



## HIGH TEMPERATURE CORROSION ON MATERIALS TO THE ENVIRONMENT

Ike Onyeka

*Department of Mechanical Engineering, Federal Polytechnic Oko, Anambra State, Nigeria*  
*Corresponding author: Ikeonyeka48@gmail.com ; +2348060679172*

### Abstract

High temperature corrosion is referred to a chemical attack from gasses, sold, molten salts, or molten metal's, typically at temperatures above 400°C to 750°F

High temperature corrosion is a significant concern in various industries, particularly those dealing with high temperature processes like diesel engines, gas turbines, and furnaces. It leads to material degradation, impacting structural integrity and potentially causing environmental problems. The primary environment impacts are related to air pollution and global warming, as well as the release of corrosive substances into the environment. High temperature corrosion is a mechanism of corrosion that takes place when gas turbines, diesel engines, furnaces and other machinery that come in contact with hot gas contaminates, these is caused by chemical attack from gases salts, and is a liquid les corrosion attack that can greatly affect some applications.

**Keywords:** High temperature corrosion, Turbines, Furnaces, Material degradation, Air pollution and global warming

### INTRODUCTION

These play an increasingly important role in the selection of materials, in particular within the power generation industry. The demand for engines to operate at higher temperatures to obtain greater engine efficiencies along with continuous exposure to aggressive environment and high-stresses implies that materials are being pushed beyond their original design limits. Most metals operating in ambient gases are thermodynamically unstable and will generally react to form oxides, sulfides, carbides or mixture of reaction products, depending on the their composition and their operating environment, At low temperatures and low humidity, surface reactions may be negligible or unnoticeable, however as temperature increases, in most cases, reaction rates will increase, The corrosion resistance of an alloy becomes very important, many industrial environments contain several corrosive contaminates that can leave molten salt or ash deposits on metal. Surfaces during high temperature operation will play a significant role in the corrosion mechanism. High temperature corrosion is most prevalent in the hot sections of the gas turbine engines, due to the combination of high temperature sulfur baring gases and atmospheric contaminates present in it. Considerations need to be taken specifically amongst critical rotating components with the hot section of the gas engine to ensure its safe operations of the components that sit within the turbine section of the engine which include, guide vanes, shrouds, blades, disks and the dovetail-style.

### LITERATURE REVIEW

High temperature corrosion that is widely causing problem to the material includes, Ash/salt deposit, carburization corrosion, halogen corrosion, metal dusting corrosion, molten metal corrosion,

