HE AND CPT OF ASTM A470 IN VCI 337 ED ECOLINE 3690

The buildup of damage due to localized corrosion, pitting, stress, corrosion cracking and corrosion fatigue, in low pressure steam turbine blades, discs and rotors is a primary cause of most of turbine failures. Localized corrosion inhibitors can be used to protect steam turbines from the subsequent environment during shutdown and routine maintenance.

La creazione di un danno dovuto alla corrosione localizzata, alla vaiolatura, alla tensocorrosione, alle cricche da corrosione e alla fatica da corrosione, nelle pale, nei dischi e nei rotori delle turbine a vapore a bassa pressione è la causa primaria della maggior parte delle rotture delle turbine. Gli inibitori della corrosione localizzata possono essere utilizzati per proteggere le turbine a vapore dall'ambiente conseguente durante il fermo e la pratica manutentiva.

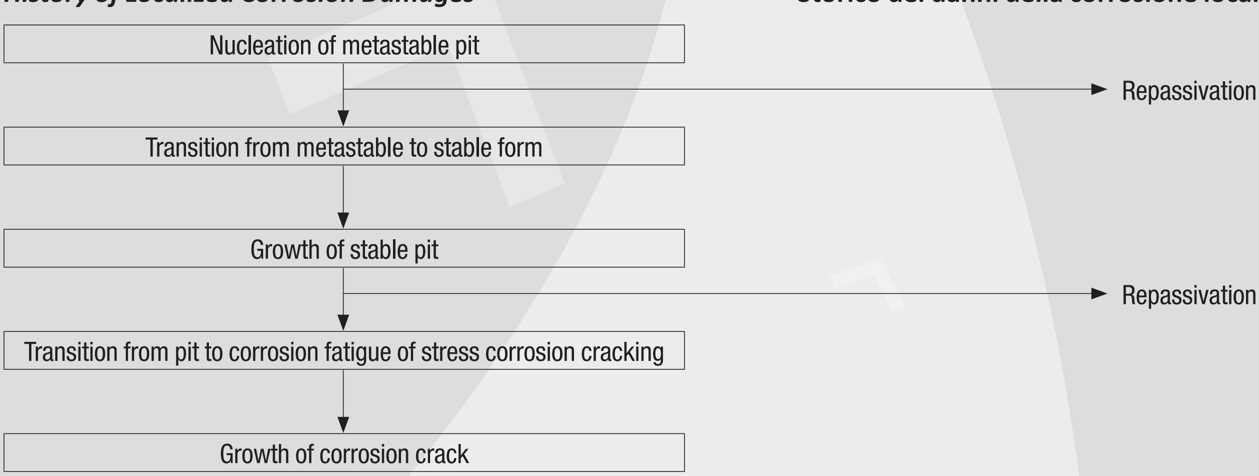
***Table 1:** Steam Turbine Blade Failure Mechanisms*

Tabella 1: meccanismi di rottura delle pale di turbine a vapore

Failure Mechanism	**Resultant Damage**	**Cause(s) of Failure**
Corrosion	Extensive pitting of airfoils, shrouds, covers, blade root surfaces	Chemical attack from corrosive elements in the steam provided to the turbine
Creep	Airfoils, shrouds, covers permanently deformed	Deformed part subjected to steam temperatures in excess of design limits
Erosion	Thinning of airfoils, shrouds, covers, blade roots	1) Solid particle erosion from very fine debris and scale in the steam provided in the turbine 2) Water droplet erosion from steam which is transitioning from vapor to liquid phase in the flowpath
Fatigue	Cracks in airfoils, shrouds, covers blade roots	1) Parts operated at a vibratory natural frequency 2) Loss of part dampening (cover, tie, wire, etc.) 3) Exceeded part fatigue life design limit 4) Excited by water induction incident - water flashes to steam in the flowpath
Foreign/Domestic Object Damage (FOD/DOD)	Impact damage (dents, dings, etc.) to any part of the blading	Damage from large debris in steam supplied to the turbine (foreign) or damage from debris generated from an internal turbine failure (domestic) which causes downstream impact damage to components
Stress Corrosion Cracking (SCC)	Cracks in highly stressed areas of the blading	Specialized type of cracking caused by the combined presence of corrosive elements and high stressed in highly loaded locations
Thermal Fatigue	Cracks in airfoils, shrouds, covers, and blade roots	Parts subjected to rapidly changing temperature gradients where thick sections are subjected to high alternating tensile and compressive stresses during heat-ups and cooldowns or when a water induction incident occurs where the inducted cool water quenches hot parts

History of Localized Corrosion Damages

Storico dei danni della corrosione localizzata



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Inhibition effectiveness of VCI 337 and Ecoline 3690 products was confirmed with electrochemical corrosion techniques in different concentrations of inhibitor and Stress corrosion cracking/ Crevice corrosion tests in Anodic potential range.
The Object of this phase Research were:
1. *to investigate possible side effect VCI inhibitors to cause Hydrogen Embrittlement*
2. *to define Critical Pitting Temperature*

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Typical Locations of Disc Rim Cracking.

