SolarPACES 2023, 29th International Conference on Concentrating Solar Power, Thermal, and Chemical Energy Systems

Thermal Energy Storage Materials, Media, and Systems

https://doi.org/10.52825/solarpaces.v2i.924

Published: 26 May 2025

Corrosion Suppression Coatings for Molten Nitrate Salt

Sarah Yasir[1,*], Indrat Aria[2], and Chris Sansom[1]

[1]University of Derby, UK

[2]Cranfield University, UK

*Correspondence: Sarah Yasir, s.yasir@derby.ac.uk

Abstract. The use of solar energy for power generation provides an efficient sustainable energy solution. Among a number of technologies developed for power generation using solar energy, concentrating solar power (CSP) is encouraging because it makes use of mature technology in the power block. Thermal energy storage (TES) is added to CSP, making it competitive with other power generation technologies and delivering dispatchable energy. Molten salts are one of the materials of choice for the TES. Although the use of molten salts as heat transfer fluid and thermal storage in CSP has various advantages, storage tanks and pipework can be highly susceptible to corrosion. Different approaches have been adopted to suppress corrosion including the use of specialised alloys and high purity molten salts; however, both contribute to a substantial increase in construction and operating costs.

In this study, a literature review is provided on coatings to suppress the hot corrosion of the storage vessels and pipework containing molten salts. There has been widespread use of anticorrosion coatings for numerous applications, providing guidelines to develop anticorrosion coatings for TES. Various important factors to be considered for choosing coating material are described herein. To date, several published studies discuss the corrosion resistance of different alloys and coatings for different applications. This study reports on corrosion tests and oxidation tests, while making comparison between different alloys with use of data extracted from literature. Among other materials studied the nickel aluminium alloys exhibit very promising properties as protective coating.

Keywords: Thermal Energy Storage, Molten Nitrate Salts, Corrosion Resistant Coatings

1. Introduction

The capability of TES integration in the CSP plants makes them more appealing than other renewables technologies because of its high practicality and proficiency commercially [1–8]. Dispatchability is significant to supply power through grid on demand. For continuous power generation, a reasonably priced and consistent energy storage method is required [9,10]. The LCOE of CSP is significantly reduced with the use of TES, A decrease in LCOE of about 10% has been stated for integrating a 12-hour storage capacity TES system. TES is an order of magnitude lower cost than electrical (battery) storage.

An extended literature search revealed that the scientific and technical papers dedicated to the development of anticorrosion coatings for solar thermal applications are limited. This literature review deals with the critical aspects which are related to the good performance and long-term viability of TES system. The use of coating does not only allow corrosion protection for container material but also protects the molten salt from the ingress of corrosion products. Corrosion-resistant structural materials are quite expensive, and protective coatings allow less expensive materials to be used for the structures.

2. Corrosion suppression

Hot corrosion becomes uncontrollable by the super alloys alone at elevated temperatures for extended time duration. One of the solutions to this situation is to apply shielding coating layer to low-alloy steel [11]. Protective coating can be divided into two basic groups: diffusion and overlay coatings. Diffusion coatings are formed by diffusion of one or more elements into the surface of the metal to be protected.

