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Can Stainless Steel Meet the Challenges of Future Cryogenic Engineering Systems?

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As the demands on cryogenic engineering systems continue to evolve with advancements in high-energy physics, novel fusion devices, and the expanding hydrogen economy, the question arises: can stainless steel rise to the challenge? Relying in superconducting magnet technology, the magnetic fields required for a variety of very ambitious engineering projects are increasingly high: 16 T for FCC –hh (the hadronic version of the Future Circular Collider), 12 T for EU DEMO (the European fusion device that will succeed ITER) and 23 T for ARC (the Affordable, Robust and Compact fusion device of the Massachusetts Institute of Technology). However, this increase in magnetic field is not accompanied by an increase in the size of the cryogenic engineering systems, thus the need for high-strength structural materials becomes increasingly apparent.
The physical and mechanical properties of high-strength austenitic stainless steels and their importance for the structural integrity of cryogenic engineering systems are discussed. A state –of –the art 316LN will be compared with a very high strength grade: FXM-19. Challenges faced in the processing of the material and how they are translated to the cryogenic mechanical properties are also discussed.
Additionally, results issued from cryogenic tests on an unconventional high - manganese high - nitrogen grade (P506) are presented, showing how promising the properties of this grade at cryogenic temperature are.
This work highlights the crucial role of high-strength austenitic stainless steels in ensuring the safe and reliable operation of cryogenic engineering systems. Furthermore, it emphasizes the critical need for the development of these materials to advance fusion energy technology, high-energy physics, and high-temperature superconductors.

Submitters Country

Switzerland

Author: AVILES SANTILLANA, Ignacio (CERN)

Co-authors: RUIZ PALENZUELA, Berta (Universidad de Oviedo (ES)); RODRIGUEZ CASTRO, Enrique (University Carlos III (ES)); Dr SGOBBA, Stefano (CERN)

Presenter: AVILES SANTILLANA, Ignacio (CERN)

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