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## ABSTRACTS

# WELDING IN THE WORLD

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## TECHNICAL PAPERS

***IIW-1914-08 (ex-doc. II-1658r1-07/II-A-183r1-07)***

Determination of residual stresses in Low Transformation Temperature (LTT-) weld metals using X-ray and high energy synchrotron radiation

*A. Kromm, Th. Kannengiesser, J. Gibmeier, Ch. Genzel (Germany), V. van der Mee (The Netherlands)*

***IIW-1936-08 (ex-doc. II-1675-08)***

Study of hot cracking behaviour of 14Cr-15Ni-2.5Mo Ti-modified fully austenitic stainless steels using Varestraint and hot ductility tests

*A.K. Bhaduri, G. Srinivasan, B. Raj (India), A. Klenk (Germany)*

***IIW-1929-08 (ex-doc. II-1678-08)***

Examination of joints of different weld metals

*J. Heinemann, J. Tuchtfeld (Germany)*

***IIW-1928-08 (ex-doc. II-1693-08/II-A-193-08)***

Shielding gas oxygen additions as a means of curbing nitrogen degassing during the autogenous arc welding of nitrogen-alloyed stainless steel

*M. Du Toit, P.C. Pistorius (South Africa)*

***IIW-1916-08 (ex-doc. IV-932r1-07)***

Thick plate CO<sub>2</sub>-laser based hybrid welding of structural steels

*J.K. Kristensen (Denmark)*

***IIW-1930-08 (ex-doc. IV-961-08)***

Interaction between laser beam and arc in hybrid welding processes for dissimilar materials

*C. Thomy, F. Möller, G. Sepold, F. Vollertsen (Germany)*

***IIW-1933-08 (ex-doc. SG-212-1129r1-08)***

Development and application of on-line weld modelling tool

*W. Zhang, Y-P. Yang (United States)*

## ANNOUNCEMENTS

Coming events

## RESEARCH SUPPLEMENT

***IIW-1905-08 (ex-doc. XII-1917r1-07)***

**Henry Granjon Prize Competition 2007 Winner, Category A**

Utilization of the arc light emission emitted during TIG welding to monitoring this process

*M.Ś. Węglowski (Poland)*

***IIW-1925-08 (ex-doc. SC-Auto-020r1-08)***

Friction stir spot welds between aluminium and steel automotive sheets: Influence of welding parameters on mechanical properties and microstructure

*G. Figner, R. Vallant, T. Weinberger, H. Schröttner, H. Pašič, N. Enzinger (Austria)*

# DETERMINATION OF RESIDUAL STRESSES IN LOW TRANSFORMATION TEMPERATURE (LTT-) WELD METALS USING X-RAY AND HIGH ENERGY SYNCHROTRON RADIATION

## ABSTRACT

Crack and fatigue resistance are relevant evaluation criteria for welded joints and are decreased by tensile residual stresses resulting from the welding and cooling process, while compressive residual stresses can have a positive influence on the characteristics mentioned. In order to generate compressive residual stresses, a set of post weld treatment procedures is available, like shot peening, hammering, etc. These procedures have the disadvantage that they are time and cost extensive and have to be applied after welding. As another point, such technologies can only produce compressive stresses at the top surface, i.e. can only contribute to the reduction of the risk of cracks initiated at the surface, like fatigue cracks. A chance to generate compressive stresses over the complete weld joint during the welding procedure is offered by the so-called Low Transformation Temperature (LTT -) filler wires. Compared to conventional wires, these materials show lower phase transformation temperatures, which can work against cooling-related tensile stresses, resulting from respective shrinkage restraint. In consequence, distinct compressive residual stresses can be observed within the weld and adjacent areas. The strength of these fillers makes them potentially applicable to high-strength steel welding. Welds produced with different LTT – filler wires have shown different levels and distributions of the resulting residual stresses depending on the specific transformation temperature. The transformation temperatures are determined by temperature measurement. Classical X-ray diffraction as well as diffraction methods using high energy synchrotron radiation have been used for residual stress analysis. By means of high energy synchrotron diffraction in reflection mode residual stress depth gradients can be determined non-destructively. The phase selective nature of the diffraction measurements enables the simultaneous determination of the phase specific residual stresses of all contributing crystalline phases within one experiment. The application of white beam diffraction implies recording of a multitude of diffraction lines within the energy range of the provided energy spectrum of the white beam. By this means phase specific residual stress depth distributions up to distances of 150 µm below the surface can be analysed for steel using the energy dispersive set-up of the HMI-beamline EDDI at the Bessy site, Berlin, providing an energy range between 20-150 keV. As a side effect quantitative phase analysis can be carried out using white energy dispersive diffraction e.g. the determination of the content of retained austenite in the weld.

**IIW-Thesaurus keywords:** *Filler materials; Low temperature; Reference lists; Residual stresses; Temperature; Transformation.*

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Doc. IIW-1914-08 (ex-doc II-1658r1-07/ II-A-183r1-07) recommended for publication by Commission II "Arc Welding and Filler Metals".

