ECONOMICALLY WELDING IN A HEALTHY WAY

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ABSTRACT

The metalworking sector (turnover 970 billion € a year) represents 8% of the total EU business. Welding is the most important joining technique in this sector; there are about 730,000 full time and 5.5 million welding related jobs in Europe.
Welding has also a great impact on health for it is physically high demanding leading to a high percentage of sick leave (yearly about 160 working hours per welder). These high sick leave costs are extremely threatening the financial position of SMEs, endangering their competitiveness.
Aiming at addressing these topics of global interest to the welding communities an EU project – ECONWELD was developed. This project intends to stop the downward spiral in which welding is at the moment, by:

1. ***Reducing welding costs and improving welding production for European SMEs*** by coming up with solutions and guidelines for (flexible) mechanization of welding, including modular fixture and clamping design.

2. Making welding a healthier and more attractive profession by reducing the amount of welding fumes and by lighten the welding activities; by developing new solutions to improve the work conditions (ergonomics and work flow).

The results obtained in ECONWELD are expected to increase competitiveness of SMEs in Europe and to contribute for improvement of the image of the welding related professions.

KEYWORDS

Welding production; Welding Costs; Welding fumes; Sick leave of welders; Virtual Welding

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1. INTRODUCTION

Welding is a particular technology in the sense that it is needed in almost all kinds of metallic constructions, from bridges to cars and planes to structures. In this sector; there are about 730,000 full time and 5.5 million welding related jobs in Europe. A threat for these jobs is that welding is moved to Asian low wages countries, leading to a decrease in European welding and welding related jobs with 3% each year (meaning 165,000 people). Another drawback is that welding has a great impact on health for it is physically high demanding leading to a high percentage of sick leave (yearly about 160 working hours per welder)[1]. These high sick leave costs are threatening the financial position of SMEs, endangering their competitiveness.
ECONWELD-Economically welding in a healthy way, aims at addressing these topics through a jointly approach, by addressing the welding costs, productivity and environmental aspects. The reduction of welding costs is to be reduced by improvement of production through the identification of solutions and development of guidelines for (flexible) mechanization of welding, including modular fixture and clamping design. The benefits and possibilities of alternative high speed and/or high deposition welding processes will be demonstrated.
The benefit of the environment around welding will focus on new solutions to improve the work conditions (ergonomics and work flow) and on Improving health and safety at work for welders. ECONWELD aims at coming up with solutions to reduce welding fumes at the source, a smart exhaust arm moving to the exact welding spot, a helmet with sensors indicating when the fume concentrations exceed safety limits as well as prototypes of welding torches with better ergonomics and fume extraction capabilities.

2. THE MOTIVATION FOR ECONWELD

Economical welding together with healthier welding involves ergonomics, design and development of new equipment (welding torch, helmet, exhaust), shop organisation and last but not least expertise at the welding process itself.

Welding and its associated techniques are the most wide spread used professional technologies for manufacturing constructions and goods in different areas of industry, see table 1. An integrated solution for problems mentioned in this proposal is needed in (almost) all industrial sectors.

Table 1 Industrial sectors and industrial groups

Industrial sector	Industrial Groups included
Automotive	Vehicle and trailer manufacturing, automotive systems and parts manufacturing
Aircraft/aerospace	Aircraft parts and systems manufacturing, missile and space vehicle manufacturing
Electronics/medical	Electronic components and instruments, medical instruments and equipment
Light industry	Materials handling equipment, industrial tools, fluid, powder and air transmission equipment, pipes & tubing, service industry machinery, household appliances
Heavy industrial manufacturing	Construction machinery, farm machinery, shipbuilding & repair, military armoured vehicles, engine, turbine & power transmission equipment, oil & gas field machinery

Construction	Bridge, tunnel and pipeline construction, structural metal products
Repair & maintenance	Oil & gas production and distribution, primary metals industries, metal forging & stamping, mining operations, electrical power generation

Welding is used in thousands of units of business activities, SMEs as well as large industrial companies employing some hundreds of welders. Welding production requires the compliance with special regulations within the occupational safety as well as protection of employees' health and life.

2.1 Technological need

ECONWELD addresses the technological need through three main points of interest:

2.1.1 Reduction of welding costs

To improve their competitiveness European SMEs need to reduce their welding costs. This can be done by mechanised welding. Design rules for mechanised welding of products are needed while products often are designed for *manual welding*. By mechanising welding, the welding speed can be largely increased so the process can become more economical efficient. It can also improve the quality of the joints made, while the high welding speeds implies a low heat input into the base material; often the amount of rework needed is largely decreased. These last two facts are especially interesting when welding **(Ultra) High Strength Steels** (e.g. cold rolled grades). The new production possibilities (High Strength Steels etc.) will enlarge product ranges.

