Development of Welding cost estimation model based on the feature concept

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A new feature-concept applied in cost estimation model for a weld assemblage: Additional Information

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Abstract:

This paper presents a cost estimation model of weld assemblages. It is based on the product decomposition into parts and then into assemblages. The study is about a proposition of an original definition of welding and preparing features attributed to each assemblages.
This proposed approach is based on knowledge modelling at the level of process and product perception. The decomposition of the product into features and the identification of cost features remain manual. The proposed model consists in combining two cost estimating model applied to the products and to the processes on one hand, we have used an analytic model for the formalizing of the welding time, of the electrode consumption and of gas consumption according to the different parameters of the preparing and the welding features. The decomposition into features allows to formalize the time estimating expertise related to the welding. On the other hand, we have used the parameter method for the cost structuring caused by the different feature cost preparing and by the feature cost welding.

Key words: costs estimation, Feature model, feature cost, welding.

1. INTRODUCTION

The setting up of a reliable system concerning the estimation of costs, takes a considerable importance for the manufacturing enterprises working on request. The accuracy and the rapidity given by a cost estimating method contribute to the order confirmation by the client.

The manufacturing cost is generally obtained by the produce of a part manufacturing time and the manufacturing time estimation methods namely [1]:

- **the analytic method**: which allows to evaluate a product manufacturing time thanks to the decomposition of an elementary manufacturing operation set. We define, for each operation, the necessary time from which we can calculate the manufacturing cost: « manufacturing time multiplied by the manufacturing hourly cost ».
- **the parameter method:** which is based on the utilization of mathematical relations founded on the informations gathered by the enterprise so as to be able to determine if there exist the correlations between the different times and the manufacturing operations.
- **the analogue method: which** is based on the classification and the indexes of the products to manufacture by the enterprise according to morpho-dimensional criteria and to quality. The new product cost is estimated by comparison with reference to the last newly indexed products.

The analytic method consists in describing and developing the whole of operations necessary for the production of the product, this method is known for its accuracy and by its slowness as well. To replace the analytic approach, many enterprises move towards the analogue and the parameter methods. If these methods are relatively rapid, it is because they are essentially synthetic and function in total darkness. They provide the product cost according to certain characteristics which limit the negotiating transparency of marketing men.

In the field of mechanics, several works have been carried out, in particular in the cost estimating of forged parts [2], of cylindric parts [3], of parts machined by the application of the analogue method [4], of parts machined by the application of the parameter method [5], etc. The cost calculation for most of these methods depends on the accuracy of the machining time estimating method.

The present evolution of cost estimating methods [6] [11], consists in integrating at the same time the product geometric and technical characteristics which will remain the same during the whole manufacturing process. This presents the modelling basis by feature. This method is used, throughout this study, to develop an application of welded assemblages for metallic structures.

In this paper, we propose the modelling principle of an assemblage mechano-welded by two features: «a preparing feature and a welding feature» so as to calculate the time relative to each operation using the analytic model. Then, we apply the principle of feature cost for each activity allowing to estimate the assemblage total cost.

In the first part, we'll present the method of welded assemblage time and cost estimation. Then, we will explain the decomposition of a structure into assemblages. This work results in the introduction of new notions of welding and preparing features.

In a second part, we will describe the relation between the technological features and the welding time calculation. For this, we will give details of the analytic models developed for each type of features. Finally we will present the concept feature cost which allows the cost estimating relating to each operation then the application of this concept to preparing cost estimating (borders machining, weld pointing, ...) and to welding.

2. COST AND TIME ESTIMATING MODEL OF WELDED ASSEMBLAGES

The purpose is to provide a model which integrates the information necessary to define the product and its manufacturing process, so as to answer a cost and time estimation. So we propose two parts in this model.

The first part is that of a geometric and technological description of assemblages in welding features and in preparing features.

The second part defines how to conceive these features. The second part defines how to conceive these features. The cost estimating model proposed is based on the definition of the volume of the material added in welding by a geometric description of the welding joint in the assembling area. The knowledge of the filling metal characteristics and the welding mass flow, allow the determination of the welding time for each welding feature. The parameter method for the cost structuring generated by the different feature costs which compose the process "preparing and welding".

