

**10th International Seminar
Numerical Analysis for Weldability**

**September 24 – 26, 2012
Graz - Seggau**

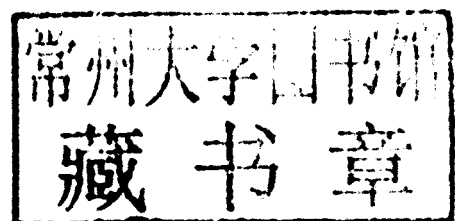
WELCOME NOTE

information to the seminar

**10th International Seminar
Numerical Analysis for Weldability**

**September 24 – 26, 2012
Graz - Seggau**

**ABSTRACTS
&
AUTHOR INDEX**



sorted according to final programme



Institute for Materials Science and Welding

To the
Participants of the 10th International Seminar
'Numerical Analysis of Weldability'

Univ.-Prof. Dipl.-Ing. Dr. techn.
Christof Sommitsch
Head of the Institute

Kopernikusgasse 24/I
A-8010 Graz

Tel. +43 (0316) 873-7180
Fax +43 (0316) 873-7187

christof.sommitsch@tugraz.at
office@iws.tugraz.at
<http://iws.tugraz.at>

DVR: 008 1833 UID: ATU 574 77 929

Graz, September 2012

10th International Seminar 'Numerical Analysis of Weldability'

Welcome

We welcome you very cordially at *Schloss Seggau* at the 10th International Seminar 'Numerical Analysis of Weldability'.

Please enjoy the beauty of the castle and the wine area of Southern Styria. If you have any questions please do not hesitate to contact any member of our group (you can recognize us by our orange name badges).

SCIENTIFIC PROGRAMME

Please find the final programme in your folder.

Authors are kindly asked to provide necessary information and material to the session chairmen. Please also check functionality of your presentation devices, such as computer etc., ahead of time. Assistance from our team will be available.

The final manuscripts which have not yet been submitted must be uploaded during the time of the conference. Please ask for support at the registration desk.

POSTER SESSIONS

The posters are accessible during the whole seminar. Coffee breaks are served in the poster session rooms. All authors are kindly asked and invited to stay with their posters during the breaks. If you need assistance with your poster, please contact **Bernhard Sonderegger** or **Johannes Tändl**.

MANUSCRIPTS

After the conference the manuscripts will be sent out for the peer-review process. After possible revision you must submit the original files and artwork. Detailed instructions will be communicated at a later time.

MEALS

All meals during the seminar will be served in the 'Speisesaal' in the new part of the castle.

Vegetarian meals are available.

TRANSPORTATION

All participants who want and/or need assistance in organizing transportation to the railway station or the airport after the seminar can put their desired time of departure and destination into a list which will be available at the registration desk. For any questions please contact the registration desk.

SOCIAL EVENTS

Welcome party (Sunday, September 23, 2012, 19:00 hrs)

The welcome party will take place at the 'Glockenwiese' (bad weather: 'Fürstenzimmer') in the upper castle courtyard. After a cocktail with a musical performance of the band 'La Trombalia' (trumpet music), we will have a joint dinner in the 'Speisesaal'.

Knight's banquet in the great hall of Schloss Kornberg (Monday, September 24, 2012, 19:00 hrs)

Bus departure to *Schloss Kornberg for the knight's banquet at 18:00 hrs!* The busses will wait in front of the castle.

Styrian Evening (Tuesday, September 25, 2012, 18:30 hrs)

Austrian miner sword dance: performance of a group from St. Martin/Sulmtal. Afterwards visit of the historic wine cellar at *Schloss Seggau* with wine tasting. Please take a sweater with you. After this event we will have a Styrian Evening with Styrian buffet in the 'Speisesaal'.

If you have any questions, need assistance or something else, please do not hesitate to contact any member of our team. We wish you a pleasant stay at Seggau castle and a most successful seminar.

Christof Sommitsch, Norbert Enzinger, Isabella Scheiber
and the many members of the organizing team.

