SUSTAINABLE DEVELOPMENT PROBLEMS FOR GALVANIZED SHEETS AND THEIR JOINING

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Abstract: "Sustainable development" is a concept largely used in the case of galvanized sheet metal and their joining. Electroplating process itself has many implications, but also requires special precautions because of potential emissions and environmental damage. When calculating life cycle cost at welding, a lot of factors must be taken into account, which are schematically presented in the paper. Main classes of emissions that are generated during joining (laser welding, MIG brazing, laser brazing, plasma brazing) of galvanized sheets are presented. All these data is presented compared to other classes of materials.

1. Introduction

"Sustainable development" designates the totality of forms and methods of socio-economic development, at their foundation stands at first the insurance of equilibrium between these socio-economic systems and the elements of the natural capital.

The most used definition for "sustainable development" is the one given by the WCED (World Commission for Environment and Development) which states that "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [10]. At present day, the concept of sustainable development is extended to the quality of life in its complexity, on an economic and social aspect.

2. "Sustainable development" concept

The first factor that contributes to the degradation of the environment is the energy consumed in all the stages to produce and operate the products, from their production, manufacturing, joining, transportation, usage, including their packaging and their disposal. The diminution and control upon the impact on the environment represents the mission of the strategy entitled "sustainable development" and constitutes one of the principal directions at present days and in the next period of time.

Implementation of sustainable development concept can be achieved through innovation at concept and technologic level. The process is multi and inter disciplinary. One can build sustainable based on advanced conceptual models (functionality, safety, neutral or low impact on the environment), using materials with superior physical and mechanical characteristics (recyclable and with low embedded consumption of primary resources and energy), applying constructive systems and related technologies (safety, flexibility, low energy consumption, minimal impact to environment) [10]. The usage of energy on the entire life service, also called operational energy, is one of the most important factors in exploitation.

Considering the huge amount of energy and materials used, environmental impact is increasingly viewed as a necessary condition during the design process. Moreover, this aspect must be considered in all phases, including production, operation and end life cycle. Life cycle analysis (Life Cycle Analysis - LCA) is the best way of determining the environmental impact of products or processes.

LCA is a methodology for assessing the environment and potential associated with a product by [10]:

- compiling an inventory of entry and output data of a system;
- potential environmental impact assessment associated with input and output data;
- interpretation of results in relation to study's objectives.

LCA studies the possible impact of products on the environment, from raw material acquisition through the production, use and disposal. General categories of environmental impact to be considered include the use of resources, human health and ecological consequences (according to ISO 14040).

In this context, a number of impact categories have been defined, for which contributions can be calculated. These are indicators of LCA. By performing an LCA analysis quantitative information can be obtained regarding the contribution of product to climate change and resources reduction. Later they can be compared with other similar results (keeping the same limit conditions).

The principle of LCA analysis is relatively simple: for every stage of life cycle are investigated quantities of materials and energy used and the emissions associated with these processes. Emissions (the most used is the emission of CO_2) are then multiplied by characterization factors proportional to their power, each having a different impact on the environment. Often one is chosen as a reference emission and the result is presented equivalent to the impact of the reference substance.

The elements of LCA require access to international data base, specific to each product/process/material. The entry data necessary to different stages of life cycles are presented in figure 1.