3. WELD ASSEMBLAGE MODELLING

The modelling of a weld assemblage takes into account the preparing operation which itself depends on the chosen welding process and on the weld position. For each assemblage, we define two types of features: welding feature and preparing feature.

3.1 Decomposition of a mechano-weld structure

We propose an approach based on the decomposition of the metallic structure to weld in N assemblages. This structure will be called "P" in the next part of this paper, (fig. 2). Each assemblage is carried out by two types of operations: preparing operations and welding operations. This decomposition is given by the set of assemblages which also includes the weld technical parameters.

In the approach of the assemblage decomposition (fig. 2), the survey of the mechano-weld structure, since its conception plans the weld joint number for each assemblage. We attribute for each given assemblage A_{ij}, K_{ij} welding features associated to preparing features.

Each assemblage may contain one or several welding features and after that one or several preparing features.

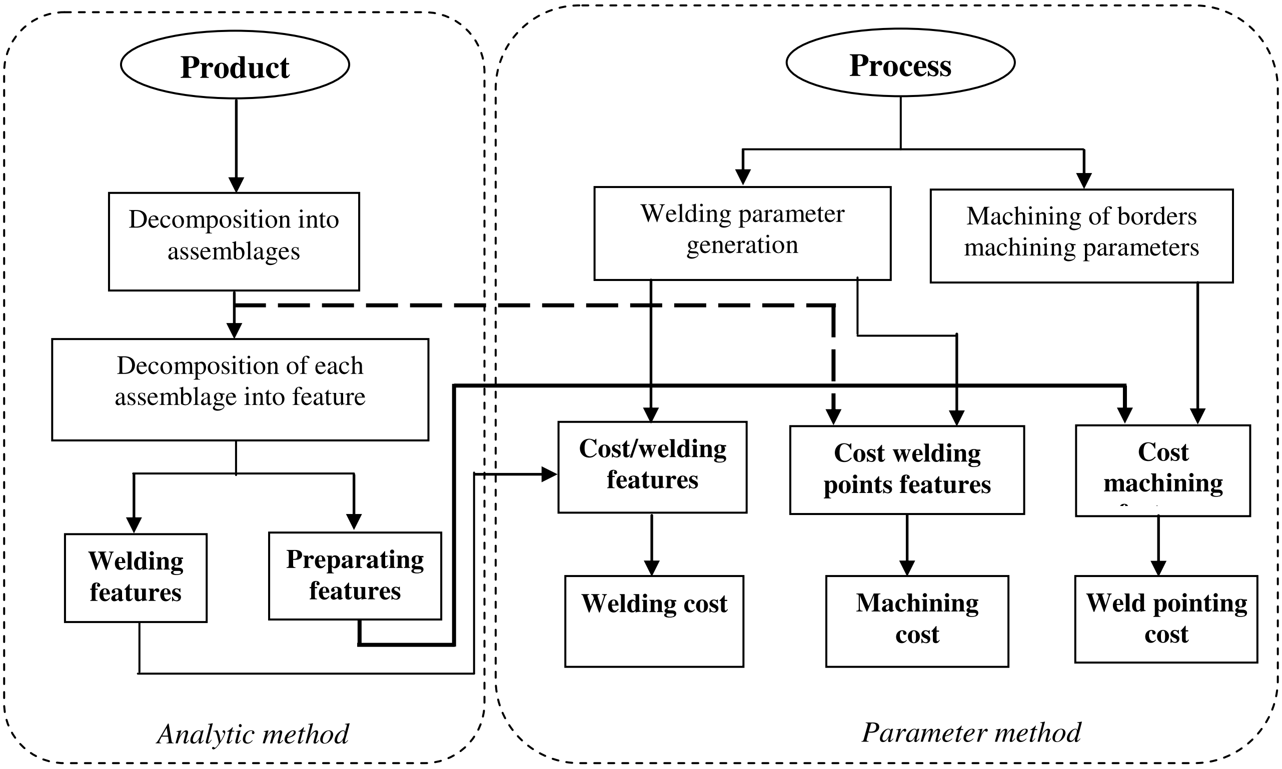


Figure 1: Model proposed for the welding cost estimation

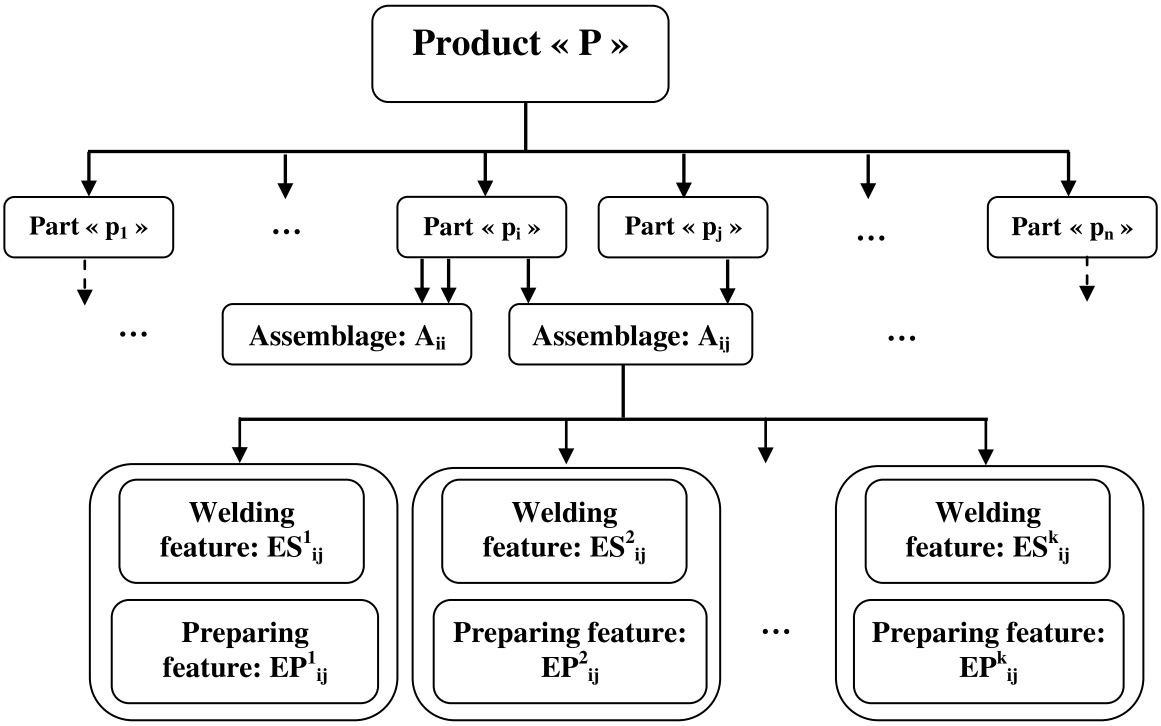


Figure 2: Approach of a decomposition for welding and preparing features

The welding and preparing features concepts rest on the analysis approach of the following characteristics:

- Shape characteristics: they describe geometric shapes often peculiar to an application feed in welding;
- material characteristics : they correspond to the nature of basic materials, their treatment, etc. ;
- the process characteristics : they collect the informations about the welding process (arc, resistance, etc), etc. ;