2.1.2 Reduction of welding fumes

The reduction of welding fumes is necessary to improve the shop floor conditions for welders thus reducing the sick leave (both short term and long term) caused by welding fumes. This reduction is a technological, complex problem which needs to be solved three fold:

- **Reduction at the source**: most frequently used welding processes are MIG/MAG (also named GMAW = Gas Metal Arc Welding) and SMAW (Shielded Metal Arc Welding), used in about 70% of the welding jobs. Thus, work on reduction of fumes at the source should be concentrated on these processes. For GMAW and SMAW, reduction of the welding fumes can be achieved by lowering the temperature of the meld droplet splitting from the filler wire and using condensation nuclei in the shielding gas.

- **Ventilation and exhausts**: there are several options to control the air at the shop floor, but they are certainly not for very effective situations. For SMEs it is hard to know what type of ventilation they need. Next to this, most systems are rigid, though welders as well as welding equipment need to be very flexible in their positions and movements. New, (partially) automatic moving exhaust arms, torches with reversed exhaust etc. are necessary to ensure the flexibility of welders, thus increasing their productivity. Also, global guidelines for exhaust design of shop floors are being asked by SMEs. To analyse the local situation, it is necessary to develop simulation techniques of the fume flows on the shop floor, depending on welding process, product dimensions as well as organisation of the work shop. Thus simulations can largely reduce the time needed to determine if a work shop is properly ventilated.

- **Personal protection**: main issue here would be solved by using a smart welding helmet, warning the welder for high concentrations of welding fumes. Thus he can decide to use

additional ventilation, or to stop welding in a given moment. A helmet like this does not yet exist.

2.1.3 Predictive virtual welding tool

Welders are exposed to too high stresses and strains (bad ergonomics) as well as relatively high concentrations of welding fumes, combined with high radiation (UV, infrared). A software tool for virtual welding is needed to enable designers, engineers etc. to determine if their products are weldable in an ergonomically justified and technically efficient way. For development of this predictive tool, a lot of input is necessary, like guidelines on ergonomics, welding process-material combinations, rules for optimised welding order, welding fume "production" per process per material and other health and safety hazards.
A tool like this will be produced by the ECONWELD partners and it is expected to be useful to large groups of SMEs to make their products more welder-friendly, thus reducing sick leave, increasing welder job satisfaction and productivity.

2.2 Scientific need

Many injuries are long term problems, so especially (small) SMEs become troubled by these personnel costs[1]. Most of the welders go on an early retirement because they are physically not able to carry out their work any longer.
With a new level of understanding of improved processes and health risks, the entire welding industry will benefit and progress. This approach can only succeed when there is a combined scientific effort of research on welding, ergonomics, materials science, software development and design. This combined scientific effort can only be carried out at a European level and by a European approach due to the fact that a wide expertise is needed. Furthermore, it is a true European problem to be solved.
One might start thinking it could be best to skip the welder and mechanise the entire welding shop. This has turned out to be no proper option in practice. Often, welding jobs are too complicated or specialised for mechanisation. Also, the contours of the products to be welded often are difficult to translate for the software of a welding robot, or the batch size is too small for the efforts needed in automation. Also, the experience and metallurgical knowledge of practical welders is needed to ensure good products.

Welding is a physical demanding job. Safety hazards include the potential for fire or explosion and injuries from radiation, electrical shock, or materials handling. Health hazards (see table 2) are exposure to fumes released during welding as well as bad ergonomical situations on the welding shop floor.

Table 2 Heath hazards due to welding

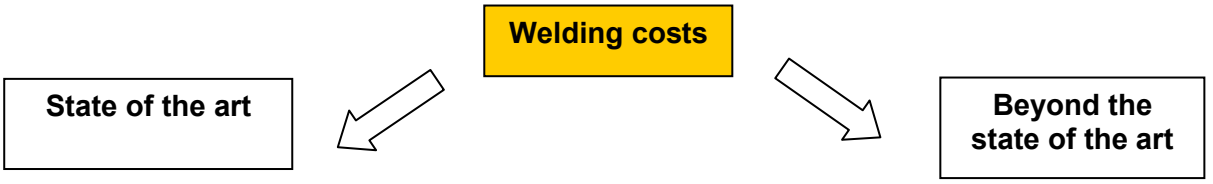
Fume	Gases	Radiant energy	Other hazards
Aluminium; Cadmium Chromium; Copper Fluorides; Iron Lead; Manganese Magnesium; Molybdenum Nickel; Silica Titanium; Zinc	Carbon dioxide Carbon monoxide Nitrogen oxide Nitrogen dioxide ozone	Ultraviolet Visible Infrared	Heat Noise Vibration Bad ergonomics

[1] Mind e.g. a 10-person company obligatory paying 1 welder on sick leave…

The influence of welding fumes on the human body differs for each material. Some have only a short term influence, while others have a long term destructive influence on parts of the human organism, e.g. manganese with a potential to cause Parkinson-like diseases. Regarding welding fumes, EU as well as national maximum accepted concentrations (MAC values) have been legally described. These MAC values are decreasing in several countries to decrease the health risk for welders. For SMEs it often is difficult to upgrade their production systems to work with the latest MAC values.

