Impact Objectives

- Develop very fine bainitic-austenitic steels cost-effectively from leaner medium carbon alloys via thermomechanical ausforming using shorter processing times
- Produce trial products, test using laboratory rolled materials, and precisely stipulate recommendations for full-scale production parameters

Harder, better, faster, stronger

Drs Carlos Garcia-Mateo, Lieven Bracke, Mahesh Somani, Andreas Latz and Professors David A. Porter and Francisca G. Caballero discuss their project, which aims to develop new and efficient ways to manufacture steel products that last longer under higher stress conditions

Clockwise from top left: Dr Carlos Garcia-Mateo, Dr Lieven Bracke, Dr Mahesh Somani, Dr Andreas Latz, Professor David A. Porter and Professor Francisca G. Caballero

To begin, what are the overarching aims of the TIANOBAIN project?

CGM: Excellent combinations of strength and toughness can be obtained from high-carbon nanobainite, but this requires high levels of alloying and long heat treatments. This project will develop very fine bainitic-austenitic steels more cost effectively from leaner, medium carbon alloys using shorter processing times via thermomechanical ausforming. Tensile strengths above 1,600 MPa are the benchmark to make hot rolled steels with enhanced wear resistance combined with good toughness.

MS: The constant demand for steels that provide excellent combinations of properties in respect of ultra-high strength, good toughness and excellent wear-resistance using cheaper alloying and more environment-friendly production routes, necessitates further investigation into the viability of obtaining nanostructured bainite from steels grades with lower carbon contents than previously developed. Previously, the main focus for ausforming was in the non-recrystallisation temperature regime, but the primary aim of this investigation will be to introduce deformation in austenite close to the intended low temperature bainite transformation temperature.

What will the impact of this work be? Who will benefit from the research?

LB: If the objective can be reached, this would give access to a new class of ultra-high strength materials, which are expected to be excellent in terms of toughness and will extend the lifetime of steel components subject to extreme abrasion. Such a product range would be beneficial for at least three industries. First, the steel producers, who will be able to put an advanced, high value added product into the market. Second, equipment producers (for example, in the mining industry), will be able to produce better equipment, also with a high added value. Thirdly, the end users of this equipment, as they will be able to use their equipment for a longer time and in more extreme conditions. Also, from an ecological point of view, the longer lifetime without loss of performance will reduce the cradle-to-cradle carbon foot print of the components produced from nanobainitic steel.

MS: The quest for new super high strength steels (SHSS) stems from the need to simultaneously obtain the increased performance offered by weight reduction, optimal safety, reduced manufacturing costs and reduced environmental impact. There have been different steel design concepts and innovative processes involved in the design of the new generation of SHSS with improved strength and ductility properties. The novelty of this project lies in the fact that the concept of nanostructured bainite will be transferred to steels bearing much lower carbon contents by transformation of low temperature deformed austenite into bainite. A strong austenite possessing a high dislocation density and a large driving force will result in finer plates of nanostructured bainite. The project will help introduce medium carbon steels and the necessary thermomechanical procedures to obtain nanostructured bainite. It is conceivable that this medium carbon nanobainitic steels will be of interest to all applications where economical high-performance steels are required. To begin with, it is envisaged that the developed microstructures will be applied in engineering applications in the transport industry and wear-resistant purposes, for example in the mining industry.

The consortium involves two major steel producers: thyssenkrupp and OCAS (ArcelorMittal). Can you talk about their role and why their participation is important to the success of TIANOBAIN?

AL: Within the framework of a Research Fund for Coal and Steel (RFCS) project, it is possible to divide the multitude of tests and investigations among several partners. With two strong partners from industry, the work load of each partner is kept on a reasonable level. Due to the involvement of the industrial partners from the beginning and their interest in developing industrially feasible steels, we are optimistic that the project results will find their way into industrial application.

LB: The industrial partners have two main roles to play in addition to the agreed work as defined in the project's work plan. The first is to make sure that the products being developed have properties of commercial interest for steel producers and their customers. Second, the industrial feasibility from a processing point of view has to be ensured.

Are there any challenges you have had to overcome through this work so far? If so, how was this achieved?

AL: Even with state-of-the-art laboratory equipment, measuring the transformation kinetics of the investigated steels is a huge challenge. Due to the combination of a needed high-accuracy dilatation measurement and high material strengths, especially at low deformation temperatures, we are working at the limit of modern laboratory equipment. Thus, special care needs to be taken when choosing the final specimen geometry and process parameters.

Can you talk a little about the trial products and recommendations for full-scale production parameters you are planning to develop?

AL: Since the investigated steels show promise for both heavy plate as well as fine strip production, we plan to investigate two different final product thicknesses for the addressed products. Despite finding a promising alloying concept, our focus lies on the production parameters, starting from the final rolling passes up to the final coil/plate temperature.