- assemblage characteristics : they regroup the linking conditions, the position and orientation of parts, the assembling type, etc.

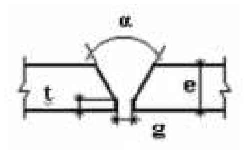
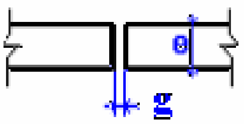
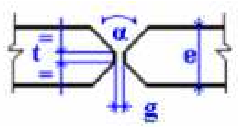
3.2 Feature model

3.2.1 Preparing features

The preparing feature includes the machining of borders in V, X etc and also the positioning of the parts to weld one according to the other (gap, alignment, pointing, etc). It is principally defined by the geometric shape which defines the space to be filled with the filling metal. Table I presents examples of preparing features in V, in straight borders and in X.

Among these preparing features, there are some which are technically and economically recommended, we mention here: recommended preparing features ».

Table I: An example of a preparing feature parameter

	Diagram	Features parameters	
Preparing feature « End to End in V »		Thickness	**e**
		Basic metal	**steel**
		Preparation form	**En V**
		Chamfer opening angle	***α***
		Clearance apace	***g***
		Heel or height of the flat	**t**
Preparing feature « End to End with vertical borders »		Thickness	**e**
		Basic metal	**steel**
		Forme de préparation	**En I**
		Clearance apace	***g***
Preparing feature « End to End in X »		Thickness	**e**
		Basic metal	**steel**
		Preparation form	**En X**
		Chamfer opening angle	***α***
		Clearance apace	***g***
		Heel or height of the flat	**t**

3.2.2 Welding feature

According to the welding process and techniques, the weld joint is obtained in one or several processes executed by the operater. The welding feature is principally defined by the parameter presented in table II.

