Technological capabilities of the CS350M corrtest potentiostat for corrosion process investigation

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Abstract: *Corrosion remains one of the most significant challenges affecting the durability, reliability, and economic performance of metallic materials used in industrial, engineering, and technological applications. Accurate evaluation of corrosion behavior requires advanced electrochemical techniques capable of providing rapid, reliable, and quantitative information regarding corrosion mechanisms and rates. In recent years, potentiostatic and galvanostatic electrochemical systems have become indispensable tools for corrosion research due to their high sensitivity and analytical capabilities. Among these systems, the CS350M Corrtest Potentiostat has attracted considerable attention because of its multifunctional design and wide range of electrochemical measurement techniques. The present study investigates the technological capabilities of the CS350M Corrtest Potentiostat for corrosion process analysis and evaluates its effectiveness in electrochemical corrosion research. Particular attention is devoted to the application of the instrument for potentiodynamic polarization measurements, Tafel analysis, electrochemical impedance spectroscopy (EIS), open-circuit potential monitoring, and corrosion rate determination. The operational principles, measurement accuracy, data acquisition capabilities, and analytical performance of the instrument were examined under laboratory conditions. The results demonstrated that the CS350M Corrtest Potentiostat provides highly reproducible electrochemical data and enables comprehensive characterization of corrosion processes occurring at metal–electrolyte interfaces. Potentiodynamic polarization studies allowed accurate determination of corrosion potential, corrosion current density, and Tafel slopes, while EIS measurements provided detailed information concerning charge-transfer resistance, double-layer capacitance, and protective film properties. The integrated software environment facilitated real-time data acquisition, processing, and interpretation of electrochemical parameters. The instrument exhibited excellent sensitivity in detecting variations in corrosion behavior under different experimental conditions, including changes in electrolyte composition, inhibitor concentration, and surface treatment. The versatility of the CS350M system makes it suitable for investigating corrosion mechanisms, evaluating corrosion inhibitors, studying protective coatings, and assessing material performance in aggressive environments. The findings indicate that the CS350M Corrtest Potentiostat represents a powerful and reliable electrochemical platform for corrosion research. Its broad range of analytical functions, high measurement precision, and advanced data-processing capabilities provide significant advantages for both fundamental corrosion studies and practical industrial applications. The study confirms the effectiveness of the instrument as a valuable tool for modern corrosion science and electrochemical material characterization.*

Keywords: *CS350M Corrtest Potentiostat, corrosion investigation, electrochemical impedance spectroscopy, Tafel polarization, corrosion rate, electrochemical analysis, corrosion monitoring, electrochemical characterization, metallic materials, corrosion science*

INTRODUCTION

Corrosion is a naturally occurring electrochemical process that results in the gradual deterioration of metallic materials through their interaction with surrounding environments. The phenomenon affects a wide range of industrial sectors, including oil and gas production, chemical processing, transportation, construction, energy generation, and marine engineering. It has been estimated that corrosion-related damage accounts for significant economic losses worldwide, leading not only to increased maintenance and replacement costs but also to safety risks and reduced operational efficiency of engineering systems. The investigation of corrosion mechanisms and the development of effective corrosion prevention strategies require accurate and reliable analytical techniques capable of characterizing electrochemical processes occurring at metal-electrolyte interfaces. Traditional gravimetric and chemical methods have long been used for corrosion evaluation; however, these approaches often require extended exposure periods and provide limited information regarding the kinetics and mechanisms of corrosion reactions. Consequently, electrochemical methods have become increasingly important in modern corrosion research due to their rapid response, high sensitivity, and ability to provide quantitative information about corrosion behavior.

Electrochemical techniques such as open-circuit potential (OCP) monitoring, potentiodynamic polarization, Tafel extrapolation, linear polarization resistance (LPR), cyclic voltammetry, and electrochemical impedance spectroscopy (EIS) have become standard tools for investigating corrosion processes. These methods enable researchers to determine critical electrochemical parameters including corrosion potential, corrosion current density, polarization resistance, charge-transfer resistance, double-layer capacitance, and corrosion rate. The information obtained from such measurements contributes significantly to understanding corrosion mechanisms, evaluating corrosion inhibitors, assessing protective coatings, and predicting material performance in aggressive environments. The effectiveness of electrochemical corrosion studies largely depends on the capabilities of the instrumentation employed. Recent advances in electrochemical measurement technology have led to the development of sophisticated potentiostat/galvanostat systems that combine high measurement accuracy with advanced data acquisition and analysis capabilities. Among these instruments, the CS350M Corrtest Potentiostat has emerged as a versatile electrochemical workstation widely utilized in corrosion science, materials research, energy storage investigations, and electrochemical sensor development.

