BRAGECRIM Newsletter

4th Edition: December 2018

BRAGECRIM - Smart Connected Manufacturing

Dear reader,

we welcome you to the 4th edition of the BRAGECRIM newsletter. In the following pages you will find updates about recent activities within the different BRAGECRIM projects with content ranging from current research results, kick-off and final meetings over contributions to conferences to publications.

We hope that you will enjoy reading this newsletter edition!

Best regards,

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Handover of BRAGECRIM coordination

Sarah Ekanayake leaves Bragecrim project and hands over to Dominik Wolfschläger

Dear colleagues and BRAGECRIM partners,

My employment at the WZL in Aachen is almost over. At this point I want to thank all of you for the great research exchange, the inside view into the Brazilian culture and the wonderful time. I always enjoyed the work within the BRAGECRIM initiative and I hope to see you again soon.

The coordination tasks will be handed over to my dear colleague Dominik Wolfschläger.

Dominik Wolfschläger started his employment as research associate at WZL in November. He studied physics at RWTH Aachen University and is interested in data processing and analysis. As exchange student, he lived in Pouso Redondo, Santa Catarina, Brazil for one year in 2010/2011. Therefore, he possesses a profound personal connection to Brazil and is looking forward to start working with you.

Kind regards,

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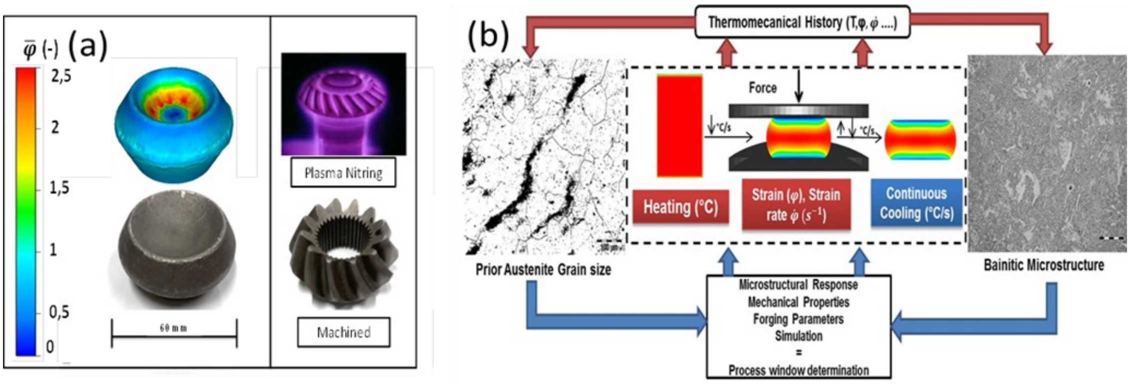
Bainitic Forging Steels

Energy efficient manufacturing chain for advanced bainitic steels based on thermomechanical processing



(a) Forged gear preform and ist equivalent strain field. Machined and plasma nitrided finished gear.

(b) Overall flux of process window determination.

Aiming at energy consumption reduction conventional heat treatment is being replaced by thermomechanical processing. This replacement is being assessed by means of continuous cooling bainitic steel which is being employed for production of forged components. The optimal processing window is being determined by multiple thermomechanical parameters. These include conventional hot forging, combined forgings (two steps) and bainitic field forgings. Furthermore, finite element method (FEM) of all forging courses and parameters are being carried out in order to converge in a coherent model for the employed steel with the commercial software forge NTx 2.1.

Thermomechanical analysis by dilatometry experiments, performed at IWT- Bremen, enables the study about the phase transformations which occur during continuous cooling of the material. As extension of the Gleeble testing, an in-process measurement of the materials transformation are being performed to allow an in-situ control of the microstructure evolution. This analysis generate a deeper understanding of the transformation kinetics and the eddy current signals. Additionally, in-situ high energy synchrotron X-ray diffraction experiments were carried out in Deutsches Elektronen-Synchrotron (DESY), in order to study development of the bainite microstructure under different process conditions.

The thermomechanical parameters comprehend a wide array of variables, including different forging temperatures, deformation degrees, cooling regimes and sample geometries. Moreover, different strain rate effects are being assessed utilizing different presses in Brazil. All of these parameters impacts are being evaluated through microstructural response by means of light optical microscopy. Qualitative and quantitative data of these microstructural responses are also being built. Sequentially, scanning electron microscopy, x-ray diffraction and electron backscatter diffraction will also be carried out.

