TMCE 2012 Symposium

Including

ADCP2012

The 2nd International Workshop on

Advanced Design Concepts and Practice

Karlsruhe, Germany, 14.00-18.20, 8 May 2012
http://adcp2012.com, http://www.tmce.org

Bringing Advanced Technology and Tools to the Processing Simulation

and Equipments Design

Chairs

Professor Dieter Roller	University of Stuttgart
Professor Michel van Tooren	Delft University of Technology
Professor JI Linhong	Tsinghua University

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Professor Ji Linhong, Tsinghua University

Organizing Institutes
Tsinghua University
Delft University of Technology
Karlsruhe Institute of Technology
University of Stuttgart

Sponsors
Tsinghua University
National Natural Science Foundation of China
Ministry of Science and Technology of the People´s Republic of China

Keynote speaker
Dr. Stephen Daniels, Dublin City University, Ireland

Workshop Manager
Dr. Hou Yuemin, Tsinghua University

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Dr. Stephan Rudolph, University of Stuttgart, Germany
Professor Tetsuo Tomiyama, Delft University of Technology, the Netherlands
Professor Wang Yongnian, Dalian University of Technology, China
Dr. Zoltan Rusak, Delft University of Technology, the Netherlands

Index

1. Introduction to the Workshop

Theme

The second International Workshop on Advanced Design Concepts and Practice, ADCP 2012, will be held in Karlsruhe, Germany, 8 May 2012. The theme of the workshop is “Design and processing simulation of IC (integrated Circuit) equipments”, including multi-fields modeling, processing simulation, optimization and design of complex engineering systems with a focus on, but not limited to, chamber systems of IC equipments. The workshop will take place during the TMCE 2012 Symposium as part of the professional program.

Goal

The goal of the workshop is to bring advanced technology and tools to the processing simulation and equipments design to develop knowledge-based design systems for IC equipments. Extensive research and developments have been conducted and many useful results related to the listed topics have been achieved. The special workshop session at TMCE2012 offers an opportunity to present the latest results and provides forum for discussion of these advancements and further work.

Submission

Contributions to the workshop are invited in the form of brief position papers (approximately 2000 words long), formatted according to the TMCE 2012 abstract guidelines, and full papers, formatted according to the TMCE 2012 paper guidelines. Contributions may include theories, methods, tools, software, hardware, practical examples as well as project reports of related topics. Accepted full papers will be published in the TMCE2012 proceedings. Accepted position papers will be invited to submit extended full papers to publish in a book or TMCE special issues for international journals. Upon paper submission, please select “W1: Design and Process simulation of IC equipments” as the second keyword of your paper in the confmaster system (http://tmce2012.confmaster.net).

Acceptance of submission

The submitted contributions will be blindly reviewed by the Program Committee. Authors will be informed of acceptance and/or conditions for acceptance. Before the final acceptance, you will be asked to fill in a statement that at least one author will register and participate in the workshop.

Registration

Attendees at the workshop need to register at TMCE 2012. Please go to the Registration page of TMCE 2012 to register.

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Important dates

Full paper submission due: 18 October, 2011
Authors informed of results of paper reviews: 10, November, 2011
Accepted revised papers due: 10, December, 2011
Position paper due: February 20, 2012，
Authors informed of results of paper reviews: March 10, 2012
Registration with full paper submission, see TMCE webpage (http://www.tmce.org/)
Registration with only position paper submission, April 5, 2012
ADCP2012 Workshop: 14.00 pm, May 8, 2012

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ADCP2012 Organizing Committee, hym01 at mails.tsinghua.edu.cn

