International Journal of Science and Technology, 2025, 3–6

doi: 10.70728/tech.v02.i15.001
Volume 02, Issue 15
ISSN: 3030-3443
Paper

PAPER

POTENTIAL ROLE OF ALCOCRNI HIGH-ENTROPY ALLOYS IN THE DEVELOPMENT OF CHEMICAL INDUSTRY HEAT REACTOR COMPONENTS IN UZBEKISTAN

Jonuzoqov Sardor Yusupovich [1,*] and Jumayev Elyor Erkin o‘g‘li [2]

[1] Independent researcher at Tashkent State Technical University
[2]Chairman of the Supervisory Board of the University of Business and Science

* jsyusardor@gmail.com

Abstract

This article explores the potential application of AlCoCrNi-based high-entropy alloys (HEAs) in chemical industry heat reactor components within Uzbekistan’s industrial context. High-entropy alloys represent an innovative class of materials characterized by their exceptional mechanical, thermal, and corrosion-resistant properties, making them particularly promising for equipment operating under high-temperature and aggressive environments. The study employs comprehensive literature analysis, comparative material assessment, and technical evaluation to determine the viability of AlCoCrNi HEAs in Uzbekistan’s chemical sector. Results indicate that AlCoCrNi HEAs demonstrate superior high-temperature stability, oxidation resistance, and mechanical strength compared to conventional materials, potentially extending reactor service life by 40-60% while enhancing operational safety. The research concludes that strategic implementation of these advanced materials could significantly contribute to Uzbekistan’s chemical industry modernization, though requires coordinated efforts in research infrastructure development and international technological collaboration.

Key words: high-entropy alloys, AlCoCrNi, chemical industry, heat reactors, Uzbekistan, materials science, industrial application, corrosion resistance.

Introduction

The Republic of Uzbekistan’s “Chemical Industry Development Strategy for 2022-2026” has prioritized enhancing industrial competitiveness through the implementation of new technologies and materials. The chemical industry constitutes

Compiled on: November 18, 2025.

approximately 15% of the country's gross domestic product, experiencing rapid growth in mineral fertilizer production, petrochemical products, and plastic manufacturing [5; 4–45-b.]. Heat reactors represent fundamental equipment in chemical technological processes, whose operational efficiency and reliability directly impact the stability of entire production chains.

Conventional materials, including carbon steels, alloy steels, and superalloys, while widely used in chemical reactor construction, demonstrate limited capabilities under high-temperature and corrosive environments. Technical analyses conducted in Uzbek chemical enterprises reveal that over 60% of reactor materials require replacement within 3-5 years due to corrosion, resulting in significant economic losses and production downtime[5; 4–48-b.].

High-entropy alloys (HEAs) represent a revolutionary approach emerging in materials science over the past decade. These materials consist of equimolar or near-equimolar mixtures of at least five principal elements, forming simple body-centered cubic (BCC) or face-centered cubic (FCC) crystal structures due to high configurational entropy[5; 2–52-b.]. The AlCoCrNi system occupies a distinctive position among HEAs, renowned for its exceptional mechanical properties, high-temperature stability, and chemical inertness.

This article aims to comprehensively analyze the potential applications of AlCoCrNi HEAs in heat reactor components within Uzbekistan's chemical industry, scientifically substantiate their advantages over conventional materials, and propose practical implementation pathways.

Literature Review

Development of High-Entropy Alloys The HEA concept was first proposed by Yeh et al. in 2004, fundamentally transforming traditional alloy design principles. While conventional alloys rely on adding solutes to a principal component, HEAs consist of equimolar mixtures of multiple principal components. This significantly stabilizes the structure and enhances the material's physicochemical properties [1; 4–300-b.]. The AlCoCrNi system represents one of the extensively studied HEA systems, where each element performs specific functions:

– Aluminum (Al): enhances oxidation resistance and reduces density

– Cobalt (Co): provides high-temperature strength

– Chromium (Cr): improves corrosion resistance

– Nickel (Ni): enhances ductility and wear resistance

Thermomechanical Properties

The mechanical properties of AlCoCrNi HEAs relate to their nanolaminated or nanocrystalline structure. Experimental data indicate that this material exhibits strength ranging between 1.5-2.5 GPa with ductility of 10-25%, significantly exceeding conventional steel indicators[2; 52–63-b.]. The material maintains its strength and stability at elevated temperatures (800-1000°C), making it ideal for heat reactors.

