Un tentativo di migliorare la resistenza alla corrosione di un acciaio zincato in continuo mediante modifiche superficiali

An attempt to improve corrosion resistance of a continuous zinc coated steel by surface modification

M. Delucchi, A. Lagazzo, Università degli Studi di Genova, DICCA

Il processo di zincatura in continuo è un processo per ottenere lamiere che possono resistere alla corrosione. In questo lavoro, i campioni ottenuti da una lamiera di acciaio zincata in continuo con rivestimento sottile sono stati modificati tramite attacco acido, riscaldamento e immersione in una soluzione contenente acido laurico per ottenere una superficie super idrofobica, di cui si è valutato il comportamento in termini di resistenza alla corrosione e resistenza idrodinamica. Analisi SEM, angoli di contatto statici, misure potenziodinamiche, misure di spettroscopia di impedenza e test fluidodinamici hanno dimostrato l'ottenimento di una superficie super idrofobica, ma non si sono rilevati aumento della resistenza alla corrosione e diminuzione della resistenza idrodinamica. Ciò probabilmente è dovuto alla disuniformità e al ridotto spessore del trattamento superficiale.

Parole chiave: Nastro zincato in continuo, superidrofobicità, resistenza alla corrosione, struttura flower-like

Continuous sheet galvanizing is a process to obtain coils which can resist corrosion. In this paper samples obtained from a thinly coated continuously galvanized steel sheet were modified through etching, heating and immersion in a solution containing lauric acid to obtain a superhydrophobic surface, whose behavior was analyzed in terms of anti-corrosion and anti-drag performances. SEM, static water contact angles, potentio-dynamic tests, electrochemical impedance spectroscopy and fluid dynamic tests demonstrated that the final surface was superhydrophobic, but the anti-corrosion and anti-drag properties were not improved, probably due to the non-uniformity and the very low thickness of the surface treatment.

Keywords: Continuous HDG, super hydrophobicity, corrosion resistance, flower-like structure

INTRODUCTION

Continuous sheet galvanizing is a process in which the surface of a continuous ribbon of steel is coated on both sides with a thin layer of zinc. The coating is applied to improve corrosion resistance. Several papers report the modification of metal surfaces to obtain superhydrophobic surfaces [1][2][3][4], but a continuous HDG steel has not yet been analyzed. In the present work this pristine material was modified to evaluate the possible production of a desirable texture, morphology and surface energy to obtain a super-hydrophobic surface, with the final aim to verify the improving of its anti-corrosion and anti-drag performances.

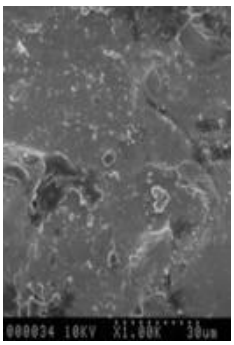
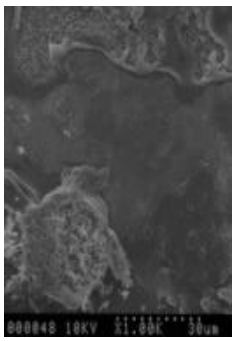
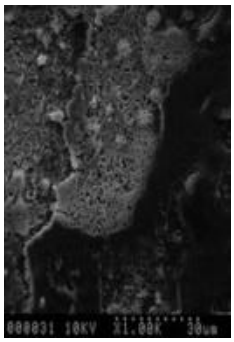
MATERIALS AND SAMPLES

The specimens were obtained from steel coils subjected to continuous sheet galvanizing. The Zn layer thickness ranges between 20 and 30 μm. The surface is composed by irregular clusters or arrangement of scale-like structures. The modified zinc surface was obtained with three steps: i) etching in 1 mol/l NaCl - 5% acetic acid solution with the addition of some drops of hydrogen peroxide for 60 sec; ii) heating in a water bath at 90 °C for 20 min and cooling in air for 30 min; iii) immersion in an ethanol solution of lauric acid 30 mmol/L at room temperature for 1 h.

RESULTS AND DISCUSSION

The surface morphology of the different samples was determined using SEM (Tab. 1).
The pristine material is inhomogeneous. Some ZnO on the surface can be present, owing to the relatively high chemical activity of the galvanized steel. During etching some corrosion products, due to the reaction with HCl, can be found, i.e. the platelets with a lamellar shape visible in the bottom part of the micrograph; some pits and flat surfaces are present, too. After the water bath the uneven surface is still present, with an increased porosity. The modification with lauric acid produced a deposition of flower-like micro-nano structures.

Tab. 1 – Morfologie e angoli di contatto – *Morphologies and contact angles*

Material	Pristine	After etching	After water bath	After immersion in LA
SEM image				
Contact angle (°)	118	80	90	160

The treatment with lauric acid produced a superhydrophobic surface, with CA of about 160° (Tab. 1). It can be explained considering the surface morphology, and the action of the fatty acid which, through adsorption and chemical bonding, acts as surface energy reducer.
The electrochemical measurements were performed with a GAMRY – Multichannel system Interface 1010ET with a classic three electrode set-up. The samples were maintained in NaCl 3%.
All the tests showed that the treatment does not increase the anticorrosion properties of the zinc layer; the modified superhydrophobic surface reveals a higher thermodynamic tendency for corrosion and a lower electrochemical stability.