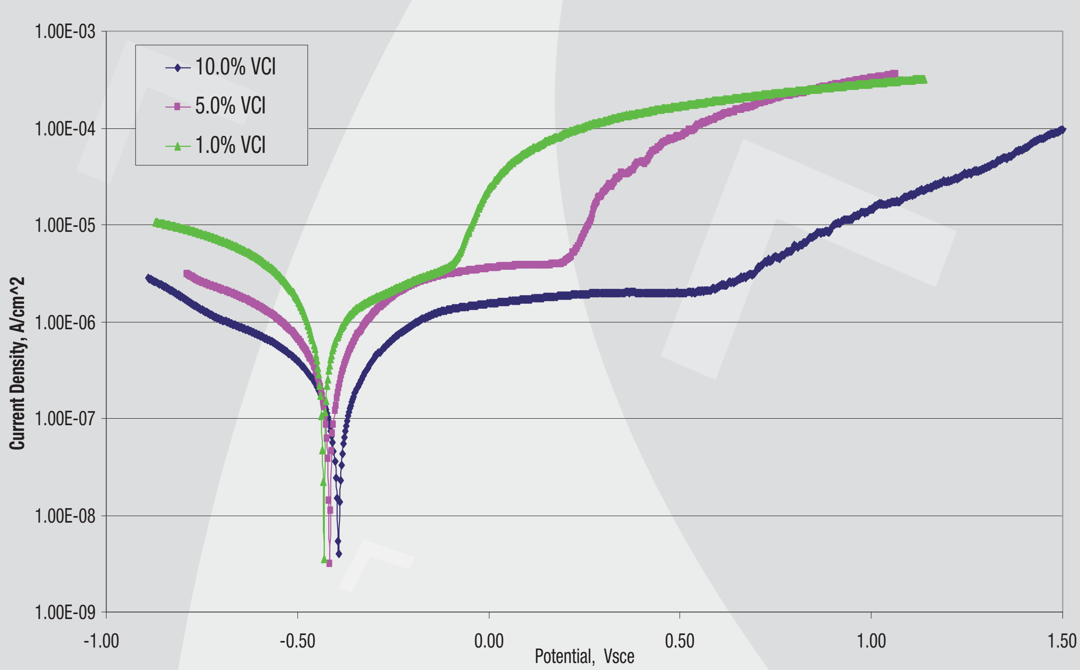
Localizzazione tipica della criccatura del cerchione.

L'efficacia inibitoria dei prodotti VCI 337 ed Ecoline 3690 è stata confermata da test di corrosione elettrochimica in concentrazioni differenti di inibitori e test su formazione di cricche o crepe da corrosione in area di potenziale anodico.
Gli obiettivi di questa fase di ricerca erano:
1. investigare il possibile effetto collaterale degli inibitori VCI di causare fragilità dovuta all'idrogeno
2. definire la temperatura critica di vaiolatura.

Table 2: *Critical pitting Temperature (ASTM G150). Corrosion Tests on ASTM A470 in different solutions of VpCI 337 and Ecoline 3690*

Tabella 2: temperatura critica di vaiolatura (ASTM G150). Test di corrosione secondo ASTM A470 in differenti soluzioni di VpCI 337 ed Ecoline 3690

Environment	Inhibitor Concentration %	# of Tests
water +200 ppm Cl- 1.0 4	1.0	4
water +200 ppm Cl- 5.0 4	5.0	4
water +200 ppm Cl- 10.0 4	10.0	4
water +200 ppm Cl- 50.0 4	50.0	4