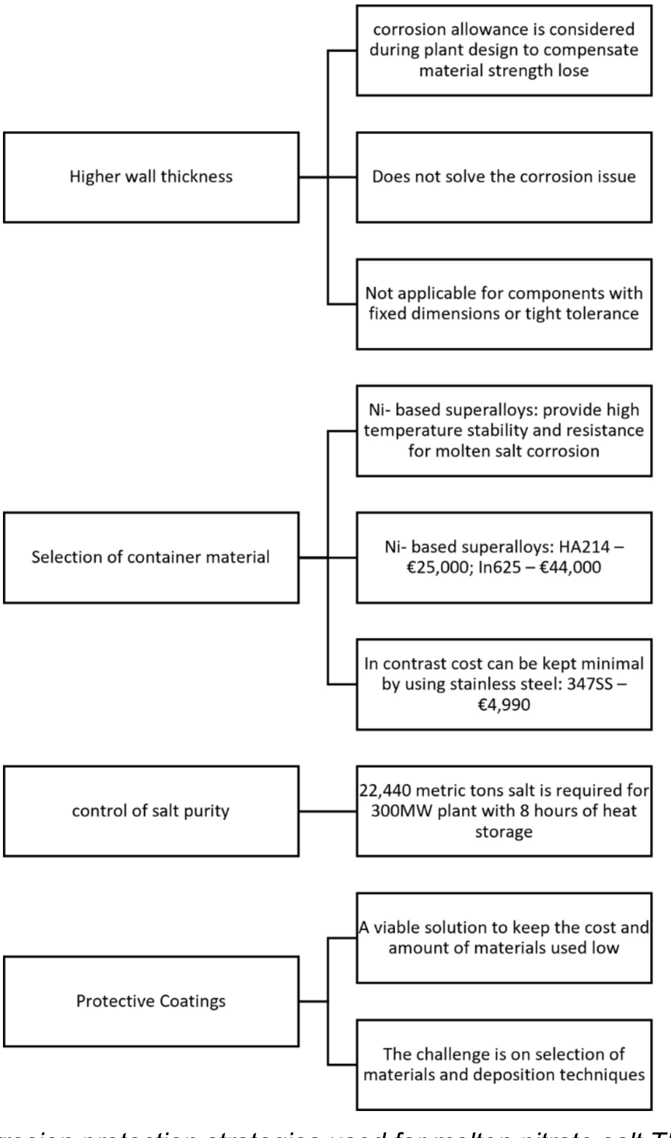

Figure 1*. Current corrosion protection strategies used for molten nitrate salt TES. Higher wall thickness, use of high purity salt, selection of specialised alloys is among the different strategies currently employed for corrosion suppression.*

A number of factors need to be considered while choosing coating material suitable for use in molten nitrate salts environment. The coatings should necessarily own a capacity to form a steady, slow-growing, passivating surface oxide to offer an obstruction between the coating, alloy, and environment, hence providing oxidation and hot corrosion resistance. Coatings should have microstructural strength to keep their protective properties for prolonged service life, even at high temperatures, and have resistance to cracking or spallation under mechanical and thermal stresses induced during operation. They should offer resistance to developing fissures to preserve coating strength when under the influence of thermal and mechanical stresses. The size and the shape of the material to be coated are crucial in order to select the most suitable deposition technique. Coatings can be tailored for a specific application by controlling their elemental composition, their microstructure, and by selection of manufacturing process.

Regarding the elemental composition, only limited materials behave in a satisfactory manner in molten nitrate salt at temperatures above 550ºC Table 1 [12]. It was reported that refractory metals such as cobalt and nickel, and alloys like NiMo, TiAl, austenitic stainless steel, and Ni-Cr-Fe corroded rapidly due to rapid oxidation and/or dissolution in the molten salt in a study with several metals, alloys and ceramics [13]. It was hypothesised that coatings must include a high concentration of elements such as Al, Cr, and Si which tend to form a protective scale [14].

3. Compatible materials for structural components

The suppression of hot corrosion is a major technical challenge in materials selection and structure design for TES. High temperature nickel-based alloys are the logical choice for mechanical strength, oxidation and corrosion resistance, as corrosion kinetics increase with elevated temperatures, however, the cost of nickel-based alloys are nearly four times more expensive than iron-based steels [15,16]. The corrosion behaviour of carbon steel A36 at 316ºC has been studied and weight losses were found to be modest with corrosion rates of about 5 µm/year, implying they can be used in the cold parts of the plant [17]. The study by Sandia entailed a review of problems and lessons learned from operation of the Solar Two power tower after its demolition in 2009, including corrosion rates for two Fe-Cr-Ni alloys (SS321 and SS34) and two nickel alloys (HA230 and In625) in contact with solar salt at 400, 500, 600 and 680ºC [15].

Corrosion is insignificant at 400ºC for all the studied alloys. Material performance is also excellent at 500ºC. At this temperature, both nickel alloys form protective nickel oxide, which does well in protecting the base alloy. A different scenario is observed at 680ºC. Corrosion at this temperature is severe for all the alloys with metal losses greater than 450 µm/year. The corrosion resistance of steels under these conditions depends on the formation of a protective oxide scale rich in Cr, which is similar to what happens during oxidation in high temperature gaseous atmospheres. However, an important difference when using molten salt is that chromium compounds are soluble in nitrate salt and prevents the formation of a protective oxide scale (passivation) [18]. This results in non-protective and/or fast-growing oxide formation and in the increment of material degradation due to higher corrosion rates [19].

