کد سند: RO-S-F-28-02	معاونت پژوهشی	پژوهشگاه نیرو
تاریخ صدور: ۱۳۹۹/۴/۲۲		
تاریخ ویرایش: ۱۳۹۹/۵/۱۵	فرم خلاصه انگلیسی طرح/پروژه	

Project Title: Development of an age-hardening cobalt base alloys with CoAl precipitates

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Project Financial Code:	380115	***Project Quality Code:***	PDRPN03
Type of Project/Program:	Research project	***Assistant:***	-

Project Staff:

Keywords:

Cobalt base alloys, High entropy alloys, Microstructure, Mechanical properties, Tensile test, Compression test, Hardness test, Heat treatment, Precipitation

Project Necessity:

- Finding the optimized age hardening treatment
- Understanding the age hardening mechanisms and the phases which form during the treatment

Project Goals:

Developing an age-hardening Co-base alloy based on the system Al-Co-Cr-Fe-Ni

Abstract: (Font: Times New Roman 12)

Co-base superalloys are one the most important high temperature materials for making gas turbine components are The main strengthening mechanisms in Co-base superalloys are solid solution and secondary phase (carbides) hardening mechanisms. The first Co-base alloy strengthened by precipitation hardening mechanism was reported in 2006 by Sato et al [1]. The reported alloy was developed based on the Co-Al-W system, and the precipitates which leaded to the increase in strength were Co_3(Al,W) particles which had formed during the aging treatment. Results reported by Sato has led to the development and discovery of other age hardening Co-base alloys, and the research in this field are still in progress.

Recently we have found a Co-rich age hardening alloy based on the system Al-Co-Cr-Fe-Ni. The precipitates which form in our alloy are CoAl particles with a BCC phase structure and are different with Co_3(Al,W) particles with a FCC phase structure. Because the thermal stability of CoAl phase is higher in comparison with Co_3(Al,W) phase, therefore

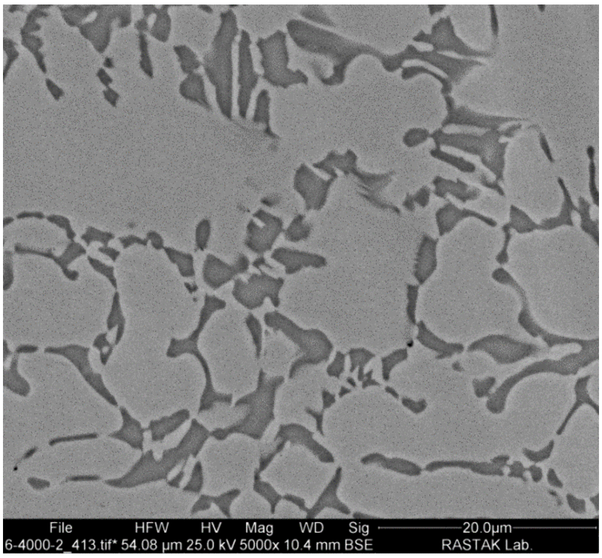
better high temperature strength is expected for the alloy developed in our group. Further research should be performed to optimize the heat treatment process for this alloy. Moreover, research should be performed to comprehensively understand the aging process of this alloy. Therefore, this proposal is prepared to reach these goals.

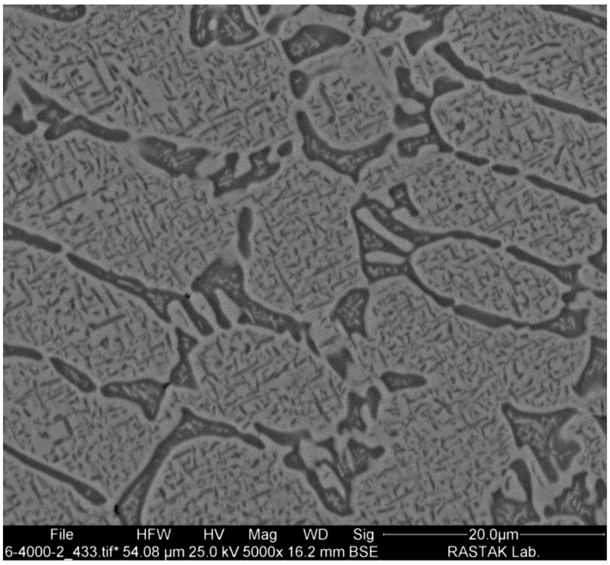
Steps and Methodologies: (Font: Times New Roman 12)

Alloy ingots were prepared via arc melting the high purity constituent elements (Ni(99.9%), Co(99.99%), Al(99.999%), Fe (99.9%) and Cr (99.9%)) under a Ti-gettered high purity argon atmosphere. The prepared ingots were remelted four times to achieve compositional homogeneity. By using a water-cooled copper mold, the homogenized ingots were suction casted into 4 cm long and 8 mm diameter rods. The chemical compositions of the prepared alloys were examined by EDAS technique to investigate if the prepared alloys have the same composition as designed alloys. The structures of the alloys were identified by X-ray diffraction at voltage of 30 kV, current of 50 mA and the scanning speed of 2/min. For microstructural investigations each sample was sectioned perpendicular to its length. The sectioned surfaces were then ground and polished for the metallography and microstructural analysis. The microstructural analyses were performed using both optical microscopy (OM) and scanning electron microscopy (SEM). For evaluating the mechanical properties of the alloy, hardness and compression tests were used. For performing the compression tests, two cylindrical samples with 1 cm height and 5 mm diameter were prepared, and tests were performed according to the standard ASTM E9.

Main Results (technical outputs, patents, papers, books, reports, etc.):

A cobalt-rich high entropy alloy with composition Al13Co41Cr15Fe10Ni18 is designed and made in the system Al-Co-Cr-Fe-Ni. The microstructure of the alloy consists of dendritic and interdendritic regions. XRD results show that the alloy consists of BCC and FCC phases. Heat treatment were performed on alloys and it was observed that after heat treatment CoAl precipitates form in the alloy. Different heat treatments were performed on the alloy. Hardness test were performed on alloys after heat treatments and optimized heat treatment was selected. The compression mechanical properties of the alloy were investigated and excellent combination of strength and ductility was observed. Effect of Al concentration on the microstructure and mechanical properties of the alloy is investigated. It is observed that with increasing the Al content, the compression yield stress of the alloy increases however the ductility decreases. Room temperature tensile test were performed on alloys and the mechanical properties of alloy was investigated. The mechanical properties of alloy was compared to the mechanical properties of some commercial Co-base alloys.





Comparison between the microstructure of alloy before and after heat treatment