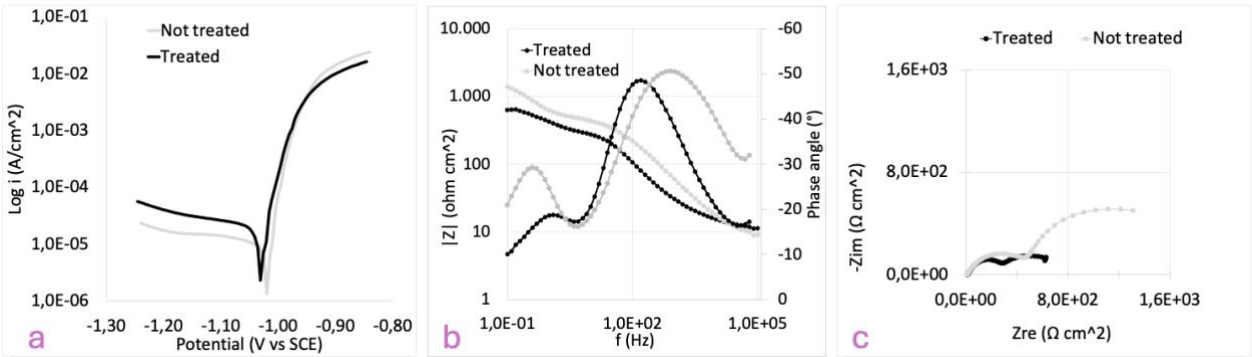


Fig. 1 Test elettrochimici: a) polarizzazioni potenziodinamiche, b) e c) Impedenza elettrochimica, diagrammi di Bode e Nyquist - *Electrochemical tests: a) potentiodynamic polarization curves, b) EIS Bode plot, c) EIS Nyquist plot*

The potentio-dynamic tests were performed using a rheometer Anton Paar MCR 301 equipped with a rotor of 50 mm in diameter and 1.5 mm in thickness. In the experimental setup, the rotor is immersed in a rectangular vessel filled with distilled water (Fig. 2); it was evaluated the torque for the rotation of the rotor-disk, treated and not treated in the lower part, in a water tank at different angular speeds.

The curves are almost overlapped.

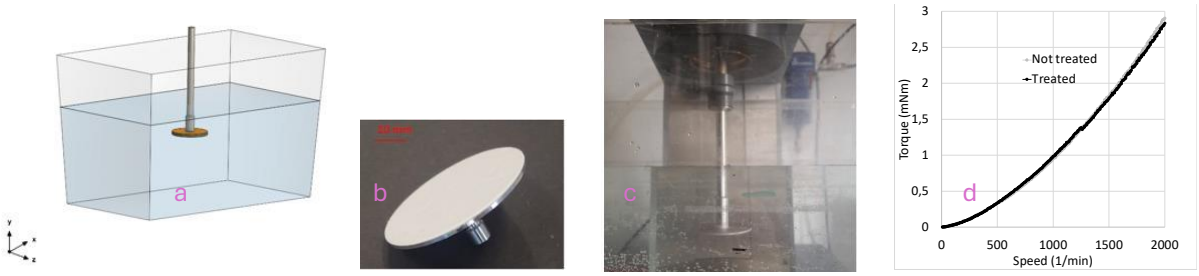


Fig. 2 Prove fluidodinamiche, a) assetto sperimentale del reometro, b) disco, c) disco rotante in acqua, d) risultati – *Fluid dynamic tests: a) experimental set-up, b) disc, c) rotating disc in water, d) results*

CONCLUSIONS

Despite several attempts, producing a superhydrophobic surface with good corrosion resistance and low drag resistance has not yet been successful. Nevertheless, the study demonstrates that even if super hydrophobicity of the surface can be a result, it cannot be directly related to anti-corrosion and anti-drag properties; this surface modification produces very thin and not homogeneously deposited nano-micro structures that do not improve the behavior of the pristine continuous zinc coated steel.

REFERENCES

[1] Yuping Li et al., simple method for the fabrication of superhydrophobic surfaces on hot-dip galvanized steel, Applied Physics A (2023) 129:468.
[2] Thet Htet Naing et al., Corrosion-resistant superhydrophobic films on galvanized steel by one-step electrodeposition, Materials Today Communications 35 (2023) 106241.
[3] Xue-sen Lv et al., A facile method for constructing a superhydrophobic zinc coating on a steel surface with anti-corrosion and drag-reduction properties, Applied Surface Science 562 (2021) 150192.
[4] Lei Cao et. al, Corrosion-resistant and friction-reducing performance of super-hydrophobic coating on hot-dip galvanised steel in a 3.5% NaCl solution, Lubrication Science. 2021;33:325–334.

ACKNOWLEDGMENTS

Activity funded by the European Union Next Generation EU, via PRIN PNRR 2022 grant, project code P2022CZ5KZ (“SLIPS”)