Postures which are maintained for too long expose the welder to cumulative stresses and strains. In manual welding the position of the welder (bending towards the welding zone) is stressful, often leading to back injuries. Although the welding torch doesn't seem to be very heavy, holding it in a stable position for some minutes gives one a different view at the meaning of the word "heavy". There are many types of tools used by the welder, these vary by shape, size, weight, and power source. Some tools are simple but others are complicated to operate. A side effect of using certain power tools is vibration (slag removing), which can affect the entire body and cause neck and back pain, numbness, tingling, aching, stiffness, headache, or blurred vision. Besides the effects from vibration tools used can cause other types of musculoskeletal problems. Proper use should include worker awareness of the ergonomic principles involved to safeguard against musculoskeletal injury. No, or very limited, guidelines are available at the moment.
It is remarkable that workplaces often are not designed to fit the needs of the workers but most of the time exactly the other way around. Welding introduces many challenges to the field of ergonomics, which are at this moment only just being understood. Europe has to find solutions for problems such as RSI among welders (Repetitive Strain Injury) [8] and Cumulative Trauma Injury (CTI), both resulting in lower productivity, more sick leave and workers less satisfaction. If Europe is not able to manage this, costs for sick leave will bankrupt SMEs in time.

3. THE FUTURE THROUGH ECONWELD EYES

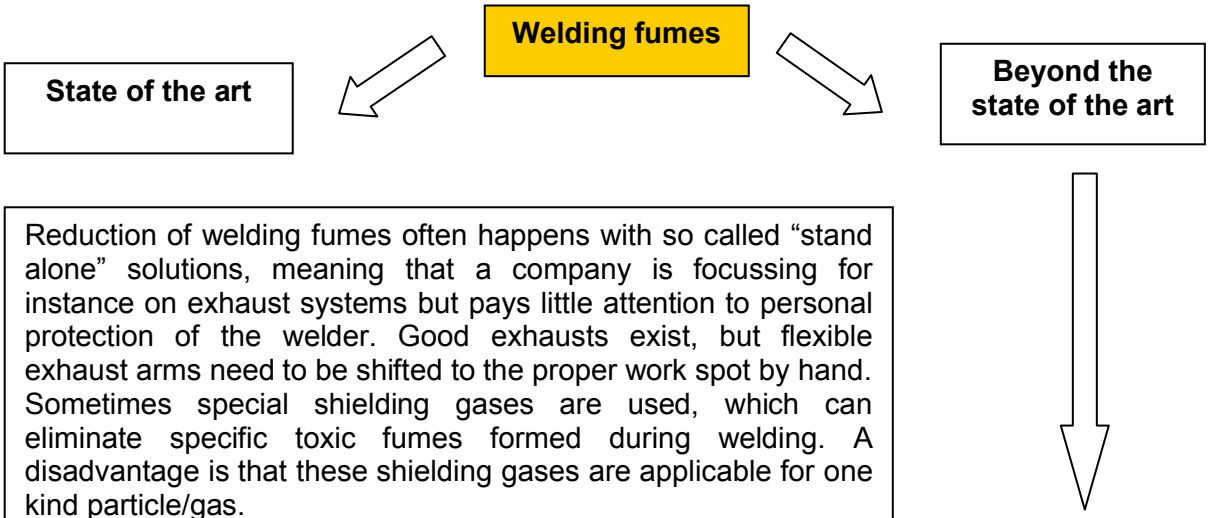


Most important way to reduce welding costs in Europe is mechanisation of welding; after all the main part of product costs is labour costs. Many SMEs have robots which are often used in a isolated sub-optimisation of welding activities. This means that only welding itself is automated. When companies have chosen a certain type of mechanisation the optimisation process often ends. This leads to missed opportunities and a longer time for return of investment and less competitiveness.

The project aims at:
- Total concept of automation (from product design to welding and materials handling).
- Flexible mechanisation, since most European SMEs have small batches of products.
- Design of modular fixtures and clamping devices.

Guidelines will be established for designing **products for mechanised welding**. Also, guidelines for designing **modular fixtures and clamping devices** for mechanised welding will be made.