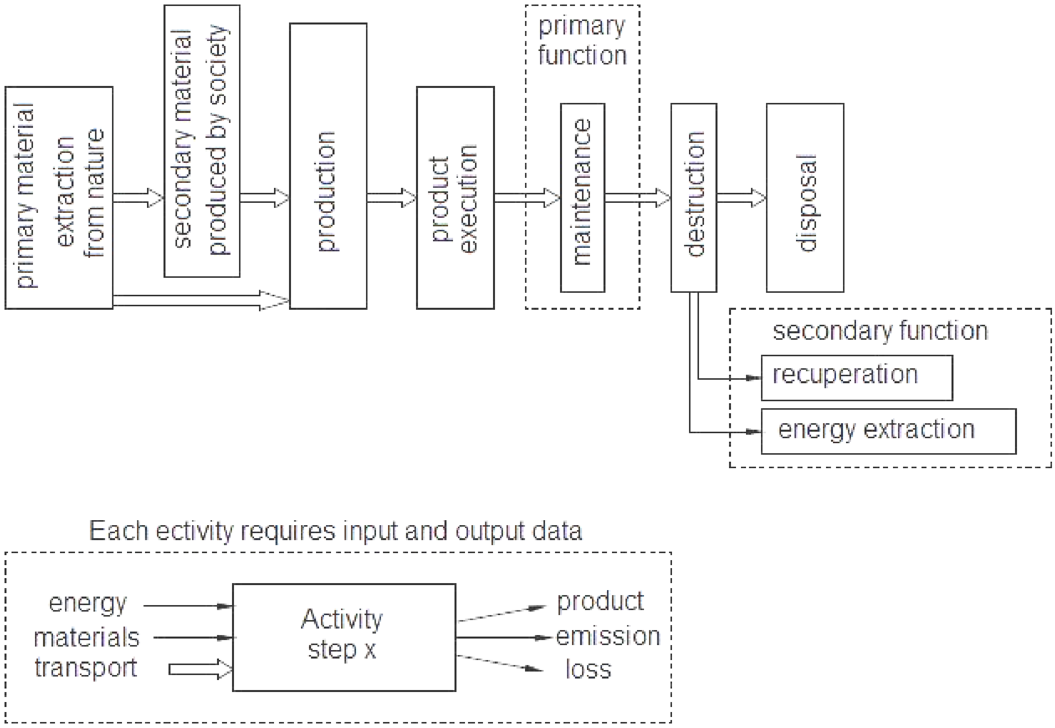

Figure 1 Stages of life cycle of a product and entry data for LCA [10]

3. Life cycle cost of welded products

When talking about life cycle cost, it involves all the other activities linked to it and shown in figure 2. It requires cost reduction of all non-productive activities and simultaneously maximizing the utility U by reducing the need of energy, filler material, shielding gas and increasing productivity [1]. For minimum life cycle cost, the function F should meet the following condition:

$$F = \frac{U}{U + \sum_{1}^{j} Cj(NP)} = Maximum \qquad (1)\ [1]$$

That is why the goal is to reduce consumption of energy and material at every stage and enhance utility of the process through better efficiency, improve duty cycle of equipment etc. Minimizing life cycle cost in welding is complex, as there is no definite loading (to maximize U) in welding (figure 2).

Life cycle cost is, in presence of diversity, not unique. Process with diversity invites multiple problems difficulty in process learning and standardization, complex procedure to achieve energy efficiency, inventory management, quantifying environmental impact, health and safety hazards etc.