Alloys constituent such as Cr, W and Mo can produce soluble anions and can be readily extracted from the surface oxide scales formed on the alloys [20]. HR120 and Mo332 exhibited corrosion product with similar concentrations of Ni, Fe, and Cr, while HR224 showed partial surface oxidation after 3000 hours, which was attributed to the high concentration of Al [17]. Alloys with stabilizing additions of niobium, such as SS347 or titanium, for instance SS321, are known to diminish stress corrosion cracking. The corrosion rate of SS347 has been reported to be smaller than SS321 by 30-40% for temperature up to 600°C, spallation, on surface of SS321, could be the reason[15]. The corrosion rates at 600°C have been observed to be twice compared to 500°C, as reaction kinetics usually display an Arrhenius relationship. The corrosion rates at 680°C have been reported to be two orders of magnitude larger than at 600°C [15]. The corrosion rates of 8.6 and 9.0µm/yr have been reported for AISI316L and AISI321H austenitic stainless steel, upon immersion in solar salt at 550°C [21]. Corrosion rate of stainless steel in molten salt is reported to speed up with the rise in temperature, the composition of oxide scales and the corrosion mechanism change with different temperatures [22].

The effect of impurities present in molten nitrate salts has been investigated in A36 and A516 at 316ºC [23],[24]. No significant difference in corrosion rate was observed in A36 with an addition of up to 1.3% chloride at 316ºC [23]. The effect of chloride becomes more substantial after 1000-hour exposure to the salts. After exposure to $NaNO_3$-KNO_3-$NaNO_2$, stainless steel was proposed to be better compared to carbon steel for corrosion resistance at higher temperature [25]. IN625 has been stated to have better performance in molten nitrate salts compared to other studied ferrite steel and stainless steels [26]. Stainless steels are described to behave better in molten nitrate salts as compared to ferritic steels [27].

Table 1. *Beneficial and detrimental aspects of elemental constituents of alloys [12].*

Elemental Constituent	Beneficial Aspects	Detrimental Aspects
Ni	Provides strength.	Prone to destructive interaction with sulphur.
Co	Provides microstructural stability and strength.	Prone to destructive interaction with sulphur.
Al	Major contributor to providing strength Contributes to oxidation resistance	Large concentration lowers melting point.
Cr	Contributes to oxidation resistance to 816ºC. Reduces Al requirement for formation of alumina scale.	Lowers creep strength.
Ta	Enhances hot corrosion and oxidation resistance. Improves strength.	
Si	Enhances oxidation and hot corrosion resistance.	Large concentration leads to formation of brittle phases.
Hf, Y, Y2O3	Improve adherence of alumina and chromia scales.	Large amounts are detrimental.
Pt	Improves oxidation and hot corrosion resistance.	

3.1 Aluminide coatings

Aluminide coatings have been used widely and shown to be beneficial for corrosion protection in molten nitrate as well as other molten salts [28][29][30]. The aluminide has been reported to form a thin corrosion resistant layer of $LiAlO_2$ upon reaction with Li in molten K/Na/Li carbonates at 650ºC [31].

A minimum of 25 (at%) of aluminium in FeAl intermetallic has been reported as required to develop a continuous $LiAlO_2$ oxide layer in Li/K carbonate melt at 650ºC [32]. Slurry aluminide coatings, a low-cost option, has been reported to develop a thin $NaAlO_2$ layer in molten Solar salt at 600ºC and 580ºC, although the protection mechanisms still not well identified [19][33][29]. Aluminides have a great amount of interest for coating material as they provide corrosion resistance up to temperatures above their mechanical strength limit. Aluminides with appropriate quantities of aluminium forms alumina scales. They possess low densities, high melting points, good thermal conductivities, and excellent high temperature strengths.

3.2 Ni-based coatings

Performance of pure nickel coatings is very poor, but Ni-based coatings have been reportedly used to provide wear, oxidation or hot corrosion resistance [34]. Intermetallic are proposed for high temperature use because their strength increases with temperature. Therefore, the use of an intermetallic material which forms an alumina scale, with nickel as base material is very encouraging. Ni-based alloys possess higher resistance to molten nitrate corrosion compared to Fe-base alloys, however considerably costly. The corrosion resistance of Ni-based alloys in molten nitrate-nitrite salt, has been reported to improve with Ni concentration in these alloys [18][35]. Ni based intermetallic and coatings have been explored to ease molten salt corrosion.

