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USING THE DECISION THEORY IN CHOSSING A WELDING EQUIPMENT WITH ULTRASOUNDS

Nicoleta RACHIERU
University of Pitesti, Romania

*Corresponding author e-mail: nicoleta.rachieru@upit.ro

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Abstract. For any vehicle, the electric equipment is a basic component, of which functionality has repercussions on consumption, pollution, driving comfort, road safety, etc. Car manufacturers pay special attention to improving the price quality ratio and customer satisfaction. In this sense, they are constantly concerned by refurbishment and use of the latest research results in production processes.
This paper presents the aspects the operation of ultrasonic welding in the technological process of car wiring manufacturing and the use of a method from decision theory to replace the current ultrasonic welding equipment, respectively, the welding machine with ultrasounds Minik II, with a more productive modern variant and which leads to a superior welding quality.
Keywords: auto wiring, ultrasounds, ELECTRE method, Minic II

INTRODUCTION

The electric system or the electric component of o vehicle consist in the ensemble of the electrical and electronic equipment generators and consumers, which are installed on bord. These components are connected to each other by cables and electrical conductors. Hence the importance of wiring in the automotive industry [1, 2].
• Electricity generation and storage;
• Ensuring a constant voltage for the supply of the receivers;
• Ensuring the operation of the car's engine (spark or diesel compression);
• Ensuring comfort parameters in the passenger compartment;
• Providing lighting outside the vehicle and in the passenger compartment;
• Optical and audible signalling, etc.

A **vehicle wiring** is the totality of the cables that make the electrical connections between the electrical and electronic devices on board the car. The vehicle wiring consists of several modules, which are subassemblies joined by a common element, the basic wiring.

The modules are subassemblies of the vehicle wiring, which are intended to supply certain elements of the car, which may be in the basic package or may be optional, offered by the manufacturer, at the customer's request.

The basic wiring includes all the standard modules that come with the vehicle in its basic version, and that ensure its operation. The basic wiring is made up of several elements:

- Contactors (slippers);
- Cables (wires, conductors);
- Gaskets for sealing;
- Cases;

- The elements that support the wiring;
- Hoses;
- Boxes;
- Sleeves;
- Insulating tape.

MANUFACTURING PROCESS FOR AUTOWIRRING

The manufacturing process of a car wiring, within the specialized companies, is carried out in several stages (fig.1).

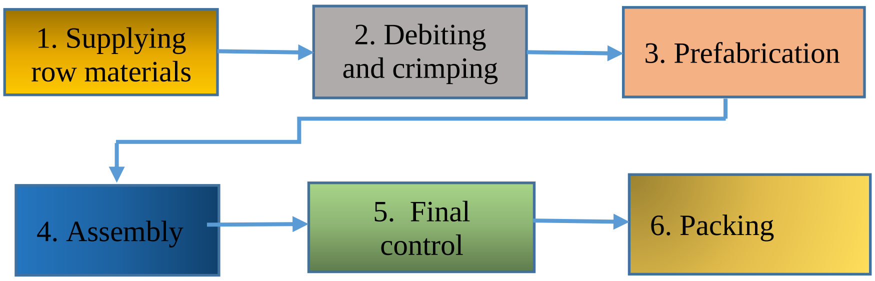

Fig.1 The manufacturing process of a car wiring – main stages

Stage 1 - Supplying for the Cable Cutting Section raw materials.

In the first stage of the process, three main activities are performed:

- Reception of the raw materials (administratively and physically point of view);
- Control quality point of view of the received components;
- Storage and destocking.

Stage 2 - Debiting and Crimping.

During this operation, several processing cycles are performed:

- Cutting and stripping;
- Application of sealing gaskets on wires;
- Crimping.

Stage 3 - Prefabrication.

In the prefabrication stage, a series of successive operations take place, depending on the customer's requirements, established by the wiring design:

- Twisting the cables;
- Crimping ring contactors;
- Mowing of contactors;
- Insertion of contactors in housings;
- Ultrasonic welding;
- Sealing.

Stage 4 – Assembly

After performing the operations described above or only part of them, the processed cables are sent to the assembly section. During the assembly stage, we encounter several operations, such as:

- Application of wiring support elements;
- Thread matting.

Stage 5 - Final control

- The finished product obtained after the final assembly is controlled in terms of visual quality and dimensional control tools. If it is found that the wiring doesn`t meet the requirements specified in internal and customer standards, it will be stored separately for refurbishment.
- The most important phase of the control is the control of the functionality of the wiring (electrical verification).
- After the verification is completed, to the wiring a label indicating the status of the product (compliant or non-compliant) is attached, and then it is sent to the finished product warehouse for packaging, respectively to the reconditioning section, depending on the test result.

Stage 6 - Packing

- At this stage, the finished products are placed in wooden containers in the warehouse, from where they are picked up by trucks for delivery.

