Title : Introduction to Refractories
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Overview of Refractory materials

Refractories are heat resistant materials used in almost all processes involving high temperatures and/or corrosive environment. These are typically used to insulate and protect industrial furnaces and vessels due to their excellent resistance to heat, chemical attack and mechanical damage. Any failure of refractory could result in a great loss of production time, equipment, and sometimes the product itself. The various types of refractories also influence the safe operation, energy consumption and product quality; therefore, obtaining refractories best suited to each application is of supreme importance.

This course discusses the types, characteristics and properties of various refractories. There is an outline of energy conservation and therefore the cost savings. The course covers 6 sections:

Overview of Refractory materials

Section -1: Refractory Overview Types of

Section -2: Refractories Insulating

Section -3: Refractories Selection of

Section -4: Refractories

Section -5: Heat Loss and Energy Conservation

Section -6: Refractory Applications in Industry

Overview of Refractory materials

Section 1 : Refractories are inorganic, nonmetallic, porous and heterogeneous materials composed of thermally stable mineral aggregates, a binder phase and additives. The principal raw materials used in the production of refractories are: the oxides of silicon, aluminum, magnesium, calcium and zirconium and some non-oxide refractories like carbides, nitrides, borides, silicates and graphite.

The main types include fire-clay bricks, castables, ceramic fiber and insulating bricks that are made in varying combinations and shapes for diverse applications. The value of refractories is judged not merely by the cost of material itself, but by the nature of the job and/or its performance in a particular situation. Atmosphere, temperature, and the materials in contact are some of the operating factors that determine the composition of refractory materials.

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Usage of Refractories :

Refractories are used by the metallurgy industry in the internal linings of furnaces, kilns, reactors and other vessels for holding and transporting metal and slag. In non-metallurgical industries, the refractories are mostly installed on fired heaters, hydrogen reformers, ammonia primary and secondary reformers, cracking furnaces, incinerators, utility boilers, catalytic cracking units, coke calciner, sulfur furnaces, air heaters, ducting, stacks, etc. Majority of these listed equipment operate under high pressure, and operating temperature can vary from very low to very high (approximately 900°F to 2900°F). The refractory materials are therefore needed to withstand temperatures over and above these temperatures. Listed below is the sample melting temperatures of key metallurgical elements where refractory application is critical.

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Due to the extremely high melting point of common metals like iron, nickel and copper, metallurgists have to raise furnace temperatures to over 2800°F. Furnaces are lined with refractory materials such as magnesia, which has a melting point of 5070 degrees.

Requirements of right refractories include :

Its ability to withstand high temperatures and trap heat within a limited area like a furnace;

Its ability to withstand action of molten metal , hot gasses and slag erosion etc;

Its ability to withstand load at service conditions;

Its ability to resist contamination of the material with which it comes into contact;

Its ability to maintain sufficient dimensional stability at high temperatures and after/during repeated thermal cycling;

Its ability to conserve heat.

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Important properties of refractories are: chemical composition, bulk density, apparent porosity, apparent specific gravity and strength at atmospheric temperatures. These properties are often among those which are used as 'control points' in the manufacturing and quality control process. The chemical composition serves as a basic for classification of refractories and the density, porosity and strength is influenced by many other factors. Among these are type and quality of the raw materials, the size and fit of the particles, moisture content at the time of pressing, pressure at mould, temperature, duration of firing and the rate of cooling.

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Characteristics of refractories >> Melting Point

Melting temperatures (melting points) specify the ability of materials to withstand high temperatures without chemical change and physical destruction. The melting point of few elements that constitute refractory composition in the pure state varies from 3100°– 6300°F as indicated in the table below:

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Size and Dimensional Stability:

The size and shape of the refractories is an important feature in design since it affects the stability of any structure. Dimensional accuracy and size is extremely important to enable proper fitting of the refractory shape and to minimize the thickness and joints in construction.

Porosity:

Porosity is a measure of the effective open pore space in the refractory into which the molten metal, slag, fluxes, vapors etc can penetrate and thereby contribute to eventual degradation of the structure. The porosity of refractory is expressed as the average percentage of open pore space in the overall refractory volume.

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High porosity materials tend to be highly insulating as a result of high volume of air they trap, because air is a very poor thermal conductor. As a result, low porosity materials are generally used in hotter zones, while the more porous materials are usually used for thermal backup.

Such materials, however, do not work with higher temperatures and direct flame impingement, and are likely to shrink when subjected to such conditions. Refractory materials with high porosity are usually NOT chosen when they will be in contact with molten slag because they cannot be penetrated as easily.

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Bulk Density : The bulk density is generally considered in conjunction with apparent porosity. It is a measure of the weight of a given volume of the refractory. For many refractories, the bulk density provides a general indication of the product quality; it is considered that the refractory with higher bulk density (low porosity) will be better in quality.

An increase in bulk density increases the volume stability, the heat capacity, as well as the resistance to abrasion and slag penetration.

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Cold Crushing strength

The cold crushing strength, which is considered by some to be doubtful relevance as a useful property, other than it reveals little more than the ability to withstand the rigorous of transport. It can be seen as a useful indicator to the adequacy of firing and abrasion resistance in consonance with other properties such as bulk density and porosity.

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Pyrometric Cone Equivalent

Refractories due to their chemical complexity melt progressively over a range of temperature. Hence refractoriness or fusion point is ideally assessed by the cone fusion method. The equivalent standard cone which melts to the same extent as the test cone is known as the pyrometric cone equivalent (PCE). According to ASTM C24 - 01, PCE is measured by making a cone of the material and firing it until it bends to 3 O’clock.

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Representative PCE values for selected refractories include cones 33-34 for super duty fireclay, cones 29-31 for medium duty fire clay and cones 36-37 for a 60% alumina product. The cone values reported for refratories are based on a defined standard time

– temperature relationship, so different heating rates will result in different PCE values. PCE can be useful for quality control purposes to detect variations in batch chemistry that result from changes or errors in the raw material formulation.

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Refractoriness points to the resistance of extreme conditions of heat (temperature > 1800 °F) and corrosion when hot and molten materials are contained while being transported and/or processed.

The ability to withstand exposure to elevated temperatures without undergoing appreciable deformation is measured in terms of refractoriness. The refractoriness under load test (RUL test) gives an indication of the temperature at which the bricks will collapse, in service conditions with similar load. However, under actual service where the bricks are heated only on one face, most of the load is carried by the relatively cooler rigid portion of the bricks. Hence the RUL, test gives only an index of the refractory quality, rather than a figure which can be used in a refractory design. Under service conditions, where the refractory used is heating from all sides such as checkers, partition walls, etc. the RUL test data is quite significant.

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High temperature Creep :

Creep is a time dependent property which determines the deformation in a given time and at a given temperature by a material under stress. Refractory materials must maintain dimensional stability under extreme temperatures (including repeated thermal cycling) and constant corrosion from very hot liquids and gases. The criterion of acceptance usually adopted is; that compressive creep (deformation at a given time and temperature under stress) for normal working conditions of load and temperature shall not exceed 0.3% in the first 50 hours of the test. This figure has been found to indicate that the creep rate falls by a negligible amount at the end of the stipulated period, and therefore the refractory can be considered safe to use for a much longer time.

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- **Jot down the requirements of a refractory material.**
- **What for refractories ar used?**
- **Discuss various properties of a refractory material**
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