The CS350M Corrtest Potentiostat is designed to perform a broad range of electrochemical techniques through precise control of electrode potential and current. The instrument integrates multiple electrochemical functions, including potentiodynamic polarization, cyclic voltammetry, chronoamperometry, chronopotentiometry, electrochemical impedance spectroscopy, and galvanostatic measurements. Its advanced hardware architecture and dedicated software platform enable high-resolution data collection, real-time monitoring, and comprehensive analysis of electrochemical systems. One of the major advantages of the CS350M system is its ability to investigate corrosion processes over a wide range of experimental conditions. The instrument allows accurate measurement of corrosion parameters for various metallic materials exposed to different electrolytes, temperatures, inhibitor concentrations, and surface treatments. In addition, its capability to perform electrochemical impedance spectroscopy provides valuable information regarding interfacial processes, protective film formation, coating performance, and corrosion inhibition mechanisms. Despite the growing use of the CS350M Corrtest Potentiostat in electrochemical laboratories, comprehensive evaluations of its technological capabilities for corrosion process investigation remain relatively limited in the scientific literature. A detailed assessment of its analytical performance, measurement versatility, and applicability to corrosion

studies is therefore necessary to support its effective utilization in both academic research and industrial applications. The present study aims to investigate the technological capabilities of the CS350M Corrtest Potentiostat for corrosion process analysis. Particular attention is devoted to evaluating its performance in potentiodynamic polarization measurements, Tafel analysis, electrochemical impedance spectroscopy, corrosion rate determination, and electrochemical monitoring of metallic materials. The findings of this study are expected to provide valuable insights into the practical advantages of the instrument and its role in advancing modern corrosion research and electrochemical characterization technologies.

MATERIAL AND METHODS

The electrochemical investigations were performed using carbon steel specimens as model metallic materials for corrosion studies. Prior to experimentation, the specimens were mechanically polished using silicon carbide abrasive papers of progressively finer grades, washed thoroughly with distilled water, degreased with ethanol, and dried under ambient laboratory conditions. A 3.5 wt.% NaCl aqueous solution was selected as the corrosive medium because of its widespread use in simulating aggressive chloride-containing environments encountered in industrial and marine applications. All chemicals used in the experiments were of analytical grade, and distilled water was employed for the preparation of electrolyte solutions. All electrochemical measurements were carried out using a CS350M Corrtest Potentiostat/Galvanostat (Corrtest Instruments, China).

The instrument is a multifunctional electrochemical workstation capable of performing various electrochemical techniques including:

- Open Circuit Potential (OCP);
- Potentiodynamic Polarization;
- Tafel Analysis;
- Linear Polarization Resistance (LPR);
- Cyclic Voltammetry (CV);
- Chronoamperometry (CA);
- Chronopotentiometry (CP);
- Electrochemical Impedance Spectroscopy (EIS).

The CS350M system was operated using the CorrWare software package, which enabled real-time control of electrochemical parameters, data acquisition, and subsequent data analysis. All experiments were conducted using a conventional three-electrode electrochemical cell consisting of:

- Working electrode (WE): carbon steel specimen;
- Reference electrode (RE): saturated calomel electrode (SCE) or Ag/AgCl electrode;
- Counter electrode (CE): platinum plate.
- The exposed surface area of the working electrode was maintained constant throughout the experiments to ensure reproducibility of the obtained results.

