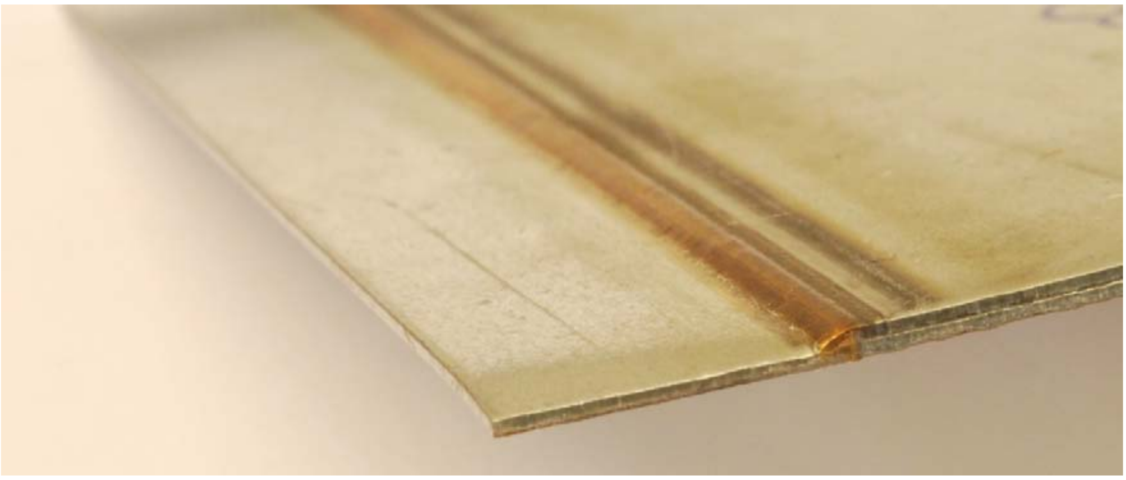
Lean Exterior Brazing – II (LEX-B)



Project within FFI – Sustainable Production Technology

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1. Executive summary

The project aimed at reducing the cost for visible exterior joints by using arc brazing processes. The objectives were to secure new cost efficient brazing technology, as an alternative to laser brazing, that may result in new possibilities for truck cabins and to develop a vision based monitoring system for improved in-line control.

Demands have been identified regarding the joining process, process control and design aspects.

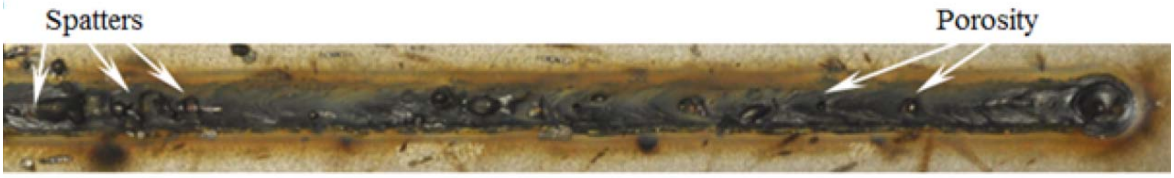
A new arc brazing process (TIG based) has been evaluated and fulfills the demands on the joint. The demonstrator selected is a door to a truck cabin.

A system for in-line control has been developed that can detect and localize defects.

2. Background

Welding and brazing of steels coated with zinc tends to give instable process, depending on type and thickness of zinc coating. The main reason for this is the low melting and boiling point for zinc (419°C and 907°C). The boiling point for zinc is far below the melting point for steel (the melting point for mild steel is around 1450 to 1520°C). Vaporizing of liquid zinc, from the zinc coating, can be almost explosion like (the volume increase from liquid phase to gaseous phase is more than 2000 times) and will disturb the arc in fusion welding as well as form bubbles in the melted weld pool. These instabilities often result in irregular bead, porosity and spatter.