Work prescriptions for alternative welding processes to get higher deposits or higher welding speeds will be written. Alternative welding processes involved are: MIG/MAG welding with 2 wires (tandem), hybrid welding –combined laser and arc welding process-, high deposition and velocity welding processes (Time, Rapid Arc etc.).



Reduction of welding fumes often happens with so called “stand alone” solutions, meaning that a company is focussing for instance on exhaust systems but pays little attention to personal protection of the welder. Good exhausts exist, but flexible exhaust arms need to be shifted to the proper work spot by hand. Sometimes special shielding gases are used, which can eliminate specific toxic fumes formed during welding. A disadvantage is that these shielding gases are applicable for one kind particle/gas.

ECONWELD offers an integrated approach (source, surrounding and welder) on welding fumes :

1) Lower the droplet temperature. One of the main causes for formation of fumes at MIG/MAG welding is the high temperature of the metal droplets coming from the wire. The droplet temperature will be lowered by using pulsed-MIG welding with special pulse parameters, combined with additions to the shielding gas, reducing the surface tension of the transferred droplets.

2) Early condensation of welding fumes. Another option is to ensure the fumes condense as quickly as possible after formation, not leaving the welding arc at all. This can be done by addition of condensation nuclei to the shielding gas. Thus, welding fumes won’t interact with the welder.

3) N*ew welding torch concepts.* MIG/MAG welding torches will be developed and tested in the project: a welding torch with lateral aspiring openings and the inverse welding torch, aiming at decreasing the amount of fumes drastically.

4) Green filler wires. A source of welding fumes is the material of the filler wire. Some manufacturers claim to supply so called ‘green wires’ with a lower emission rate of welding fumes. These wires will be tested and compared with traditional wires for MIG/MAG welding. It will be investigated which element(s) have to be added/lowered to minimize the amount of welding fumes and by which elements they can be replaced to maintain the necessary (mechanical) properties of the filler wire.

5) Exhaust development. A lot of good welding fume extraction equipment is available, but only when working at a fixed place of work these systems will do their job. Problems are encountered when products are large; the welder has to move the exhaust hood from weld to weld with him. This is annoying and in practice thus not done. This means that in practice good exhausting equipment is not very effective and the welder is still exposed to a lot of welding fumes. *In this project a “smart” exhaust arm will be developed which is able to move to the place of welding automatically.* Position sensors as well as sensors detecting start and stops of welding have to be developed.

Sick leave among welders

State of the art

Much is known about the influence of welding fumes on the human body. Standards and guidelines have been set up for protecting the welder and his immediate surrounding from welding fumes and radiation. The welding helmet, part of the welders personal protective equipment (PPE), is always used. Most traditional helmets are designed for protection to radiation. Nowadays some helmets also protect the welder against fumes. But when is a welder sufficient protected against welding fumes? No helmet available now notifies the welder when fume concentrations are dangerously high.
Hardly any effort has been put into understanding the ergonomics of welding. There are no ergonomically guidelines on welding. In work shops, very little attention is paid to ergonomics.

Beyond the state of the art

New will be a prototype smart helmet which warns the welder when fume concentrations exceed safe limits (**MAC value**). Furthermore, guidelines will be established for ergonomically welding leading to a decrease in sick leave due to physically bad welding conditions, containing:
- Product design with welders' ergonomics in mind.
- Aids for ergonomic welding in relation to different products (dimensions, structure) to be welded.
- Awareness at the shop floor for good ergonomic practice.

Virtual Welding

State of the art

No good virtual welding tools are available on the market to help designers to make welder-friendly designs (ergonomics). Most software available is used for calculating welding costs, heat input, preheating temperatures and welding parameters based on material selection, welding process and material dimensions etc and is rather simple and one-purpose only.

Beyond the state of the art

The software tool to be developed should enable product designers and engineers to calculate new solutions for the best ergonomic and minimised fume productions by easily changing the input parameters. Thus, designers can reduce stresses and strain on welders in an early stage.

4. CONCLUSION

Safety and profit in welding operations are major important factors. Through the years the effort in conciliating both topics has been obvious, mostly because the welding community realized that it was impossible to go on without safety and that safety is crucial to reduce costs. However, at present, the research efforts that lead into improvements were done individually; or intending to optimize welding parameters and methodologies to increase productivity, or developing ergonomical/health and safety improvements to reduce workers absence - but never making a jointly analysis aiming at reaching conclusive (and industrially feasible) results.

To focus ergonomics, health and safety and productivity costs in a jointly approach is an ambitious goal of ECONWELD.

The impact of the project will be the reduction of sick leave of welders due to better working conditions and the availability of simple ergonomical tools – both aspects allied to the reduction of process costs.