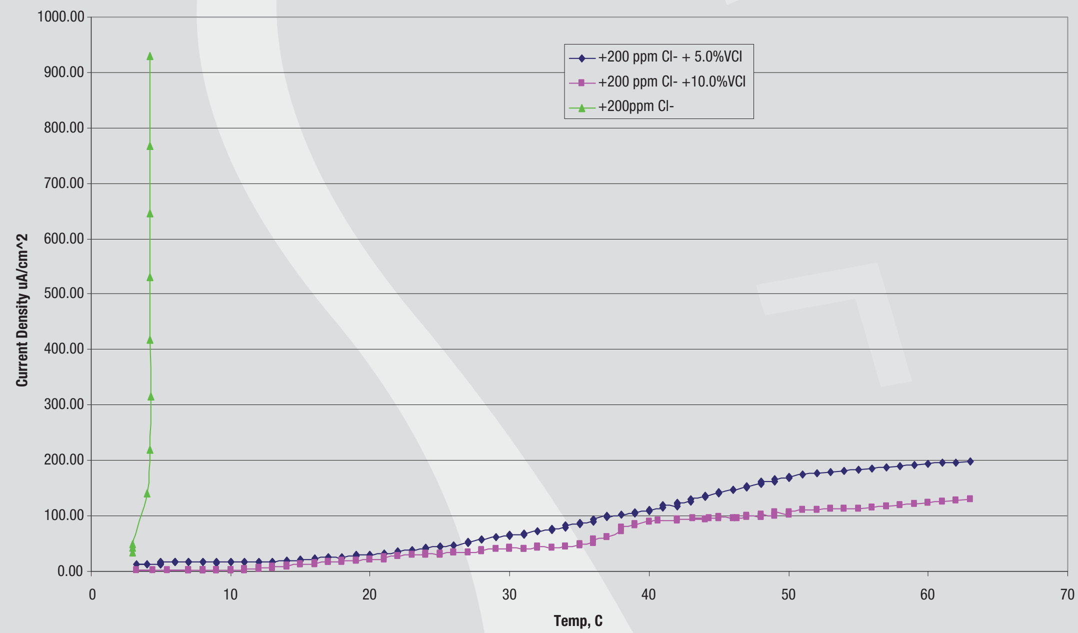


Plot 1. Corrosion Behavior of ASTM A-470Steel in +200ppm Cl- with different %VCI 337 in Solution ASTM G61

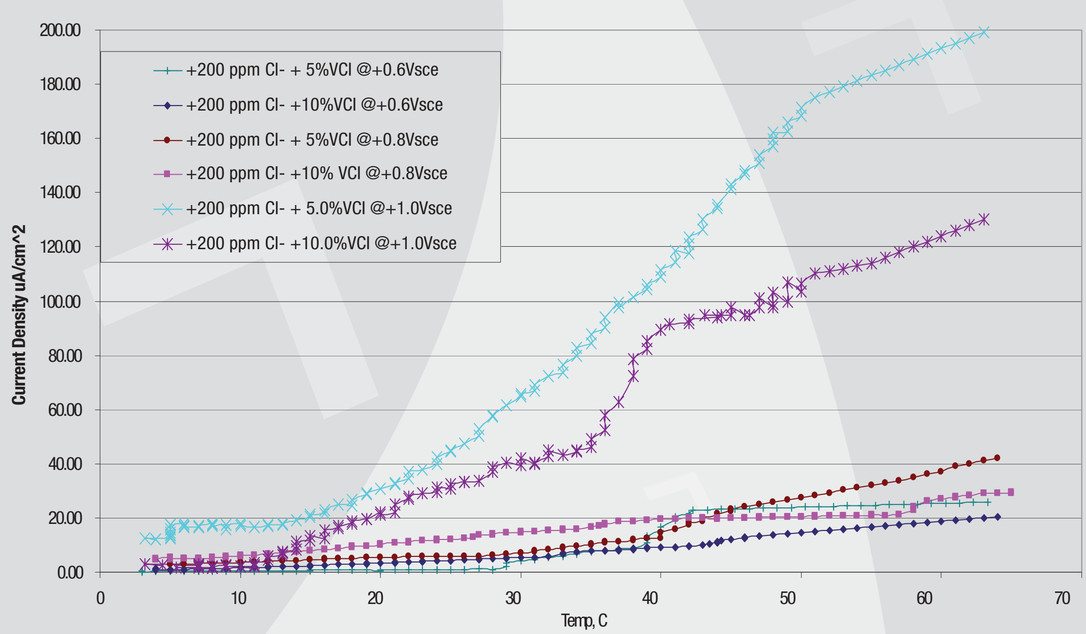
Table 3: Electrochemical Polarization Behavior of ASTM A470 in Different Solutions

Tabella 3: Comportamento di polarizzazione elettrochimica di ASTM A470 in differenti soluzioni

