Industrial applications of thermal sprayed coatings in Venezuelan steelmaking industry

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Abstract. The metal components subjected to high temperature conditions, abrasive wear, corrosion, impact, etc.; tend to present degradation of manufacturing material, causing the failure imminent of the component. One of the alternatives to minimize or eliminate such effect is the application of ceramic coatings, which are thermal insulators and exhibit high mechanical strength. Its extreme hardness, coupled with the low friction properties and chemical stability, allowing its use in a wide variety of applications. Therefore, the following paper describes the application of thermal sprayed coatings obtained by HVOF and Plasma technologies like alternative to protect the metallic equipment in different venezuelan industrial sectors, such as to operate under aggressive conditions of service, such as the steelmaking nationals industries. This study presents applications cases of ceramic-based coatings, in order to minimize the sticking of metallic material in components of reduction reactor of FINMET® and MIDREX™ process.

1. Introduction

In the venezuelan steel industrial park, located on the rivers sides of the Orinoco, adjacent to the mains Venezuelan iron ore mines, there are service conditions with high temperatures, wear and corrosion. These conditions have been studied by Corrosion Research Center of the National Polytechnic University (UNEXPO), which aim to develop protective coatings that reduce failure of metal components, which in turn is consistent with the research policies established by the Venezuelan government in 2011. In Venezuelan steelmaking processes such as direct reduction processes had been found that one of the metallurgical phenomena that can affect the continuity process is the adherence of ore pre-reduced iron ore to metal components of reactors. This condition limits the transfer of material or fluid to the point of stopping operations, as in the case of reactors grills cones in the process FINMET® and the screws of briquetting machines in the MIDREX™ process. One alternative to minimize or eliminate this effect is the application of ceramic coatings, which are insulating materials having high mechanical strength, extreme hardness, low friction properties and chemical stability, resulting in a less rough surface which minimizes sticking. Therefore, as described below the application of HVOF and Plasma thermal sprayed coatings represents an alternative to avoid these failures.
2. Direct reduction technologies
A direct reduction process (DR) is used for obtaining metallic iron units, from the chemical interaction between iron ore units and reduction gases such as H\textsubscript{2} and CO obtained through reforming of methane (CH\textsubscript{4}) or natural gas, to a process temperature near to 800° C.

2.1. MIDREX\textsuperscript{TM} technology
The Midrex™ Direct Reduction is a process of moving bed shaft furnace where the reducing gas moves counter-current to the lump iron ore or iron ore pellet solids in the bed. The reducing gas (from 10-20% CO and 80-90% H\textsubscript{2}) is produced from natural gas using Midrex’s CO\textsubscript{2} reforming process and their proprietary catalyst (instead of steam reforming) [1]. The reduced ore is compacted by briquetting machines to minimize re-oxidation. This process requires the feed material to the pockets compaction system through feed screws of HK40 austenitic steels.

2.2. FINMET technology
The Finmet process is a DR of fluidized bed, in which the gas is introduced into train of reactors connected in series, where it flows counter-current contacting the ore from the ore feed systems, like the above process is reduced material compacted into briquettes [2]. For the fluidization of the ore is necessary to increase the gas velocity, so that a grid is used with perforated carbon steel cones (See figure 1 (b)).

3. Cases thermal spray coating application
To continuation are presented two studies cases in the Venezuelan steelmaking industries.

3.1. Application No. 01
The first case is related to the company: Venezolana de Prerreducidos de Caroni CA (VENPRECAR), which develop the MIDREX\textsuperscript{TM} hot briquetted process.

The application was made in the screw briquetting machine feeders, these recurring failures occur sticking reduced fine ore causing plugging and pulling her down the team (See figure 2). The different parts of the axle-Speyer analyzed indicate that the base metal is effectively formed by the steel HK40, which has a hard coating by welding with a low nickel content (11.43%), causing the formation of ferrite, which is associated with the magnetization of the material, facilitating the formation of a crust [3].

3.2. Application No. 02
The second case is related with the Orinoco Iron S.C.S. that development the FINMET ® fluidized bed Process.

