

# High Temperature Corrosion of Austenitic Stainless Steel in Simulated Rocket Combustion Gas

Tosapolporn Pornpibunsompop

Metallurgical and Material Engineering Division  
Defence Technology Institute  
Pakkret, Nonthaburi, Thailand  
tosapolporn.p@dti.or.th

**Abstract**—The corrosion at elevated temperature of austenitic stainless steel was investigated in simulated rocket combustion gas. The composition of rocket combustion gas was reviewed and selected only dominated species; hydrogen chloride and carbon dioxide. The experiment was set up in laboratory and the environment was prepared in order to observe effect of high temperature corrosion factors (humidity and environmental compositions). CO<sub>2</sub> was supplied by commercial and HCl was prepared by mixing concentrated hydrochloric acid and distilled water to intended concentration. The corrosion testing chamber made by ceramic tube was used for this investigation. The result shows that wet condition tends to accelerate corrosion product formation on stainless steel surface and decrease defensive capability of protective film. The corrosion by hydrogen chloride is relatively more aggressive than carbon dioxide. Hydrogen chloride attacks not only specimen's surface, but internal corrosion also. The protective film was destroyed and chloride ions can pass through such film in order to chemically react with specimen's surface. The corrosion products mainly composed of well-known ferrous oxide (Wütite (FeO) → Magnetite (Fe<sub>3</sub>O<sub>4</sub>) → Haematite (Fe<sub>2</sub>O<sub>3</sub>)) and Fe<sub>2</sub>O<sub>32</sub> which resulted from oxy-chlorination reaction. Moreover, because of applied high temperature, precipitation of intermetallic compounds could be detected at the area and chromium depleted zone originated.

**Keywords**—High temperature corrosion; Austenitic stainless steel; Rocket combustion gas

## I. INTRODUCTION

[1,2] Rocket combustion and internal combustion engine are an example of combustion system which needs extraordinary material capable of operation exposed to high temperature combustion gases without noticeable component damage in critical components. The high demands of material which have variety of properties such as strength, toughness, fatigue resistance, creep resistance, manufacturability, and not least resistance to degradation by corrosive environment especially most metal alloys are unstable in those high temperature corrosive environment which includes oxidation phenomena are highly exothermic. The most important issue for high temperature corrosion is choosing material for service at high temperature and, absolutely, numerous parameters must be considered for appropriate material selection.

One of most chosen material for high temperature application is austenitic stainless steel because of its oxidation resistance (the presence of the Cr-rich surface oxide as a protective film), good mechanical strength at high temperature, much higher intrinsic creep strength than ferritic grade, and can improve additional critical properties by adding some alloying elements. However, [3] the chromium oxide gradually loses its protective capability if a wet atmosphere is present above 600°C, insofar as chromia reacts with water vapour to form a volatile product and if chromium cannot diffuse fast enough to the surface to replenish the oxide with Cr, film becomes Fe-rich and is rendered non-protective. Austenitic stainless steel will be attacked by corrosive environment. Addition of some alloying elements can improve high temperature corrosion resistance because they can form oxide that has superior corrosion resistance above 1000°C.

Rocket combustion gas can destroy structure and platform components made by alloy and stainless steel because it composes of various kinds of strong corrosive specie. Chloride and oxide of carbon plays a vital role on corrosion of austenitic stainless steel for several decades. [4] The variation of chloride ion concentration usually acts on the solid surface by forming an adsorption film or inducing formation of a corrosion products layer, which has ability to prevent corrosion anions from being diffused, and causes more and more chloride ions accumulated on the surface of metal. Ultimately, the stainless steel is destroyed. [5,6] The corrosion products caused by corrosive specie can be graphically predicted by Ellingham's diagram with thermodynamic principle. For austenitic stainless steel, Fe, Cr, and Ni are the main chemical compositions and forms ferrous chlorides (FeCl<sub>2</sub>, FeCl<sub>3</sub>) via oxy-chlorination reaction, chromium chlorides (CrCl<sub>2</sub>, CrCl<sub>3</sub>), and nickel chlorides (NiCl<sub>2</sub>) at elevated temperature. Chlorine under some suitable conditions may cause accelerated corrosion resulting in increased oxidation, metal wastage, internal attack, void formations, and loose non-adherent scales. Moreover, corrosion by chloride can be severe in air, but may be further enhanced by SO<sub>2</sub>, which may cause intra-deposit sulfation of alkali chlorides releasing HCl(g) or Cl<sub>2</sub>(g) close to the metal surface. In case of corrosion by alkali chlorides, they may react with the metal