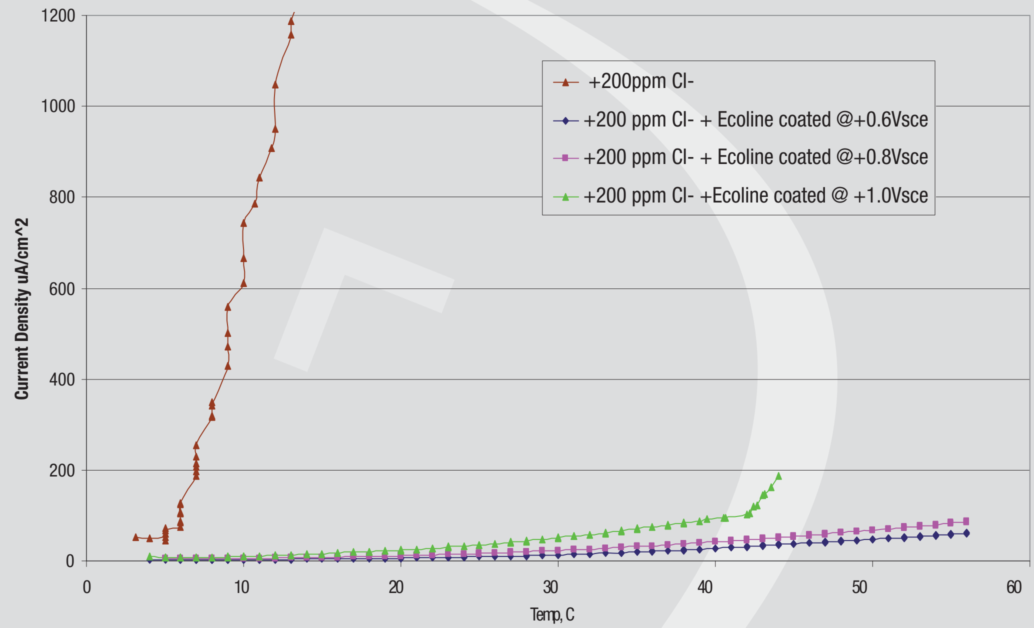
Sample	Ec, mVsce	Ic uA/cm^2	Eb, mVsce	CR, Mpy	Passive Range mVsce	Ipss uA/cm^2
200ppm Cl- +0.0%VCI	-675	1.47	-450	0.63	None	NA
200ppm Cl- +1.0%VCI	-460	0.389	+45	0.17	-300 to +20	3.12
200ppm Cl- +5.0%VCI	-415	0.304	+240	0.13	-200 to +200	3.22
200ppm Cl- +10.0%VCI	-392	0.0832	+1060	0.04	-100 to +950	1.92



Plot 2. Critical Pitting Temperature Tests on ASTM A470 with VCI 337 at applied anodic applied potential of +0.2VSCE, ASTM G150



Plot 3. Critical Pitting Temperature Tests on ASTM A470 with VCI 337 at different anodic applied potentials, ASTM G150

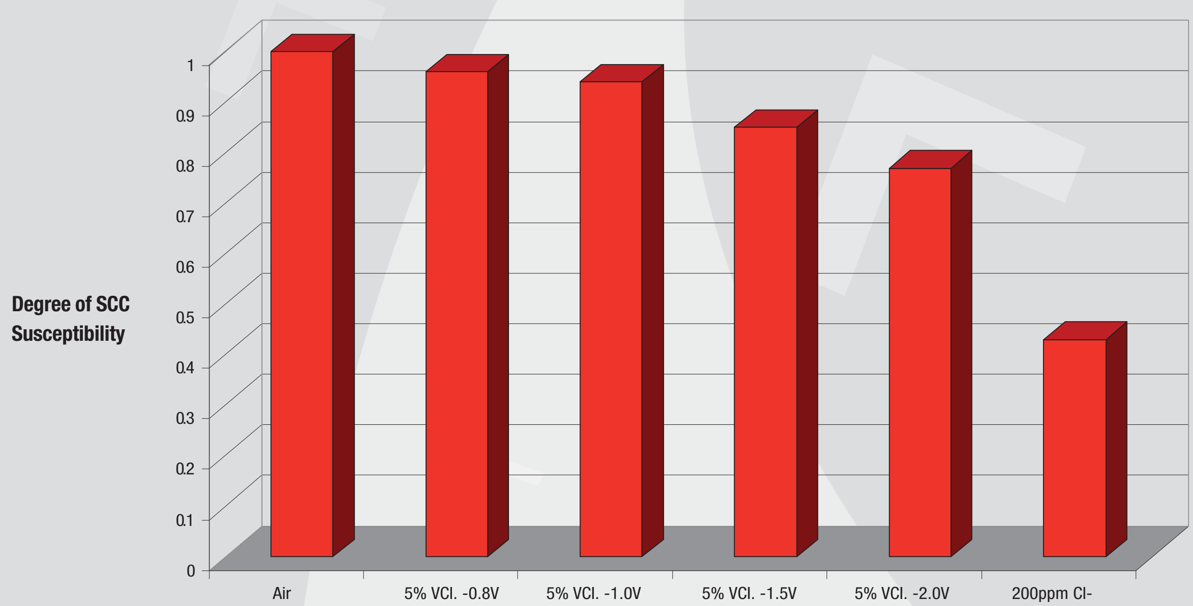


Plot 4. Critical Pitting Temperature Tests on ASTM A470/Ecoline 3690 at different anodic applied potentials, ASTM G150