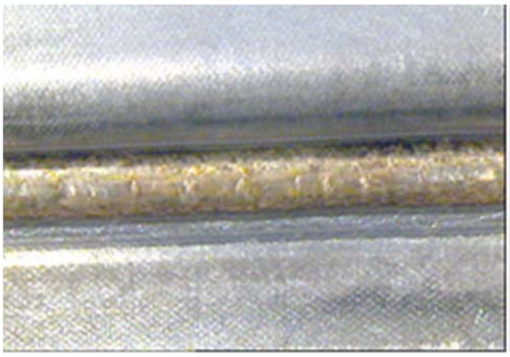
Examples of typical brazing defects porosity, spatter, bad wetting to the bottom sheet and bad wetting to the top sheet (Source J Wirth, EWM 2012)

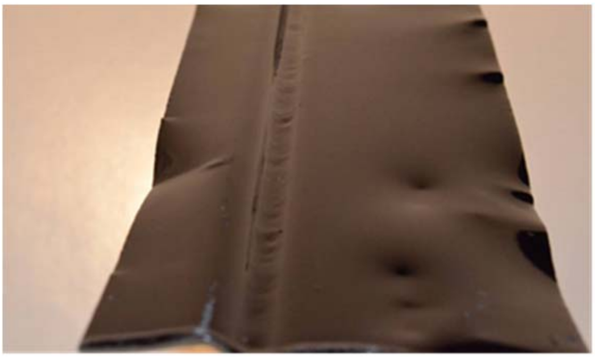


Laser welding of galvanized steel in a zero gap lap-joint that resulted in spatter and pore formation (J Ma et al. 2012)

Today laser brazing is successfully used in the automotive industry but there is an interest in finding alternative processes with lower cost.

This project is a follow-up project to the pre-study KEEX, also financed by VINNOVA (D-nr: 2010-01333). The pre-study showed possible alternatives to laser brazing with special TIG process variants or even a special MIG process variant to make a visible joint (a flanged edge roof joint). In LEX-B a lap joint on a door to a truck cabin will be in focus.





Result with TIG brazing with Plasmatron and MIG brazing with EWM ColdArc. NOTE! The sheet has been deformed by handling and not from the joining process. (From the pre-study KEEX, D-nr 2010-01333)

3. Objective

The objective with this project was to show an alternative brazing method to laser brazing of an automotive part. The automotive part selected was a door to a truck cabin. The material was zinc coated mild steel (type DC04). The joint was a lap joint with 1.2mm sheet at the bottom and 0.8mm sheet on top.

Demands on the joint were:

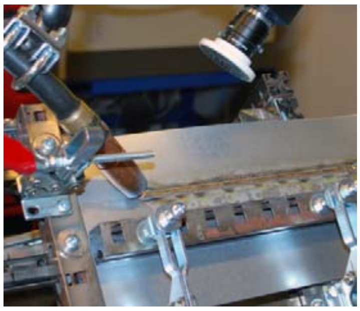
- No surface defects that may affect painting (no surface breaking pores, no visible cracks)
- Good appearance (preferably no spatter, flat and even shape of the bead, regular transition between the bead and the sheet, preferably small amount of soot and easy to remove)
- Tensile strength (in tensile-shear test) not less than 300MPa
- Travel speed 120 cm/min or higher
- No zinc burn-off on the rear side

The zinc burn-off requirement is not a purely aesthetical requirement but is important for the corrosion resistance of the joint. Looking at the rear of the joined sheets some partial melting of zinc is visible as a shiny stripe along the joint. This is acceptable and hard to avoid. Zinc “burn-off” however, is visible as white powder, zinc oxide, which falls off easily. This is not acceptable.

Three alternative brazing methods were selected:

- Plasmatron, that is TIG brazing with constricted arc achieved by directed and focused gas flow from defined angle in the gas cup
- forceTIG, that is TIG brazing with constricted arc achieved by extreme cooling of the TIG electrode
- MIG brazing with CMT, that is one of the newer low energy input MIG methods





4. Project realization

The project was conducted by researchers from Swerea KIMAB and University West in cooperation with experts from end user companies in the automotive industry, Volvo Trucks and Scania CV.

Personnel in the project modules were chosen according to need. The project management group consisting of representatives from each part decided on manning for the different modules. The participating companies and organisations were Volvo Trucks, Scania CV, University West and Swerea KIMAB.

The following 8 modules were defined in the project.

M0: Project leading
Results: Protocols.

M1: Gathering and development of process equipment, material, fixtures, demonstrator.
Results: Equipment and material produced and demonstrator chosen.