During the wiring manufacturing process, the ultrasonic welding operation (fig.2) is part of the category of pressure welding methods, with mechanical energy. No additive material is used. The energy source used is the ultrasonic waves applied locally on two or more stripped ends of the electrical conductors, which are pressed together on their contact surfaces, creating the final joint [3]. *Ultrasound* is a high frequency vibration (over 16,000 cycles/second) that cannot be perceived by human hearing. The welding operation is the stage preceding the sealing in the technological process, it is performed on the Minic II ultrasonic welding machine and the steps to be completed are:

1. *Setting up the machine* – Are manually inserted in the working window the sections of cables to be welded. For example, S = 2x2.035mm^2 = 0.7 mm^2, S being the cumulative section of the two conductors. This means that two cables with a section of 0.35mm^2 are welded. The machine automatically sets the welding parameters: amplitude, energy, width of the welding node.
2. *The welding execution* (fig.3) - The stripped conductors at the ends are placed on top of each other on the sonotrode (the one with the largest section is placed first, directly on the sonotrode, and the others are placed over the first, in descending order of section size), then depress the foot pedal with which the machine is equipped.

Fig. 2 Welding operation with ultrasounds

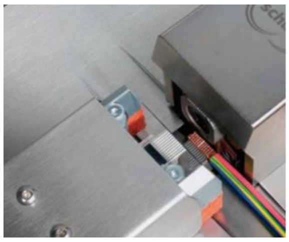

Fig. 3 Welding operation with ultrasounds

3. *Weld checking* – It is checked under the microscope for defects, then test the tensile strength and check the degree of compression of the conductive cores with a frequency of 1/10.

The operation is performed with a Minic II Ultrasonic Welding Machine (fig. 4), designed by Schunk Sonosystems to weld conductors made of non-ferrous materials.

Fig.4 Minic II [4, 5]

CASE STUDY. USING THE ELECTRE METHOD TO REPLACE THE ULTRASOUND WELDING MACHINE

Possible solution for replacing the machine

The aim is to replace the current machine from the welding station with a new one. In this sense, several solutions have been sought, in order to increase productivity, and also to be economically advantageous. The variants considered were:

- The welding machine with ultrasounds *Dual Head SpliceRite*, manufactured in 2016, by the Sonobond Ultrasonic Company, with 2 welding heads;

- The welding machine with ultrasounds *TelsoSplice TS3*, manufactured in 2016 by the Telsonic company;
- The welding machine with ultrasounds *Minic III*, manufactured in 2017 by the Schunk Sonosystems company.

The manufacturers provide some information on the characteristics of the three machines (Table 1).

Table 1. Characteristics of the possible variants

Equipement	**Price** (euro)	**Manufacturing year**	**Power** (kW)	**Welding time** (s)
Dual Head SpliceRite	35 000	2016	3,5	4
TelsoSplice TS3	30 000	2016	3	5
Minic III	28 000	2017	3	4,8

Choosing the optimal solution using the ELECTRE Method

In order to decide which is the optimal variant for replacing the means of production from the welding station of the electrical connections, the multicriteria decision method ELECTRE was used. It is one of the most widely used methods in decision theory. The ELECTRE method (Elimination et Choix Traduissent la Realite) was developed in 1967 by Bertrand Roy. It is a tool used to facilitate a decision - making process with certainty [6, 7, 8]. In applying the method, the following steps are followed:

1. *Establishing the variants,* noted with V_i (i=1,m) *and establishing the criteria*, noted with C_j (j=1,n).

- *The decisional variants* are:

V_1 = Dual Head SpliceRite;
V_2 = TelsoSplice TS3;
V_3 = Minic III.

- *The decision criteria* are:

C_1 = Purchase price;
C_2 = Power (electricity consumption;
C_3 = Welding time.

The consequences of the variants for each criterion considered are established (Table 2)

Table 2. Consequences of variants of each criterion

V_i/C_i	**C_1 (euro)**	**C_2 (kW)**	**C_3 (s)**
V_1	35 000	3,1	3,2
V_2	30 000	2,9	4,0
V_3	28 000	3	3,6

The following important coefficients are considered: k_1=0,5; k_2=0,3; k_3=0,2.

2. *The realization of the matrix utilities is considered* (table 3).

Intermediary utilities are calculated with the following relations:

$$u_{ij} = (a_{ij} - a_{jmin})/(a_{jmax} - a_{jmin}), \text{ for minimization;} \quad (1)$$

$$u_{ij} = (a_{jmax} - a_{ij})/(a_{jmax} - a_{jmin}), \text{ for maximization.} \quad (2)$$

Table 3. Matrix utility

V_i/C_i	**C_1**	**C_2**	**C_3**
V_1	0	0	1
V_2	0,2857	1	0
V_3	1	0,5	0,5
Σ_j	0,5	0,3	0,2

The total utilities of the three variants are

U_{T1}=0+0+1=1
U_{T2}=0,2857+1+0=1,2857
U_{T3}=1+0,1666+0,5=1,6666

3. *Calculation of the matching indicators* (table 4) between two variants according to the relation:

$$C(V_g, V_h) = \frac{\sum k_j}{k_1 + k_2 + \ldots + k_m} \quad (3)$$

were:

$k_j(j = 1\ldots m) =$ the importance coefficients of the considered criteria;