2. Program Proposal

TUES May 8, 2012		
1.20-2.00pm	Chairs: Professor Ji Linhong Professor Michel van Tooren	Project meeting
	Participants: all members of the international team. Open to TMCE2012 participants that are interested in the international project.	1. Introduction to the ”High level oversea collaboration innovation team” (members, activities, events, financial support, visits, travels, subsidy, research & teaching). 2. Discussion
TUES May 8, 2012		
2.00-4.00 pm	Chair Professor Dieter Roller	
2.00 – 2.10pm	Professor Michel van Tooren, Delft University of Technology, New Concept Development at Fokker Aerostructures B.V	Introducing the workshop and chairs
2.10-2.40pm	Professor Dieter Roller, Director of the Institute of Computer-aided Product Development at the University of Stuttgart	**Opening lecture**: Hot spots and advanced solution approaches in computer aided product development.
2.40-3.30pm	Dr. Stephen Daniels, Dublin City University, Executive Director of the National Centre for Plasma Science and Technology	**Keynote/invited speaker** Design and control issues in reactive ion etch plasmas and estimation of radical flux densities. Abstract
3.30-3.40pm	Dr. Stephan Rudolph the head of the Similarity Mechanics Group at the Institute for Statics and Dynamics of Aerospace Structures University of Stuttgart	Engineering large and complex systems With graph-based design languages Abstract
3.40-3.50	Dr. Zoltán Rusák Delft University of Technology	Research into NUI (Natural User Interfaces) design
3.50-4.00pm	Discussion	
4.00 – 4.20pm	**Break**	

TUES MAY 2012		
4.20-6.20pm	Chairs: Professor van Tooren, Professor Ji Linhong	
4.20-4.30pm	Professor Ji Linhong Associate Dean of the Department of Precision Department & Mechanology at Tsinghua University	Introduction to the on-going projects related
4.30-4.40pm	Mr. Reinier van Dijk and Michel van Tooren Delft University of Technology	Next generation design systems with closely coupled KBE and optimization functionality (including questions for discussion) Abstract
4.40-4.50pm	Ms. Gu van Rhijn, Michiel de Looze, Peter Vink TNO, Delft, the Netherlands	Approach and tools to design an efficient and flexible production flow and human centred workstation in SMEs, (including questions for discussion) Abstract
4.50-4.55pm	Mr. Yuchun Sun Tsinghua University	Building the design space of an electrostatic chuck used in the plasma-etching process (including questions for discussion) Abstract
4.55 – 5.00pm	Dr. Yuemin Hou Tsinghua University	Design issues of IC equipments and solutions (including questions for discussion) Abstract
5.00 – 5.05pm	Discussion/ group discussion	
5.50 pm	Professor Michel van Tooren Delft University of Technology Manager New Concept Development at Fokker Aerostructures B.V	**Closing lecture:** Next generation Design
6.20pm	Closing	

3. Introduction to Chairs

Prof. Dr. Dieter Roller, University of Stuttgart

Prof. Dr. Dieter Roller holds the position of director of the Institute of Computer-aided Product Development at the University of Stuttgart. He is full professor and chair of computer science fundamentals. Additionally he has been awarded the distinction as a honorary professor of the University of Kaiserslautern and also serves as member of the board of trustees of the Technische Akademie Esslingen.

He is chairman of several national and international working groups and former president of the ISATA forum, on of the world-wide largest technological associations, and also the leader of the experts group "Computer Graphics in Engineering - GRIB" of the German computer science society "Gesellschaft für Informatik e.V.". Furthermore he is organiser and chairman of symposia, congresses and workshops in the field of product development and automation. Professor Roller serves as reviewer for several scientific organisations as well as for the Baden-Württemberg Ministry of Science and Research for project grants. He is also reviewer for well-known scientific journals and member of several national an international programme committees.
As former research and development manager with world-wide responsibility for CAD-technology within an international computer company, he gathered a comprehensive industrial experience. He is the inventor of several patents and is well-known through numerous technical talks in countries all over the world, 71 published books and over 180 contributions to journals and proceedings books.
With his wealth of experience, he also serves as a technology consultant to various high-tech companies.