Table II: Parametring of a welding feature

Welding feature	
Technical parameters	
Basic metal	Example : steel
Thickness	e (mm)
Assembling type	Example : End to End
Welding position	Example : Flat
Welding process	Example : SMAW
Number of re-starting	z

Welding intensity	I (A)
Type of current	Example : continued
Electrode diameter	ϕ (mm)
Electrode output	ρ
Protection gas density	D
Geometric parameters	
Weld section	SS
Height of weld	h

4. TIME AND COST CALCULATION

4.1 Analytic method calculation of the welding time

To estimate the feature welding time for an assemblage, we propose an approch based on the evaluation of the welding section from a geometric modelling.

4.1.1 Geometric modelling

Fig. 3 presents the approach to calculate the welding section based on the geometric parameters of the corresponding feature preparing.

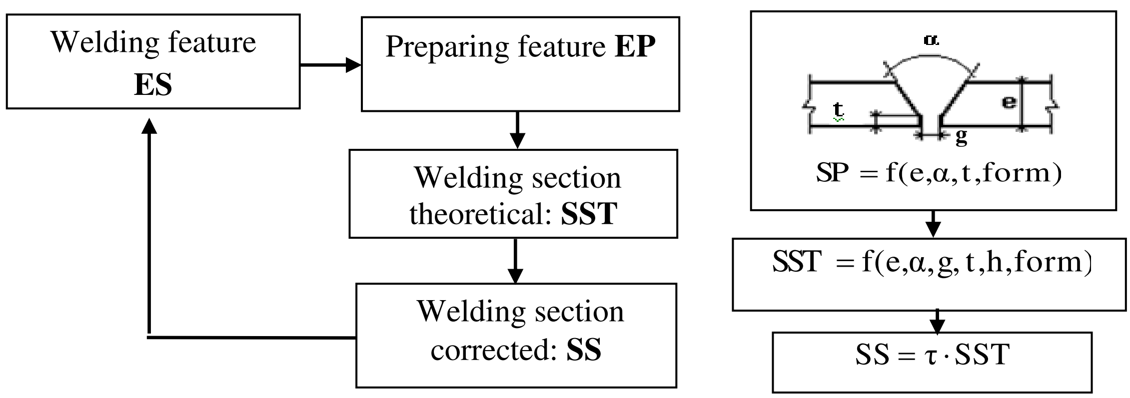


Figure 3: The geometric modelling approch of a welding section

The geometric modelling related to each preparing feature must be saved in a technical data base.

To explain the approach we are going to treat the example of preparing feature end to end in V. Fig. 4 presents a geometric modelling in order to determine the welding section.

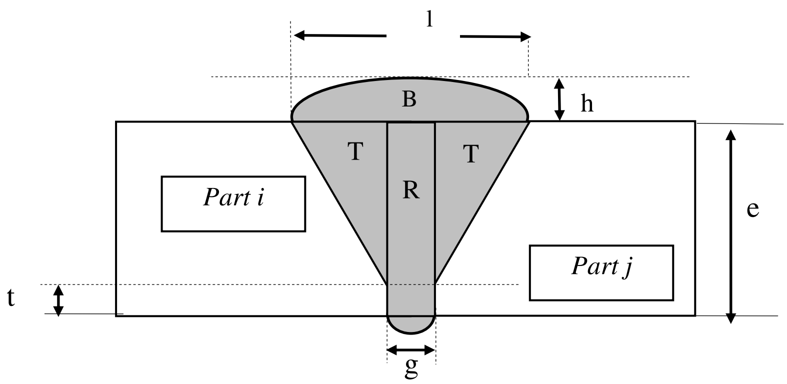


Figure 4: Geometric modelling of a welding feature « End to End » in V

The preparing feature section marked « SP » is represented by two times the surface T.