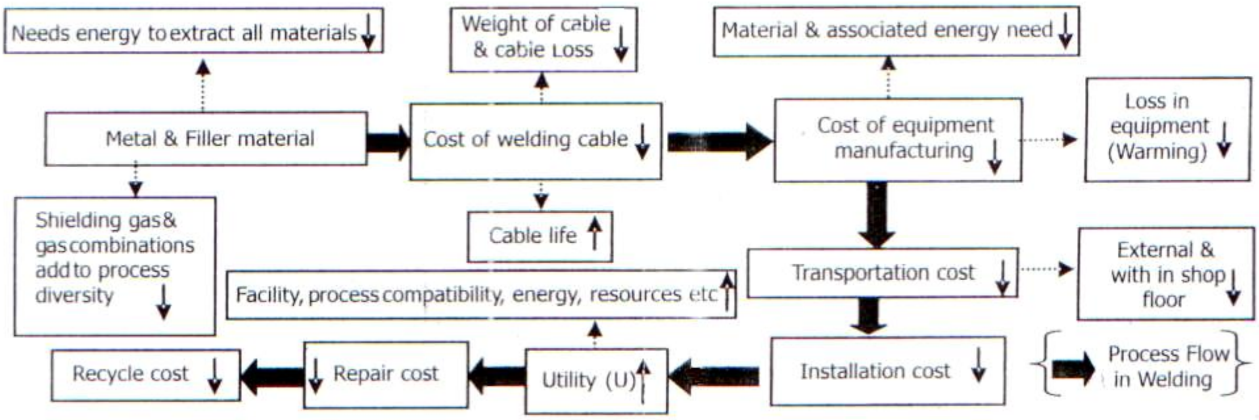

Figure 2 Life cycle cost for a typical arc welding process [1]

4. Joining of galvanized sheets

Welding and brazing may be used for the joining of galvanized sheets [2]. Among the joining processes that can be applied for this kind of sheets, one can find:

a. Shielded metal arc welding (SMAW). In general, the conditions are the same as for the uncoated steel, with the observation that the root opening is higher for some particular cases, to allow full penetration and drainage [8]. Weaving action ahead of the molten pool should be used for the advance of the welding arc.

b. Gas metal arc welding (GMAW). Short circuiting transfer mode should be used, since it produces less damage to the zinc coating than the spray transfer mode. Spatter formation tends to increase with the thickness coating and may be reduced when decreasing the diameter of the welding wire.

c. Flux cored arc welding (FCAW) may be applied with success, since a lot of new products are available on the market, especially the self shielded kind of products, which ensure low penetration and high welding speeds.

One of such products is the Safdual Zn (T 3T Z VH1 H5 according to EN ISO 17632-A) from SAF-FRO [9], metal cored wire suitable for automatic and manual single run welding of galvanized, zinc plated or prepainted thin sheets from 0,8 to 3 mm.

Main applications for this type of wire include: car industry, shipyards, air conditioning equipments.

The recommended welding positions are presented in figure 3.

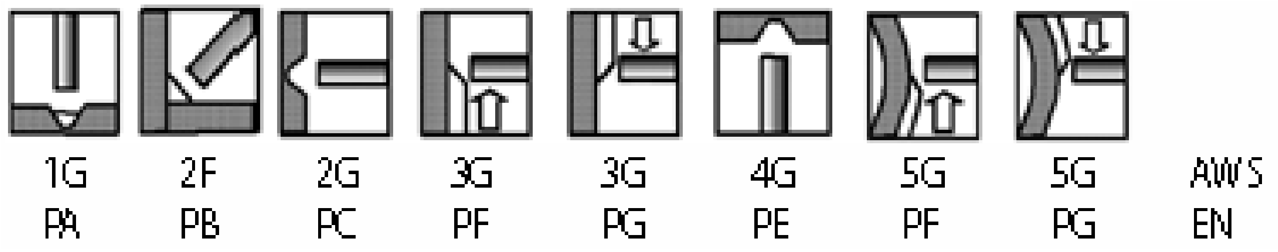

Figure 3 Recommended welding positions for Safdual Zn flux cored wire [9]

This type of wire may be used in the working conditions presented in table 1, only with dc^-, recommended gases include Ar/CO_2 mix.

Table 1 Main parameters for FCAW welding of galvanized sheets [9]

Diameter, mm	Minimum		Maximum	
	Voltage, V	Current, A	Voltage, V	Current, A
1,0	9,5-10	50-60	20-25	250
1,2	9,5-10	50-60	21-25	350
1,6	10-12	60-80	17-26	400

d. Laser welding may also be used for the welding of galvanized sheets, the problems appearing are connected with environmental protection issues.

e. Brazing and soldering. Induction brazing with high frequency is suitable for coated sheets, using filler alloys of silicon bronze or 60% copper – 40 % zinc. Soldering requires the usage of organic flux, the most popular solder composition is 40% tin – 60 % lead.

f. Resistance welding is recommended only for sheets thin coatings (thinner than 5 mm) since a thicker coating leads to a shorter life for the copper electrode.

