



# High-temperature corrosion of aluminized-AISI 1020 steel with NaCl and Na<sub>2</sub>SO<sub>4</sub> deposits

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**Abstract.** High-temperature corrosion of aluminized-American Iron and Steel Institute (AISI) 1020 steel with sodium chloride (NaCl) and sodium sulphate (Na<sub>2</sub>SO<sub>4</sub>) deposits was studied using isothermal oxidization in a dry air environment at 700°C for 49 h. NaCl and Na<sub>2</sub>SO<sub>4</sub> deposits on the aluminide layer interfered with protective alumina/aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) scale formation on the steel substrate. Chlorine and sulphur gases (Cl<sub>2g</sub> and S<sub>g</sub>, respectively) released into the atmosphere corroded the protective Al<sub>2</sub>O<sub>3</sub> layer. Corrosion of the Al<sub>2</sub>O<sub>3</sub> layer was also due to local formation of iron oxide (Fe<sub>2</sub>O<sub>3</sub>). Fe<sub>2</sub>O<sub>3</sub> growth is attributed to ferric chloride (FeCl<sub>3</sub>) vaporization. S<sub>g</sub> diffusion into the Al<sub>2</sub>O<sub>3</sub> scale via Al<sup>3+</sup> vacancy defects led to the formation of aluminium sulphide on the aluminide layer surface. Cl and S consequently induced hot corrosion of the aluminized steel, thereby increasing cyclic oxychloridation and sulphidation rates at high temperatures.

**Keywords.** Aluminized 1020 steel; hot corrosion; oxychloridation; sulphidation; alumina/aluminium oxide (Al<sub>2</sub>O<sub>3</sub>).

## 1. Introduction

Cold-rolled American Iron and Steel Institute (AISI) 1020 steel is a material suitable for engineering components because of its relatively low cost compared with that of high-alloy steel. This steel is used in heat exchangers, oil gas tanks, high-pressure water pipes and other equipment for fossil fuel power plants. Alkali metal sulphates produced by low-grade fuel combustion react with sodium chloride (NaCl) from ocean breezes at elevated temperatures, forming sodium sulphate (Na<sub>2</sub>SO<sub>4</sub>), which severely corrodes the material by oxidation, sulphidation or chloridation, thus rendering it prone to hot corrosion [1–3]. Therefore, the presence of NaCl and Na<sub>2</sub>SO<sub>4</sub> deposits on engineering material components at high temperatures causes rapid degradation of the material [4,5]. In this regard, hot-dipped aluminide steel has great potential in engineering components for harsh environments. Several studies have reported that the aluminium (Al) coating and its alloys can improve carbon steel resistance to oxidation at high temperatures [6–8]. The aluminide layer on steel can supply Al atoms and form a protective aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) layer.

To widen the application range and service life of aluminide steel, hot-corrosion behaviour and its related mechanism must be characterized. Therefore, we studied the effects of NaCl and Na<sub>2</sub>SO<sub>4</sub> deposits on the surfaces of aluminized and bare

steel (AS and BS) by isothermally oxidizing them at 700°C for 49 h in a static-air environment. The corrosion kinetics was analysed to determine the parabolic rate constant of corrosion ( $k_p$ ). Oxidized AS samples were characterized by both optical and scanning electron microscopy (OM and SEM, respectively), energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD) to determine the possible corrosion causing mechanisms.

## 2. Experimental

### 2.1 Specimen preparation

A commercial cold-rolled AISI 1020 steel plate with a chemical composition of 0.2C–0.05P–0.05S–0.5Mn (wt%; iron [Fe]-balanced) was cut into specimens with dimensions of 20 × 10 × 2 mm<sup>3</sup>. Before Al deposition, all specimens were ultrasonically cleaned with a solution of 5% sodium hydroxide (NaOH) and 10% phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) and then covered with Al welding flux pasta. Commercial Al–0.5 wt% silicon (Si) was melted in an alumina (Al<sub>2</sub>O<sub>3</sub>) crucible at 700°C, and the specimens were then dipped for 16 s in a molten Al bath. After the aluminizing process, oxide flux deposited on the surface of the aluminized specimens was