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AG 52 - FSW Processing

Sent to: members of AG 52 FSW
Processing and B Pekkari

Report and minutes

No 4

from the meeting **24-25 February 2009** at Technical University of Denmark, Lyngby, Denmark.

Present:

Lars Cederquist, SKB, Sweden (chair)
Mathias Lundin, SWC, Sweden (secr)
Magnus Andersson, ESAB, Sweden
Sylve Antonsson, ESAB, Sweden
Sören Claesson, Bodycote, Sweden
Johan Fremling, SAPA Technology, Sweden
Leif Magne Kaalaas, Marine Aluminium, Norway
Olga Mishina, FORCE Technology, Sweden
Kati Savolainen, Helsinki University of Technology, Finland
Henrik Schmidt, Technical University of Denmark, Denmark
Mikael Soron, ESAB Welding Equipment, Sweden
Mikael Tigerström, SKB, Sweden
Cem Tutum, Technical University of Denmark, Denmark (guest)

Minutes from the meeting

1. Opening of the meeting (08.30 h)

In the absence of the elected chairman Lars Mohlkert the secretary, Mathias Lundin, opened the meeting thanking Henrik Schmidt for the invitation to the Technical University of Denmark, DTU.

Apologies where noted from Joakim Hedegård and Teresa Öberg.

2. Approval of the agenda

The agenda was approved with the addition of a presentation by Kati Savolainen under item 6.

3. Minutes (nr 3) of the last meeting in Haugesund

The secretary briefly went through the minutes which were approved with no changes.

4. Election of new chairman

Lars Mohlkert has renounced his chairmanship on account of his change of employer and field of work. The members were asked to consider the proposal for new chairman as proposed in the meeting invitation. No objections were presented before the meeting and the participants were in favour.

As proposed Lars Cederquist was elected new chairman for AG 52 FSW Processing.

5. Short presentation of the organisation and activities of new participants

Johan Fremling, new to the group, is newly employed at SAPA Technology. He comes from KTH where he recently finished his exam as Welding Engineer, IWE. SAPA uses FSW for coolers for the railway vehicle industry and ABB as well as for long lengths panels for trains (Victoria line) and ship building.

Johan informed that SAPA has a PhD student at KTH that makes fatigue testing of FSW profiles.

Cem Tutum, PhD student at DTU, was welcomed to the meeting as he was invited to make a presentation under item 6. He works with modeling and optimization of FSW parameters and evaluation of residual stress. He plans to be finished in 6 months.

6. Presentations

a) *Quality of FSW in steel at Sandvik Process Systems (Hertel)*

Patrik could not attend the meeting. His presentation was again postponed to the next meeting.

b) *Thermal and Flow Modelling of FSW using Comsol (Schmidt)*

Henrik presented the same presentation (**Appendix 1**) as he recently did at the COMSOL conference (software).

He combines a local (friction) and a global (thermal) model. Temperatures from the global model are applied as boundary conditions for the local model making it more realistic.

Henrik spent many years to work out how to combine the equations for the plastic heat generation versus the friction heat generation.

The result is influenced by the boundary conditions such as e.g. type of backing. He showed some post processed figures to describe the heat flow. He discussed full sliding versus full sticking and talked about the big discussion on shear layer characteristics and influence.

Henrik meant that the threads don't really produce a downward motion of the material, this since it sticks closest to the tool. It only redistributes the pressure and heat generation, avoiding forming of a void. To expect downward motion is to expect full sliding which is not happening. The rotation is 10 times the downward motion, 2 mm per rotation with full sliding.

Questions were raised concerning the possibility of different tools, different welding speed (that is, real high welding speed, like 10 m/min). He showed actual calculation with the COMSOL tool.

In the patent it says that FSW is a friction process. However, Henriks model shows it's a "shearing process". This statement stirs up some friction in the academic community.

The output is temperature distribution but not that an actual weld is produced.

Henrik states that there will always be a shear layer, hence a mechanical process and not a friction process. He means it's closer to cutting than friction. The shear layer increases with higher rpm. That is also seen when a tool is extracted, with low rpm you don't see the threads while with higher rpm the probe is cleaner.

Should we call the process Shear Stir Welding (SSW)? This seems to be a controversial theory.

c) *Optimization of welding parameters for minimizing residual stresses in FSW (Cem Tutum, PhD student at DTU)*

Cem presented (**Appendix 2**) simulation of residual stresses from FSW for optimization. The parameters used are travel speed (v_{weld}) and rotation (w_{rot}). Uses a thermal model combined with a mechanical model. The model is possible to use for other welding processes. TPM (Thermo-Pseudo-Mechanical) model.

Thermal expansion in front of the tool makes the material try to yield into pressure. After the tool passes the material transforms into tension.

The modelling was made with 2D and the tool only as a heat source (no rotation).

The boundary for yield stress is set to 200 MPa at 20 °C and 10 MPa at 475 °C (linear). 15-20 minutes for simulations which are made in ANSYS.

In the model increased welding speed gives higher residual stress. Increased rpm has lower influence.

The model shows that the big increase in residual stress occurs at relatively low welding speed. It seems that when increasing the welding speed the stress level gets more constant.

Discussion on the practical value of this simulation.

Sören meant that the calculation he gets shows high residual stress, however, when tested in practice residual stress is not that high.

Olga meant that practical tests show that rotation has influence on the residual stress level.

Cem used welding speeds lower than production parameters. Looking at the trend for the welding speed it seems that there could be little influence from increased welding speeds at levels of production welding speeds.

d) Development of automatic procedure using heat input control at SKB (Cederqvist)

Lars presented about automatic/adaptive process control at SKB when producing the copper canisters for nuclear waste (**Appendix 3**).

Use power input instead of heat input. The control aims to maintain the power input to be in the middle of the process window.

