5Cr15Co3Mo4. 2Ti5. 5Al0. 06Zr0. 15C0. 015B

MAR-M200 59. 5Ni9Cr10Co12. 5W1. 8Nb2Ti5Al0. 05Zr0. 15C0. 015B

MAR-M246 59. 8Ni9Cr10Co2. 5Mo10W1. 5Ta1. 5Ti5. 5Al0. 05Zr0. 14C0. 015B

Rene 41 56Ni19Cr10. 5Co9. 5Mo3. 2Ti1. 7Al0. 01Zr0. 08C0. 005B

Udimet 700 59Ni14. 3Cr14. 5Co4. 3Mo3. 5Ti4. 3Al0. 02Zr0. 08C0. 015B

TMD-103 59. 8Ni3Cr12Co2Mo6W5Re6Ta0. 1Hf6Al