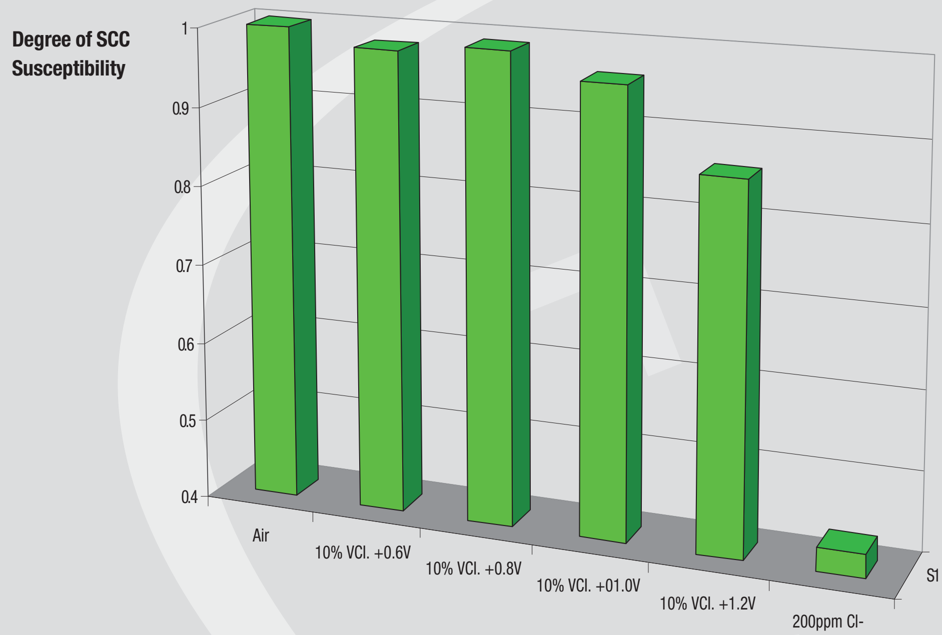
Table 4: *HE Corrosion Tests on ASTM A470 using the slow strain rate techniques in 5% VCI 337 solutions, Strain Rate = 5x10-7 cm-1*

Tabella 4: Test di corrosione HE su ASTM A470 utilizzando le tecniche di velocità di deformazione lenta in soluzioni al 5% di VCI 337, Velocità di deformazione = 5x10-7 cm-1

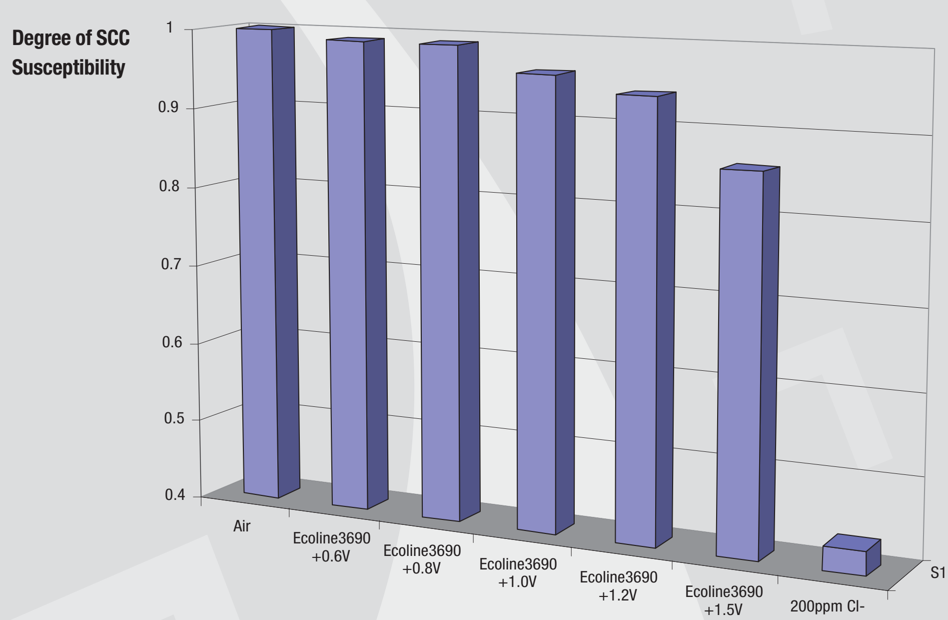
Environment	Applied potential, Vsce	# of Test each alloy
water +200 ppm Cl-	-0.80	2
water +200 ppm Cl-	-1.00	2
water +200 ppm Cl-	-1.50	2



Plot 5. Slow Strain Rate tests on ASTM A470 at different Cathodic Potentials, ASTM G129, in Different Solutions at , 5x10^-7 sec-1



Plot 6. Slow Strain Rate tests on ASTM A470 at different Anodic Potentials ASTM G129, in 10%VCI 337 Solutions at , 5x10^-7 sec-1



Plot 7. Slow Strain Rate tests on ASTM A470 at different Anodic Potentials ASTM G129, Ecoline3690 coated in +200ppm Cl- Solutions at , 5x10^-7 sec-1

Table 5: *SCC Corrosion Tests on ASTM A470 using the slow strain rate techniques in Ecoline 3690 coated samples, Strain Rate = 5x10-7 cm-1.*

Tabella 5: Test di corrosione SCC (Stress Corrosion Cracking) su ASTM A470 utillizzando le tecniche di velocità di deformazione lenta su campioni rivestiti di Ecoline 3690, velocità di deformazione = 5x10-7 cm-1.

