

3rd Edition: June 2018

Dear reader,

we welcome you to the 3rd 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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AdaptiveSBO (

Phase 1 of the Project AdaptiveSBO has been successfully finalized

In order to assure a high performance of dynamic manufacturing systems, the project AdaptiveSBO developed a data-driven adaptive simulation-based optimization (SBO) method that derives optimized machine assignment and dispatching rules according to the current state of a manufacturing system in real-time. The approach couples an SBO method determining optimized rules for shop floor control with a framework for the data exchange between the SBO method and the manufacturing system. In this way, the optimization always considers the current state of the system.



The simulation model is used to evaluate the performance of possible solutions gen-

erated by a genetic algorithm. Good solutions are derived through iterating this simulationbased optimization approach. The solutions are fed back to and applied on the shop floor. The developed approach is able to react on dynamic and stochastic effects such as fluctuation processing times, machine breakdowns, absence of workers and rush orders.

The project team has developed significant research results that have been published in highranked scientific journals, such as the International Journal of Production Research and the CIRP Annals - Manufacturing Technology, and have been presented at leading scientific conferences, such as the CIRP General Assembly, the "WGP Jahreskongress", the Winter Simulation Conference or the IFAC World Congress, among others. Moreover, the project has enabled a fruitful cooperation with several short working missions and long-term study missions of the associated professors and students. In this way, the project provides a basis for a longterm cooperation that will be continued in future joint research.



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BRAGECRIM - Smart Connected Manufacturing

In the last months, the team of the project AdaptiveSBO developed valuable results concluding the project and giving an outlook on possible future research directions. The paper "Datadriven production control for complex and dynamic manufacturing systems" has been accepted for presentation at the 2018 CIRP General Assembly in Tokyo, Japan, and will be published in the high-ranked journal CIRP Annals - Manufacturing Technology

Digitalization allows for production control based on the current state of a manufacturing system. Thereof, the paper proposes and applies a data-driven adaptive planning and control approach using simulation-based optimization to determine most suitable dispatching rules in real-time under varying conditions. The data integration between the real manufacturing system and the simulation model was implemented through a data-exchange framework. The approach was evaluated in a scenario of a Brazilian manufacturer of mechanical components for the automotive industry, achieving better operational performance compared to the planning procedure previously applied by the company as well as in comparison to static dispatching rules.

An alternative approach was shown in the paper "Potential of a Multi-Agent System Approach for Production Control in Smart Factories", which has been accepted for presentation at the 2018 IFAC Symposium on Information Control Problems in Manufacturing in Bergamo, Italy, and for publication in IFAC PapersOnLine. Multi-Agent Systems (MAS) are a promising approach to exploit new trends and technologies in the context of Industry 4.0 in order to achieve improved planning and control performance. This paper applies an MAS approach to control the production in job shop manufacturing systems. Within a simulation study based on a real industrial case, the approach achieves a good performance compared to the standard scheduling approach applied by the considered company. The paper "Towards a simulation-based optimization approach to integrate supply chain planning and control" has recently been presented at the 2018 CIRP Conference on Manufacturing Systems in Stockholm, Sweden, and will be published in Procedia CIRP. This paper developed a concept for extending the data-driven method for production control to an integrated supply chain planning and control. The adaptive simulation-based optimization approach is capable of dealing with complex systems as well as considering a dynamic environment with stochastic behavior. A test case was presented to evaluate the computation time feasibility and the solution quality. The method provided a convergence to a best solution in different experiments within short amounts of time, coping with the requirements of complex and uncertain scenarios.



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Bainitic Forging Steels

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



a) Temperature distribution simulated after upsetting forging; b) Steel Bainitic Microstructure; c) Expansion curves at different deformation degrees of HSX130HD steel during dilatometry experiment at 850°C.

The processing windows for forging experiments are being determined, detecting the phase transformations during the cooling process. The useful processing parameters range is being determined for the material processing in laboratory experiments and by means of FEM simulation.

Different forging routes are planned in the project as deformation in the austenitic, ferritic and bainitic fields and also combinations of forging steps at different temperatures. Thus, initial experiments of forging in the austenitic field with were carried out with two different cooling methods (free cooling in air and air controlled flow) and three deformation degrees (20%, 40%, 60%) were performed at UFRGS - Brazil (figure a), aiming to verify metallurgical and mechanical properties of the material (figure b).

Thermomechanical analysis by dilatometry experiments were performed at IWT- Bremen, enabling to study the phase transformations which occur during continuous cooling of the material. The bainitic transformation start and end temperatures were defined through expansion curves obtained in the experiments (figure c). The results will allow the understanding of strain and cooling rates influence in the phase transformation and final properties.

Forging tests has been perform at forging temperature of 1170°C. The commercial numerical simulation software Forge NTx 2.1 was employed for a reverse analysis method of the forging experiment. It was possible to correlate the local temperature of the specimen obtained by thermal analysis with infrared camera and the simulation for this specific experimental condition, predicting the local temperature in the material during forging stroke using FEA (Finite element Analysis). These results are important to establish a database that will be used to determine the process window parameters for the steels under investigation in the project.