In order to achieve high surface hardness and good wear properties by friction, the treatment of plasma nitriding is being investigated. Therefore, different temperature and treatment time parameters were tested. In the investigated situations, it was possible to obtain zone of compounds (white layer) in all nitrided samples above 450 °C, regardless of temperature and treatment time. In addition, plasma nitriding contributes significantly to the increase in surface hardness, even under conditions where the white layer has not been detected.

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ForCover

Evaluation of sheet metal covers to improve tool life in forging

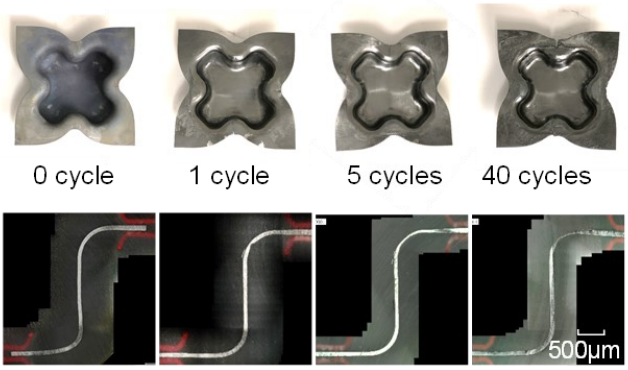

Fig. 1: Thickness of the die covers after different forging cycles

Tooling costs in closed-die forging industry nowadays are still one of the main challenges since they stand up to 15-35% of the total costs. The currently used methods for prolonging tool life are rather cost intensive and still require rework and exchanges of the forging die after a certain time. Therefore, the concept of “ForCover”, the acronym for “forging die covers”, was proposed to increase lifetime and decrease exchange time of forging dies. By applying this inexpensive and easy-to-exchange die cover, the mechanical and thermal loads during forging will mainly affect the die covers instead of forging dies.

In recent works, the die cover concept was successfully applied on an industry relevant geometry for 40 forging cycles and proved the protective effects of die covers regarding the thermal loads. In the designed case, a cross geometry that can be used to produce typical cross components, e.g. universal joint, was selected as die geometry. The die covers were made from 1 mm thickness sheets of 22MnB5, a press hardening steel, by deep drawing operation. Heat treatment was conducted to increase the hardness of the die cover to around 540HV. During the 40 forging cycles, the thickness of the die covers decreased but no distortions or folds occurred. In the most critical region of the die covers, a thickness change of 0.6 mm was observed due to mechanical wear. However, it was found that with an increasing number of forging cycles, the thickness reduction of die cover reduced, which indicated the possibility of a longer service life. Besides, by applying the die cover, both the maximum temperature and temperature amplitude inside forging dies was decreased by 40 °C according to measurements.

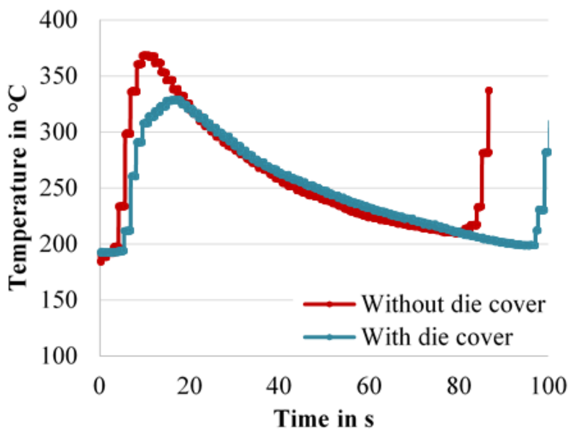

Fig. 2: Temperature evolution inside the forging dies with and without the die cover (the first forging cycle)

Further works will focus on investigation of applying the die cover concept in multi-stage forging processes and exploration of service life and protective effects of die covers.

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Learnstruments

Development of Learnstruments for ensuring the transition of Brazilian and German manufacturing companies to Industry 4.0

Fig. 1: Factory operation screen.

As the development of the Learnstrument reaches its refinement phase, the feedback and test results from external users becomes more important, as such, the last version of the tool has been tested and the feedback given by a total of 32 respondents.

Aiming to address the transitions towards I 4.0, the Learnstrument places the learner as the decision maker in a virtual industry who must guide his or her factory to become competitive in this new context. To do so, he or she selects improvement projects both at the factory and process level to achieve performance indicators levels that are set as goals. In this process the user is presented to design principles of I 4.0, a myriad of relevant technologies and process improvements to select from, getting acquainted to them to make meaningful choices to reach the proposed goals. By selecting an option to implement, the user can see the effect of the selected changes visually in the production floor and its impacts in the performance indicators.