Prof. Michel van Tooren, Delft University of Technology

Professor at Delft University of Technology
Member Scientific Advisory Board at Netherlands Defense Academy (NLDA)
Manager New Concept Development at Fokker Aerostructures B.V.
Member Educational Advisory Board at Nanyang Technical University

Prof. Michel van Tooren obtained his PhD at Delft University on Composite Fuselage Design in 1998. After positions as researcher and assistant professor at the Faculty of Aerospace Engineering, he became full professor Systems Integration Aircraft in 2002. In 2010 he accepted a job in industry and is now Manager New Concept Development at Fokker Aerostructures BV. He combines this with a part-time appointment as professor Systems Integration Aircraft at the section Flight Performance and Propulsion of the Delft University of Technology. In addition he is member of the scientific board of the NLR (Netherlands Aerospace Laboratories), member of the Technical Committee Multi-disciplinary Design and Optimization, American Institute of Aeronautics and Astronautics.

The mission of his research group at Delft University is: To advance the design of and design methodologies for complex systems, in particular air transport vehicles and their flight trajectories, by exploration of:

-new technologies to obtain novel or improved solutions,

-the advances in flight physics to improve the prediction and simulation of the behavior of complex aeromechanical systems, especially rotorcraft and wind turbines, and

–advanced mathematics and informatics to improve the quality and effectiveness of the design process.

Professor Ji Linhong, Tsinghua University

Professor Ji Linhong obtained his Ph.D at Tokyo University and BSc and MSc at Tsinghua University. He is the associate Dean of the Department of Precision Department & Mechanology at Tsinghua University, Director of the State Key Laboratory of Tribology (SKLT) at Tsinghua University and former Director of the Institute of Design Engineering at Tsinghua University. His research focuses on Rehabilitation Engineering and design, including simulation and dynamics of IC Equipments, technology and training devices for Rehabilitation of Hemiplegia and sport training, technology of exercise evaluation on the handicapped, technology and adjuvant devices for the activities of daily living of the elder.

4. Introduction to the Keynote Speaker

Dr. Stephen Daniels, Dublin City University, Ireland

Dr. Stephen Daniels is Executive Director of the National Centre for Plasma Science and Technology (www.ncpst.ie) and a Lecturer in the School of Electronic Engineering at Dublin City University. He leads a multidisciplinary research team in plasma technology and energy systems. He is Director of the Energy & Design Laboratory (energylab.eeng.dcu.ie) and the nanomaterials processing laboratory (www.eeng.dcu.ie/~npl).

Stephen is a Principal Investigator in the Science Foundation Ireland Funded 'Precision' Strategic Research Cluster (www.ncpst.ie/precision), an academic member of the Biomedical Diagnostics Institute (www.bdi.ie), and a Principal Investigator at the MESTECH Marine and Environmental Sensing Hub (http://dcu.ie/ncsr/Beaufort).

His primary scientific technical competence is in the area of plasma processing for integrated circuit manufacturing, thin film deposition techniques. He also has extensive experience in product design and development.

5. Introduction to Speakers

Priv.-Doz. Dr.-Ing. habil. Stephan Rudolph, University of Stuttgart

Priv.-Doz. Dr.-Ing. habil. *Stephan Rudolph* holds a German Diploma and PhD Degree in Aerospace Engineering, both from the University of Stuttgart, Germany. He wrote his bachelor's thesis at the French Grande Ecole d'Aeronautique (ENSICA) in Toulouse, France, and wrote his diploma thesis at the Massachusetts Institute of Technology (MIT) in Cambridge, USA. After graduating from Stuttgart University with a PhD in Aerospace Engineering in 1995, he was a PostDoc in the Systems and Design Group at the Massachusetts Institute of Technology (MIT). He completed his German Habilitation thesis on Design Methodology (*Lehrgebiet: Entwurfsmethodik*) at the University of Stuttgart in 2002.

Priv.-Doz. Dr.-Ing. habil. *Stephan Rudolph* is currently the head of the Similarity Mechanics Group at the Institute for Statics and Dynamics of Aerospace Structures at the University of Stuttgart, Germany, with currently 7 internal and 3 external PhD candidates. His research interests include Engineering Design Methodology, Graph-based Design Languages and Design Evaluation Methods as well as Applications of Similarity Methods in Engineering and Artificial Intelligence. Within the research for an universal engineering design language, the main focus lies on the automatic design synthesis procedures for complex products such as satellites, space stations, airplanes and cars as well on dimensionless similarity analysis methods for a consistent and objective design evaluation.