3.3 Nickel Chrome coatings

Nickel chrome coatings have been found to present protection against spalling and sputtering in aggressive environment of sulphate and vanadate salts at 900°C [36][37]. High chromium alloyed steels have demonstrated higher corrosion protection via formation of a slow growing continuous chromium oxide or chromate spinel layer [27]. However, solubility of Cr in the nitrate salt leads to depletion of chromium in the substrates and Cr-dissolution in molten salt [13][38]. Therefore, it is expected that materials with a significant amount of chromium will perform poorly in contact with nitrate salt.

3.4 Nickel Aluminide coatings

Nickel aluminide is proposed as a very promising material to be used as anticorrosion coating for molten nitrate salts. Favourable physical and mechanical characteristics, such as high melting temperature, high thermal conductivity, attractive stiffness, good oxidation resistance and metal-like electric conductivity [16]. Nickel aluminium coatings are reported in a number of cases with different compositions and have been seen to enhance the oxidation resistance of the substrate material. Nickel aluminium coatings are suggested to have a strong grip to substrate, offering strong adhesion and reducing the thermal mismatch between substrate material and coatings, in case of nickel or iron-based alloy substrate [39]. This type of coating has been seen to have the ability to form protective aluminium-oxide layers, resulting in exceptional oxidation resistance, which prevents further diffusion of reactants into the substrate material [40].

Greater amount of aluminium increases high temperature oxidation resistance, but it compromises the creep strength and load-bearing capability, so it is kept to less than 6% level [41]. Tortorelli observed that aluminium content must be over 30-35 at% threshold to provide protection against nitrate salts, however higher concentrations of aluminium constraint ductility and fabricability [13]. Therefore, the value of corrosion potential will be influenced by the stoichiometry of coatings and a careful control of the elemental composition will be crucial. Several studies have showed the promising properties of this alloy as anticorrosion coating [42]. Five intermetallic phases formed with nickel aluminide are $NiAl_3$, Ni_2Al_3, NiAl, Ni_5Al_3 and Ni_3Al [43][44].

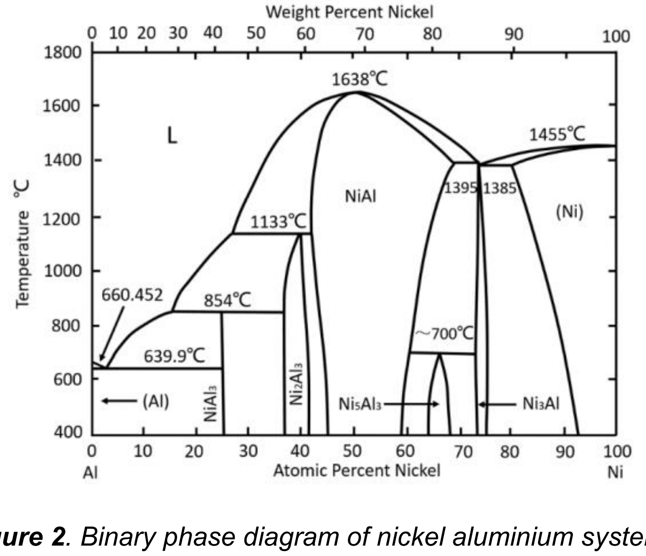

***Figure 2**. Binary phase diagram of nickel aluminium system [44]*

One of the causes of coating failure might be differences in thermal expansion coefficient among coating and substrate material. Bond coating of some material can be used for overcoming this mismatch. Applying a NiCrAlY bond coat prior to nickel aluminide coatings to increase the bond strength and decrease thermal expansion coefficient mismatch, provides good protection to the substrate in air and molten salt environments at 900°C [45]. It has been reported that addition of rare earth metal as for example yttrium can increase the strength of the coating and also enhances nucleation of Al_2O_3 growth during the high temperature oxidation tests [16]. Formation of NiO, $NiAl_2O_4$, and Al_2O_3 oxides on Ni_5Al coating at 900ºC for 100 cycles provided better hot corrosion resistance in comparison with bare super alloy [46][47]. Ni_3Al coatings have shown a reasonable corrosion rate in $NaNO_3$-(KNO_3)-Na_2O_2 environments while NiAl functioned quite well [13].