## EXPLANATION OF THE PARAMETERS

1. **Ash/Salt Deposit Corrosion:** in some industrial processes, ashes and salts are deposited on the surface of process components. In certain instances, the deposit is scale which leads to reactions between the ash/salt and the protective oxide layer on the metal alloy or otherwise reduces the oxide layer. When the oxide layer reforms, a little more of the subtract metal is consumed, any breakdown of the protective oxide layer reduces the material resistance to corrosion and consume metal /material reduces wall thickness eventually leading to failure.
2. **Carburization Corrosion:** this is a phenomenon where carbon is incorporated into the material. Carbon bonds react with chromium and chromium carbides formed, especially at grain boundaries, this leads to embrittlement of the materials. The bonding of chromium to carbon results in chromium depletion in the matrix, reducing the resistance of the metal to oxidation and sulfidation, but problems with carburization can occur in processes where gas mixtures containing Co or hydrocarbons, such as Methane, Propane and naphtha come into contact with material of high temperature. The extent of carburization will depend on the gas and the chemical composition of the material. Carburization often causes the alloy to experience embrittlement or degradation of other mechanical properties .Processes and petrochemical piping is examples of where design and material accommodation must be made for the potential development of carburization. Sometimes, materials are intentionally carburized to increase hardness and wear resistance. This process does come at a cost over time as certain mechanical properties are reduced and material is consumed; also carburization is a problem, for instance, in steam reforming plants and cracking furnaces used in ethylene production.
3. **Halogen Corrosion:** many materials/metals react readily with halogen gases, i.e fluorine, Bromine, Iodine and Astatine, at elevated temperatures form volatile metal halides. These materials can suffer severe high temperature corrosion, industrial processes where fuels or feedstock's are contaminated with impurities such as sodium or potassium allow halogens to react with these impurities to form Nacl and Kcl.
4. **Metal Dusting Corrosion:** this is a form of carburization that occurs in high temperature environment where carbon is present, including CO, CH<sub>4</sub> or other hydrocarbon gases. It is common in equipment used in heat treatment, such as furnace retorts, gaskets, fans etc; severe attacks may occur after a year in service, often at the interface between metal and refractoriness, the result is pitting of the metal and thinning of the sections. Alloys that have been found to suffer metal dusting includes; Carbon steel, Cr-My steel, stainless steels, Fe-Ni-Cr alloys (iron and nickel based alloy) copper, silicon, and chromium and Aluminum are commonly added to provide metal dusting resistance.
5. **Molten Metal Corrosion:** Liquid metals are often used as heat transfer media i.e. the use of liquid sodium in nuclear reactors, for instance, the contaminate material which is in contact with the molten metal, is subjected to molten metal corrosion. It is best to consider how molten metal react with the materials in the containment system
6. **Molten Salt Corrosion:** molten salt are used in industries such as heat treating, nuclear energy, concentrated solar power, i.e. where salt provides thermal storage and heat transfer and also the extraction of reactive metals like molten metal corrosion, the contaminate material which is in contact with the molten salt is subject to corrosion, molten salts remove the oxides scale from metal surfaces, so corrosion may take the intergranular attack.

7. **Oxidation Corrosion:** Oxidation is the most important high temperature corrosion reactions and often present even when other forms of corrosion dominate. The creation of an oxide layer generates a protective scale that helps resist many types of corrosion. So reducing environments where there is no excess oxygen available hinders material/metal tendency to generate the oxide scale and are generally more susceptible to corrosion. The rate of oxidation for metal increases as the temperature increases. Many oxidation problems are caused when an alloy is used in a temperature range exceeding its capability. Oxidation of this type may form scaling and internal voids that's effect the integrity of the material, structural capability of the material, for instance, oxidation in air may occur in many industrial processes; i.e. heat treatment furnaces are often heated by electrical resistance, so that alloys are oxidized by the oxygen in the air. In many industrial processes, heat is generated by combustion, such as mixing air with natural gas. Alloys in these environments may be oxidized by oxygen in the air, but other products of combustion such as H<sub>2</sub>O, CO<sub>2</sub> may also affect the oxidation reaction.

## THE EFFECTS OF HIGH TEMPERATURE CORROSION ON MATERIALS TO THE ENVIRONMENT

As the performance demands on specific material tend to increase at temperature increases, so do the types of corrosive attacks to which metal/materials is likely to be subjected, now, when we think of significant industries and applications that are most likely to face the combined effects of high temperature with corrosive environment includes, Gas and steam turbines, Heat Treating, Mineral Processing, Chemical Processing, Pulp and paper, Waste Incineration, Fossil Fuel Generation.

High temperature corrosion performance is a form of corrosion that does not require the presence of liquid electrolyte environments are often classified as either oxidizing or reducing depending on the level of oxygen present .An oxidizing atmosphere generally contains excess free oxygen, a reducing atmosphere generally increase the corrosive effect of sulfidation, carburization, nitridation and ash/salt deposit corrosion. Hot corrosion and fuel/ash corrosion are usually related to liquid salt deposits that destroy the protective oxide scale on the metal surface.

## EFFECTS ON ALLOYING ELEMENTS

Good resistance of carburization tends to go hand in hand with oxidation resistance, increased contents of chromium (Cr); silicon (Si); Nickel (Ni) and Aluminum (Al) increases resistance. Also, just as the oxidation, the addition of rare earth metals are reactive elements such as Titanium (T); Zirconium (Zr) Yttrium(Y) has higher positive resistance effect.