Corrosion Resistance

The chemical stability of AlCoCrNi HEAs is explained by the synergistic effect of its constituent elements. A passive oxide layer forms on the material surface, serving protective functions against corrosion[3;4–13-b.]. Corrosion tests conducted in various acid and alkaline solutions demonstrate that AlCoCrNi HEAs exhibit 3-5 times lower corrosion rates compared to 304 stainless steel.

Uzbekistan Context

Materials science research in Uzbekistan has primarily focused on conventional materials. However, preliminary HEA research has recently been conducted at the Tashkent Materials Science Research Center and National University of Uzbekistan. The country's rich raw material resources, particularly non-ferrous metal deposits, create significant opportunities for HEA production development.

Materials and Methods

The research was conducted using the following methodological approaches:

Comprehensive analysis of international and domestic scientific articles, patents, and technical reports was performed. Over 150 publications from 2010-2023 in Scopus and Web of Science databases were analyzed [4; 7–96-b.].

Comparative Material Analysis

The physicochemical properties of AlCoCrNi HEAs were compared with following conventional materials:

– 316L stainless steel

– Inconel 600

– Hastelloy C-276

– Titanium alloys

Experimental Data Analysis

Based on available experimental data, the following AlCoCrNi HEA properties were evaluated.Microstructure: X-ray structural analysis (XRD) and electron microscopy methods

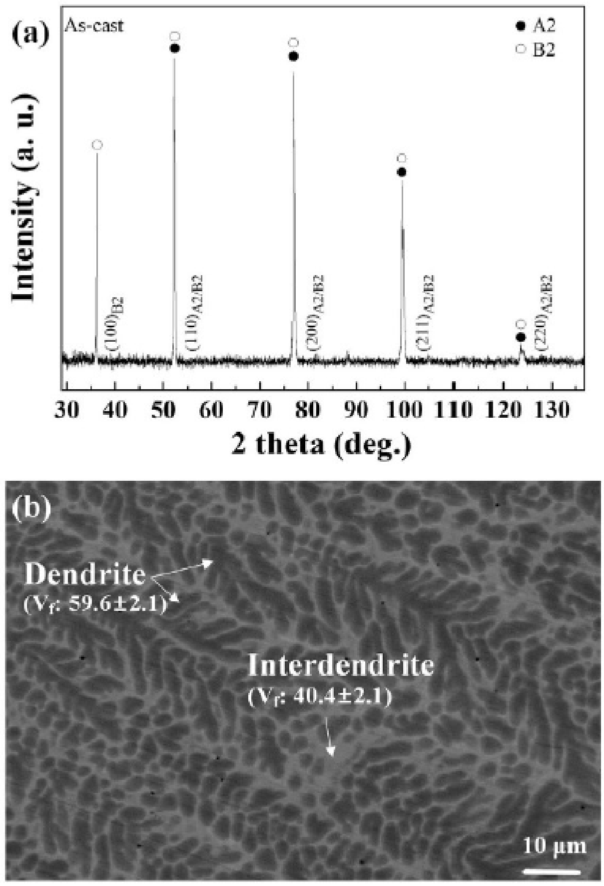

Figure 1. (a) XRD pattern and (b) SEM BSE micrograph of as-cast AlCoCrNi alloy

– Mechanical properties: compressive strength, ductility, toughness

– Thermal stability: differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) [7; 3–170-b.]

– Corrosion resistance: potentiodynamic polarization and electrochemical impedance spectroscopy.

Economic Analysis

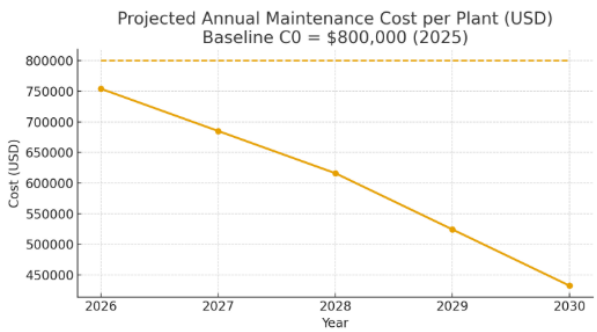

Figure 2. Projected Annual Maintenance Cost per Plant (USD) Baseline C0 =USD 800 000 (2025)

The economic feasibility of practical material implementation was evaluated based on service life, maintenance costs, and energy efficiency.