Electrodeposited slurry aluminide and nickel-aluminide coatings have been found to perform better than uncoated material, for corrosion resistance in solar salt at 580ºC. Ni_3Al coatings are much preferred to be used as corrosion resistant coatings as they possess strength at raised temperature, oxidation protection and creep properties. Ni3Al coatings on stainless steel substrates have been found to be protective in the presence of NaNO3:KNO3 salt environments, with the potential to extend the lifetime of components such as the storage tank systems [48]. Laser re-melting of Ni_3Al coating has also been observed to enhance the hot corrosion resistance [49].

3.5 Cost estimation

Material cost calculated for a molten salt container of size ~35m diameter, ~12.5m height (30 mm thick wall) made with SS347 costs ~€ 3.5M, while for HA214 ~€ 8.6M and ~€ 15.8M for HA214 [50]. Total cost of same size container including 30mm SS347 and 100 µm thick, air plasma spray deposited Ni_3Al coatings with 25% coating efficiency was given as ~€ 4M, implying Ni_3Al coatings enable low manufacturing cost with accomodated wall thickness [50].

4. Conclusion and outlook

The main conclusion of this literature review is that the suppression of corrosion in TES is a challenging task. The different solar thermal technologies have been reviewed, leading to the conclusion that CSP coupled with molten salt heat transfer fluids represents the perfect combination of high efficiency and heat storage capability. However, to make the most of this combination it is crucial to reduce hot corrosion by molten salt in component systems. The literature review revealed that there is still a lot to be done in order to find the ultimate solution to this problem. There is much to learn from other technologies in the field of hot corrosion.

Among the molten salts used as TES and HTF, Solar Salt $NaNO_3$ (60wt%) KNO_3 (40wt%) and related compositions are the most employed till now because of its low melting point and low cost. There is a need to study anticorrosion coating to be used with Solar Salt ($NaNO_3$ (60wt%), KNO_3 (40wt%)) for thermal energy storage components. In contrast to system components of other technologies dealing with hot corrosion, recoating of molten salt storage and distribution components is not straight-forward. Therefore, it is crucial that the coating survive many thermal cycles and performs its protective role for many years during plant operation. It would be interesting to see if future work focuses on different coating deposition techniques. Corrosion tests in molten salt and oxidation tests in air should be carried out to understand the underlying mechanisms and to distinguish between oxidation and corrosion results. Field tests should be carried out to observe the coatings in the real environment with fluctuating solar flux, wind and dust, compared to the steady temperatures in laboratory tests.

In conclusion this review document shows the potential for Plasma sprayed Ni_3Al protective coating on SS347 to suppress corrosion and defines the future directions in this field.

However more research is needed for investigating the Ni_3Al coatings on other substrate materials.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article. Additional information on data can be made available upon reasonable request from the corresponding author.

Author contributions

Sarah Yasir: Methodology, investigation, visualization, writing—original draft, data curation, formal analysis.

Adrianus Indrat Aria: Methodology, conceptualization, validation, visualization, supervision, formal analysis, writing — review and editing.

Chris Sansom: writing — validation, review, and editing.

Competing interests

The authors declare that they have no competing interests.

Funding

No funding was needed for this work.

Acknowledgement

Cranfield University and University of Derby.

References

[1] B. Brand, A. Boudghene Stambouli, D. Zejli, The value of dispatchability of CSP plants in the electricity systems of Morocco and Algeria, Energy Policy 47 (2012) 321–331. https://doi.org/10.1016/j.enpol.2012.04.073.

[2] H. Price, D. Kearney, F. Redell, R. Charles, F. Morse, Dispatchable solar power plant, AIP Conf Proc 2033 (2018). https://doi.org/10.1063/1.5067068.

[3] A.M. Yasin, The Impact of Dispatchability of Parabolic Trough CSP Plants over PV Power Plants in Palestinian Territories, International Journal of Photoenergy 2019 (2019). https://doi.org/10.1155/2019/4097852.

[4] M. Bošnjaković, V. Tadijanović, Environment impact of a concentrated solar power plant, Tehnički Glasnik 13 (2019) 68–74. https://doi.org/10.31803/tg-20180911085644.