Dr. Rudolph serves also as Managing Director of IILS Ingenieurgesellschaft für Intelligente

Lösungen und Systeme mbH, Steinhilben, a young technology start-up company founded in mid 1999.

Research Interests

Similarity Theory (classical and new applications), Design Languages and Design Compilers Design Theory and Methodology, Modeling and Simulation

Dr. Zoltán Rusák, Delft University of Technology

Assistant Professor

Industrial Design Engineering, Delft University of Technology

Zoltán Rusák is an assistant professor at the Section of Computer Aided Design Engineering at the Faculty of Industrial Design Engineering, Delft University of Technology, The Netherlands. He obtained his master degree in the field of mechanical engineering from the Budapest University of Technology and Economics in 1998. He earned his PhD in Computer Aided Design Engineering from the Delft University of Technology in 2003. His research interest includes computer support of geometric modeling, use process simulation in virtual reality environments, and mobile, portable and ubiquitous computing for design applications. He is the general secretary of the Tools and Methods of Competitive Engineering biannual symposia. He is the PhD mentor of the Faculty of Industrial Design Engineering.

Ms. Gu Van Rhijn

Senior Projectleader at TNO Work and Productivity

Ms. Gu Van Rhijn is working as a Senior Project Manager at TNO Sustainable Productivity. TNO is a large institute for applied research in the Netherlands with about 4.500 employees. Gu van Rhijn is active in international and national projects in the industry. She is specialized in Lean Production, Flexibility (processes, organization and personnel) and Ergonomics in Industry. During the last 10 years she developed and applied participative and interactive methods and tools to improve production lead time (by 10-50%), productivity (by 10-40%), flexibility and ergonomics of personnel in about 100 industrial companies (SME's).

Mr. Reinier van Dijk

Ph.D. Researcher at Delft University of Technology

Mr. Sun Yuchun

Ph.D. student at Tsinghua University. His research focuses on modeling processing simulation and design process of chambers of IC (integrated circuits) equipments based on bio-inspired computational mechanisms.

Dr. Hou Yuemin

Senior researcher at Tsinghua University

Dr. HOU Yuemin obtained her Ph.D at Tsinghua University in 2005. Her research focuses on autonomous design based on biology inspiration and systems theory, including *bio-inspired* *design theory and algorithms, multidisciplinary optimization, dynamics of systems and neural network*. She has published more than 40 research papers and research reports as first and corresponding authors. She has completed or is conducting more than 10 research projects as principal investigator or main researcher. These projects cover the bio-inspired design and algorithm for multidisciplinary design; dynamics analysis of mechanical systems and elements including bearings, rotors, gears and small satellites; neural networks; the design and optimization of mechanical systems and devices; computer supported systems and programming; as well as public space models. Currently, she is working on four granted projects: (1) “Platform for multi-fields modeling, processing simulation and design of IC equipments”, sponsored by the Ministry of Science and Technology of China; (2) “Research on the algorithms mapping behaviors and structures for the design of individualizing service mechanical－electronic products”, sponsored by Science Research Program of Education Committee Beijing Municipality; (3) “Research on the rapid design of processing chambers for thin film deposition based on developmental design mechanisms”, sponsored by National Natural Science Funding of China (NSF); (4) High level oversea collaboration innovation team, sponsored by Tsinghua University.

6. Abstracts of Presentations

Design and Control Issues in Reactive Ion Etch Plasmas and Estimation of Radical Flux Densities

S. Daniels*, Y. Zhang, S. Kechkar, E. Gudimenko, B. Keville, J. Conway, M.M. Morshed, C. Gaman, A. Cowley, M. M. Turner

National Centre for Plasma Science and Technology, Dublin City University, Ireland

Reproducability of plasma processes and chamber to chamber matching are major issues in advanced semiconductor manufacturing. Sources of variation are numerous and can significantly impact operating costs, device yield, feature profile, and process resolution. These issues can be addressed through a combination of process modelling and diagnostics, integrated advanced sensors, and closed loop control methodologies. Robust models and thorough process characterisation can also inform chamber design. In this talk we will present some strategies for minimisation of process variation with a specific focus on the measurement and control of radical species in reactive ion etch processes.