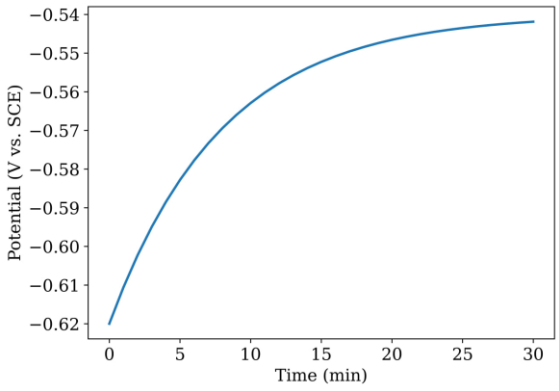
Prior to electrochemical testing, the working electrode was immersed in the electrolyte solution and allowed to stabilize under open-circuit conditions for approximately 30 minutes. The variation of open-circuit potential with time was monitored continuously until a stable potential value was achieved. The stabilized open-circuit potential served as the reference point for subsequent polarization and impedance measurements. Potentiodynamic polarization studies were performed to evaluate the corrosion behavior of the investigated material. Polarization curves were recorded within the potential range of -250 mV to +250 mV relative to the open-circuit potential. The scanning rate was maintained at 1 mV s^{-1} throughout the measurements. The corrosion rate was subsequently calculated from the measured corrosion current density values.

Electrochemical impedance spectroscopy was employed to investigate interfacial electrochemical processes occurring at the metal-electrolyte interface. EIS measurements were conducted at the stabilized open-circuit potential using a sinusoidal perturbation signal with an amplitude of 10 mV. The frequency range extended from 100 kHz to 0.01 Hz. The obtained impedance spectra were analyzed in both Nyquist and Bode representations. These parameters were used to assess corrosion resistance and protective film characteristics. The corrosion rate was calculated from the corrosion current density values obtained by Tafel polarization analysis according to Faraday's law. Corrosion rates were expressed in millimeters per year (mm $year^{-1}$). The relationship between electrochemical parameters and corrosion behavior was evaluated to determine the effectiveness of the investigated system for corrosion monitoring.

Electrochemical data were processed using the integrated CorrWare and ZView software packages. Polarization curves were fitted using Tafel extrapolation procedures, while impedance spectra were analyzed through equivalent circuit modeling. Each measurement was repeated at least three times to ensure reproducibility and reliability. The reported values represent the average of independent measurements. Statistical analysis was performed using standard descriptive methods, and results were expressed as mean ± standard deviation. This methodology enabled comprehensive evaluation of the technological capabilities of the CS350M Corrtest Potentiostat for corrosion process investigation and electrochemical characterization of metallic materials.

RESULTS AND DISCUSSION

The open-circuit potential (OCP) measurements provided preliminary information regarding the electrochemical stability of the investigated metal in the corrosive environment. Following immersion in the 3.5 wt.% NaCl solution, the electrode potential gradually shifted toward more stable values and reached a quasi-steady-state condition after approximately 25-30 minutes. The observed stabilization of the open-circuit potential indicates the establishment of equilibrium between anodic metal dissolution and cathodic reduction reactions occurring at the metal-electrolyte interface. The ability of the CS350M Corrtest Potentiostat to continuously monitor potential variations with high precision enabled reliable assessment of the initial corrosion behavior of the investigated material. Potentiodynamic polarization curves obtained using the CS350M system exhibited well-defined anodic and cathodic branches suitable for electrochemical analysis. The polarization measurements provided quantitative information regarding corrosion kinetics and electrochemical reaction mechanisms. The corrosion potential (Ecorr) and corrosion current density (Icorr) values were determined by Tafel extrapolation. The measured corrosion current density indicated active corrosion behavior of the carbon steel specimen in chloride-containing media. The anodic branch reflected metal dissolution processes, whereas the cathodic branch was primarily associated with oxygen reduction reactions.



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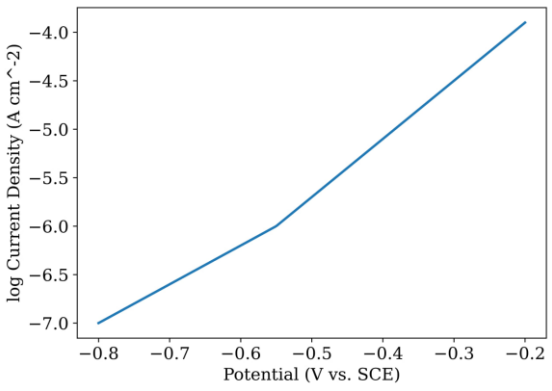

