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TQM model for the competitive advantages of an electromechanical company

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Abstract. The present work shows the results of a study realized in an electromechanical company aiming at the qualification of a particular process, completely automatized. The work has been carried out by the employment of statistical techniques and instruments of Problem Solving. In particular, the determination of the causes of the main problems on this line has been realized by means of instruments such as the Ishikawa Diagram and Scatter Plots and Stratification. It was made the attempt to intervene on the main causes of the problems and to reduce each time the dispersion of the output values around the tendency value.

Keywords: Total Quality Management, Performance, Process Capability, Performances.

1 Introduction

Improving performance in manufacturing and servicing is the basic objective of modern operations management approaches. Benchmarking, reengineering and TQM rely on the hypothesis that critical success factors may be improved, either through quantum leaps or continuous improvement of the underlying processes [1]. Though many researchers consider total quality management (TQM) to be an important organizational innovation, often authors include TQM among management fads [2], [3], [4]. A great deal of empirical research investigates the relationship between TQM and performance. Some authors find positive results [5], [6], [7], [8], other researchers fail to find any significant link [9], [10] and some studies even identify an inverse relationship [11]. In the light of these findings, numerous authors highlight the need for a deeper investigation of the relationship between TQM and performance and the creation of further bridges between organizational theory and TQM [12], [13], [14], [15]. This study explores the link between TQM and performance within an electromechanical company. Such group, which produces and distributes all over the world low tension electric equipment for the installation in the civil, industrial and service sector buildings, controls 16 big operating units situated in the four continents,

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while its trade-mark is found in 24 countries with an autonomous distribution network and with specialized products optimized for the needs and the quality and normal standards of the various markets. The high rate of renewal of the products of the range is an immediate sign of the will of development of the Group, which, in fact, places itself with authority among the big industrial poles working in the Sector, capable of proposing really original solutions to the international market. This ability of innovation is transferred to the products as a research of high performance, as a continuous development of new and more advanced solutions turned to increase the functionality of the electric plants [16], [17]. According to this point of view, the production of a new line of magnetothermal switches has been started in the plant, differing from the one of the rest of the plant for the high degree of automation adopted in the realization of component of the switch: the magnetothermic group.

2 The Methodological Approach and the Case Study

The process concerning the work is formed by only one machinery which produces a component of the magnetothermic switch: the magnetothermic group [18], [19]. The pieces entering the machine are some semi-finished and some raw materials; particularly we find: a bimetal tape, steel tapes (two separate units), clamps, screws, copper plait, movable contacts. The machine uses steel tapes and bimetal tape as guides for the progress, which, of course, is synchronised on the three directrixes corresponding to the tapes; the machine production capability is of 50 pieces a minute; this number is not casual, since it is relative to the frequency of the electric network. All the operations fulfilled by the machine are controlled, for the most part, by cams and levers; therefore the process is mostly mechanical, while the electronic part is devoted above all to the control of the operations [20]. The whole process is decomposable into several sub-processes, as it is evident in Figure 1. Some of them can be defined "special", because they are subject to be criticized: Screwing, Spot-welding.

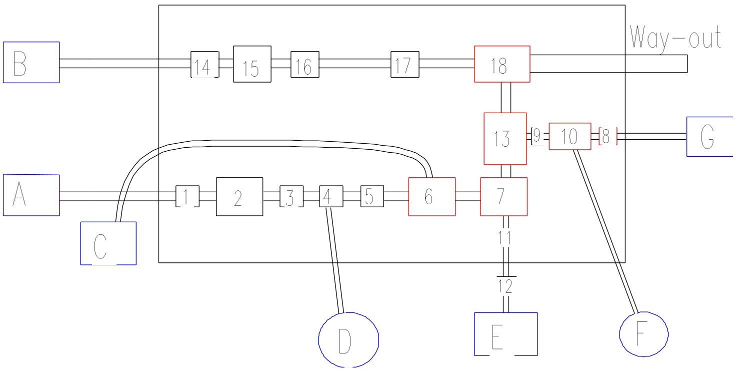


Fig. 1. Plant and Industrial Process.

KEY:
A = loading terminal tape
B = loading tape blinding electrode
C = loading screws
D = loading terminals
E = loading bimetal tape
F = loading movable contact
G = loading coil plait
1 = motoring over group
2 = terminal shearing pressing
3 = first folding
4 = loading clamp
5 = second folding
6 = screwing screw-clamp
7 = spot-welding bimetal-terminal
8 = fattening plait
9 = shearing plait
10 = spot-welding plait-movable contact
11 = progress tape bimetal
12 = bimetal roller leveling
13 = spot-welding bimeta-plait
14 = pliers of progress
15 = electrode shearing die
16 = folding of sliding electrode
17 = shearing of sliding way out
18 = spot-welding electrode-bimetal
Way out = conveyer on the way-out

The study of the special processes is part of the homologation and it is very important to keep under control the parameters which influence the processes themselves in order to be able to guarantee a quality level as constant as possible during the production [21],. So that a product might be defined qualitatively acceptable, it must respect some specifications that can be summed up as follows:

1. dimensional specifications - height of bimetal - position of bimetal - position of the electrode;
2. structural specifications: seal of the spot-welding - couple to unscrew the screw out of the clamp < 0.8 N/cm

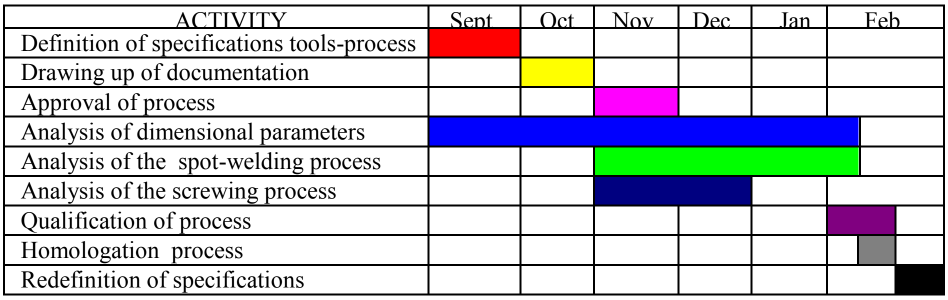
The dimensional specifications have margins of tolerance rather limited owing to their importance for the functionality of the article; and their control is remitted to very precise instruments and is effected at constant intervals [22], [23]. The structural specifications have a manual “tearing” control as the magnetothermic group must not bear particular efforts since it is placed in a hole; therefore it is the worker who must judge if the seal of the weldings is sufficient. As to the screw, there is a pre-gauged screw-driver in order to effect a control of the type “go-not go”. After a careful study, it came out that, above all in the first times of production, a spot-welding, in particular, was very fragile, in some cases to the point of breaking at the least contact. This information, based on experience, turned us to the welding to be controlled and to pay more attention to this part of the process. Let us start, then, by examining the special processes and the critical parameters that control their functioning.

2.1 The special processes

The special processes determined are screwing and welding. Let us start by describing the first one. Screwing consists in screwing a screw on a clap, so that, by means of the steel tape, shorn, folded and closed between screw and clamp, the whole forms the “terminal” part of the magnetic group. The process takes place automatically by means of the Weber wrench, that proceeds and screws down a screw previously carried by the compressed air from the container and stopped in position by an ashlar with an elastic terminal. We defined six parameters characterizing this operation: 1) the twisting moment of the Weber; 2) the screwing time; 3) the quality of the screw; 4) the quality of the clamp; 5) the position of the clamp; 6) the position of the screw. The spot-weldings are resistance weldings without contribution of material. The principle of functioning is based on the Joule effect, that is on the increase of temperature due to the passing of current, with the consequent melting of the two metals and their welding. The contact resistance of the two materials, which must be by far superior to all the others in order to be able to weld, depends on several components, and particularly: 1) on the nature of the materials in contact; 2) on the state of the surfaces of the materials; 3) on the pressure to which the surfaces in contact are exposed; 4) on the temperature of the materials. As to the spot-welding process, some possible causes of variability have been defined, and particularly the following parameters are considered relevant:1) heat or current of welding; 2) time of approach of the electrodes; 3) welding pressure; 4) electrodes; 5) material to be welded; 6) presence of oil on the materials.

3 The Improvement of the process

The homologation of the process started with the definition of the specifications of the tools and equipments, particularly of the critical tools, of the specifications of the electrodes for the spot-weldings, of the tools for the maintenance and of the welding parameters. Then we passed to the definition and drawing up of the documentation of line management and the approval of the process followed. After this work, the machine started production, and at this point the work of qualification of the process is inserted, with a chronology which is reported in the following Gantt diagram (Figure 2):



ACTIVITY	Sept	Oct	Nov	Dec	Jan	Feb
Definition of specifications tools-process	🟥					
Drawing up of documentation		🟨				
Approval of process			🟪			
Analysis of dimensional parameters	🟦	🟦	🟦	🟦	🟦	🟦
Analysis of the spot-welding process			🟩	🟩	🟩	🟩
Analysis of the screwing process			🟦	🟦		
Qualification of process						🟪
Homologation process						▨
Redefinition of specifications						⬛

Fig. 2. Planning Of The Activity Of Homologation Of Process.

In the selection of the parameters to be controlled, we wanted to test the process under the worst conditions, and on the base of the workers' experience, some choices have been made for the spot-welding and for the type of bimetal that had caused greater problems in the past. As to the spot-welding to be controlled, we chose the one that welds the bimetal to the terminal group. This operation is reported with the number 7 in figure 1 and whose criticality is confirmed by the fact that it is the only one to be controlled, even if with a tearing test of manual type. Let us start with the qualification of the process of screwing.

3.1 Screwing

We saw what are the parameters that can influence the process. In order to verify which of the following variables influence determinately the process, we formed a working group for defining the critical aspects of the phenomenon and the causes that have determined them. For this purpose an Ishikawa Diagram (Figure 3) has been made as the basis for the following analyses.

