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Metallurgical investigation into the failure of an iron ore sintering car pallet

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ABSTRACT

A failure analysis on premature cracking of a sintering car pallet in an integrated steel plant is presented. A detailed study on the microstructural and mechanical properties of the failed component has been carried out. Microstructurally, the amount of pearlite in the ferritic–pearlitic matrix was found to be significantly higher (~65.8%) than normally expected in materials used for elevated temperature application. A thin layer of flake and vermicular graphite (degenerate graphite) was found just beneath the casting skin although interior of the matrix contained normal spheroidal graphite. In few occasions, the presence of undesirable spiky and exploded graphites was also noticed. The material exhibited lower yield stress (312 MPa), tensile strength (457 MPa) and Charpy impact energy (3.4 J) indicating poor strength and toughness of the casting. The improper graphite morphologies in the sinter car pallet acted as stress raisers and produced cracks under dynamic thermal cycling and external loads experienced during the sintering process resulting in its premature failure.

1. Introduction

Sinter machine is basically a closed loop chain of several movable sintering car pallets, and each pallet consists of sinter car body, insulation piece, roller sets, grate bars, and side plates. In the sintering process, a pre-mixed burden of base mix essentially consisting of iron ore fines, fluxes, sinter return fines, and coke breeze in specified proportions is charged onto the sintering car pallets which move at a constant speed (1.8 m/min) and enter an ignition hood furnace where the top surface of the sinter bed is ignited through series of stationary burners. The temperature of the ignition furnace remains at ~1423 K (1150 °C). An air suction is applied beneath the grate bars via number of wind boxes and the whole charge is fused layer by layer through controlled burning of coke breeze used as solid fuel in the base mix. Thus the ignition front at the top layer moves forward to complete the sintering process. After discharge of the sinter, the pallet again goes back under the charging hopper to be loaded with base mix and the sintering process continues. A full cycle of sintering process takes almost 108 min to complete.

As sintering is a high temperature process, the whole sintering car pallet, particularly the side plates, grate bars and the car body is subjected to extremely high thermal cycling. From the point of ignition to the discharge end, the pallet cars are exposed to high temperature, and thereon the temperature subsequently decreases to ambient condition when it is back to the charging point. Hence, each of the sinter pallet cars experiences periodic thermal expansion and contraction during the process of sintering. The working temperature range of the sinter car body at which the fracture occurred was approximately 323 K to 773 K (50 to 500 °C). Apart from the thermal load, the pallet cars are also subjected to heavy dynamic loading conditions. From the point of

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charging up to the discharge end, besides the pallet weight of ~8000 kg, a pallet car carries substantial amount of burden weight (~6010 kg) and experiences tremendous air resistance (~4000 kg) due to 650 kg/mm^2 pressure drop across the sinter pallet. Moreover, at the time of pallet reversal after discharging of sinter, a pallet car is also supposed to endure sudden impact load or jerk of high magnitude which may result into cracking or untimely failure of the various sinter pallet components.

The present work deals with the metallurgical investigation of a prematurely failed sintering car pallet received from an integrated steel plant. The engineering drawing of the sinter car pallet is shown in Fig. 1. The sinter machine consisted of around 130 numbers of sintering car pallets. The material used in the sinter pallet car conformed to GGG 60 grade cast iron of DIN 1693 standard (presently EN-GJS-600-3 grade in European Standard EN 1563) which is basically a ferritic–pearlitic grade spheroidal graphite (SG) cast iron. One of pallets failed prematurely during operation within 3 months of service, while the expected service life of sinter car pallet is around 20–25 years. The sudden failure of the sinter pallet involved huge cost due to the production loss and replacement of the failed component. Although the fracture of side plates [1] and pallet axle [2] are often noticed in sinter plant operation, but premature failure of pallet car body is not a common phenomena under similar working conditions and has not been reported in literature. Hence, the present work was found unique in nature and a sincere effort was made towards detailed metallurgical investigation encompassing visual inspection, light microscopy, image analysis, mechanical testing and scanning electron microscopy of the cracked sinter car pallet which failed prematurely in service.

2. Experimental

2.1. Chemical analyses

As-received material for the metallurgical investigation was cut using horizontal band saw cutter using kerosene oil as lubricant. Chemical analysis of the sintering car sample was carried out using a Rigaku, Japan make ZSX Primus II model X-ray fluorescence (XRF) spectrometric method. The carbon (C) and sulphur (S) contents were analysed using sample chips in a Bruker, Germany make G4 ICARUS model carbon–sulphur analyser.

2.2. Microstructural characterization

Small sized specimens (20 mm × 20 mm × 10 mm) were cut from the failed pallet near the fractured region. The specimens were prepared by following conventional metallographic technique and polished samples were etched with 2% nital solution. Metallographic examinations were carried out under Olympus make inverted type optical microscope in both etched and unetched conditions to observe the crack profiles and microstructural phases, respectively.

Quantitative estimation of phases was carried out using as-polished specimen in a Leica, Germany make Q600 model image analysing system using LAS V4.6 proprietary software at 200× magnification. For this purpose, measurements were taken on 10 arbitrarily chosen fields and average value is reported.

2.3. Evaluation of mechanical properties

Hardness measurements were carried out on the surface and interior of the metallographic specimen by Rockwell indentation method using an Instron Wolpert make series R-Testor® 600 model hardness testing machine at 150 kg load. Thirty such measurements were taken at different locations and the average value is reported in Brinell hardness (BHN).

Tensile and Charpy test blocks were cut from the failed sinter car pallet body near the fracture. Tensile tests were carried out on round cross-section specimens in a screw-driven Instron make 1195 model mechanical testing machine at a cross-head speed of 2 mm/min using 5000 kg full scale load in accordance with ASTM E8M [3] standard. Three identical samples were tested and the average properties are reported.

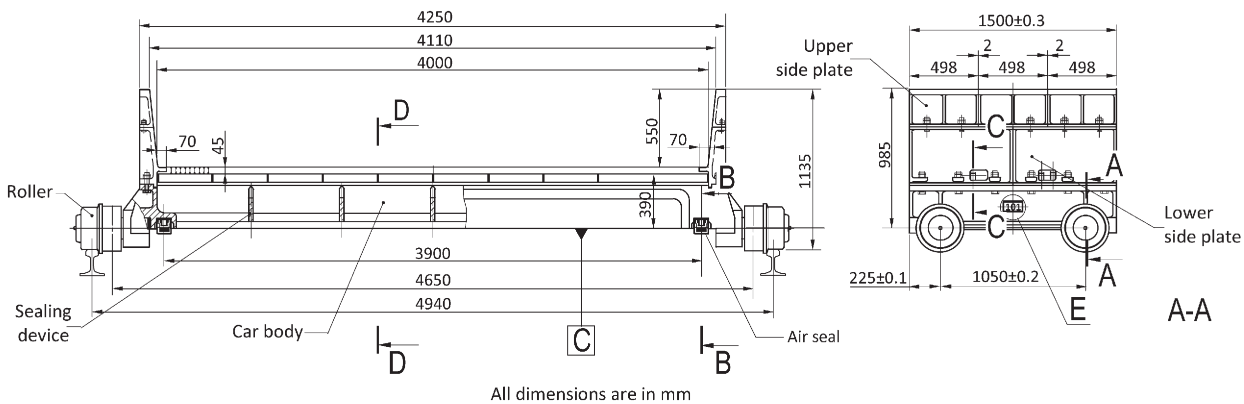

Fig. 1. Engineering drawing of the sinter car pallet.