M2: Identification and development of equipment for monitoring.
Results: Monitoring equipment for arc brazing.

M3: Stability development for arc brazing in lap joint, including joint properties.
Results: Gate: Evaluation of results against demands, choice of best process. Intermediate report.

M4: Monitoring and controlling possibilities for arc brazing processes.
Results: Report and further work recommendations.

M5: Development of robustness for chosen arc brazing process.
Results: Verified and approved arc brazing process. Intermediate report.

M6: Production of demonstrator with monitoring and control tests.
Results: Status report and chosen monitoring and control concept.

M7: Evaluation of system and economy.
Results: Economy calculations, seminar.

M8: Report and knowledge distribution.
Results: Final report, seminar, articles, conference contribution.

5. Results and deliverables

Three alternative brazing methods were selected in the project:

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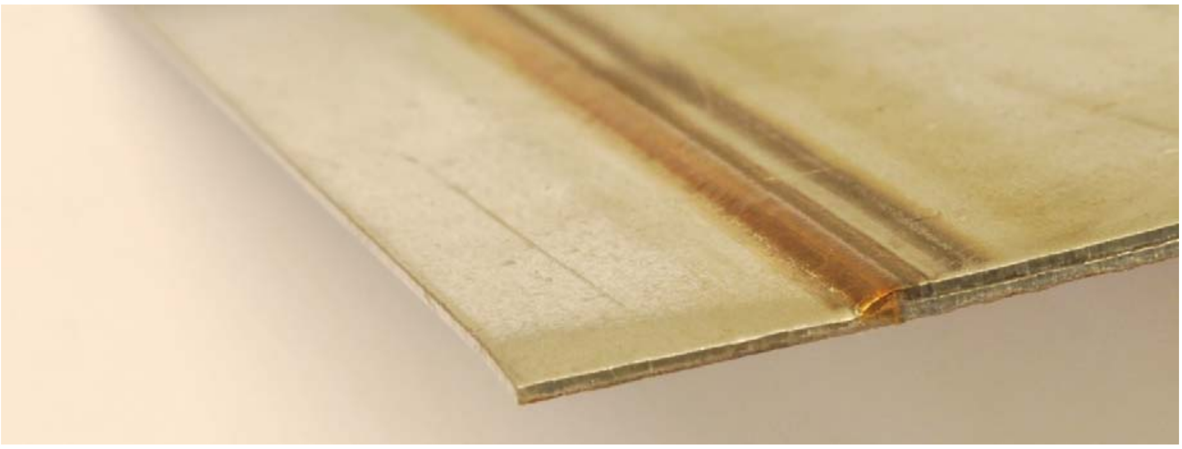
The quality of the brazed joint produced with the two TIG methods are comparable with those that are produced with laser brazing. In the selected joint configuration, a lap joint without gap, in combination with zinc coated steel zinc vapor occasionally give rise to disturbances that may result in a pore, a spatter particle or irregular joint. The vision based monitoring system that is developed within the project can be used to automatically detect and locate such disturbances which facilitates quality control. There will also be tests made with a controlled gap between the sheets to allow zinc vapor to escape without causing disturbances.

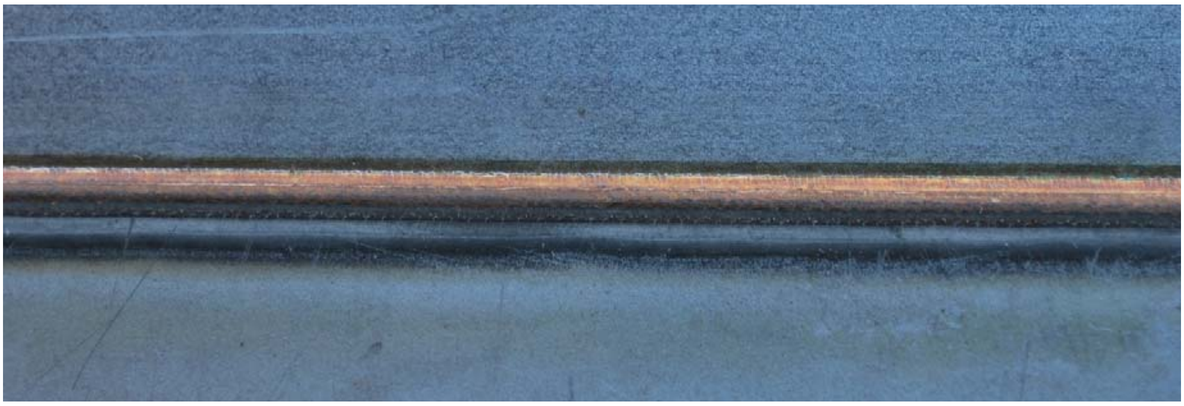
The quality with the MIG brazing method was also quite good but 3-4 times more filler wire is needed with equal travel speed as with the two TIG methods. The size of the braze joint therefore becomes much larger and was considered too large for the demonstrator in the Lex-B project, the door to a truck cabin.