Additionally, in-situ experiments will be performed at the thermo-mechanical simulator Gleeble in order to achieve a better understanding about the evolution of phase transformations on-line. These results are important to: (i) future application of surface treatments; (ii) forging experiments at different fields and (iii) forging experiments with different die geometries.



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ForCover

Evaluation of sheet metal covers to improve tool life in forging



Figure 1. Experimental application of two geometries

The ForCover, acronym for "forging covers", is a concept aiming to prolong tool life and decrease repair costs of forging dies. The basic idea is to replace the surface of a forging die by an inexpensive and easv-toexchange sheet metal part (forging cover). The forging cover protects the forging die from the high-level thermal and mechanical load during the process and can be easily exchanged after being worn out.

In recent works, the forging cover concept was experimentally applied on two different geometries. An axisymmetric geometry to pro-

duce gear blanks and a cross geometry presents typical components like a universal joint. In both cases, the forging covers made of 22MnB5 sheet have a longer service life than ten forging cycles, which is the maximum service life of the forging covers developed in the first phase of this project. The forging cover made for gear blanks went through 18 forging cycles without failure and the forging cover for universal joint went through 40 forging cycles without distortions and excessive deformations. Simulation models were built and validated by the experiments. The simulation results indicate that using the forging dies, so that the forging dies reach the steady state earlier and in a lower temperature range than the forging dies without forging covers. Therefore, the total thermal loads of forging dies were decreased significantly. In addition, the mechanical loads and wear were decreased by using forging covers according to simulation results as show in Figure 2.

Besides the exploration of industrial geometries, the boundary conditions and process parameters of applications are also being studied, such as the tribo-condition using different forging parameters and the manufacture process of forging covers.

In the next steps, the wear and plastic deformation of the forging dies with and without forging covers will be compared. Moreover, evaluations of the service life of both forging covers and forging dies will be performed.







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Prediction of surface residual stress induced by ball burnishing through neural networks

Improve product life cycle by the appropriate choice of a manufacturing operation and by a correct process design is one of the motivations of this BRAGECRIM project, whose focus consists of investigating the effects of turning and ball burnishing on the workpiece surface and subsurface. Regarding to this, high levels of surface compressive residual stress are sought, as they contribute to the increase of fatigue resistance.

Within this scenario, an artificial neural network (ANN) was developed in order to predict residual stress values after ball burnishing, as well as optimizes process parameters in order to increase the intensity of surface compressive residual stress.



Ball burnishing experiments in AISI 1060 high carbon steel were conducted under different values of pressure, number of passes and material properties. Both input (burnishing feed and number of passes) and output (residual stress values) parameters were employed for training the ANN.

A comparison between the residual stress values obtained experimentally and from the ANN (during training, validation and test phas-

es) together with the corresponding percentage error is given in Figure 1. From the 16 experiments concerned with the training phase, the maximum difference between experimental and predicted residual stress was of 9% (test #8). In spite of this high value, the proper way to assess the performance of a neural network is based on the results of the test phase. Under this condition, the highest error values were 0.55, 1.73, 1.43 and 0.96%, thus suggesting that the proposed model is capable of satisfactorily predicting surface residual stress under new ball burnishing conditions.

After the optimization procedure, it was noted that compressive residual stresses of higher intensity were obtained for the material in the hardened condition and that the higher the burnishing pressure and number of passes, the more compressive the residual stress.

More details about the results can be found in: Magalhaes, F.C.; Ventura, C.E.H.; Abrao, A.M.; Denkena, B.; Breidenstein, B.; Meyer, K. Prediction of surface residual stress and hardness induced by ball burnishing through neural networks. International Journal of Manufacturing Research, 2018(accepted for publication).



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UFmg Learnstruments

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



The innovations towards an Industry 4.0 are having a disruptive influence on the manufacturing industry by establishing an interplay of smart factories, smart products and smart services embedded in an internet of things and services also called industrial internet. Meeting the future needs for learning and in-work training requires the development of new learning conductive technologies, materials and methods.



In a first step, relevant principles of Industry 4.0 as well as qualification profiles for current and future engineers have been identified and described. In parallel, a generic framework for the development of Learnstruments was developed. Now, on this basis, a concrete Learnstrument to convey the principles of Industry 4.0 is being realized in the form of a virtual learning environment by using the game engine Unity. Learners are confronted with challenges in the form of small learning games that focus on changes regarding the Learnstruments are objects which automatically demonstrate their functionality to the learner. They use existing and new information and communication technology (ICT), aim at increasing the learning and teaching productivity, provide adequate learning goals to the user and support the user in achieving the learning goals. Learning takes places predominately through experiential and problem-based learning. Due to a high degree of realism, the acquired knowledge can be transferred more easily to the industrial practice.



factory layout and production planning. They decide for themselves which new technologies to apply, to further develop their factory in order to cope with these challenges. To support the decision-making process, learners get access to relevant information in the form of texts, audio recordings and videos. By facing and solving these challenges, learners develop an understanding of the transition towards a more connected Industry 4.0 reality, highlighting its benefits and difficulties, the technologies that enable it and the design principles to realize its potential.

