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Understanding changes leading to deterioration of Ni- and Co-base heat resistant cast alloys during service in temperatures between 1000-1300°C and the ND method of its early detection

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A variety of manufacturing, aerospace, and energy industries depend on reliable heat and creep resistant materials able to perform well for a longer time in increasingly demanding conditions such as temperatures much above 1000°C, load, mechanical, or thermal shock, and oxidation. A number of new generation alloys and superalloys designated for service in such extreme environments have recently been developed. Though these alloys offer certain improvements in oxidation resistance, high temperature mechanical properties, and longer creep life, they are still structurally unstable in high temperatures especially those above ~1000°C. It is only a matter of time to when they decay to the point they cannot hold the service condition any longer and fail.

The behavior of alloys during long exposure to extreme conditions is complex, and cannot be accurately predicted on the basis of laboratory experiments and/or metallurgical models alone, without verification of its significance through service experience and actual service part evaluation. Therefore, an extensive metallurgical study of manufacturing components made of Fe-, Ni-, and Co-base heat resistant cast alloys has been performed in past years. The structural changes after long exposure to service temperature above 1000°C, heavy load, vibration, and thermal stress have been carefully observed. The key structural changes contributing to alloy decay are: dissolution of one type of carbides and precipitation of the other, carbide coalescence and growth, dendrite re-crystallization, grain growth, and oxidation on grain boundaries that become depleted in Cr, weaker, and splintered. These changes are known to promote creep and cracking that significantly affect the alloy lifespan. However, another, not fully recognized aspect associated with the structural changes of heat resistant alloys during extreme service condition is the appearance of a weak magnetism that tends to increase as the alloy deteriorates.

The subject alloys are austenitic and theoretically 100% paramagnetic (do not attract magnets). Prolonged exposure to heat triggers a gradual transformation of the alloy from paramagnetic to ferromagnetic (eventually the alloy starts attracting magnets). The origination of the magnetism in the paramagnetic alloys was investigated and explained. The magnetism was measured in some of these alloys using a unique proprietary probe capable of detecting even extremely weak magnetism in early stages of alloy deterioration, when no obvious structural changes of the alloy can be seen. It was also found that the ferromagnetism of the alloys is proportional to the level of alloy deterioration. Testing the level of magnetism in the austenitic heat resistant alloys could potentially be an excellent tool for the evaluation of the current alloy condition and remaining life.

Biography

Zofia Niemczura has a PhD and attained her DSc in Physical Metallurgy from Academy of Mining and Metallurgy (AGH) in Krakow, Pl., 1994. She completed her PhD and MD in Metallurgy and Materials Science from School of Materials Engineering, Technical University of Poznan, Pl., where she worked as an Associate Professor. Next, she was Researcher and Visiting Lecturer at University of IL. in Chicago and then accepted the Staff Engineer position in Arcelor Mittal LLC Global R&D, Chicago. Her main research focus in recent years was heat resistant alloys deterioration mechanism and prevention, tool steel, alloy selection and evaluation, failure analysis of manufacturing equipment, and defects in steel sheets. She was granted two USA patents (one is pending), and is the recipient of several recognitions during her carrier in Poland and in USA. She has 33 publications, two books and the student textbook on Mechanical Metallurgy.

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