[5] R. Li, H. Zhang, H. Wang, Q. Tu, X. Wang, Integrated hybrid life cycle assessment and contribution analysis for CO2 emission and energy consumption of a concentrated solar power plant in China, Energy 174 (2019) 310–322. https://doi.org/10.1016/j.energy.2019.02.066.

[6] O. Achkari, A. El Fadar, Latest developments on TES and CSP technologies – Energy and environmental issues, applications and research trends, Appl Therm Eng 167 (2020) 114806. https://doi.org/10.1016/j.applthermaleng.2019.114806.

[7] F.J. Pérez, V. Encinas-Sánchez, G. García-Martín, M.I. Lasanta, M.T. De Miguel, Dynamic pilot plant facility for applications in CSP: Evaluation of corrosion resistance of A516 in a nitrate molten salt mixture, AIP Conf Proc 1850 (2017) 226–231. https://doi.org/10.1063/1.4984503.

[8] S. Han, C. Zhang, Y. Wu, Y. Lu, J. Niu, Study on Flow and Heat Transfer Performance of Molten Salt Based Nanofluids in Shell and Twisted Tube Heat Exchanger with Shutter Baffle, Int J Thermophys 44 (2023). https://doi.org/10.1007/s10765-022-03134-6.

[9] D. Barlev, R. Vidu, P. Stroeve, Innovation in concentrated solar power, Solar Energy Materials and Solar Cells 95 (2011) 2703–2725. https://doi.org/10.1016/j.solmat.2011.05.020.

[10] J. Gasia, L. Miró, L.F. Cabeza, Review on system and materials requirements for high temperature thermal energy storage. Part 1: General requirements, Renewable and Sustainable Energy Reviews 75 (2017) 1320–1338. https://doi.org/10.1016/j.rser.2016.11.119.

[11] H. Singh, B.S. Sidhu, D. Puri, S. Prakash, Use of plasma spray technology for deposition of high temperature oxidation/corrosion resistant coatings - A review, Materials and Corrosion 58 (2007) 92–102. https://doi.org/10.1002/maco.200603985.

[12] S. Bose, High temperature coatings, Butterworth-Heinemann, 2017.

[13] P.F. Tortorelli, P.S. Bishop, J.R. DiStefano, Selection of Corrosion-Resistant Materials for Use in Molten Nitrate Salts, Oak Ridge National Laboratory, Tennessee, 1989.

[14] I.A. Podchernyaeva, A.D. Panasyuk, Protective Coatings on Heat-Resistant Nickel Alloys (Review), Powder Metallurgy and Metal Ceramics (2000) 434–444.

[15] A. Kruizenga, D. Gill, Corrosion of iron stainless steels in molten nitrate salt, Energy Procedia 49 (2013) 878–887. https://doi.org/10.1016/j.egypro.2014.03.095.

[16] J.T. Chang, a. Davison, J.L. He, a. Matthews, Deposition of Ni–Al–Y alloy films using a hybrid arc ion plating and magnetron sputtering system, Surf Coat Technol 200 (2006) 5877–5883. https://doi.org/10.1016/j.surfcoat.2005.08.138.

[17] A.M. Kruizenga, D.D. Gill, M. Laford, Materials Corrosion of High Temperature Alloys Immersed in 600 ° C Binary Nitrate Salt, Sandia Report SAND 2013- (2013) 1–57. https://doi.org/10.2172/1088090.

[18] J.W. Slusser, J.B. Titcomb, M.T. Heffelfinger, B.R. Dunbobbin, Corrosion in Molten Nitrate-Nitrite Salts, Journal of Metals 37 (1985) 24–27. https://doi.org/10.1007/BF03259692.

[19] P. Audigié, V. Encinas-Sánchez, M. Juez-Lorenzo, S. Rodríguez, M. Gutiérrez, F.J. Pérez, A. Agüero, High temperature molten salt corrosion behavior of aluminide and nickel-aluminide coatings for heat storage in concentrated solar power plants, Surf Coat Technol 349 (2018) 1148–1157. https://doi.org/10.1016/j.surfcoat.2018.05.081.

[20] C. Sequeira, High Temperature Corrosion in Molten Salts, Trans Tech Publications, 2003.