Environment	Applied potential, Vsce	# of Test each alloy
water +200 ppm Cl-	-0.80	2
water +200 ppm Cl-	-1.00	2
water +200 ppm Cl-	-1.50	2

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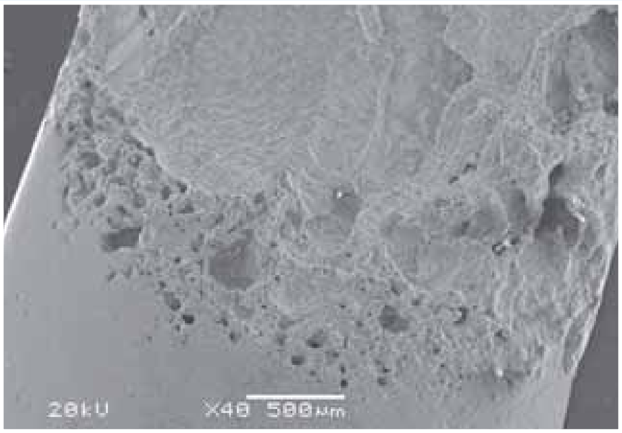
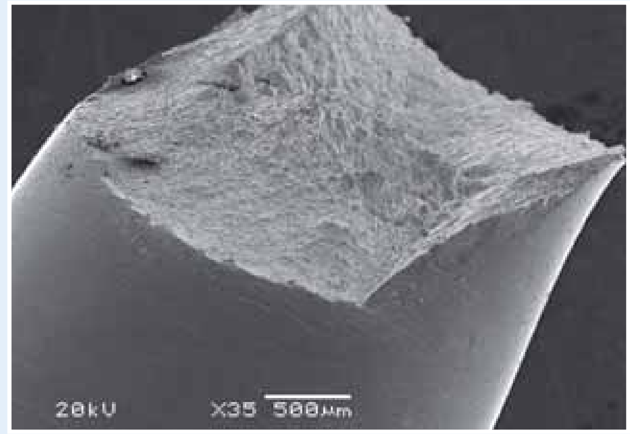
SCC of ASTM A470

+200ppm Cl- (-0.2 Vsce)

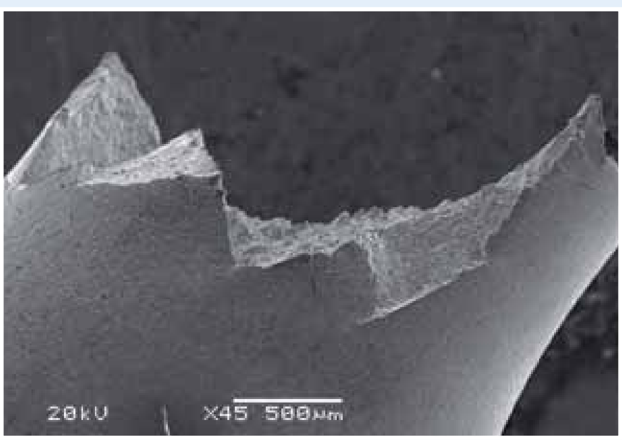


+10.0% VCI, (+1.0Vsce)