Ultimately, how do you see the results will be transferred to ensure real world application?

DP: The steel producers involved will lead the way in applying the results. The results are also being made available to a wider audience within the steel producing community through our publications and the final report.

LB: The expectation is that the materials will exhibit a unique combination of properties in terms of wear resistance, toughness and ductility, which should make them a suitable candidate to extend the lifetime of highly solicited components. As such, the results generated can be expected not only to have an economic impact, but also an ecological one.

What is the timescale of the project and what has been achieved to date?

CGM: After one year, we are on track with the proposed plan, meaning that first work package has been completed and we are keenly involved in the second work package. Specifically, we have finished designing the alloys and producing them as 30 kg casts; evaluating cleanliness and homogenisation problems; assessing hot strength of austenite and non-recrystallisation temperatures; and determining continuous cooling transformation (CCT) and isothermal time-temperature-transformation (TTT) diagrams. These last points are critical for the determination of some critical process parameters needed for the development of fine bainite via ausforming route.

How are you planning to communicate and disseminate the results of the project?

CGM: In general terms, it is the job of the consortium to publish and present the most relevant outcomes of the project in high impact factor journals and related conferences. So far, we have published a review paper on the subject titled 'Transferring Nanoscale Bainite Concept to Lower C Contents: A Perspective' in the journal Metals, and the work has been presented at EUROMAT 2017, the European Congress and Exhibition on Advanced Materials and Processes. An abstract has been also approved as an invited oral presentation at Thermec 2018, an international conference on processing and manufacturing of advanced materials.

Meeting demand for strong, efficient steel alloys

*For the **TIANOBAIN** team, success means developing new manufacturing process and steel alloys that last longer and perform better, with the potential to benefit the entire steel industry and society as a whole*

Industries dependent on steel are beginning to demand products designed for niche applications. These applications often require products and machinery that can resist extreme situations of wear and abrasion. High-carbon nanobainite is one product that meets these requirements. However, it is expensive to make, requiring high levels of alloying and extreme temperature treatments during the manufacturing process.

In order to more efficiently design products with the same qualities of strength and toughness, the TIANOBAIN team is turning to the process of ausforming. This method involves austenite deformation below the recrystallization temperature and before the bainitic transformation. The project's aim is to create novel, superior steel product compositions and the processes required to manufacture them.

COLLABORATION IS ESSENTIAL

TIANOBAIN is a collaborative project between the University of Oulu in Finland, the National Centre for Metallurgical Research (CENIM-CSIC) in Spain, and steel industry partners thyssenkrupp Steel Europe AG and OCAS (ArcelorMittal). Together, the team has the research background, industry knowledge and equipment necessary to develop, test and manufacture innovative steel products. The complexity and time-consuming nature of this project necessitates a strong collaboration, as no single partner could achieve these goals alone. In addition, having such high-profile industry partners not only ensures that the research results are considered with immediate commercial applications in mind, but also highlights the needs and interests of industry in finding new solutions.

UNLIMITED POSSIBILITIES

The material processing methods being developed here are so novel that even project members have difficulty defining the precise number of applications these materials could serve. However, it is likely that the project will benefit the entire steel making industry by producing steel that meets economical high-performance standards. 'Although the effects of prior austenite state are considered in different European projects, none of them explored the ausforming route to produce nanostructured bainite,' explains Dr Carlos Garcia-Mateo of CENIM-CSIC. These longer-lasting, higher-durability steels will mean products and equipment built from steel will perform better and last longer.

According to Dr Andreas Latz of thyssenkrupp, early results are promising. 'We have investigated the transformation kinetics of promising steel alloys for the different ausforming processes and can now begin to choose the most promising alloys and process parameters for the first pilot plant simulations,' he reveals. Of course, these early successes have not been easy to achieve, as measuring the transformation kinetics of such innovative steels is a huge challenge that is capable of pushing even the most cutting-edge laboratory technology to its limits.

MULTIPLE BENEFITS TO SOCIETY

As the world's industries aim to reduce emissions, the environmental benefits of extending the life of manufactured products are being increasingly recognised. Reducing the overall amount of steel that needs to be produced by extending the lifetime strength and durability of products is a key way in which the steel industry can contribute to climate change efforts. This will also have economic benefits for all downstream industries who manufacture, purchase and use steel-based equipment. Society can benefit too, from longer lasting infrastructure projects that require less repair and save economic and environmental resources. As the project team moves forward, they are focused on implementing the results they produce into commercial applications as soon as possible and share their new knowledge and techniques with industry and academic colleagues.

Project Insights

FUNDING
Research Fund for Coal and Steel (EU-RFCS 709607)

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• University of Oulu • National Centre for Metallurgical Research (CENIM-CSIC) • thyssenkrupp Steel Europe AG • OnderzoeksCentrum voor de Aanwending van Staal (ArcelorMittal)

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