[21] A. Gomes, M. Navas, N. Uranga, T. Paiva, I. Figueira, T.C. Diamantino, High-temperature corrosion performance of austenitic stainless steels type AISI 316L and AISI 321H, in molten Solar Salt, Solar Energy 177 (2019) 408–419. https://doi.org/10.1016/j.solener.2018.11.019.

[22] Q. Gao, Y. Lu, Q. Yu, Y. Wu, C. Zhang, R. Zhi, High-temperature corrosion behavior of austenitic stainless steel in quaternary nitrate molten salt nanofluids for concentrated solar power, Solar Energy Materials and Solar Cells 245 (2022). https://doi.org/10.1016/j.solmat.2022.111851.

[23] S.H. Goods, R.W. Bradshaw, Corrosion of Stainless Steels and Carbon Steel by Molten Mixtures of Commercial Nitrate Salts, J Mater Eng Perform 13 (2004) 78–87. https://doi.org/10.1361/10599490417542.

[24] R.W. Bradshaw, W.M. Clift, SANDIA REPORT EFFECT OF CHLORIDE CONTENT OF MOLTEN NITRATE SALT ON CORROSION OF A516 CARBON STEEL, 2010. http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online.

[25] C.M. Kramer, W.H. Smyrl, W.B. Estill, Corrosion of Fe alloys in NaNO 3 -KNO 3 -NaNO 2 at 823 K, Journal of Materials for Energy Systems 1 (1980) 59–65. https://doi.org/10.1007/BF02833362.

[26] A. Soleimani Dorcheh, R.N. Durham, M.C. Galetz, Corrosion behavior of stainless and low-chromium steels and IN625 in molten nitrate salts at 600oC, Solar Energy Materials and Solar Cells 144 (2016) 109–116. https://doi.org/10.1016/j.solmat.2015.08.011.

[27] a. G. Fernández, M.I. Lasanta, F.J. Pérez, Molten salt corrosion of stainless steels and low-Cr steel in CSP plants, Oxidation of Metals 78 (2012) 329–348. https://doi.org/10.1007/s11085-012-9310-x.

[28] A. Soleimani Dorcheh, M.C. Galetz, Slurry aluminizing: A solution for molten nitrate salt corrosion in concentrated solar power plants, Solar Energy Materials and Solar Cells 146 (2016) 8–15. https://doi.org/10.1016/j.solmat.2015.11.024.

[29] P. Audigié, N. Bizien, I. Baráibar, S. Rodríguez, A. Pastor, M. Hernández, A. Agüero, Aluminide slurry coatings for protection of ferritic steel in molten nitrate corrosion for concentrated solar power technology, 070002 (2016). https://doi.org/10.1063/1.4984416.

[30] A. Agüero, F.J. García de Blas, M.C. García, R. Muelas, A. Román, Thermal spray coatings for molten carbonate fuel cells separator plates, Surf Coat Technol 146–147 (2001) 578–585. https://doi.org/10.1016/S0257-8972(01)01435-9.

[31] C.S.S. Ni, L.Y.Y. Lu, C.L.L. Zeng, Y. Niu, Evaluation of corrosion resistance of aluminium coating with and without annealing against molten carbonate using electrochemical impedance spectroscopy, J Power Sources 261 (2014) 162–169. https://doi.org/http://dx.doi.org/10.1016/j.jpowsour.2014.03.076.

[32] J.G. Gonzalez-Rodriguez, M. Cuellar-Hernández, M. Gonzalez-Castañeda, V.M. Salinas-Bravo, J. Porcayo-Calderon, G. Rosas, Effect of heat treatment and chemical composition on the corrosion behavior of FeAl intermetallics in molten (Li + K)carbonate, J Power Sources 172 (2007) 799–804. https://doi.org/10.1016/j.jpowsour.2007.05.010.

[33] B. Fotovvati, N. Namdari, A. Dehghanghadikolaei, On coating techniques for surface protection: A review, Journal of Manufacturing and Materials Processing 3 (2019). https://doi.org/10.3390/jmmp3010028.

[34] S.B. Mishra, K. Chandra, S. Prakash, B. Venkataraman, Characterisation and erosion behaviour of a plasma sprayed Ni3Al coating on a Fe-based superalloy, Mater Lett 59 (2005) 3694–3698. https://doi.org/10.1016/j.matlet.2005.06.050.

[35] M. Spiegel, J. Mentz, High temperature corrosion beneath nitrate melts, Materials and Corrosion 65 (2014) 276–281. https://doi.org/10.1002/maco.201307076.