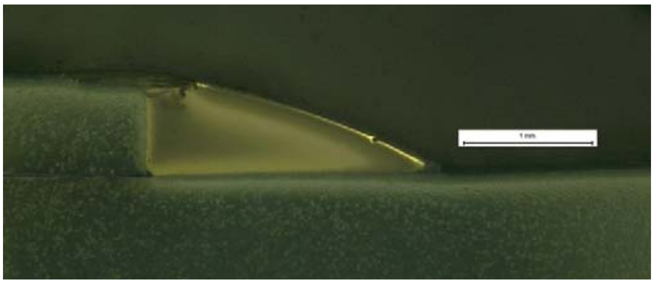
The travel speed was very high with the forceTIG, 3 m/min, which is in the same region as laser brazing. With Plasmatron and also CMT the travel speed was lower, 1.2 m/min but for this application that travel speed fulfills the requirements.

Copper vapor from the filler wire did affect the life time of the cathodes in the two TIG methods. Especially the forceTIG process was very sensitive to the copper vapor that condenses on the electrode. The forceTIG electrodes are not designed to be ground. The electrodes are fixed in a holder for enhancing the cooling and if they are ground that will change the tool center point which means that the robot torch position must be calibrated. With the Plasmatron the electrode can be ground several times and the electrode position is adjusted to give corrected tool center point after re-assembled. In the cost comparison analysis made in the project it was shown that the difference in cost for electrodes is substantial and a major reason for selecting the Plasmatron process as the most promising alternative to laser brazing. It should however be noted that in other applications both TIG methods are very interesting brazing processes.