$\sum k_j$ = the sum of the importance coefficients of the criteria for which the condition is met: $U(V_g) \geq U(V_h)$

$$\begin{aligned} &C (V_1, V_2) = k_3/(k_1+k_2+k_3)=0,2/(0,5+0,3+0,2)=0,2 \\ &C (V_1, V_3) = k_3/(k_1+k_2+k_3)=0,2/(0,5+0,3+0,2)=0,2 \\ &C (V_2, V_1) = (k_1+k_2)/(k_1+k_2+k_3)=(0,5+0,3)/(0,5+0,3+0,2)=0,8 \\ &C (V_2, V_3) = k_2/(k_1+k_2+k_3)=0,3/(0,5+0,3+0,2)=0,3 \\ &C (V_3, V_1) = (k_1+k_2)/(k_1+k_2+k_3)=(0,5+0,3)/(0,5+0,3+0,2)=0,8 \\ &C (V_3, V_2) = (k_1+k_3)/(k_1+k_2+k_3)=(0,5+0,2)/(0,5+0,3+0,2)=0,7 \end{aligned} \quad (4)$$

Table 4. Matching indicators

	V_1	**V_2**	**V_3**
V_1	-	0,2	0,2
V_2	0,8	-	0,3
V_3	0,8	0,7	-

4. *Calculation of discordance indicators* (table 5) with relation*:*

$$D(V_g, V_h) = \begin{cases} 0, & dacă \quad U(V_g) \geq U(V_h) \\ \frac{1}{\alpha}\max\{|U(V_g) - U(V_h)|\} \end{cases}; \quad (5)$$

for $U(V_g) \geq U(V_h)$, α= the maximum difference between the maximum utility and the minim one;

It is considered α=1.

D (V_1, V_2) = max {|0-0,2857|, |0-1|}=1
D (V_1, V_3) = max {|0-1|, |0-0,166|}=1
D (V_2, V_1) = max {|0-1|}=1
D (V_2, V_3) = max {|0,2857-1|, |0-0,5|}=0,7413
D (V_3, V_1) = max {|0,5-1|}=0,5
D (V_3, V_2) = max {|0,5-1|}=0,5

Table 5. Discordance indicators

	V_1	**V_2**	**V_3**
V_1	-	1	1
V_2	1	-	0,7413
V_3	0,5	0,8334	-

5. *Choosing the optimal option (table 6)* takes place through successive operations of outclassing the variants with the help of outclassing relations of the form:

$$\begin{cases} C(V_g, V_h) \geq p \\ D(V_g, V_h) \leq q \end{cases}; \quad (6)$$

where p and q are thresholds, a pair of values between 0 and 1 (p is as close as possible to 1, q is as close as possible to 0). From the outclassing relations results a series of graphs G (*p*, *q*) from which the optimal variant is deduced. As p decreases and q increases, the variant that outclasses all the others is obtained. The thresholds p (optimism threshold) and q (pessimism threshold) are initially considered as follows: p = 1 and q = 0. 5. Pairs of values are chosen: p = 1, q = 0; p = 0.7, q = 0.3; p = 0.5, q = 0.5; p = 0.3, q = 0.7; p = 0.2, q = 0.8.

„No” means that V_g not outclasses V_h.

„Yes" means that V_g outclasses V_h.

For the pairs p=1, q=0; p=0,7, q=0,3 does not appear outclasses.

For the pairs p=0,5, q=0,5; p=0,3, q=0,7, appear 2 relations of outclasses: between V_3 and V_1, V_3 and V1.

For the pair p=0,2, q=0,8 appear 2 relations of outclasses: between V_2 and V_3 and between V_3 and V_1.

Relations of outclasses are represented through a graph (fig. 5), in which the outclass is represented by an orientated arch from g to h.

Table 6. Outperforming relationships

Comparative variants (V_g, V_h)		V_1, V_2	V_1, V_3	V_2, V_1	V_2, V_3	V_3, V_1	V_3, V_2
C (V_g, V_h)		0,2	0,2	0,8	0,3	0,8	0,7
D (V_g, V_h)		1	1	1	0,7413	0,5	0,5
1	p=1, q=0	No	No	No	No	No	No
2	p=0,7, q=0,3	No	No	No	No	No	No
3	p=0,5, q=0,5	No	No	No	No	Yes	Yes
4	p=0,3, q=0,7	No	No	No	No	Yes	Yes
5	p=0,2, q=0,8	No	No	No	Yes	Yes	Yes

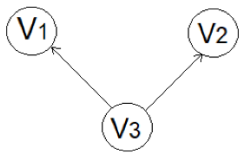

Fig.5 Outclasses situations

CONCLUSIONS

The offer on the market of ultrasonic welding machines is varied, being necessary tounderline the taken decision regarding the variant of purchased equipment. In this situation, the use of a choice method from Decision Theory is required. Of course, the result will be analyzed and discussed before moving to manufacturing implementation. It can be seen in Fig. 5 that the optimal option is the V3 variant, that means the Minic III ultrasonic welding machine from Schunk Sonosystems. The company decides to purchase this machine. During the test period, the new variant will be compared with the current situation at the welding station through specific tests.

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