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# STUDY OF HOT CRACKING BEHAVIOUR OF 14Cr-15Ni-2.5Mo Ti-MODIFIED FULLY AUSTENITIC STAINLESS STEELS USING VARESTRAINT AND HOT DUCTILITY TESTS

## ABSTRACT

Studying the hot cracking behaviour of 14Cr-15Ni-2.5Mo Ti-modified austenitic stainless steel is an important weldability consideration because this material solidifies in the prior austenitic mode without any residual delta ferrite and also contains titanium. Hot cracking in this material is attributed to the formation of low melting phases in the solidifying weld metal and in the heat-affected zone that lead to cracking due to shrinkage stresses and restraint imposed on the weld joint. Different heats of this fully austenitic alloy, containing 0.022-0.025 % P, 0.75-1.00 % Si and 0.21-0.42 % Ti, as well as 316L stainless steel (SS) were investigated. Both Varestraint and hot ductility tests were used to evaluate the hot cracking susceptibility of these alloys. Longitudinal Varestraint tests were carried out at four strain levels of 0.5, 1.0, 2.0 and 4.0 %, and the brittleness temperature range (BTR) was evaluated during testing. The Varestraint test results indicated that this material has a very high hot cracking susceptibility during autogenous welding, as the total crack length and maximum crack length in both the weld and heat-affected zone as also the BTR values were very high compared to that of SS 316L. Hot ductility tests were also conducted on using a Gleeble thermo-mechanical simulator to determine the nil ductility temperature (NDT). The NDT of this material is lower than SS316L, with the material containing higher titanium and silicon. This paper discusses the results of the hot cracking behaviour of this fully austenitic SS material using the longitudinal Varestraint and hot ductility tests.

**IIW-Thesaurus keywords:** *Austenitic stainless steels; Cracking; Defects; Ductility; Hot cracking; Mechanical properties; Reference lists; Stainless steels; Steels; Thermal cycling.*

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Doc. IIW-1936-08 (ex-doc II-1675-08) recommended for publication by Commission II "Arc Welding and Filler Metals".

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# EXAMINATION OF JOINTS OF DIFFERENT WELD METALS

## ABSTRACT

Nickel and nickel-base alloys are vitally important to modern industry because of their ability to withstand a wide variety of severe operating conditions involving cryostatic applications, high stresses, high temperatures, corrosive environments and combinations of these factors. The manufacturing industry of nickel alloys therefore has to deal with different standardised testing procedures, which have to be executed depending on the application. The article gives an overview of applied testing procedures in different application fields.

**IIW-Thesaurus keywords:** *COD; Corrosion tests; Cryogenics; High temperature; Temperature; Liquefied gases; Mechanical properties; Nickel alloys; Testing.*

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Doc. IIW-1929-08 (ex-doc II-1678-08) recommended for publication by Commission II "Arc Welding and Filler Metals".

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## SHIELDING GAS OXYGEN ADDITIONS AS A MEANS OF CURBING NITROGEN DEGASSING DURING THE AUTOGENOUS ARC WELDING OF NITROGEN-ALLOYED STAINLESS STEEL

### ABSTRACT

This study examined the influence of oxygen additions (0.5 % to 2.0 %) to argon-rich shielding gas on nitrogen degassing during the autogenous arc welding of a high-manganese nitrogen-alloyed austenitic stainless steel, previously commercially available under the trade name of Cromanite. Autogenous arc welding of this steel in inert shielding gas results in considerable nitrogen losses from the weld pool, characterised by an unstable arc, spattering and violent metal expulsion from the weld pool. Oxygen additions to the shielding gas stabilise the arc and curb nitrogen-induced porosity, but at least 2.0 % oxygen (by volume) is required to maintain the weld metal nitrogen content at the level of the parent material prior to welding. The beneficial effect of oxygen additions to the shielding gas is attributed to the formation of a solid  $\text{MnCr}_2\text{O}_4$  spinel phase on the weld pool surface during welding, which retards nitrogen degassing by reducing the area available for the adsorption of nitrogen atoms prior to their recombination to form  $\text{N}_2$ . This layer has a granular, irregular appearance and presents a less effective barrier to nitrogen degassing than the continuous, uniform liquid slag layer that forms when the Cr-Ni 300-series austenitic stainless steels are welded in oxygen-containing shielding gas mixtures.

**IIW-Thesaurus keywords:** *Absorption; Arc welding; Austenitic stainless steels; Cavities; Defects; Degassing; Gases; Nitrogen; Oxides; Oxygen; Porosity; Reference lists; Stainless steels; Steels.*

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Doc. IIW-1928-08 (ex-doc II-1693-08/ II-A-193-08) recommended for publication by Commission II "Arc Welding and Filler Metals".