CONTENT

I Melt Pool & Arc Phenomena

Monday, September 24, 09:05 - 12:20 hrs

MP&AP1	Keynote Multi-physical finite element simulation of an electromagnetic weld pool support in full-penetration high power laser beam welding of metal plates M. Bachmann, Vj. Avilov, A. Gumenyuk, M. Rethmeier	1
MP&AP2	A numerical and experimental study of heat and mass transfer during GTA welding of different austenitic stainless steels K. Koudadje, M. Medale, C. Delalondre, J. M. Carpreau	2
MP&AP3	Different strategies to simulate a deep penetration welding process M. Gatzen, K. Chongbunwatana	3
MP&AP4	Simulation of heat and fluid flow with the free surface in 3D gas tungsten arc welding X. Kong, O. Asserin, S. Gounand, P. Gilles, J.-M. Bergheau, M. Medale	4
MP&AP5	Numerical simulation of arc and metal transfer in gas metal arc welding M. Hertel, U. Füssel, M. Schnick, U. Reisgen, O. Mokrov, A. Zabirov, A. Spille-Kohoff	5
MP&AP6	Multiphysics modeling of GTAW process and experimental validation for investigating the weld pool formation S. SREEDHAR, S. Rouquette, F. Soulié, G. FRAS	6
MP&AP7	Modelling of the droplet formation process in GMA welding O. Semenov, V. Demchenko, I. Krivtsun, U. Reisgen, O. Mokrov, A. Zabirov	7
MP&AP8	Study of the explosion effect in electrode metal droplets of binary AlMg alloys in GMA welding U. Reisgen, O. Mokrov, A. Zabirov, I. Krivtsun, V. Demchenko, O. Lisnyi, I. Semenov	8

II Modelling tools & computer programs

Monday, September 24, 13:50 - 16:45 hrs

MT&CP1	Keynote Numerical Simulations of micro-, macro-, and mega-scale structurization by welding processes M. Mochizuki	9
MT&CP2	Towards the industrial application of welding simulation via standardisation C. Schwenk, D. Tikhomirov, B. Lenz, J. Hildebrand	10

MT&CP3	Optimization of a heat source using ABC algorithm L. Wittwer, N. Enzinger	11
MT&CP4	Simulation of multi-pass welding of high strength steel H. Gao, R. K. Dutta, M. J. M. Hermans, I. M. Richardson	12
MT&CP5	Hybrid intelligent technique based models for estimating weld bead width and depth of penetration from the infra-red thermal images of weld pool N. Chandrasekhar, M. Vasudevan, A. K. Bhaduri, T. Jayakumar	13
MT&CP6	Linear friction welding of high strength chains: modelling and validation K. Mucic, J. Lopera, F. Fuchs, N. Enzinger	14
MT&CP7	OMS: A computer algorithm to develop closed-form solutions to multicoupled, multiphysics problems P. F. Mendez, N. Stier	15

III Cracking Phenomena

Tuesday, September 25, 08:30 - 10:35 hrs

CP1	Keynote Modelling of hot cracking phenomenon in welding with a coupled cellular automaton- finite element model A. Niel, C. Bordreuil, F. Deschaux-Beaume, G. Fras	16
CP2	Finite element analysis of the cast pin tear test T. C. Luskin, B. T. Alexandrov, J. C. Lippold, S. L. McCracken	17
CP3	Numerical investigations of hydrogen assisted cracking in duplex stainless steel microstructures T. Mente, T. Böllinghaus	18
CP4	Experimental and numerical analysis of local thermomechanical behaviour for hot cracking assessment in welds C. Gollnow, T. Kannengiesser, R. Lauer, M. Dong, R. Riekers	19
CP5	Simulation of multipass welding of a steel pipe including modelling of hydrogen diffusion and fracture mechanics assessment H. G. Fjær, S. K. Aas, V. Olden, D. Lindholm, O. M. Akselsen	20
CP6	Numerical analysis of liquation cracking in aluminium alloy welded joints J. Martikainen, E. Hiltunen, V. Karkhin, S. Ivanov	21

IV FSW

Tuesday, September 25, 11:05 - 12:30 hrs

FSW1	Keynote Novel approaches to modelling metal flow in friction stir spot welding A. Reilly, H. R. Shercliff, G. J. McShane, Y. Chen, P. Prangnell	22
------	---	----