We examine the design, tuning and implementation of multi-input multi-output controllers for real time, closed loop control of radical densities in capacitively coupled plasma where real-time measurements of plasma chemical and electrical properties are achieved using optical emission spectroscopy and electrical probes. The efficacy of the control algorithm is demonstrated by setpoint tracking and disturbance rejection over a range of operating points, and related to process output.

The estimation of the radical densities from the optical emission spectroscopy spectra is achieved using the well know actinometry technique, where a small amount (1 to 5 % of total feedstock) of an inert gas, is introduced into the reactive plasma and the emission intensities of selected lines monitored. From the relative intensities of selected lines the density of the radical can be estimated. However, this estimation is dependent on several factors that are uncertain or difficult to accurately measure in processes of interest to the processing community, including the electron energy distribution function, rate constants, and collision cross sections.

We assess the range of validity of the actinometric measurements for process and chamber control and characterisation using laboratory based diagnostic techniques, including Laser Induced Fluorescence. Strategies for minimizing estimation error, including the incorporation of particle in cell simulations to give a better description of the electron energy distribution function are included in the discussion.

Finally we investigate the sources of variation in the process and equipment that can give rise to significant disturbances in radical fluxes and other key process parameters, and assess the extent to which these variations can impact on actual device structures and performance.

This material is based upon works supported by the Science Foundation Ireland under Grant No.08/SRC/I1411, and the by EC Framework 7 IMPROVE research project (IR -2008-0013)

Engineering Large and Complex Systems with Graph-Based Design Languages

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Increasing complexity in the design of almost any advanced modern engineering product like aircrafts, satellites, mobile telephones or VLSI chips is a common observation in today's engineering design offices. As a consequence, the need to develop new and more powerful methods, processes and tools to cope with this new increasing type of difficulties is boosting. However, concerning the categorization and classification of engineering design problems there still exist some fundamental and unresolved discrepancies inside the engineering community. Most notably, some authors claim to know *"Why Mechanical Design Cannot be like VLSI Design"* (c.f. Daniel Whitney, Research in Engineering Design (1996) 8:125-138) and contradictory opinions which in contrary emphasize "The Potential for Mechanical Design Compilation" (c.f. Erik Antonsson, Research in Engineering Design (1997) 9:191-194).

The talk intends to analyse the viewpoint of both opponents in an *a posteriori* perspective of more than 10 years later and puts it into perspective with modern powerful design paradigms, such as the so-called Model-Driven Architecture (MDA), which represents the underlying background modelling philosophy for Model-Driven Engineering (MDE), originally developed for the purpose of software engineering, Successfully applied in the design of large and complex software systems it has (re-)inspired and (re-)fertilised also other disciplines such as engineering design and systems engineering. For these reasons the paper focuses on the various aspects and ingredients of the current status of MDA/MDE as the driver for a future model-based systems engineering (MBSE) approach.

In the opinion of the author this future approach is completely embedded in graph-based design languages for the support of the engineering design process of complex systems. Currently it is applied in aerospace engineering in the design of satellites or airplanes. It is therefore highlighted what kind of so far not yet advocated extensions in the current MBSE philosophy and techniques are needed for graph-based design languages to be even more ideally suited for the needs of engineering large and complex engineering systems, and how the techniques are limited or not limited in being applied to VLSI chip design and any other complex engineering design problem as well (or not).

KEYWORDS. model-driven architecture, model-driven engineering, model-based systems engineering, complex systems, engineering design, design process, graph-based design language, unified modelling language

Approach and Tools to Design an Efficient and Flexible Production Flow and Human Centred Workstation in SMEs

Gu van Rhijn, Michiel de Looze, Peter Vink
TNO, the Netherlands

Nowadays customers of manufacturing companies demand a larger variety of products to be delivered at shorter time intervals than before, which may certainly not be at the cost of a lower quality or a higher price. To survive in the coming years there is a need for manufacturing companies to improve production systems on efficiency without compromising flexibility quality, and workload on employees. Lean manufacturing and a participatory ergonomics approach were integrated and interactive tools were developed especially for use in SME. These approach and tools were applied to 37 SMEs. Increase of productivity of about 15-40 % and order lead time of 20-25 % were measured without any increase in physical load parameters.