Results with Inocon Plasmatron





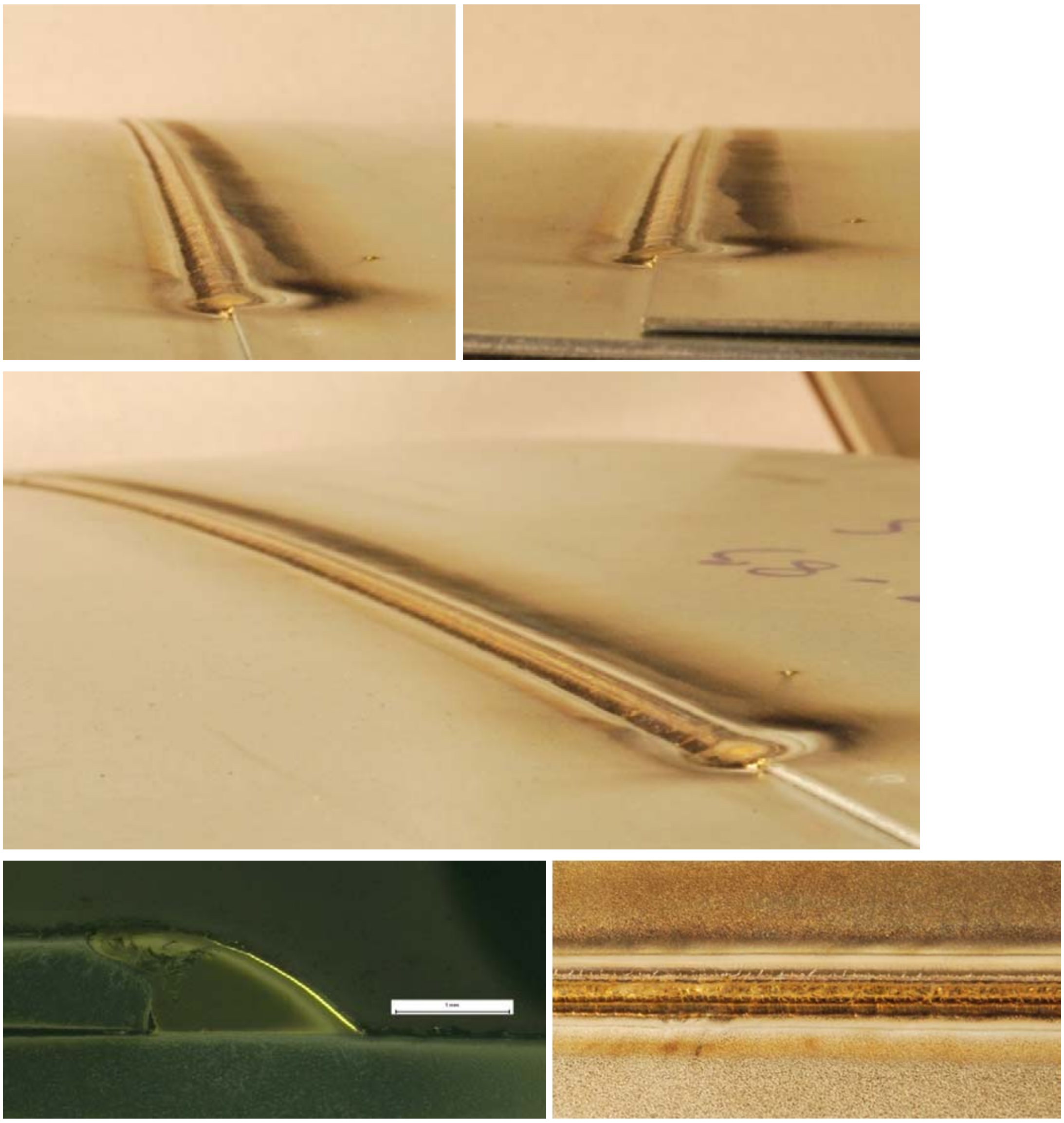


Good results with Plasmatron in straight a lap joint

Typical welding data (Filler material: Bercoweld B60 or CastoMag 45706, CuSi3Mn)

Welding current:	95-105A
Arc voltage:	13-14V
Wire feed speed (wire Ø1.2mm):	1.2-1.3m/min
Travel speed:	1.2m/min
Shielding gas:	100% Ar, gas flow rate 8 l/min

Results with EWM forceTIG

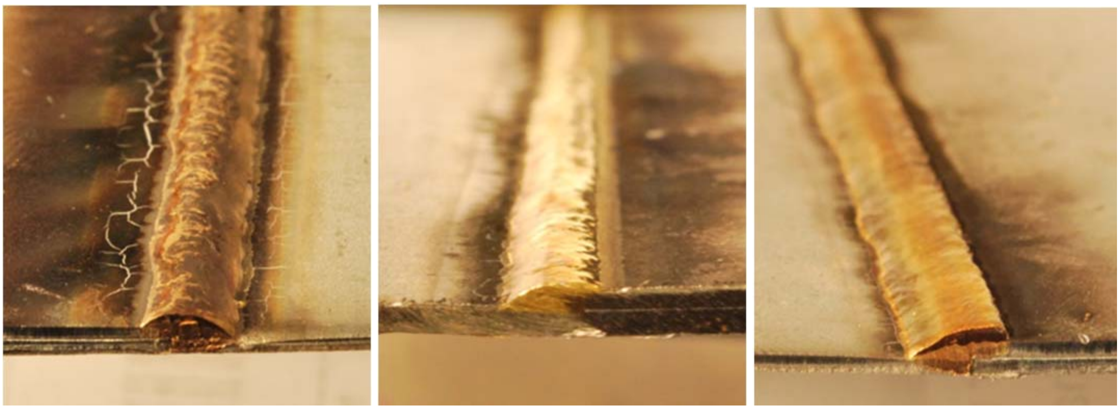


Good results with forceTIG. The brazing filler wire was Esab OK Autrod 19.30 (CuSi3Mn1) Ø1.2mm