FSW2	Material flow study during friction stir welding process using computational fluid dynamics simulation M. Awang	23
FSW3	An estimation of variable stresses on friction stir welding tool M. Mehta, G. M. Reddy, A. V. Rao, A. De	24
FSW4	Physical and numerical simulation of microstructure evolution in friction stir spot welding of AA6082 Z. Gao, J. T. Niu, F. Krumphals, N. Enzinger, C. Sommitsch	25

V Residual stresses & distortion

Tuesday, September 25, 14:00 - 16:05 hrs

RS&D1	Keynote Simulation of welding stresses for fatigue design of welded tubular connections C. Acevedo, J. M. Drezet, A. Nussbaumer	26
RS&D2	Equivalent inherent strain method for prediction of welding induced distortion A. Mendizabal, M. San Sebastian, A. Echeverria	27
RS&D3	Finite element analysis of weld residual stress in an UOE linepipe subjected to mechanical expansion S. W. Wen, M. Connelly	28
RS&D4	Welding of thick steel plates under rough environmental conditions J. Klassen, T. Nitschke-Pagel, K. Dilger	29
RS&D5	Numerical analysis of welding distortion behavior of a car door R. Thater, W. Perret, M. Rethmeier	30
RS&D6	Development of phase transformation-induced compressive residual stresses around the weld joint: Numerical modeling T. Alghamdi, S. Liu	31

VI Microstructure modelling in WM & HAZ

Tuesday, September 25, 16:35 - 17:40 hrs

MM&H1	Keynote Progress in modeling of multi-phase multi-component precipitation kinetics in Al and Fe-based alloys E. Kozeschnik	32
MM&H2	Fracture toughness evaluation of thin Fe-Al intermetallic compound layer formed at reactive interface of dissimilar metal joints N. Kyokuta, M. Koba, T. Araki, S. Nambu, J. Inoue, T. Koseki	33
MM&H3	Calculation of three-dimensional grain shape statistics from two-dimensional EBSD orientation data J. Zachrisson, J. Börjesson	34

VII Service behaviour of welded structures

Wednesday, September 26, 08:30 - 09:55 hrs

SB&WS1	Keynote Prediction of bearing capacity and fracture mode of spot welds of high strength steels D. Fabrègue, S. Dancette, V. Massardier, J. Merlin, R. Estevez, T. Dupuy, M. Bouzekri	35
SB&WS2	Fracture mechanical analysis of cross tension test for high-strength steel spot welded joints F. Watanabe, S. Furusako, H. hamatani, Y. Miyazaki and T. Nose	36
SB&WS3	Simulation of the mechanical behavior of dissimilar welded joints between Ni-based alloy and steel T. Klein, C. Feuillette, M. Speicher, A. Klenk, K. Maile	37
SB&WS4	Numerical simulation on the effect of HAZ softening on static tensile strength of HSLA steel welds W. Maurer, W. Ernst, R. Rauch, S. Kapl, R. Vallant, N. Enzinger	38

VIII Processes / miscellaneous

Wednesday, September 26, 10:30 - 11:55 hrs

MT&CP1	Keynote Simulation of micro-plasmapowder deposition for advanced welding torch design K. Alaluss, G. Bürkner, P. Mayr	39
MT&CP2	A multi-physic level set approach for the simulation of the hybrid laser / GMAW process O. Desmaison, G. Guillemot, M. Bellet	40
MT&CP3	Mathematical model of plasma jet for plasma arc brazing B. E. Carlson, H.-P. Wang, G. A. Turichin, Y. A. Valdaitseva, S. Y. Ivanov, V. A. Karkhin	41
MT&CP4	Soldering of aluminum matrix composites SiCp/A356 and kovar alloy J. T. NIU, X. T. Wang, Z. Gao, D. f. Cheng	42