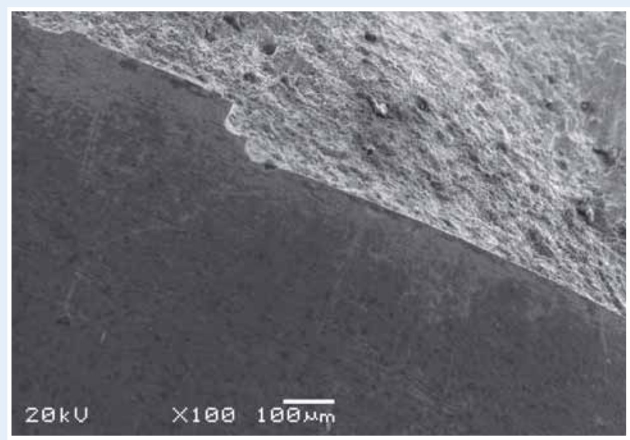


SCC of ASTM A470 - E= +1.0 Vsce

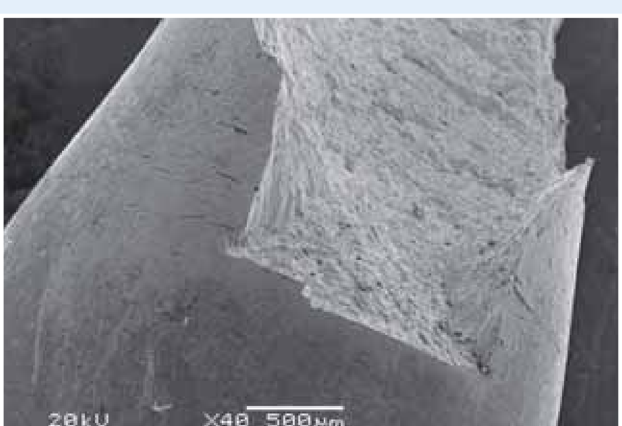
+200ppm Cl-

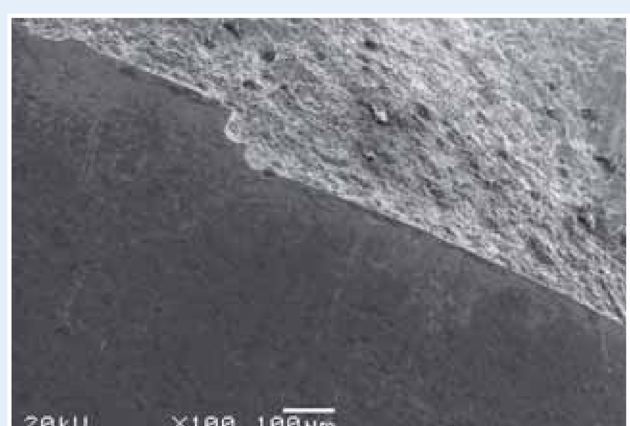


+10.0% VCI



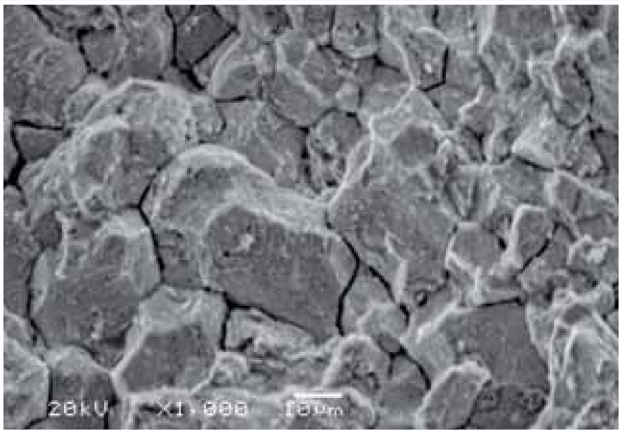
SCC of ASTM A470 - E= +1.0 Vsce, 10.0% VCI A