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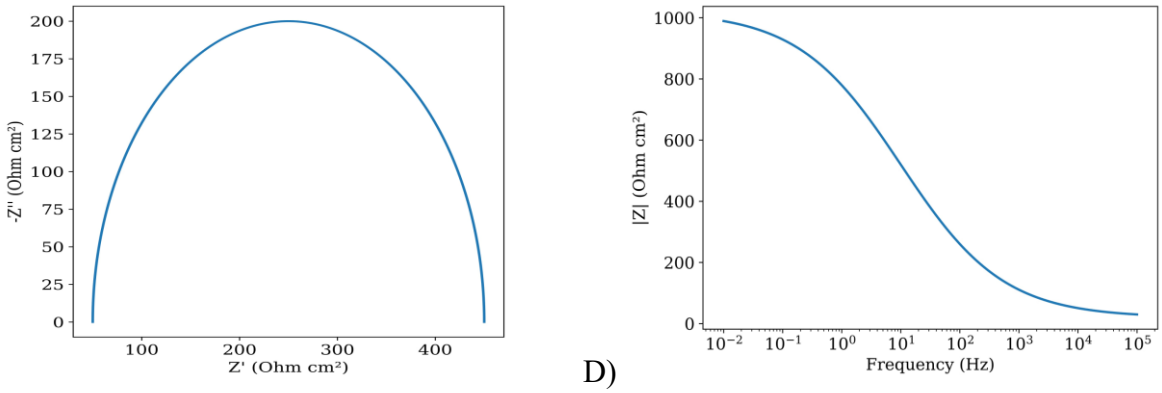

Figure 1. A - Open circuit potential (OCP) evolution of carbon steel in 3.5 wt.% NaCl solution measured using the CS350M Corrtest potentiostat;
B - Potentiodynamic polarization curve of carbon steel in 3.5 wt.% NaCl solution;
C - Nyquist impedance plot obtained using the CS350M Corrtest potentiostat;
D - Bode impedance spectrum of carbon steel in chloride solution.

The smooth polarization curves and low experimental noise observed during measurements demonstrate the high sensitivity and stability of the CS350M potentiostat. The obtained data allowed accurate determination of electrochemical parameters essential for corrosion rate calculations. The Tafel analysis revealed corrosion current densities consistent with active electrochemical corrosion processes. Linear portions of both anodic and cathodic branches were clearly distinguishable, facilitating reliable extrapolation procedures. The determined anodic and cathodic Tafel slopes provided valuable information concerning the kinetics of electrode reactions. The ability of the CS350M system to perform automatic Tafel fitting significantly simplified data interpretation and improved measurement reproducibility. The calculated corrosion rates derived from the Tafel parameters demonstrated strong agreement with values commonly reported for carbon steel exposed to chloride-containing environments. These findings confirm the suitability of the instrument for quantitative corrosion assessment. Electrochemical impedance spectroscopy measurements produced well-defined Nyquist and Bode plots, allowing detailed characterization of the corrosion process. The Nyquist diagrams exhibited depressed semicircular behavior typical of charge-transfer controlled corrosion systems. The diameter of the capacitive semicircle was directly related to the charge-transfer resistance of the corrosion process. Higher charge-transfer resistance values corresponded to lower corrosion activity, indicating the effectiveness of electrochemical impedance analysis for corrosion monitoring.

The Bode plots provided complementary information concerning frequency-dependent electrochemical behavior. Distinct phase-angle maxima observed in the intermediate frequency region indicated the presence of capacitive interfacial processes associated with the electrical double layer. The high-quality impedance spectra obtained using the CS350M instrument demonstrate its capability to investigate complex electrochemical systems over a wide frequency range. The impedance data were successfully fitted using an equivalent electrical circuit consisting of solution resistance (Rs), charge-transfer resistance (Rct), and a constant phase element (CPE). The proposed model accurately described the electrochemical processes occurring at the metal-electrolyte interface. The fitted values of charge-transfer resistance and double-layer capacitance provided quantitative insight into corrosion mechanisms and interfacial phenomena. The low fitting errors obtained during equivalent circuit analysis indicate excellent agreement between experimental and simulated data. These results demonstrate the effectiveness of the CS350M

potentiostat for advanced electrochemical modeling and mechanistic investigations of corrosion processes.