The next steps are practical evaluations of the Learnstrument, the collection of data from its usage, implementation of the required changes and determination of a distribution model.

Workshops:

Learning for the Fourth Industrial Revolution: a Virtual Factory Learnstrument Moderators: Henrique Rozenfeld, Omar Chaim (Universidade de Sao Paulo), Bernd Muschard (Technische Universität Berlin). 15th Global Conference on Sustainable Manufacturing, Technion University Haifa, Israel, September 25th-28th, 2017. Student Presentations on

Learnstruments and Learning Factories Moderators: Bernd Muschard, Jan Philipp Menn, Felix Sieckmann (Technische Universität Berlin). 15th Global Conference on Sustainable Manufacturing, Technion University Haifa, Israel, September 25th-28th, 2017.

Papers:

• Learnstruments: Learning-conducive artefacts to foster learning productivity in production engineering

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: Nubia Carvalhoa, Omar C. Chaim, Edson Cazarini, Mateus Gerolamoa, Bernd Muschard. 21. Okt. 2017, 15th Global Conference on Sustainable Manufacturing, Technion University Haifa, Israel, September 25th-28th, 2017. (Link to paper)

• Insertion of Sustainability Performance Indicators in an Industry 4.0 Virtual Learning Environment

Authors: Omar C. Chaim, Edson Cazarini, Henrique Rozenfeld (University of SaÌ*f*o Paulo), Bernd Muschard (Technische Universital^ˆt Berlin). Procedia Manufacturing, Volume 21, 2018, Pages 446-453, 21. Okt. 2017, 15th Global Conference on Sustainable Manufacturing, Technion University Haifa, Israel, September 25th-28th, 2017. (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, 15th Global Conference on Sustainable Manufacturing, Technion University Haifa, Israel, September 25th-28th, 2017. (Link to paper)

• Changes in the contents and forms of human work in industry 4.0: Limitations and potentialities

Authors: Nubia Carvalho; Esdras Paravizo; Edson Cazarini; Daniel Braatz. Journal Laboreal - Virtual Platform on Real Work Organized by the University of Porto, Portugal. ISSN 1646-5237. (Awaiting evaluation)



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DD-Metro

Defect detection improvements with lock-in thermography and CT



In the context of the IDD-Metro - Non-Destructive Impact Damage Detection on Carbon Fiber Reinforced Plastics - project, the parties - CECS/UFABC, LABMETRO/UFSC and WZL, RWTH Aachen - have worked in the development of a new method to extract point clouds of composite samples from phase image acquired with lock-in thermography. The method is based on image fusion, which allows determining regions of the composite samples with and without defects. The proposed method is definitely a step forward in the direction of full automation of 3D data acquisition using lock-in thermography. In parallel, experiments have been performed to investigate the CT capability to characterize low-velocity impact damages in composite samples and convolutional neural networks have been applied to classify the presence of defects in shearography images of tubes repaired with epoxy reinforced with glass fiber.

Contributions to conferences have resulted from these activities, such as the participation as speaker in the 2018 International Conference on Industrial Computed Tomography and in the 2018 International Joint Conference on Neural Networks. The work mission of a Brazilian researcher at the WZL, RWTH Aachen was also important to define the courses of the collaborative project in its second phase.



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💑 SCoPE

Development of a Digital Twin Demonstrator



The vision of the research project SCoPE is to promote individual physical manufacturing components as information carriers. Information-carrying manufacturing components comprise a digital data representation about their intermediate manufacturing states, their manufacturing history, physical properties, customizations, purpose etc., and utilize this digital data representation for communication-controlled production processes. In a next step, the project aims to move from an alphanumerical to a model-based representation of a component's state and behavior. The model-based representation takes the shape of a digital twin. A digital twin is a comprehensive virtual representation of an individual component, assembly or product. It includes the properties, condition and behavior of the real-life object (physical twin) through models and data and is coupled to its physical twin through a bidirectional network connection.

To show the promising concept of digital twins a demonstrator was developed at DiK research lab. The demonstrator consists of three parts. A physical twin represented by an electromechanical bending beam test bench, a digital twin of said test bench in the form of a CAD and a finite element method (FEM) model, and an Internet of Things (IoT) platform that collects and visualizes the generated data of the demonstrator. This way the test bench exists both in real space as a physical twin and in virtual space as a digital twin. Physical and virtual twins are connected through a multidirectional client-broker-architecture and thus have the ability to communicate with each other. The physical demonstrator can be controlled through the IoT platform from any internet capable device. Actuating the electric motors results in a bending of the clamped beam. Force sensors relay the resulting force to the platform using the Message Queuing Telemetry Transport (MQTT) protocol. The digital twin mirrors the movement of the drives and the linear guide unit and performs a finite element analysis (FEA), which calculates and visualizes the stress within the bending beam.

The demonstrator is featured in following recent journal publications:

https://doi.org/10.1016/j.mfglet.2018.02.006

https://doi.org/10.1515/itit-2017-0038



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