The theoretical welding section is given by:

$$SST = B + R + 2T \tag{1}$$

To determine « SST », it is necessary to calculate:

- the two triangles section «T » which is:

$$2T = \frac{(1-g)}{2} \ (e-t) \tag{2}$$

where $$l = g + 2(e-t) \ tg(\frac{\alpha}{2}) \tag{3}$$

- R which is the triangle surface with a length « g » and with « e »,

$$R = g \cdot e \tag{4}$$

- B is estimated at 75 % of the rectangle section of a length « l » and a width « h ».

so: $$B = \frac{3}{4} \cdot l \cdot h \tag{5}$$

According to (1), we can write that:

$$SST = g \cdot e + (e-t)^2 \, tg(\frac{\alpha}{2}) + \frac{3}{4} \cdot l \cdot h \tag{6}$$

By replacing the expression of « l » in the equation (7), we get:

$$SST = g \cdot e + (e-t) \cdot (e - t + \frac{3}{2} h) \cdot tg(\frac{\alpha}{2}) + \frac{3}{4} \cdot g \cdot h \tag{7}$$

Generally, the welder can’t respect exactly the limits of the preparing section while executing the welding operation. For this reason, we suppose that the section SST must be corrected by a coefficient « τ ».

The relation between the theoretical SST and the actual section is written:

$$SS = \tau \cdot SST \tag{8}$$

« τ » is practically near the unity in the case of an automatic application of the welding operation.

4.1.2 Welding time estimation

The principle consists in establishing a simple cost estimating system which closely associates the technical parameters (welding features), and the geometric parameters.

To determine a feature welding time, it is necessary to determine the geometric parameters so as to calculate the volume of the filling metal in the welding area. When we know the basic metal density, we can determine the weight of the weld joint and then the welding time, see the organigram present in (fig. 5).