5. Environmental protection at joining galvanized sheets

All welding processes of the galvanized sheets require special protection measures, since during welding zinc vapours are emitted; those are dangerous for the environment as well as for the health of the welding operator, and one example is the “zinc-fever”.

When using laser welding, special protection measures must be taken regarding the ventilation and filter technique, since the high energy of laser source causes evaporation from the parent material [5].

Emission measurements made for laser welding gave the results presented in table 2 and 3 [5].

Table 2 Emission values for laser welding of galvanized sheets [5]

Material	Emissions of particulate hazardous substances (mg/s) (above processing side)
unalloyed steel	1,5
X 5 CrNi 18 9	1,2
galvanized sheets	7
titanium	0,9

Table 3 Gaseous emissions of hazardous substances at laser welding of galvanized sheet [5]

Material	Emissions of gaseous hazardous substances (µg/s)		
	NO_x	CO	O_3
unalloyed steel	200	56	53
X 5 CrNi 18 9	350	28	19
galvanized sheets	800	56	<

One can see that emissions generated during welding by the galvanized sheets are higher compared to the ones generated by classic materials such as unalloyed steel, alloyed steel or titanium.

Emission measurements during laser welding of chromium nickel steel and galvanised steel as a function of the absorbed beam intensity gave the welding fume emission rates presented in table 4 [5]. The beam intensity varied between 3,18 x 10^5 and 6,67 x 10^5 W/cm^2.

Table 4 Welding fume emission rates of galvanized sheets [5]

Material	Emissions of particulate hazardous substances (mg/s) (above processing side)
chromium-nickel steel (s=3 mm, v_s = 600 mm/min)	≈ 1,5
galvanized steel (s=1 mm, v_s = 400 mm/min)	≈ 2,7

Key components of the welding fume generated at laser welding are presented in table 5. One can see that different parent material classes give different welding fumes, containing key components such as nickel oxide or zinc oxide.

Table 5 Key components of the welding fume generated at laser welding of galvanized sheets [5]

Process	Parent metal	Welding fume / key components
Laser welding	unalloyed, low-alloy steel (alloy components < 5%)	welding fume
	chromium-nickel steel (≤ 20% Cr and ≤ 30 % Ni)	nickel oxide
	galvanized sheets	zinc oxide

During joining of galvanized sheets by brazing, the main components generated are zinc oxide from the coating and copper oxide generated by the filler metal, as presented in table 6.

MIG brazing generates the highest emission quantity, while the lowest emissions are generated by plasma brazing. It was measured [5] that 4,7 mg/s of emissions are generated during MIG brazing with CuSi3 (wire diameter of 1 mm) and a zinc coating that is 45 µm thick.

Table 6 Key components of the welding fume generated at laser welding of galvanized sheets [5]

Process	Parent metal	Filler metal	Main component	Key component
MIG brazing	Galvanized steel	CuSi 3	zinc oxide	copper oxide
	Chromium nickel steel	AlBz 8		
Laser brazing	Galvanized steel	CuSi 3	zinc oxide	
	Chromium nickel steel	AlBz 8		
Plasma brazing	Galvanized steel	CuSi 3	zinc oxide	
	Chromium nickel steel	AlBz 8		
Chromium nickel steel: ≤ 20% Cr and ≤ 30 % Ni AlBz 8: Al 8,2%, rest Cu CuSi 3: Si 3%, Mn 1%, rest Cu				

6. Conclusions

6.1 The paper insists on the “sustainable development” concept, especially when taking into account galvanized sheets.
6.2 The whole of factors that are implied when performing life cycle analysis and costs are presented systematically.
6.3 The main emissions that are involved with the joining of galvanized sheets are presented comparative with other parent materials, with appreciations regarding the joining process that generates the higher quantity of gaseous or solid emissions.

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