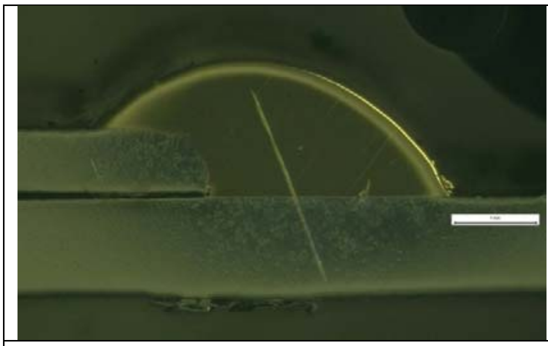
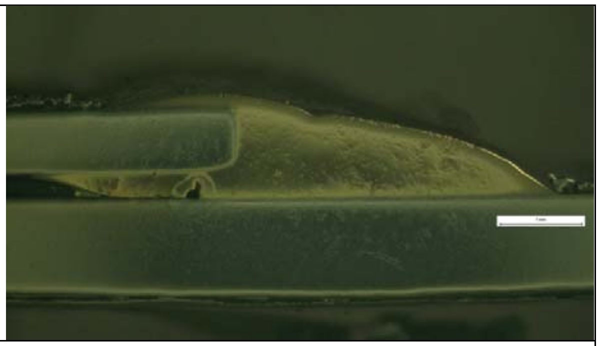
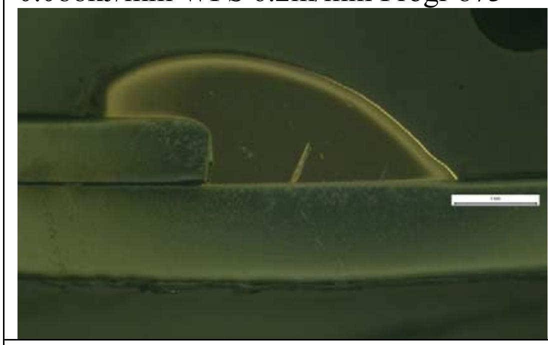
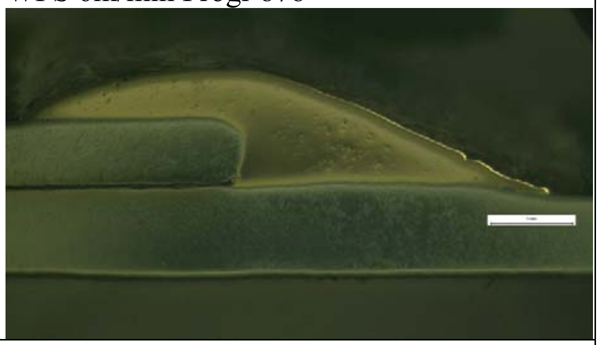
Welding current:	176A
Arc voltage:	12.5V
Travel speed:	3m/min
Wire feed speed:	3m/min
Heat input:	$\eta \cdot 0.043$kJ/mm where the efficiency factor η in TIG welding typically is estimated to about 0.7

The cross sectional area of the deposited brazing filler is 1.1mm^2

Results with Fronius CMT



Examples of good results with CMT and different brazing filler metals, CuSi3Mn1, CuAl8 and CuSn6SiMn. The travel speed was1.2m/min.

	
CuAl5Ni2 UTP A3421 117A 12.0V 0.088kJ/mm WFS 6.2m/min Progr 873	CuSn12P UTP 320 110A 10.6V 0.080kJ7mm WFS 6m/min Progr 878
	
CuSn6SiMn Bercoweld B60 134A 9.9V 0.058kJ/mm WFS 6.3m/min Progr 1183	CuSn8P CastoMag 45703 108A 9.8V 0.073kJ/mm WFS 6m/min Progr 878

Cross section of the joints made with different filler wires. The cross section area of added brazing filler is 3-4 times larger than with the Plasmatron and forceTIG.

5.1 Delivery to FFI-goals

The project contributes to the use of knowledge based production and improved competiveness in the Swedish automotive industry by using new knowledge and new technology. This can give both cost and technical advantages.

The project has also contributed to co-operation between industry and academy that enhances the competition in the automotive industry as well as a stronger research environment in Sweden. The acquired knowledge gives both the industry and the academy prerequisites for further development, also in other areas. This contributes to securing employment, to growth and to strengthen the R&D within Sweden.