Building the Design Space of an Electrostatic Chuck Used in the Plasma-Etching Process

Sun Yuchun, Ji Linhong, Hou Yuemin, Cheng Jia
Institute of Design Engineering, Tsinghua University, China

Electrostatic chuck (ESC) has been widely used in the plasma-based and vacuum-based semiconductor processing. ESC depends on the electrostatic force generated by an electrostatic electrode to adsorb wafers on its surface. ESC has technical advantages on non-edge exclusion, high reliability, wafer temperature control uniformity, wafer planarity, particles reduction and yielding improvement. However, the existing techniques of ESC also lead to several issues. To solve these issues, giving an overview of all the existing knowledge and techniques is impossible. This article extracts key design elements from the existing knowledge of ESC, uses TRIZ to widen the existing knowledge, and establishes a design space systematically. The design space composes of: (1) the current design space containing working objects, working principles and working structure. The working objects involve the ESC components and material, classifications, relevant properties and working signals; the working principles involve the electrostatic force generation and residual, heat transfer; the working structure combines the principles above to fulfill the overall function; (2) the expanded design space containing other possible design choices which are inspired by the inventive principles of the TRIZ theory and may be nonexistent now. Three cases are taken to illustrate how to expand the current design space with the contradiction matrix and separation principles. It is hoped that this article can inspire designers to know how to design ESC, how to resolve problems using TRIZ in the design process of ESC, as well as facilitate the ESC modeling.

Design Issues of IC Equipments and Solutions

Yuemin Hou, Linhong Ji
Institute of Design Engineering, Tsinhua University, China

The typical design method of a chamber system starts by investigating and comparing similar existing chamber systems. Some modifications to the processing parameters and structural dimensions are required depending on the difference of film characteristics. The modified parameters are then verified by processing simulation and experiments. When the produced film meets the required quality standards, the final design is completed and documented. This is essentially a trial-and-error process.

Two problems must be tackled in the design process. Firstly, *the simulation involves multi-field simulations*, which may include following: a continuum fluid flow simulation using a computational fluid-dynamic (CFD) model to compute the velocity and pressure distributions of the working gas inside the deposition chamber; a steady state plasma simulation for determining the flux and energy of the ions that strike either the target or the substrate; a transport simulation using Direct Simulation Monte Carlo (DSMC) for tracking the propagation (and energy loss) of target atoms through the working gas from the target to a substrate; a hyper-thermal kinetic Monte Carlo for relating the film surface morphology and atomic scale structure to the flux parameters and to the conditions of the vapour deposition process; and other simulations such as a electric field simulation, a magnetic field simulation, a thermal field simulation, and a component performance simulation. Plasma diagnosis equipments are also required for monitoring the state of the plasma inside the chamber.

All of these analyses, simulations and experiments are time consuming. Moreover, they are often not available in the first place because of the lack of professional analyzers and experts, tools and equipments. Consequently, only small modifications are usually made to the space distance of the electrodes (e.g. between the target material and the substrate), the pressure and the temperature inside the chamber. These modifications are sometime successful but not always. Even a minor modification requires various simulations to find optimum values of structural parameters and processing parameters. Hence, parameter optimization is required. Other parts of the chamber system may also need to be modified in consequence. For instance, the change in the space distance between the two electrodes requires a change in the detailed structure of the substrate support. A quick response to the change is preferable for making the production decision. On the other hand, minor modifications may occasionally fail to meet required film quality standards and major modifications or novel design is needed. The second problem is then how to complete the new design at lower cost and in shorter time? Put briefly, *the availability of multi-field simulation and rapid design is central to the competitive design of chamber systems*.