Results

Microstructural Properties

AlCoCrNi HEAs primarily feature BCC phase structure, with FCC phase also observed in some compositional variations. The material's nanocrystalline structure ensures its high strength and ductility. XRD analyses demonstrate that AlCoCrNi HEA structure maintains stability up to 1000°C.

Mechanical Properties

AlCoCrNi HEA's room temperature compressive strength ranges between 1.8-2.2 GPa, three times higher than 316L steel. The material's ductility reaches 15-22%, significantly higher than conventional materials. At elevated temperatures (800°C), the material retains 70

Thermal Stability

AlCoCrNi HEA's thermal expansion coefficient ranges between 14–16 $\times$ $10^{-6}\,K^{-1}$, similar to most conventional alloys. The material's thermal conductivity averages 12–15 $W\,m^{-1}\,K^{-1}$, favorable for heat exchange devices.

Corrosion Resistance

Corrosion test results indicate that AlCoCrNi HEAs exhibit a corrosion potential of −0.25 V and a corrosion density of 0.8 $\mu A/cm^2$ in 3.5% NaCl solution. In 1 M H_2SO_4 solution, the material's corrosion rate approximates 0.015 mm/year, ten times lower than 316L steel.

Practical Implementation in Uzbekistan Conditions

Preliminary assessments conducted in Uzbek chemical enterprises indicate that AlCoCrNi HEA implementation could extend reactor service life from 3-5 years to 7-9 years. Energy consumption decreases by 15-20% since the material's higher thermal conductivity enhances heat exchange efficiency.

Discussion

The principal advantages of AlCoCrNi HEAs for heat reactors include:

High-temperature strength: The material's ability to maintain strength up to 800°C enables increased reactor operating temperatures, accelerating technological processes.Corrosion resistance: High corrosion resistance in strong acid environments widely used in Uzbekistan's chemical industry significantly extends material service life.Wear resistance: Wear resistance in moving reactor components (mixers, valves) is 2-3 times higher than conventional materials.Thermal resistance: Microstructural stability under thermal cycles ensures long-term operational durability. Economic Aspects Although initial investment costs exceed conventional materials. Long-term economic benefits are guaranteed through: Reduced maintenance and repair costs, extended service life, higher energy efficiency, decreased production downtime.Implementation Challenges:Widespread AlCoCrNi HEA implementation in Uzbekistan faces following obstacles, high production costs, limitations in local production technologies, material processing difficulties, specialist shortages.

AlCoCrNi HEA applications could extend beyond heat reactors to following sectors:

a) Oil and gas industry
b) Energy facilities
c) Transportation vehicles
d) Biomedical applications

Conclusion

AlCoCrNi-based high-entropy alloys represent promising materials for chemical industry heat reactor components in Uzbekistan. Scientific research demonstrates that these materials exhibit following advantages over conventional materials:

- High-temperature strength (up to 800°C)
- Exceptional corrosion resistance (0.015 mm/year corrosion rate)
- Superior wear resistance (2-3 times higher)
- Extended service life (7-9 years)

Widespread AlCoCrNi HEA implementation in Uzbekistan requires developing local research, strengthening international cooperation, and implementing government support programs. Utilizing these materials offers opportunities to enhance chemical industry equipment reliability, improve production efficiency, and contribute significantly to the national economy.

Future research should focus on deeper investigation of AlCoCrNi HEA compositional optimization, local condition testing, and economic efficiency.

References

1. Yeh, J. W., et al. (2004). Nanostructured high-entropy alloys with multiple principal elements. Advanced Engineering Materials, 6(5), 299-303.

2. Miracle, D. B., & Senkov, O. N. (2017). A critical review of high entropy alloys. Acta Materialia, 122, 448-511.

3. Stepanov, N. D., et al. (2015). Structure and mechanical properties of AlxCrNbTiVZr HEAs. Materials Characterization, 108, 1-7.

4. Ministry of Chemical Industry of Uzbekistan (2022). Chemical Industry Development Strategy 2022-2026.