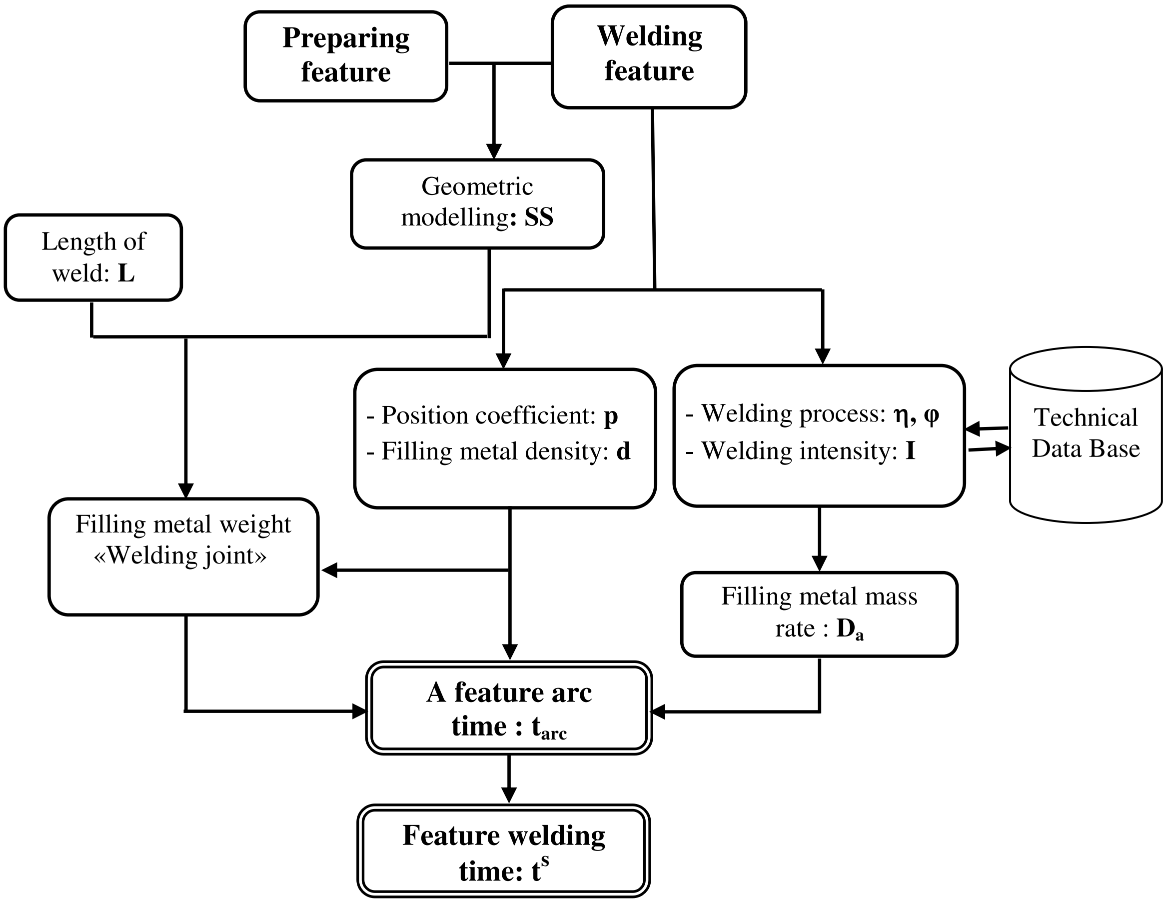


Figure 5: Welding time calculating methodology

The use of time estimating analytic method can be perfectly considered. The estimating approach of the welding time is organized around the following four stages:

Stage 1: welding volume evaluation. It is the produce of the welding section by the welding length:

$$V_s = SS \ .L_{ij} \tag{9}$$

Where L_{ij} : welding length
SS : welding section

Stage 2: Amount of Welding Wire

$$m_a = \frac{\rho \cdot V_s \ .d}{\eta} \tag{10}$$

Where d: the filling metal density
η: the process efficiency
ρ: the electrode output

Stage 3: The electrode time « t_{arc} » is the electrode and protecting gas consuming time. It is expressed by:

$$t_{arc} = \frac{m_a}{D_a} \tag{11}$$

Stage 4: the welding operation executing time is the arc time corrected thanks to the operator efficiency and to the coefficient of the positioning difficulty:

$$t^S = p \cdot \frac{t_{arc}}{\varphi} \tag{12}$$

Where φ : the process depending on the operator efficiency;
p : this coefficient depends on the complexity of the weld positioning and of the assemblage type.

Basing on the formulas (9), (10), (11) and (12), for one feature, we can write:

$$t^S = \frac{\rho \cdot p}{\varphi \cdot \eta} \frac{d}{D_a} . SS \cdot L_{ij} \qquad (13)$$

4.2 Cost estimation

4.2.1 Definition of the cost feature approch

We adopt the cost feature definition proposed [5] and [6]:

«A feature cost is a grouping of costs associated to resources consumed by one activity. The fundamental condition cares about the homogeneity of the resources consumed by the feature cost which allows to associate them to an indicator »

The feature cost modelling objective is to provide a model which integrates the necessary information to the definition of the product and of its manufacturing process so as to ensure a cost estimation in a preparing phase to the manufacturing.

4.2.2 Cost parameter formulation

For a given manufacturing process, the concept feature cost allows on one hand to estimate the direct cost corresponding to the manufacturing operation by determining for each of them the indicator of the corresponding « feature cost ».

Given « C_i » the activity cost « i » and $R_i = R_1, R_2, \ldots, R_k$ the whole of the resources consumed for this activity. By definition the cost of a resource is written:

A resource cost = Inductor (number) * α_k (hour/number) * charging rate (cost/hour)

Then, a resource cost is written k:

$$C = x_i \cdot \alpha_k \cdot C_k \qquad (14)$$

Where

α_k : resource consumption coefficient k
x_i : activity inductor « i »
C_k : charging rate for the resource k
$t = x_i . \alpha_k$: is a resource consuming time

The model basic equation giving an activity cost will be then the sum total costs of different resources [3]:

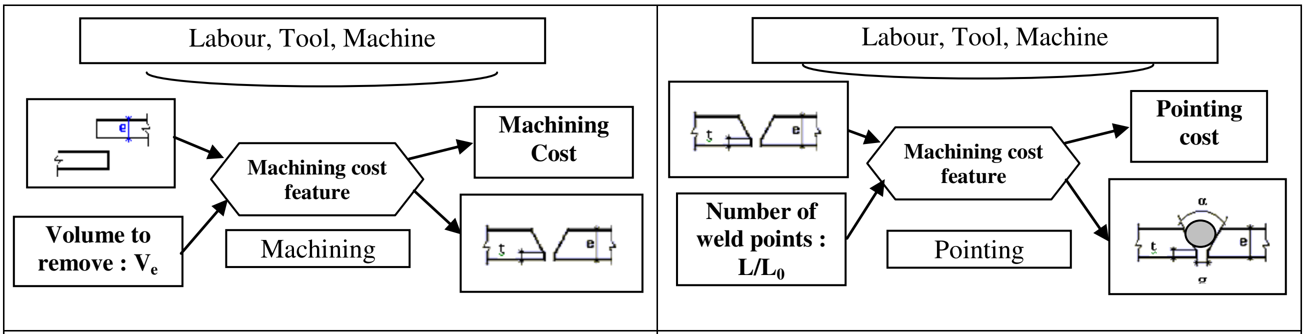
$$C_i = \sum_{k \in R_i} x_i \cdot \alpha_k \cdot C_k \qquad (15)$$

To identify the inductors, we can use several methods like the expert consulting or a detail survey of the activity or at last, basing on a sufficient number of historical data of a quite large number of inductors by selecting the most influent ones.

4.2.3 Preparing cost estimation

Each preparing feature calls for intrinsic parameters which describe the product and also for the position and the orientation geometric characteristics.

So, the cost preparation feature is composed of the cost machining feature, figure 6.a and of the pointing cost feature (fig. 6.b).



(a) The structure of the machining cost feature | (b) The structure of the pointing cost feature

Figure 6: Cost feature structure

a) Machining cost feature

It is quite evident that the machining cost feature has the volume of the material to remove indicated « V_e » as indicator. In the application of the equation (14), the machining cost is the sum total of the resources cost which compose the machining cost feature.

$$C^U = C_{MO}^{ECU} + C_{MA}^{ECU} + C_{OU}^{ECU} \qquad (16)$$

where

$C_{MO}^{ECU} = V_e \times \alpha_u \times C_u$: is the labour cost

$C_{MA}^{ECU} = V_e \times \alpha_{um} \times C_{mu}$: is the machine utilizing cost

$C_{OU}^{ECU} = V_e \times \alpha_{uo} \times C_o$: is the lubricant and tool consumption cost

C_u : Labour hourly cost

C_{mu} : machine utilizing houry cost

C_o : tool wear hourly cost

V_e : volume of material to remove

α_{um} : machine utilizing coefficient

α_{uo} : lubricate and tool consuming coefficient.

We note « α_u » the coefficient to measure the time consuming by volume of material removed, it is expressed in hour/cm^3. This coefficient is given by:

$$\alpha_u = \frac{c}{D_v} \qquad (17)$$

Where D_v : the machining volume rate.

$c \geq 1$: a complexity index: we associate to each type of preparing feature a complexity index which will be a parameter depending on the preparing technology adopted by the entreprise. It can be determined from a atatistic approch applied to each type of feature and initialized according the experience.

To calculate the machining time for the « End to End » type preparation, we can write the following relation:

$$t^U = \frac{c\ .SP \cdot L}{D_v} \qquad (18)$$

Where SP: preparing feature section of an assemblage.

L : length of the assemblage weld.

c: complexity index according to the form of preparation.

D_v: machining volume rate.

b) Pointing cost feature

The pointing allows a conformable disposition of the two parts to weld. It also allows to juxtapose the borders one according to the other and after that, it controls the space all along the weld path « L ».

We note « α_p » the coefficient which measures the time consumption it takes to make a point weld which remains subject to the difficulties of execution and of accessibility.

$$\alpha_p = \lambda \cdot t_0 \quad (19)$$

Where λ : the coefficient linked to the difficulties, with $\lambda \geq 1$

t_0 : the elementary time to achieve a point of weld

c) The resources cost of the feature "pointing cost" is principally composed of the labour cost and the weld consuming cost for the pointing.

- The labour cost for the pointing is written:

$$C_{MO}^{ECP} = \lambda \cdot t_0 \cdot \frac{L}{L_0} \cdot C_p \quad (20)$$

Where C_p : labour hourly cost for the pointing operation

L/L_0 : the number of points

- The pointing cost is the sum total of the resources costs, which compose the pointing cost feature.

$$C^P = C_{MO}^{ECP} + C_{MA}^{ECP} \quad (21)$$

We suppose that the cost of one point of weld is neglect-able compared to the total welding cost.