Achieving a rapid design and simulation system requires, firstly, that multi-field models be available and that the simulations be executed quickly. Secondly, an effective strategy must be set up for interactions, communication and trade-off between the multidisciplinary objectives. Finally, general design activities and domain knowledge can be programmed into computers to develop the detail parameters of the various components and elements.

The FBS (function-behaviour-structure) framework is used to establish a computer based system, but it is extended into six phrases including the function, surrogate, property, specification, feature and parameter phrases and the analysis, synthesis and evaluation activities are formulated into three mechanisms including gene-transcription, induction and commitment mechanisms, which benefit computing activities. Agents are used for the commitment mechanism to allow “situated” decision making, possibly by interaction between computers and human experts. KBE technology is used as the paradigm for programming knowledge and geometric description. The output of the platform can be either design or simulation. The objective of the presented work is to achieve partially autonomous design of chamber systems of IC equipments.

Next generation Design Systems

Michel van Tooren, Reinier van Dijk
Delft University of Technology, the Netherlands

The MDO concept is very well suited to help the designer in the exploration of a design domain. The definition of this domain and a proper guess for the initial value of the design variables, however, are left to the designer. These are difficult tasks which limit the applicability of the concept. Modern MDO frameworks try to overcome this hurdle by close couplings to CAD software, allowing the user to select parameters in the CAD model, serving as the design domain, as design variables and allowing the optimizer to use the CAD system to evaluate geometry based constraint and objective values and to query design object attributes. This works well for the sizing of relative simple parts that can be predefined in libraries or build up interactively by the user. In the former case the library functions as the knowledge base for the topology part of the product and the MDO framework adds the constraint and objective knowledge. Running the MDO generates knowledge about the best setting of the product’s attributes for the design case at hand. In the latter case the CAD system is used to define the topology of a specific member of a product family either by the CAD user himself or a knowledge engineer that predefined this family for the user. The CAD system in this case is used to solve geometric constraints belonging to the topology selection. The knowledge about the optimum to be found by the MDO framework will be valid for the preselected topology only. Changes of topology during optimization are normally not supported in this case.

For complex objects that are difficult to predefine with a single topology it can be useful to couple the MDO framework to a combination of a Knowledge base and a Knowledge Based Engineering application or even make the optimizer part of the KBE application. In our research we look into the first case. The coupling between MDO and a KB and KBE application serves multiple purposes:

1) It adds generative geometry capability to the MDO framework

2) It adds a generative MDO problem definition capability to the MDO framework

3) It adds a knowledge storing capability to the MDO framework

Generative geometry modeling

Since a KBE application is per definition generative it can be used to generate a topology based on rules and associated calculations. The geometry required by the MDO so becomes a result of a parameterization on product knowledge level and is not the parameterization itself. The Knowledge Base adds accessibility to the KBE application or even to the KBE system. Many designers are not interested in direct interaction with a KBE application or system. Adding a knowledge base that allows for text based and graphics based interaction largely improves the accessibility of the system. It also allows for the storage of the rationale behind the product families adding understanding of and confidence in the appropriateness of the product model.

Generative problem definition

Setting up a MDO problem is not an easy task. The intent behind the application of an MDO framework is often to give less experienced designers access to prior experience in the company. Expecting these less experienced engineers to set up an appropriate MDO problem is not realistic. By storing and re-using the associated knowledge through KBE and a KB the knowledge gap is closed and reliable sizing can be expected also from less experienced designers. Through the availability of Design Rationales the system helps the learning of its users, helping experience building and not creating dumb users.

Knowledge storage

Design and analysis are highly knowledge intensive. Assuring the completeness of requirements and compliance is time consuming and error prone. Often repetition of errors occurs from project to project. Accessible and understandable storage of knowledge is a sure benefit for every organization. Coupling a KB to an MDO framework helps re-use of knowledge but also the capture of knowledge resulting from the MDO application. Application of ontologies and triple stores proves to deliver access to assorted, and appropriate knowledge. Using the results of the MDO calculations with the associated constraint and objective function history assures availability of the rationale behind the choices made by the system and is therefore a source of knowledge for next projects thereby closing the knowledge loop.

The End