## HIGH TEMPERATURE CORROSION PREVENTIVE METHODS

Without controlling temperatures that metal/materials are exposed to, there are few ways to check and stop high temperature corrosion from forming, each type of high temperature corrosion has different causes which had been itemized above, in addition to the temperatures making it difficult to find a blanket solution. The best way to prevent any form of corrosion is by employing experts and getting your facility/equipment regularly checked for ways to improve corrosion prevention and to identify problem areas, so they can be addressed before becoming

large scale issues. in conclusion, These are the following steps to take to ensure and protect facilities/equipments against high temperature corrosion; which includes.

### **CATHODIC PROTECTION**

Cathodic protection is one of the best way to prevent corrosion in nearly every application, which include

- a. System Design: this is a protective system design that provides a full system construction of the oversight and commissioned tests that adhere to the system modeling of designs.
- b. Startup and Commissioning: cathodic protection startup and commissioning allows you to focus on business worry free and ensure the system was designed and built to industrial standards and identify any over looked systems.
- c. Surveys: cathodic protection survey are continuous survey of existing survey conducted on material to work on best preventive method to the material
- d. Pipeline and Tank Analysis Assessment: pipeline and tank analysis and assessment are helpful for identifying possible ways of assessing and evaluating the structural integrity, operational reliability and potential risks associated with the facility.

### **CONCLUSION**

High temperature corrosion poses a significant challenge to the safe, efficient, and sustainable operation of high-temperature industrial systems, particularly in the power generation, chemical processing, and turbine industries. As operational demands push materials beyond their original design limits, the susceptibility of metals and alloys to various forms of attack such as oxidation, sulfidation, carburization, halogen corrosion, ash/salt deposit corrosion, and molten metal corrosion becomes critical.

The interaction between elevated temperatures and aggressive environmental contaminants accelerates degradation, leading to loss of mechanical integrity, reduced service life, and potential operational failures. Components in hot sections of gas turbines, including guide vanes, blades, disks, and shrouds, are particularly vulnerable due to their exposure to high-stress, high-temperature, and chemically active conditions.

Without proper mitigation, high temperature corrosion not only affects equipment reliability but also has broader environmental implications, including reduced energy efficiency, increased emissions, and waste generation from premature material failure. Effective material selection, protective coatings, and operational controls are therefore essential in addressing these challenges.

### **RECOMMENDATIONS**

1. Use advanced alloys (e.g., nickel-based superalloys) and ceramic-based composites with high oxidation and sulfidation resistance.
2. Apply thermal barrier coatings (TBCs) and corrosion-resistant overlay coatings to shield metal surfaces from aggressive gases and molten deposits.
3. Implement regular inspection schedules using non-destructive testing (NDT) methods to detect early stages of corrosion.
4. Reduce airborne contaminants in process streams through filtration and pre-treatment of fuels or gases.

**REFERENCES**

- Anand, S. K. (2008). *Handbook of environmental degradation of materials*. Elsevier.
- Caillat, S., & Vakkilainen, E. (2013). *Biomass combustion science, technology and engineering*. Woodhead Publishing.
- Fontana, M. G. (1987). *Corrosion engineering* (3rd ed.). McGraw-Hill.
- K.K. Chawla. (n.d.). *Corrosion science journal*. Elsevier.
- Lai, K. Y. (2007). *High temperature corrosion and applications*. ASM International.
- Shreir, L. L., Jarman, R. A., & Burstein, G. T. (1994). *Corrosion: Metal/environment reactions* (3rd ed.). Butterworth-Heinemann.
- Uhlig, H. H., & Revie, R. W. (1985). *Corrosion and corrosion control: An introduction to corrosion science and engineering* (3rd ed.). Wiley.