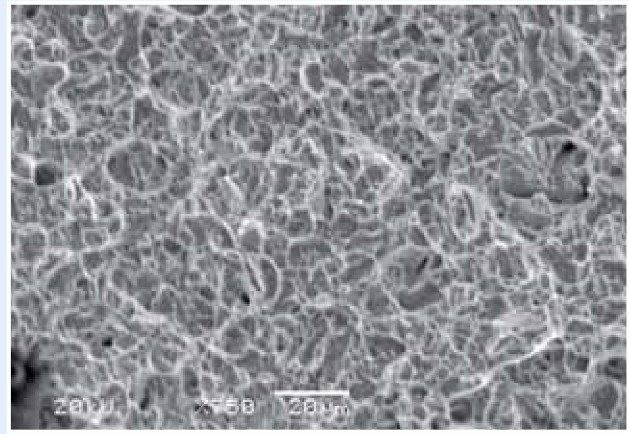


SCC of ASTM A470 - E= -0.2 Vsce

+200ppm Cl-

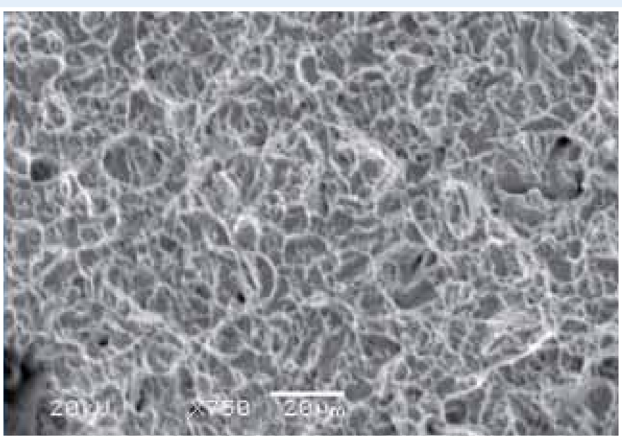


5.0% VCI

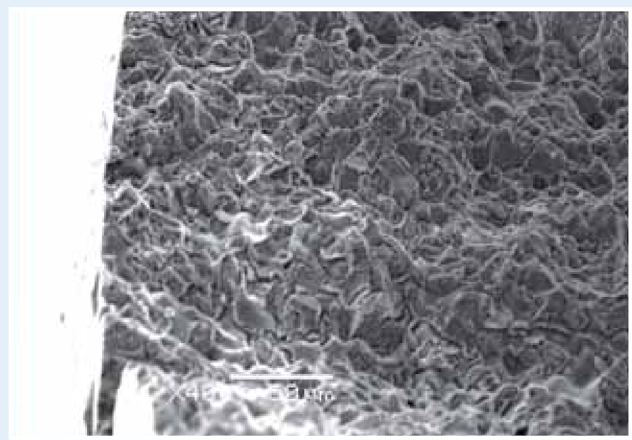


SCC of ASTM A470 - in 200ppm Cl- + 50 ppm S= +10%VCI

E= -1.0 Vsce

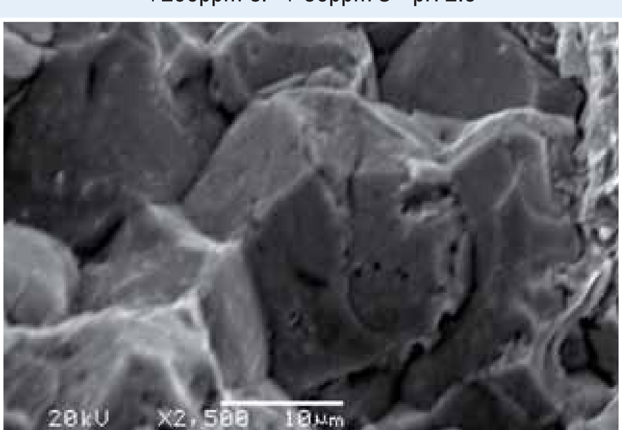


E= -1.5 Vsce

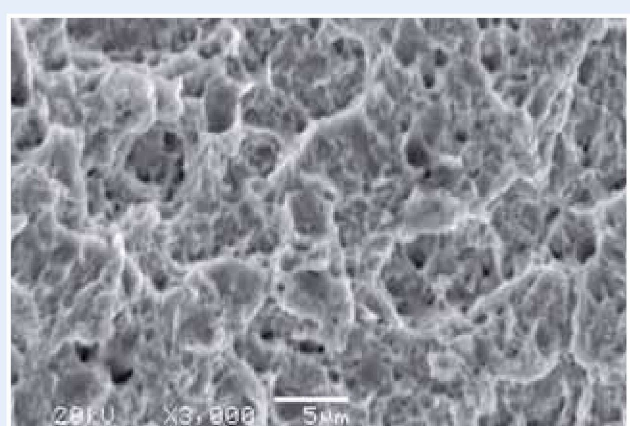


SCC of ASTM A470 - E= -1.0 Vsce

+200ppm Cl- + 50ppm S= pH 2.6



+10.0% VCI



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Summary

HE tests confirmed that none of VCI inhibitors could cause any harmful effect on ASTM A470 up to -1.5 Vsce. Presence of both VCI 337 and Ecoline 3690 inhibitors increased; critical pitting temperature to 45-50oC, while non-protect ASTM A470 showed a CPT of 8oC in 200ppm Cl- solution.

In Summary, addition of 10%VpCI337 reduces susceptibility of ASTM A470 steel to SCC and HE in a wide potential range of -1.5 to +1.0Vsce.

VpCI 337 inhibitor provides an effective corrosion protection for both ASTM A470 steel and 7050 Al-alloys during the shutdown period for the blades and discs in low pressure steam turbines, therefore its addition in the turbo-machinery systems is recommended to preserve and protect metallic components during maintenance and long term shutdown. ■

Conclusioni

I test HE hanno confermato che nessuno degli inibitori VCI potrebbe causare effetti dannosi su ASTM A470 fino a -1.5 Vsce. La presenza di entrambi gli inibitori VCI 337 ed Ecoline 3690 ha aumentato la temperatura critica di vaiolatura a 45-50°C, mentre l'ASTM A470 non protetto ha mostrato una CPT di 8°C in soluzione 200ppm Cl-.

In conclusione, l'aggiunta di un 10% di VpCI 337 riduce la suscettibilità dell'acciaio ASTM A470 a SCC ed HE in un'ampia area di potenziale da -1.5 a +1.0Vsce.

L'inibitore VpCI 337 fornisce un'efficace protezione dalla corrosione sia per acciaio ASTM A470 che per leghe di alluminio 7050 durante il periodo di fermo impianto per le pale e i dischi di turbine a vapore a bassa pressione, per cui questa aggiunta nei sistemi di macchine a turbina è raccomandata per preservare e proteggere i componenti metallici durante la manutenzione e i lunghi fermi impianto. ■