The results with the new TIG brazing technologies make it possible to use cost efficient alternatives to laser brazing. These techniques can give advantages also in other manufacturing industrial segments than the automotive.

Since the new cost efficient brazing technologies can be used also in other applications, such as mixed materials joints (with lighter materials), demands are also better met for light-weight vehicles with lower fuel consumption and reduced emission.

6. Dissemination and publications

So far the results from the project have only been disseminated within the project group. There are plans to present project results in articles and at seminars/conferences. For instance in the next FFI-conference in Katrineholm and Joining seminars in Comm. XII in IIW. Swedish joining seminars arranged by Swerea-KIMAB and the Swedish Welding Commission is also suitable for presenting results. An essence of the results should also be presented for the students in KTH and HV.

7. Conclusions and future research

In the project three different brazing processes have been evaluated as possible low cost alternatives to laser brazing. The application, door to a truck cabin, was a lap joint with 1.2 mm thickness of the bottom sheet and 0.8 mm of the top sheet. The material is zinc coated mild steel. The tested processes were:

- TIG brazing with Plasmatron
- TIG brazing with forceTIG
- MAG brazing with CMT

The main demands from the participating end users, Volvo Trucks and Scania, were:

- Travel speed 1.2 m/min or higher
- Small joint size and good joint appearance
- No surface defects, such as surface porosity, spatter or irregular joint, which can affect paint adhesion or general joint appearance
- Tensile shear strength better than 300 MPa

Plasmatron was the process that best fulfills the demands from Volvo Trucks and Scania. The travel speed was 1.2 m/min and the joint size is only slightly larger than to those in production made with laser brazing. The appearance was good and tensile shear strength was better than 300 MPa.
It is concluded that this process can be used as an alternative to laser brazing.

There is however still some risk for porosity, spatter and irregular bead with lack of wetting on one of the sheets. Volvo trucks will continue with further testing using a gap between the sheets to create an escape route for the zinc vapor.

The joint quality with forceTIG was equal to those achieved with Plasmatron. The travel speed was higher, 3 m/min, compared to the travel speed with Plasmatron (1.2 m/min). There was however some issues with copper vapor condensing on the electrode and the electrode wear with forceTIG was far higher. The electrodes for forceTIG are also intended to be thrown away without grinding (grinding will changes the Tool Centre Point). This is a big difference from Plasmatron where the electrode can be ground (the Tool Centre Point is adjusted when re-attaching the electrode in the torch).
The electrode in the Plasmatron also seemed less sensitive to copper vapor.
The cost for electrodes therefore becomes a considerable part of the total cost with forceTIG.

With the forceTIG there were also some starting problems. To get a reliable start the electrode had to be scraped with an aluminium plate before igniting the arc despite HF ignition and that the wolfram electrode is of the wolfram-cerium type. The gas cup with forceTIG is also larger than the Plasmatron gas cup and accessibility becomes slightly worse.

The results with CMT are fairly good but the joint size is too large to be acceptable in this application. The size is about 3-4 times larger than with the two TIG processes and results from the fact that the heat source and wire feed speed are not independent in MIG/MAG. The travel speed was equal to that achieved with Plasmatron, i.e. 1.2 m/min.

The visual monitoring of the brazing processes evaluated offer a non-intrusive approach to surveillance. It permits in-process monitoring and real-time detection of defects during the execution of the process. This system thereby facilitates means for improved quality control.
In order to be adapted to industrial production the monitoring system has been developed to be both physically and numerically robust (the last requirement relates to automatic change detection). The system follows the process in order to capture relevant process information in the camera field of view. The surveillance system is functional without any external illumination to make it flexible and to minimize the requirements placed on its usage.
Experimental results confirm that a commercial CMOS-camera supporting high dynamic range imaging with a relatively high frame rate (500 to 1000 fps) is sufficient to capture the major problem of zinc vaporization blow outs during the process. Several image sequences with adequate image quality clearly show the occurrences of blow outs and this information can be time synchronized with robot motion and position together with process current and arc voltage. In this fashion defects can be automatically detected and localized for further inspection.

8. Participating parties and contact persons

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