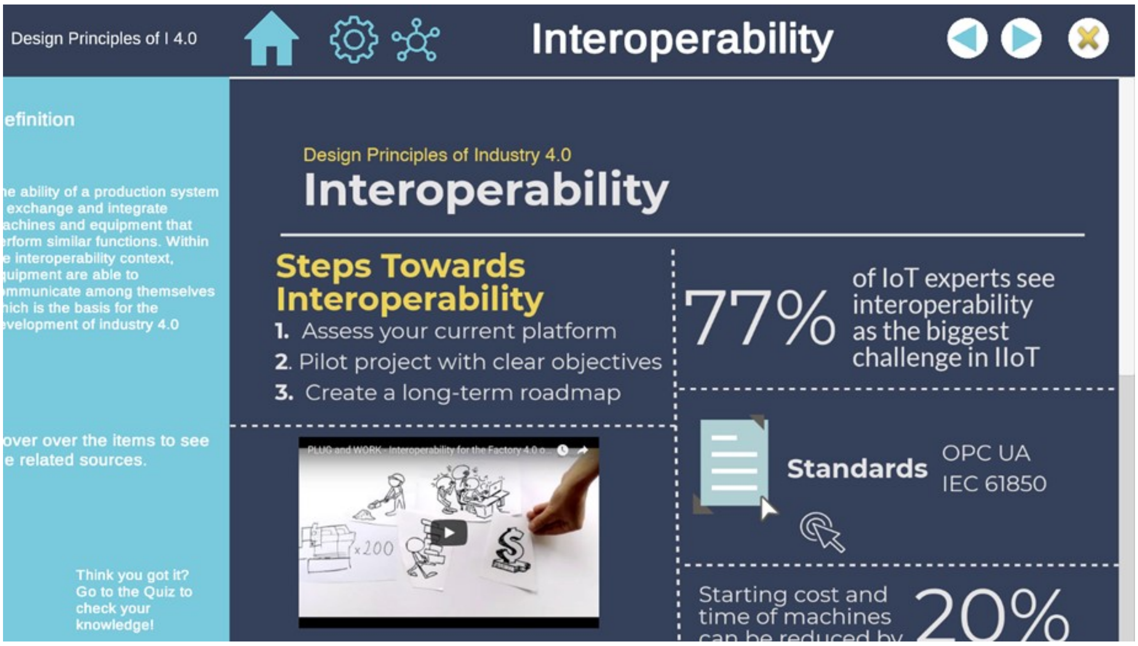

Fig. 2: The Learning Room Interface

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To test this tool, undergraduate and graduate students from the University of São Paulo and TU Berlin had access to the latest version and without external assistance have been asked to use the Learnstrument and report their answer in an online form. None of the students had any contact with the tool before. After finishing the challenge proposed in the Learnstrument, they were to send their results and fill the report. The responses were compiled leading to valuable feedback, with some of the main results listed below:

- **Motivation:** Most respondents (53.1%) declared themselves "Very motivated" or "Motivated" using the tool with 37.5% declaring themselves "Slightly Motivated" and 9.4% declaring "Not Motivated";
- **Learning:** 37.5 of the users declared to have learned I 4.0 from the experience, with 31.3% declaring have learned a little and 31.3% declaring they did not learn anything;
- **Attention Level:** A "Medium Level" of attention was the most selected level with 43.8%, followed by a "Significant Level" with 31.3% and a High Level with 25%;
- **Content:** 59.4% considered the content "Good", with 28.1% answering "Regular" and 12.5% answering "Unsatisfactory";
- In the free form questions the main results improvement points pointed were:
  - The Learnstruments initial explanation was considered insufficient
  - Some elements of the user interface were not clear
  - The difficulty of the challenge should be better adjusted

With these answers, the Learnstrument has been modified for another round of tests before it will be made available online freely for other users. In addition, the graphics are to be revised and transferred to a modern industrial environment. The idea is to distribute in a platform for companies and universities in Brazil and Germany to use it as they see fit. This platform will also contain the assets and codes developed during this project free for use, to facilitate the development of other tools as well as the link to the articles, guidelines and frameworks written in this project.

The results from this project have been and will further be compiled for publication.

