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PLASTIC FLOW INSTABILITY IN AUSTENITIC STAINLESS STEELS AT A WIDE RANGE OF TEMPERATURES: FROM MACROSCOPIC TESTS TO MICROSTRUCTURAL ANALYSIS

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Austenitic stainless steels (ASS) of AISI 304 (EN X5CrNi18-10), AISI 316L (EN X2CrNiMo17-12-2), AISI 316LN (EN X2CrNiMoN17-11-2) grades characterized by excellent mechanical properties and corrosion resistance in a wide temperature range (4 K - 900 K). Thus, they find numerous applications in the automotive, aviation, nuclear and chemical industries as well as in space and superconducting technology where temperature changes from room temperature, even to absolute zero. The collars of dipole magnets in LHC, the steel expansion joints or the jacket of the Cable-In-Conduit Conductors (CICC) in ITER are good examples of austenitic stainless steel applications. The correct design of structural elements and instrumentation that operate without breakdown throughout the service time requires an understanding of the deformation and fracture mechanisms inherent in a wide range of temperatures, from near 0 K to room temperature. The lack of in-depth recognition of these processes has become a critical problem for large research infrastructures such as LHC or ITER. The plastic behaviour of metastable austenitic stainless steels is controlled by temperature. It is seen when comparing the stress-strain curves of ASS for a tensile test at 4 K, 77 K and at room temperatures. During tensile tests of austenitic stainless steels at cryogenic temperatures (4 K), unusual behaviour is observed – plastic flow instability. This effect also called a discontinuous plastic flow, is reflected by stress oscillations on the stress-strain curve. Moreover, the Lüders-type effect is observed. At room temperature, in turn, for a 304 specimen with a long enough gauge length and below critical strain rate, the plastic front propagation occurs. Therefore, the different modes of plastic flow instability in austenitic stainless steels are observed depending on the temperature. When temperature approaches absolute zero the tendency of metastable ASS to diffusion-free phase transformation during plastic deformation increases. It is experimentally proven that in ASS at cryogenic temperatures, the deformation-induced phase transformation is coupled with discontinuous plastic flow. The work aims to investigate the plastic flow and hardening processes of metastable 304 and 316L steels in the context of 316LN, stable due to diffusion-free martensitic transformation. The basis is in-situ tensile tests at room temperature, registered using the DIC and EBSD methods. In this way, the development of deformation fields and the accompanying evolution of the microstructure are identified. The coupling of the observations carried out on two levels allows us to explain the differences in the mechanical and microstructural response of the considered steel grades.

DIC-enhanced experimental platform with a multi-detector array for materials testing at cryogenic temperatures
The first time the 3d full-field strain evolution was captured during a tensile test at liquid nitrogen (77K). The DIC-enhanced experimental platform with a multi-detector array is used during tensile tests of advanced materials at temperature near to 0K. The unique research tool is equipped with: (i) thermistors system to measure temperature distribution, (ii) a force link to measure applied force, and (iii) the acoustic emission system. The tested specimen will be immersed in a glass cryostat with an active and passive insulation system to maintain thermal stability during tests at 4K. The signals from multi-detector system will be simultaneously recorded together with strain field evolution background. Based on the experimental results the deformation behaviour of austenitic stainless at cryogenic temperatures can be identified. Moreover, the constitutive models of advanced materials near to 0K will be validated.

Submitters Country

Poland

Primary author: Dr TABIN, Jakub (Institute of Fundamental Technological Research, Polish Academy of Sciences, 02-106 Warsaw, Poland)

Co-authors: BRODECKI, Adam (Institute of Fundamental Technological Research, Polish Academy of Sciences, 02-106 Warsaw, Poland); Dr KAWAŁKO, Jakub (AGH University of Krakow, Academic Centre for Materials and

Nanotechnology, 30-059 Krakow, Poland); Prof. NALEPKA, Kinga (AGH University of Krakow, Faculty of Mechanical Engineering and Robotics 30-059 Krakow, Poland); Prof. BAŁA, Piotr (AGH University of Krakow, Academic Centre for Materials and Nanotechnology, 30-059 Krakow, Poland); Prof. KOWALEWSKI, Zbigniew (Institute of Fundamental Technological Research PAS)

Presenter: Dr TABIN, Jakub (Institute of Fundamental Technological Research, Polish Academy of Sciences, 02-106 Warsaw, Poland)

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