Posters

I Melt pool & arc phenomena

- | | | |
|-----|--|----|
| PS1 | Three dimensional modelling and measurement of a GTAW electric arc and heat exchanges with a metallic weld plate
D. Borel, J. M. Carpreau, B. G. Chéron, C. Delalondre, J. Anglès | 43 |
| PS2 | A time dependent model of GMAW using experimentally determined geometry of wire and droplet
M. Schnick, M. Haessler, S. Rose, M. Hertel, U. Füssel, A. Spille-Kohoff | 44 |
| PS3 | Keyhole modeling of Nd:YAG laser welding of stainless steel butt joint
K. R. Balasubramanian | 45 |
| PS4 | Analysis of heat and fluid flow phenomena of double-sided V groove welds of high-strength low alloy steel
J. Chen, A. Pittner, C. Heinze, C. S. Wu, M. Rethmeier | 46 |

II Modelling tools & computer programs

- | | | |
|-----|--|----|
| PS5 | Study of kinematic strain hardening law in transient welding simulation
M. Ottersböck, M. Stoschka, M. Thaler and H. Krampfl | 47 |
| PS6 | Analysis of laser welding process parameters using central composite design of design of experiments
K. R. Balasubramanian | 48 |
| PS7 | Numerical analysis for obtaining feasible solution on maintenance welding at blast furnace of visakhapatnam steel plant - visakhapatnam - india
A. Pandi | 49 |
| PS8 | Mathematical model of filler metal heating and melting for plasma arc brazing
B. E. Carlson, H.-P. WANG, V. A. Karkhin, S. Y. Ivanov, G. A. Turichin, Y. A. Valdaitseva | 50 |
| PS9 | Combination of geometrical simplification techniques for very large welded structures
M. Söderberg, A. Lundbäck | 51 |

III Cracking phenomena

- | | | |
|------|--|----|
| PS10 | Simulation-based hot cracking analysis in Al laser welding
F. Lu, H.-P. Wang, B. Carlson, X. Wang | 52 |
|------|--|----|

IV FSW

- | | | |
|------|---|----|
| PS11 | Thermal and microstructural modelling of Al-Al and Al-Fe friction stir spot welding
P. Jedrasiak, A. Reilly, H. R. Shercliff, G. J. McShane, Y. Chen, J. D. Robson, P. Prangnell | 53 |
|------|---|----|

PS12 Modelling heat generation by frictional and plastic dissipation in friction stir welding using a CFD approach H. B. Schmidt	54
---	----

V Residual stresses & distortion

PS13 Effect of weld pass sequence on residual stresses of a welded mild steel plate J. R. V N J Dhanyamraju	55
PS14 Prediction of welding distortions in a complex structure using finite element modelling: experimental validation A. Mendizabal, M. San Sebastian, A. Echeverria	56

VI Microstructure modelling in WM & HAZ

PS15 Simulation of phase transformations for the calculation of the welding stresses in steel structures A. S. Kurkin, E. L. Makarov, A. B. Kurkin	57
PS16: On the influence of time and temperature on material characteristics N. den Uijl, P. van Liempt, S. van Bohemen, K. Bos	58
PS17: On the modeling of austenite grain growth in micro-alloyed HS steel S700MC M. Rahman, M. Albu, N. Enzinger	59

VII Service behaviour of welded structures

PS18: The welded structure lifetime evaluation with account of technological factors A. S. Kurkin, G. P. Batov and I. N. Ponomareva	60
PS19: Application of high pressure rolling to a friction stir welded aerospace panel P. Colegrove, J. Ding, M. Benke, H. Coules	61

MULTI-PHYSICAL FINITE ELEMENT SIMULATION OF AN ELECTROMAGNETIC WELD POOL SUPPORT IN FULL-PENETRATION HIGH POWER LASER BEAM WELDING OF METAL PLATES