The application was performed on the cones of the R30 reactor grills, which were clogged by the adhering metallic fines which were dragged by the reducer gas from the reactor R20, which increases
the pressure differential on the grid affecting the fluidization process inside the reactor and in consequence causing a decreasing of the number of train operating days (See Figure 3). The cones are made with a carbon steel plate A-36 and due to the affinity of them with the metallic fines the sticking are facilitated in these high temperature conditions of the process.

![Figure 2. (a) Feeder Screw the briquetting machines. (b) Finishing the product augers with tungsten carbide thermal spray [3].](image1)

![Figure 3. Cones FINMET reactor grill clogged.](image2)

Tests were performed on a laboratory scale (See figure 4) employing coatings produced by HVOF technology. Coatings were deposited with WC-12%Co [4], and Colmonoy 88 alloy; the last in two conditions: as coated and with flame post-heat treated [4]. The process simulated conditions results indicated that the lowest adherence occurred in the WC-Co coatings exposed to 1 hr to process temperature (figure 5 (a)). Later, coated steel cones were evaluated at industrial scale and they were compared with uncoated cones. The results are showed in the figure 5 (b), where can be distinguishing that the coated cones present minor adherence.

![Figure 4. Sticking test equipment.](image3)
Figure 5. Samples tested with (a) uncoated cone. (b) coated cone.

4. Conclusions and upcoming developments

Although, the applications of thermal sprayed cermet coatings in the steel industry were successful in the present research; however, other alternatives of coatings are very interesting to probe. Thinking in upcoming developments, it’s important to highlight that the current trend in development and material selection for high temperature applications has a strong focus on based ceramic oxide coatings, which offer a high resistance to wear, corrosion, hardness, chemical stability at high temperatures and are thermal insulators [5]. Specifically, is necessary to study the applications of thermal barriers better known as TBCs (Thermal Barriers Coatings) for special alloy components. For over 30 years, the plasma sprayed yttria stabilized zirconia (YSZ) coatings, has been used for gas turbine applications, specifically the coatings of yttria partially stabilized (Y-PSZ), which have the metastable tetragonal phase. Oxides (SiO$_2$, Al$_2$O$_3$ and TiO$_2$) are used as stabilizers which prevent to the yttria suffer a harmful volume expansion that occurs during the phase changes of martensitic type tetragonal to monoclinic [6]. Recent research points to the use of different combinations of stabilizers oxides to improve properties such as thermal conductivity and fracture toughness [7, 8]. Next researches will be focus in optimization of deposition of ZrO$_2$-TiO$_2$-Y$_2$O$_3$ and Al$_2$O$_3$-TiO$_2$ systems fabricated by atmospheric plasma spray [9].

References

[1] Middle East Steel Industry 2013 Direct Reduction Process MIDREX (Venezuela: http://steelmaking.wordpress.com/2008/12/01/direct-reduction-process-midrex/)
[2] Industry Efficiency Technology Database 2013 Finmet (Venezuela: http://ietd.iipnetwork.org/content/finmet)
[3] Vásquez Z 2006 Obstrucción del Tornillo Alimentador del Sistema de Alimentación de las Máquinas Briqueteadoras de Venprecar C.A (Puerto Ordaz: Unexpo)
[4] S Stewart, R Ahmed, T Itsukaichi 2005 Surf. and Coat. Tech. 190 171
[5] Wang, Dinwiddie R B and D Porter Wallace 2010 Development of a Thermal Transport Database for Air Plasma Sprayed ZrO2-Y2O3 Thermal Barrier Coatings (Estates Unites: ASM International)
[6] Mauer, Sebold Doris, Vaßen Robert and Stover Detlev Georg 2009 Characterization of Plasma-Sprayed Yttria-Stabilized Zirconia Coatings by Cathodoluminescence (Estates Unites: ASM International)
[7] Schaedler T A, Leckie R M, Krämer S 2007 Journal of the American Ceramic Society 90 12
[8] M Milieska, K Brinkienė, R Kėzelis and Cėsnienė J 2009 Lithuanian Journal of Physics 49-1 81
[9] Liscano S 2010 Correlación de las Características Microestructurales con los Parámetros de Deposición de Recubrimientos de ZrO$_2$-10%Y2O$_3$-18%TiO$_2$ Termorrocidos por Plasma (Venezuela: Unexpo-UPM)