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# THICK PLATE CO<sub>2</sub>-LASER BASED HYBRID WELDING OF STRUCTURAL STEELS

## ABSTRACT

Laser and hybrid laser-arc welding are after two decades of intensive work now well-established processes in the welding of structural steels as well as other materials. Many results have been reported over the years and many advantages in comparison with traditional welding processes have been obtained. Very thick part laser welding using penetration depth in excess of approximately 12 mm in structural steel does however continue to be a serious challenge. This is partly due to limitations in the achievable welding depth because the penetration as a function of laser power shows a very non-linear behaviour, and partly to the large molten volume that must be controlled. Although fibre- and disc-lasers today are being developed to high powers, CO<sub>2</sub>-lasers sources are still dominating larger penetration welding. In the present investigation the potential and limitations of hybrid CO<sub>2</sub>-laser/MAG welding of thick plate structural steels have been investigated. Welds in excess of 12 mm thickness of structural steels are presented together with achieved mechanical properties as e.g. hardness, toughness and fatigue. The investigations were made using structural steels of the grades S235, S355 and S690QL.

**IIW-Thesaurus keywords:** *Combined processes; Laser welding; Mechanical properties; Photon beam welding; Plate; Radiation welding; Steels; Structural steels; Thick.*

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Doc. IIW-1916-08 (ex-doc IV-932r1-07) recommended for publication by Commission IV "Power Beam Processes".

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# DEVELOPMENT AND APPLICATION OF ON-LINE WELD MODELLING TOOL

## ABSTRACT

On-line software tool, E-Weld Predictor, has been developed to predict temperature, microstructure, stress, and distortion for arc welding processes by combining the power of numerical weld modelling and high performance computational hardware. It provides users with easy access to advanced modelling tools over the internet to quickly explore various welding scenarios. This paper reveals the underlying mathematical equations implemented in E-Weld Predictor and discusses several applications of E-Weld Predictor. One application is to understand the effect of heat input on the resulting microstructure, residual stresses and distortion for a U-groove X-65 steel butt joint. Results show that a larger heat input is likely to result in higher heat build-up, larger residual stresses and larger distortion. Another application is to calculate the cooling rates for a narrow groove X-100 steel weld. The results show that increase of preheating temperature reduces the cooling rate. It is hoped that by providing easy-to-use and accessible advanced weld models, the usage of the computational models will be increased by welding and design engineers in the industrial companies.

**IIW-Thesaurus keywords:** *Computation; Deformation; Distortion; Finite element analysis; Microstructure; Reference list; Residual stresses; Welding.*

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Doc. IIW-1933-08 (ex-doc SG-212-1129r1-08) recommended for publication by SG-212 "The physics of welding".

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## **RESEARCH SUPPLEMENT**

### **HENRY GRANJON PRIZE COMPETITION 2007**

**Winner, Category A**

**"Joining and Fabrication Technology"**

#### **UTILIZATION OF THE ARC LIGHT EMISSION EMITTED DURING TIG WELDING TO MONITORING THIS PROCESS**

##### **ABSTRACT**

Recording results of visual radiation intensity of the TIG welding arc have been presented. The correlation between welding parameters and the intensity of welding arc visual radiation has been examined. The influence of disturbances of the welding processes on its radiation intensity was examined. By using the TIG arc model described in the literature, a mathematical correlation between the welding current intensity, the welding arc length, and the intensity of visual radiation of the arc has been developed, which takes into account the uncertainty of measurements. The results are compared with data received by using artificial neuron networks. The influence of transient states of the welding arc length on its radiation intensity was examined. It was concluded, that monitoring of the TIG welding arc visible radiation can be used for monitoring of the welding process

*IIW-Thesaurus keywords: Arc welding; Dimensions; Electric arcs; Gas shielded arc welding; GTA welding; Length; Light; Monitoring systems; Radiation; Reference lists; Size.*

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Doc. IIW-1905-08 (ex-doc. XII-1917r1-07) recommended for publication by Commission XII "Arc welding processes and production systems".

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#### **FRICION STIR SPOT WELDS BETWEEN ALUMINIUM AND STEEL AUTOMOTIVE SHEETS: INFLUENCE OF WELDING PARAMETERS ON MECHANICAL PROPERTIES AND MICROSTRUCTURE**

##### **ABSTRACT**

Hybrid configurations between aluminium and steel are needed to meet today's requirements for lightweight construction in the automotive industry. Different studies showed that Friction Stir Welding (FSW) as well as Friction Stir Spot Welding (FSSW) processes are suitable for joining aluminium to steel. In this work, dissimilar FSSW of aluminium AA5754 and galvanised steel HX 340LAD were examined. In particular the influence of different spindle speeds and dwell times on microstructure and the mechanical properties of the weld were analysed. In doing so, the cross-section microstructure of the weld interface was observed by light optical microscope (LOM) and scanning electron microscope (SEM). The strength of the welds was evaluated both by tensile shear and vibration fatigue tests. The influences of the individual parameters on the weld are presented in detail. The appearance of intermetallic phases (IMPs), a severe problem for conventional fusion welding processes between aluminium and steel, were investigated for the welded samples and a link to the mechanical properties is given.

*IIW-Thesaurus keywords: Aluminium; Friction stir welding; Friction welding; Galvanised steels; Hardness tests; Intermetallics; Lap joints; Light metals; Mechanical properties; Mechanical tests; Microstructure; Process conditions; Process parameters; Reference lists; Steels; Zinc.*

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Doc. IIW-1925-08 (ex-doc. SC-Auto-020r1-08) recommended for publication by Sc-Auto "Select Committee Automotive and Road transport".

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