M. BACHMANN*, V. AVILOV*, A. GUMENYUK* AND
M. RETHMEIER*

**BAM Federal Institute for Materials Research and Testing,
Unter den Eichen 87, 12205 Berlin, Germany*

ABSTRACT

The influence of an alternating current (ac) magnetic field during full-penetration laser beam welding of thick metal plates was investigated numerically using a three-dimensional steady state model calculating for the fluid flow, temperature and electromagnetic field variables. The finite element software (FEM) COMSOL Multiphysics was used. Most important physical effects were taken into account here: Thermocapillary (Marangoni) convection, natural convection as well as the latent heat of melting/solidification phase transition. The Carman-Kozeny equation was used to account for porous media morphology in the solid-liquid transition zone. The ac magnet is located below the welded plate. The externally applied magnetic field is aligned parallel to the plate surface and perpendicular to the welding direction. The investigations were conducted for 20 mm aluminium plates. It is shown that a 70 mT(rms) ac magnetic field is enough to prevent the gravity-driven drop-out of the melt. The results of the calculations are in a good agreement with experimental data for 15 kW fibre laser beam welding of up to 30 mm thick Al-alloy plates.

A NUMERICAL AND EXPERIMENTAL STUDY OF HEAT AND MASS TRANSFER DURING GTA WELDING OF DIFFERENT AUSTENITIC STAINLESS STEELS

Koffi KOUDADJE^{*,**}, Marc MEDALE^{**}, Clarisse DELALONDRE^{*},
Jean Michel CARPREAU^{***}

^{*}EDF Research & Development, Chatou FRANCE.

^{**}Aix-Marseille University IUSTI CNRS UMR 7343, Marseille, FRANCE.

^{***}LaMSE UMR EDF-CNRS-CEA 2832, Clamart FRANCE.

ABSTRACT

Because of the important effects of weld pool convection on properties of resulting weld, a numerical model has been developed to investigate the weldability of stainless steels. In this study, the evolution of temperature and fluid flow during gas tungsten arc (GTA) welding is investigated. The physical model takes into account heat and mass transfer, electric transport and resulting magnetic field, it considers Marangoni force, self-induced electromagnetic force and buoyancy force for the weld pool convection. This model has been implemented in *Code Saturne*® (CFD open source code developed by EDF R&D) and used to compute the numerical results presented in the present paper. In order to validate the model, experimental weld beads were made with GTA process, considering different welding parameters and different 304L stainless steel sulphur concentrations. Thermal time evolutions were measured at several positions and post mortem macrographies were analyzed to determine the weld pool cross section sizes. After some fitting of surface tension and global heat loss coefficients the computed weld characteristics are in good agreement with corresponding experiments.

DIFFERENT STRATEGIES TO SIMULATE A DEEP PENETRATION WELDING PROCESS

M. GATZEN*, K. CHONGBUNWATANA*

** BLAS – Bremer Institut fuer angewandte Strahltechnik GmbH, Klagenfurter Str. 2, D-28359 Bremen, Germany
gatzem@blas.de*

ABSTRACT

Within the last two decades, the numerical simulation of welding processes has become more important due to an increase in the available computing power. However, due to the complexity of these processes a variety of different phenomena have to be considered, still resulting in a huge demand for spatial and temporal resolution and hence calculation time. Especially for the case of deep penetration laser beam welding, a vast scope of different velocities, ranging from the extraordinarily fast keyhole process to the comparatively slow melt pool dynamics, have to be considered.

In this paper, two different transient simulation approaches for a deep penetration laser beam welding process are discussed. The first describes the laser beam absorption and evaporation process resulting in the evolution of a typical keyhole, while the second model describes the melt pool dynamics and evolution of the resulting weld seam. Both models focus on different key aspects of the welding process and use different modelling techniques (FEM and FVM), dimensions of the model geometries and degrees of complexity. The adaptive time step size defines if the model can be used to simulate a welding process over nearly a second or only a few milliseconds within a maintainable calculation time.

Simulation of heat and fluid flow with the free surface in 3D gas tungsten arc welding