The temperature measurements are made with thermo couples within the tool at 3 different locations. The temperature in the tool is optimised for no voids. The temperature follows the power input.

If no adaptive control the temperature will drop 160 degrees during weld time and voids are formed.

The aim to hold 850 °C as probe temperature shows a good way to get good welds. If this temp goes down under 800 °C voids can form.

Increase in rpm is put in to the control function to generate compensation.

Current issue: what if unacceptable required power input occurs. Might go over to infra red measurement to control the temperature.

Henrik meant that the physical boundary parameters must be considered. Have huge influence from e.g. room temperature or rather the temperature of the big lump of copper.

Tuning will get steadier adaptive control of the process.

e) Entrapped Oxide particles in FSW of copper (Kati Savolainen)

Kati presented trials on the appearance of oxides inclusions depending on the use of oxide removal and shielding gas respectively. (**Appendix 4**)

The oxides that become inclusions seem to come from the joint line rather than from the surface.

When using oxide removal but no shielding gas the most oxides inclusions are formed. Oxide removal and shielding gas gives less oxides inclusions

SEM studie of as-weld condition weld shows voids depending on reaction between oxygen and hydrogen. Also shows the oxide removal and shielding gas influence on grain size. The less amount of oxides the larger the grain size.

Discussion on the reason for the grain size influence. How the oxides could influence the annealing process.

7. Report from FSW&P conference in San Francisco, February 2009

Lars summarised the conference (**Appendix 5**)

There were 68 presentations on FSW. The proceedings contains 35 of these presentations. Lars past around the proceedings which can be bought at tms.org for some 80 USD.

8. Licence and patent issues

Short discussion on the licence and patent situation.

Can we weld FSW with an unthreaded tool (probe) without a licence from December 2011? TWI's answer is yes. But there can be no features. The patent on threaded tools is valid until 2016.

Henrik meant that if he e.g. develops a threaded tool design by modelling, TWI will own it.

What happens with the site licence at e.g. Marine Aluminium in December 2011? Will the fee be reduced? Unclear!

These issues are certainly going to be argued at TWI Symposium May 2010 in Lübeck for which AG 52 should prepare questions.

AG 52 will return to the matter in coming meetings.

9. Short report on FSW standardisation activities in IIW (ISO/DIS 25239-1 to -5)

The secretary reported that IIW, after considering the DIS comments, decided on a 2nd DIS (technical enquiry) which is under preparation and expected later this spring. This has resulted in a delay for a published ISO until spring 2010.

The handling of the comments is posted at www.svets.se/ag52 (under "Info & documents"), as well as the 2nd DIS will be.

10. Reports and news coverage (fairs, articles, conferences etc)

The world's largest welding fair "Schweissen und Schneiden" in Essen will take place 14-19 September 2009. See also www.essen-welding-show.de. Esab will have a large stand to which we are all invited.

The 8th International Symposium on Friction Stir Welding will be held 20-22 May 2010 in Germany. See also www.twi.co.uk.

Next IIW Annual Assembly is 12-17 July 2009 in Singapore, see www.iw-iis.org.

ESAB Process Technical Days will be held 14-15 May 2009 in Gothenburg.

11. Working program and member issues (prospective participants etc)

Concerning the working program, the chairman meant that the development of the process would improve if issues from R&D could be presented and discussed in the group.

The working program is available at www.svets.se/ag52.

An updated list of participants is attached to the minutes (**Appendix 6**).

The secretary reported that the following members left the group due to job changes:

Lars Mohlkert, ex SAPA, Sweden (now with Tetra Pak in Lund)

Benaz Aghili, ex SKI, Sweden

Pontus Davidsson, ex SAPA Profiler, Sweden

Jukka Monnonen, ex TKK, Finland

From SAPA Johan Fremling joined the group. From TKK the group still have representatives.

From SKI (Swedish Nuclear Authority) there is not yet a representative after Benaz.

The chair reported that a representative of ESS Scandinavia in Lund, Axel Stuer, appeared at the conference in San Francisco. He shall be contacted.

Someone from SAPA Profile should be on the list.

Anna DeTry has left KIMAB and should be contacted on future participation.

Mikael Soron mentioned he might invite people from Högskolan Väst in Trollhättan for the next meeting.

Further suggestions on new members of the working group (anyone missing?) can be forwarded to the secretary.

12. Arrangement for subsequent meeting

Next meeting was decided for 13-14 October 2009 at Helsinki University of Technology, Finland.

Possible items for presentations:

- FSW of dissimilar metal joints at Helsinki University of Technology, Kati Savolainen
- Quality of FSW in steel at Sandvik Process Systems, Patrik Hertell
- Possible application, Sylve Antonsson
- Tool design (pin and shoulder) at SKB, with following discussion. Two aspects: wear and pin fracture

Please contact the chair, Lars Cederqvist, or the secretary, Mathias Lundin, on additional agenda items.

More details to come in the meeting invitation.

Future meetings:

It was considered to have the meeting after Helsinki in conjunction with the "8th International Friction Stir Welding Symposium, 18-20 May 2010, MARITIM Seehotel Timmendorfer Strand in Germany (near Lübeck).

Esab is arranging new facilities in Laxå. Maybe a meeting is suitable after fall 2010.

A future visit to TWI in Cambridge was also discussed

Olga mentioned the interest to have a meeting just on welding of steel.

13. Closure of the meeting

The chairman thanked everyone for their attendance and contribution, and Henrik Schmidt for the invitation and arrangements at DTU.

Technical visit at Technical University of Denmark

A tour of the DTU facilities was arranged after the meeting session. Henrik showed the group various technical equipments that are part of current R&D including milling machines used for FSW.

Meeting secretary



Mathias Lundin