[36] T.S. Sidhu, S. Prakash, R.D. Agrawal, Hot Corrosion Resistance of High-Velocity Oxyfuel Sprayed Coatings on a Nickel-Base Superalloy in Molten Salt Environment, Journal of Thermal Spray Technology 15 (2006) 387–399. https://doi.org/10.1361/105996306X124392.

[37] H. Singh, D. Puri, S. Prakash, Some studies on hot corrosion performance of plasma sprayed coatings on a Fe-based superalloy, Surf Coat Technol 192 (2005) 27–38. https://doi.org/10.1016/j.surfcoat.2004.03.030.

[38] M.C. Trent, S.H. Goods, R.W. Bradshaw, Comparison of corrosion performance of grade 316 and grade 347H stainless steels in molten nitrate salt, AIP Conf Proc 1734 (2016). https://doi.org/10.1063/1.4949258.

[39] S. Kumar, V. Selvarajan, P.V. a Padmanabhan, K.P. Sreekumar, Characterization and comparison between ball milled and plasma processed nickel-aluminium powders, Surf Coat Technol 486 (2008) 287–294. https://doi.org/10.1016/j.surfcoat.2006.01.051.

[40] S.C. Mishra, a. Satapathy, M. Chaithanya, P.V. Ananthapadmanabhan, K.P. Sreekumar, Wear Characteristics of Plasma Sprayed Nickel--Aluminum Composite Coatings, Journal of Reinforced Plastics and Composites 28 (2009) 2931–2940. https://doi.org/10.1177/0731684408094067.

[41] N. Cinca, J.M. Guilemany, Thermal spraying of transition metal aluminides: An overview, Intermetallics (Barking) 24 (2012) 60–72. https://doi.org/10.1016/j.intermet.2012.01.020.

[42] R. a. Mahesh, R. Jayaganthan, S. Prakash, A study on hot corrosion behaviour of Ni-5Al coatings on Ni- and Fe-based superalloys in an aggressive environment at 900 ??C, J Alloys Compd 460 (2008) 220–231. https://doi.org/10.1016/j.jallcom.2007.05.092.

[43] R. Starosta, Properties of Thermal Spraying Ni-Al Alloy Coatings, Advances in Materials Sciences 9 (2009). https://doi.org/10.2478/v10077-009-0004-2.

[44] Q. Jia, D. Li, S. Li, Z. Zhang, N. Zhang, High-temperature oxidation resistance of NiAl intermetallic formed in Situ by thermal spraying, Coatings 8 (2018). https://doi.org/10.3390/coatings8080292.

[45] B.S. Sidhu, S. Prakash, Degradation Behavior of Ni3Al Plasma-Sprayed Boiler Tube Steels in an Energy Generation System, J Mater Eng Perform 14 (2005) 356–362. https://doi.org/10.1361/10599490523382.

[46] S. Saladi, J. V Menghani, S. Prakash, Characterization and Evaluation of Cyclic Hot Corrosion Resistance of Detonation-Gun Sprayed Ni-5Al Coatings on Inconel-718, Journal of Thermal Spray Technology 24 (2015) 778–788. https://doi.org/10.1007/s11666-015-0235-1.

[47] B.S. Sidhu, S. Prakash, Evaluation of the corrosion behaviour of plasma-sprayed Ni 3 Al coatings on steel in oxidation and molten salt environments at 900 8C, Surf Coat Technol 166 (2003) 89–100. https://doi.org/10.1016/S0257-8972(02)00772-7.

[48] S. Yasir, J.L. Endrino, E. Guillén, A.I. Aria, Suppression of molten salt corrosion by plasma sprayed Ni3Al coatings, Emergent Mater 4 (2021) 1583–1593. https://doi.org/10.1007/s42247-021-00334-y.

[49] B.S. Sidhu, D. Puri, S. Prakash, Characterisations of plasma sprayed and laser remelted NiCrAlY bond coats and Ni3Al coatings on boiler tube steels, Materials Science and Engineering A 368 (2004) 149–158. https://doi.org/10.1016/j.msea.2003.10.281.

[50] S. Yasir, Development of NI3Al corrosion resistant coatings for SS347 heat storage components in presence of molten nitrate salt, Cranfield University, 2020.