X Kong^{1,2,3}, O Asserin¹, S Gounand¹, P Gilles², JM Bergheau³ and M Medale⁴

¹CEA, DEN, DANS, DM2S, F-91191 Gif-sur-Yvette, France

²AREVA NP, Paris La Défense, France

³LTDS, Ecole Nationale d'Ingénieurs de Saint-Etienne, France

⁴Ecole Polytechnique Universitaire de Marseille, Marseille, France

E-mail: xiaofei.kong@enise.fr, olivier.asserin@cea.fr

Abstract. The aim of this paper is to propose a three-dimensional weld pool model for the moving gas tungsten arc welding (GTAW) process, in order to understand the main factors that limit the weld quality and improve the productivity, especially with respect to the welding speed. Simulation is a very powerful tool to help in understanding the physical phenomena in the weld process. A 3D finite element model of heat and fluid flow in weld pool considering free surface of the pool and traveling speed has been developed for the GTAW process. Cast3M software is used to compute all the governing equations. The free surface of the weld pool is calculated by minimizing the total surface energy. The combined effects of surface tension gradient, buoyancy force, arc pressure, arc drag force to drive the fluid flow is included in our model. The deformation of the weld pool surface and the welding speed affect fluid flow, heat flow and thus temperature gradients and molten pool dimensions. Welding trials study is presented to compare our numerical results with macrograph of the molten pool.

NUMERICAL SIMULATION OF ARC AND METAL TRANSFER IN GAS METAL ARC WELDING

M. HERTEL*, U. FÜSSEL*, M. SCHNICK*, U. REISGEN**,
O. MOKROV**, A. ZABIROV** AND A. SPILLE-KOHOFF***

* *Technische Universität Dresden, Germany*

** *RWTH Aachen University, Germany*

*** *CFX Berlin Software GmbH, Germany*

ABSTRACT

The gas metal arc welding process (GMAW) is one of the most common welding processes. Present process modelling is firstly aiming for the increase of the process understanding and secondly for the development of tools to predict the properties of the resulting joint. However, the validity of actual models is still restricted by the high complexity of the process. So far the GMAW models published were either based on a complex model of the arc, neglecting the metal transfer, or combining the arc and the metal transfer models, in which the characteristics of the arc are highly simplified. Both approaches lead to serious disadvantages for the prediction of the process.

In this paper we discuss improved approaches to model the GMAW arc and the metal transfer in a more accurate manner. Therefore a MHD arc model is combined with a 2T sheath model of the non-equilibrium layer near the workpiece, and the applicability of a P1 radiation transport model is proven. Furthermore, a combination of the improved GMAW arc model with a VOF based metal transfer model is described. In the new model, metal evaporation is calculated self consistently. Calculations of the droplet formation and arc temperature distribution are in remarkable agreement with measurements.

MULTIPHYSICS MODELING OF GTAW PROCESS AND EXPERIMENTAL VALIDATION FOR INVESTIGATING THE WELD POOL FORMATION

U. SREEDHAR, S. ROUQUETTE, F. SOULIE and G. FRAS

*LMGIC, University of Montpellier 2-CNRS
Cc048, Place Eugene Bataillon 34095 Montpellier Cedex, France*

ABSTRACT

A 2D-axisymmetric model for the static Gas Tungsten Arc Welding is presented in this paper. The weld pool model was developed by considering the various driving forces in the weld pool convection such as self-induced electromagnetic, surface tension, buoyancy and the arc plasma drag force. It is found that the model can effectively be used for the prediction of weld pool shape and the temperature distribution in the fusion zone. The simulation results show the dependence of the major driving forces in the development of the weld pool geometry and a reasonable comparison with the experimental data for 304 stainless steel. A reliable experimental setup is used for the acquisition and synchronisation of different experimental data.

MODELLING OF THE DROPLET FORMATION PROCESS IN GMA WELDING

O. SEMENOV, V. DEMCHENKO*, I. KRIVTSUN*, U. REISGEN**,
O. MOKROV** and A. ZABIROV**

**Paton Welding Institute, Kyiv, Ukraine*

***RWTH Aachen University, ISF-Welding and Joining Institute, Aachen, Germany*

ABSTRACT

The mathematical model of electrode metal droplet formation during GMAW is proposed. The model concerned allows for influence of surface tension, gravitation and Lorentz force upon the droplet. For the calculation of molten metal free surface form the slender jet approximation of Navier-Stokes equations is used. The anode voltage drop is taken into account while calculating the characteristics of electromagnetic field (electric potential, current density, electromagnetic forces). Effect of anode region dimensions on the volume of detached droplets and frequency of its detachment is analyzed.