Project Papers:

- **Learnstruments: Learning-conducive artefacts to foster learning productivity in production engineering**
  Authors: Jan Philipp Menn, Bernd Muschard, Bastian Schumacher, Felix Sieckmann, Gunther Seliger, Department of Machine Tools and Factory Management (IWF), Holger Kohl, Fraunhofer Institute for Production Systems and Design Technology (IPK). CIRP Annals - Manufacturing 2018. (Link to paper)
- **Exploring gamification to support manufacturing education on industry 4.0 as an enabler for innovation and sustainability**
  Authors: Esdras Paravizo, Omar C Chaim, Daniel Braatz, Bernd Muschard, Henrique Rozenfeld. 21. Okt. 2017, Procedia Manufacturing 21, 438-445, 2018. (Link to paper)
- **Insertion of Sustainability Performance Indicators in an Industry 4.0 Virtual Learning Environment**
  Authors: Omar C. Chaim, Edson Cazarini, Henrique Rozenfeld, Bernd Muschard. Procedia Manufacturing 21, 446-453, 2018. (Link to paper)
- **Manufacturing in the fourth industrial revolution: A positive prospect in Sustainable Manufacturing**
  Authors: Nubia Carvalho; Omar Chaim; Edson Cazarini; Mateus Gerolamo. 21. Okt. 2017, Procedia Manufacturing 21, 671-678, 2018. (Link to paper)

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- **Procedure for Experiential Learning to Conduct Material Flow Simulation Projects**
  Authors: Müller, Bastian; Menn, Jan Philipp; Seliger, Günther, Enabled by Learning Factories', 7th Conference on Learning Factories, CLF 2017. Procedia Manufacturing 9, pp. 283–290. 2017. (Link to paper)

- **Learning process planning for special machinery assembly**
  Authors: Menn, Jan Philipp; Sieckmann, Felix; Kohl, Holger; Seliger, Günther ', Procedia Manufacturing Volume 23, 2018, pp. 75-80, 2018. (Link to paper)

- **Key perspectives and opportunities for skills and abilities development**
  Authors: Carvalho, N.; Cazarini, E.; Esposto, K.; Muschard, B. 'Fourth Industrial Revolution:, 1st ISSC 4.0 International Symposium on Supply Chain 4.0 - Trends, Challenges and Opportunities from 4th Industrial Revolution, SC4 - Collaborative Research Network on Supply Chain 4.0, ISSN: 2594-8342, Pages 85-87, 2017.

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IDD-Metro

Defect detection improvements with lock-in thermography and CT

Within the BRAGECRIM project Non-Destructive Impact Damage Detection on Carbon Fiber Reinforced Plastics (IDD-Metro), UFSC`s PhD student Herberth Birck Fröhlich is in Aachen since July.2018 for a period of one year. The main task of him is to conduct researches on composites images and its defects classification using machine learning and computer vision on thermography images obtained from non-destructive analysis. Regarding this topic, actual efforts are about the decomposition of thermography images containing multiple defects in order to elaborate a classification framework and generative models.

Besides that, he had also the opportunity to gain experience and discover new methods on other metrological areas, such as coordinate measurement machine systems and car parts automated classification - both corresponding to industrial projects. These new experiences obtained from both BRAGECRIM and industrial projects may benefit each other, making this stay useful for further developments on both institutes, RWTH – WZL (Aachen) and UFSC (Florianopolis), strengthening this partnership.

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SCoPE

Development of a Digital Twin Demonstrator

After 4 years of progresses and advancements, Project SCoPE finishes its activities. In the 10th Annual BRAGECRIM Meeting, the partners presented the results of the last year, which demonstrated the development of smart components interactions within smart assemblies and the improvements with a digital twin demonstrator. The project aimed at promoting individual physical manufacturing components as information carriers, comprising a digital data representation of their physical properties, manufacturing history, customizations, and more. These digital data representation would be applied in communication-controlled production processes.

One of the project studies was based on the smart components ability to communicate in the production environment and on the mapping of interactions between components, resources and one another, which led to the development of a concept for smart components interactions within smart assemblies. Following the concept, the master component will carry assembly information and components information, allowing easier and faster product customization. The new assembly flow is conducted by this master component, which will also deal with other components and resources.

Another study demonstrated that the digital twin was successfully implemented. Considering that the digital twin is an instance of the 3D CAD geometry model, which is based on the characteristics, conditions and behavior of the associate physical twin, and on data connection between them, the digital twin was successful in gathering data about its physical associate and making it available at any time throughout the lifecycle. It could also mirror the movement of the associate twin. The test case was a bending beam test bench.

During its 4 years, Project SCoPE produced a total number of 50 publications, including books and book chapters, papers in conference proceedings and in journals. The coordinators often received invitations to disseminate the knowledge generated by the project, and presented a total of 23 speeches on both academy and industry events. In addition, SCoPE also promoted 15 study missions, exchanging students between the Brazilian and German partner universities. Two study missions are still occurring. The Brazilian students from the Laboratory for Computer Integrated Design and Manufacturing (SCPM) at Unimep are conducting part of their PhD and Mestrado researches in the Department of Computer Integrated Design (DiK) at TU Darmstadt.

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