4.2.3 Welding costs estimation

Subsequent to the analytic modelling applied to the scale of a feature, according to the (relation 13) which determines the welding time, we can write:

$$t^S = \frac{p}{\varphi} \frac{m_a}{D_a} \quad (22)$$

It is to remark that there is a harmony with the feature cost approach. In fact, if we take the mass of materiel to be added as a convenient inductor for the welding operation, then we can write that the time consuming coefficient of the weld noted « α_s » as follows:

$$\alpha_s = \frac{p}{\varphi \cdot D_a} \quad (23)$$

After having estimated the total time of welding, it has become possible to make a detailed cost calculating of each consumption engendered by the welding activity.

a) The labour cost is:

$$C_{MO}^S = m_a \cdot \alpha_S . C_s \quad (24)$$

Where C_s: Labour hourly cost «UM/mn ».

b) The elctrode consuming cost is:

$$C_{EL}^S = m_a . C_e \quad (25)$$

Where C_e: electrode cost by mass unit « UM/g ».

It is clear that the consuming coefficient of the resource « Electrode» is $\alpha_S^{Electrode} = 1$

c) The gas consuming cost is:

$$C_{GA}^S = \frac{D \cdot \chi}{D_a} . m_a \cdot C_g \quad (26)$$

Where D : protection gas density in « g of gas / cm^3 »

χ : the gas volumic rate in « cm^3/mn ».

C_g : gas cost by mass unit « UM / g of gas ».

The consumption coefficient of the resource « gas » is:

$$\alpha_S^{Gaz} = \frac{D \cdot \chi}{D_a} \qquad \text{«g of gas/g of electrode »}$$

d) The consumption cost of electric energy is [19]:

$$C_{EE}^S = \frac{U.I.m_a}{60 \cdot \mu \cdot D_a} \; C_k \tag{27}$$

Were I : current intensity « A »
U : the electric current tension « V »
C_k : electric energy cost in «UM/kWh »
μ : the transformer average output

The electricity consumption coefficient is:

$$\alpha_S^{EL} = \frac{U.I}{60 \cdot \mu \cdot D_a} \qquad \text{« kWh/g ».}$$

e) The utilization cost of the welding post:

It corresponds to the cost engendered when the post in function. To determine it, it is necessary to know welding machine hourly cost, « C_{ms} ». It is expressed as follows:

$$C_{Ma}^S = \frac{m_a}{D_a} \cdot C_{ms} \tag{28}$$

The consumption coefficient of the resource (post utilization) is $\alpha_S^{Poste} = \frac{1}{D_a}$ « mn/g »

The total weld cost is the sum total of the elementary costs: labour, electrode conception, protecting gas conception, electricity consumption and welding post. It is written as follows:

$$C^S = C_{MO}^S + C_{EL}^S + C_{GA}^S + C_{EE}^S + C_{MA}^S \tag{29}$$

In any case, the raw material cost is not to neglect. It is evident that it is considered during the welding operation.

To generalize, the total welding cost of a feature « q » is the sum total of the machining cost, the pointing cost and of the welding cost for each feature.

$$C_q^T = C_q^S + C_q^U + C_q^P \tag{30}$$

The total welding cost of an assemblage (i,j) is then the sum total of all the welding costs of the feature which composes it:

$$C^T(i,j) = \sum_{q=1}^{k(i,j)} C_q^T \tag{31}$$

Where k (i,j): the number of assemblage (i,j) welding features.

<u>5. IMPLEMENTATION</u>

The proposed cost estimation model for a weld assemblage based on the concept feature is implemented to a software model for computer aided costs estimation, which is presented in [12]. The developed software constitutes an aided decision tool to calculate the cost and establish the sales conditions by the experts. It is therefore possible for him to make simulations.

6. CONCLUSION

In this paper, we have explained the concept and the basic principle peculiar to our approach of time and cost estimating in parts welding. The model by feature which we have develop, is characterized by the weld geometric description and by the volume defining of the material added in welding.

The formalization of the welding time is carried out by an analytic method of gas and electrode consumption according to the feature different geometric parameters and to the welding process. The cost estimating is assured by a parametric approach. The model includes all the stages of the welding process: preparation and weld.

To automatize the cost generating process, it is necessary to integrate the modelling of knowledge, the modelling of the arguments for the generating of preparation and weld features allowing the identifications of the features cost as well as their suitable inductors.

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