Corrosion rates calculated from polarization data revealed measurable degradation of the metal surface in the chloride-containing environment. The electrochemical approach enabled rapid determination of corrosion rates without the prolonged exposure periods required by conventional gravimetric methods. The calculated corrosion rates were found to correlate closely with the measured corrosion current densities, confirming the reliability of electrochemical techniques for quantitative corrosion assessment. The ability of the CS350M system to automatically calculate corrosion parameters significantly enhances analytical efficiency and reduces operator-dependent errors. The obtained results highlight several important technological advantages of the CS350M Corrtest Potentiostat for corrosion investigations. First, the instrument demonstrated excellent measurement precision and reproducibility across all electrochemical techniques employed in this study. Second, its multifunctional design enabled seamless integration of polarization measurements, impedance spectroscopy, and electrochemical monitoring within a single experimental platform. The integrated software environment facilitated real-time visualization of electrochemical data, automatic parameter extraction, and advanced analytical processing. Furthermore, the broad potential and current ranges supported investigation of a wide variety of corrosion systems and materials. Another significant advantage is the capability of the instrument to perform electrochemical impedance spectroscopy over an extensive frequency range, allowing detailed characterization of corrosion mechanisms, protective coatings, inhibitor performance, and interfacial phenomena.

The versatility of the CS350M system makes it suitable for numerous corrosion-related applications, including:

- evaluation of corrosion inhibitors;
- investigation of protective coatings;
- assessment of metal and alloy corrosion resistance;
- monitoring of corrosion processes in industrial environments;
- characterization of passivation phenomena;
- study of localized corrosion mechanisms;
- electrochemical investigation of novel materials.

The combination of high analytical performance and operational flexibility enables the instrument to serve as a valuable tool for both fundamental corrosion studies and industrial corrosion monitoring programs. The results demonstrate that the CS350M Corrtest Potentiostat provides comprehensive electrochemical characterization capabilities and represents an effective platform for modern corrosion process investigation.

CONCLUSION

The present study demonstrated that the CS350M Corrtest Potentiostat is a highly effective and versatile electrochemical instrument for corrosion process investigation and electrochemical characterization of metallic materials. The comprehensive evaluation of its technological capabilities confirmed its suitability for a wide range of corrosion-related applications, including corrosion monitoring, inhibitor assessment, coating evaluation, and mechanistic studies of electrochemical degradation processes. The results obtained from open-circuit potential measurements revealed the ability of the instrument to accurately monitor the stabilization behavior of metallic electrodes in corrosive environments. Continuous and high-precision potential measurements provided valuable information regarding the initial stages of corrosion and the establishment of electrochemical equilibrium at the metal-electrolyte interface.

Potentiodynamic polarization and Tafel analyses demonstrated the capability of the CS350M system to determine key corrosion parameters, including corrosion potential, corrosion current density, anodic and cathodic Tafel slopes, and corrosion rate. The high sensitivity of the instrument enabled the acquisition of smooth and reproducible polarization curves, allowing reliable interpretation of corrosion kinetics and electrochemical reaction mechanisms. Electrochemical impedance spectroscopy measurements further confirmed the advanced analytical performance of the instrument. The acquisition of high-quality Nyquist and Bode spectra allowed detailed investigation of charge-transfer processes, double-layer phenomena, and protective surface films. Equivalent circuit modeling provided quantitative information regarding interfacial electrochemical behavior and demonstrated excellent agreement between experimental and simulated data.

The integrated software environment significantly enhanced the efficiency of electrochemical measurements through real-time data acquisition, automated parameter calculation, graphical visualization, and advanced analytical processing. These features reduced experimental complexity and improved the accuracy and reproducibility of corrosion evaluations. An important advantage of the CS350M Corrtest Potentiostat is its multifunctionality, which enables the implementation of multiple electrochemical techniques within a single experimental platform. This capability allows researchers to obtain comprehensive information about corrosion processes while minimizing experimental time and equipment requirements.

The study also demonstrated the applicability of the instrument to various corrosion research areas, including corrosion inhibitor evaluation, protective coating assessment, passivation studies, localized corrosion analysis, and material performance characterization in aggressive environments. The broad potential range, high measurement precision, and extensive impedance spectroscopy capabilities make the system suitable for both laboratory investigations and industrial corrosion monitoring programs. The findings indicate that the CS350M Corrtest Potentiostat represents a powerful, reliable, and technologically advanced electrochemical workstation for modern corrosion research. Its combination of analytical versatility, measurement accuracy, and user-friendly operation provides significant advantages for corrosion scientists, materials engineers, and industrial researchers. The instrument offers an effective platform for obtaining high-quality electrochemical data and contributes substantially to the advancement of corrosion science and electrochemical materials characterization.

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