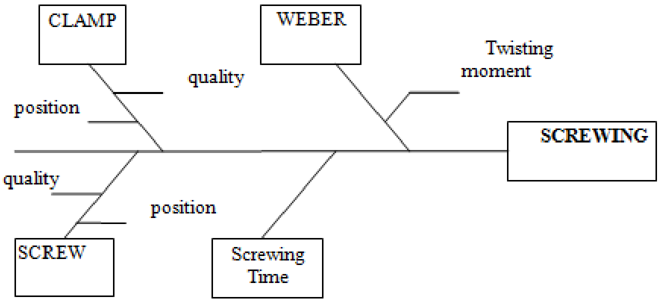


Fig. 3. Screwing - Ishikawa Diagram.

From the study of each parameter, the following considerations came out.

Quality of the Screw - We saw from the procedures of acceptance of the external supplies how the quality of the screws had an AQL of 1 per cent; but, as a matter of fact, perhaps owing to lack of precision in the acceptance tests, the quality of the screws was inferior; some lots showed trimmings of the threading, or with incomplete threads. Therefore, we took measures by paying greater attention to the quality of the lots incoming and by asking the supplier to provide for a better quality. The quality level has remarkably improved, so that the lots had no problem to pass the acceptance tests. In spite of that, however, the wrench has kept on giving problems, such as stops owing to an incomplete screwing of the screw.

Position of the Clamp - As to the position of the clamp, we have taken into consideration a magnet to block it in the right position. In fact, though the space at disposal was rather small, we found the way to place a natural magnet that made the clamp steady.

The Quality Of The Clamp - As to the quality of the clamp no anomalies were found; while for the position of the screw some modified bushes were ordered so that they might last longer with a greater capacity of seal of the screw. The other two parameters, regarding the other two variables, that is the couple of wrench and the time, are the ones that caused more troubles for the optimization, since that both are connected to other parameters; for this reason it was necessary to meet different requirements. The clamping couple of the wrench is variable by hand. However, we must bear in mind that in the specifications there is the definition of the peak moment sufficient to unscrew the screw, fixed at 0.8 Ncm; therefore, it was not possible to overcome the problem of the blocking of the wrench by simply increasing the blocking couple, which, on the other hand, should have been changed according to the quality of the lot of screws. Then, we took into consideration the time of the operation and we had to take note of the existence of unsurmontable ties: the progress speed of the terminal tape is predetermined, and at the frequency of 50 pieces per minute, if we divided the period, 1.2 second long, in 360 degrees, the wrench has only 60 of those degrees at its disposal to end the operation, that is about 2 tenths of second. On these grounds, it is evident the delicacy of the screwing operation, and it is also evident how a light decline in the quality of the screws might have influenced the process; as a matter of fact, the process itself is optimized, but its stability is strongly connected to the external components. The most significant aspect of this analysis is that, for the first time, at the company, following Deming suggestions, the staff has been involved in the phase of analysis and implementation of the solution. Such approach to the management of the problems has obtained positive replies, as regards motivation, also for other problems faced in order to achieve the homologation of the process

3.2 Spot –Welding

Also regarding the problems connected with the spot.-welding, we acted as in the previous case: an Ishikawa Diagram has been made also in this case (Figure 4).

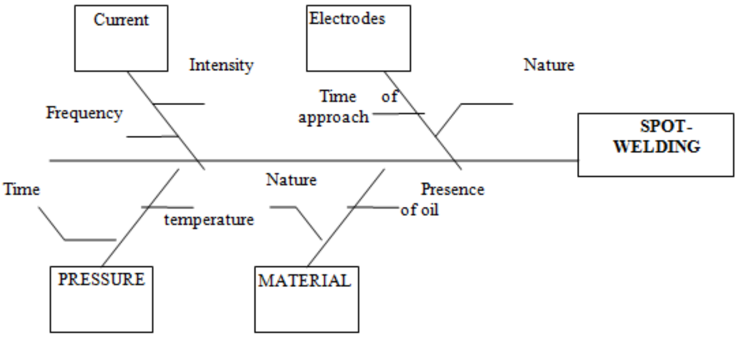


Fig. 4. Spot Welding - Ishikawa Diagram.

The variables that influence the bimetal-terminal spot-welding are reported here below: 1) heat or current of spot-welding; 2) time of approach of the electrodes; 3) pressure of spot-welding; 4) electrodes; 5) material to be welded; 6) presence of oil on the materials. A new working group was formed for the analysis of the problems connected with the spot-welding. From such work the following considerations came out: *Time Of Spot-Welding*: it is a hypothesis soon rejected, since it is tightly connected with the frequency of the electric network; *The Spot-Welding Pressure:* was the variable which caused fewer problems during its control and also a negligible variability in the process.

The pressure with which the electrodes are brought near to the sheets to be welded is given by springs guided by cams; therefore the variability of the operation is tightly depending on the characteristics of the springs. Since it is not possible to measure the pressure directly, we thought of exploiting the link between the mechanical characteristics of the springs and the thermodynamical characteristics. The relations are linear, therefore also the variabilities of the parameters are linear: 1) Pressure = f (preloading of the springs); 2) Preloading of the springs = g (temperature of the springs); 3) Pressure = f g (temperature).

The tests on the temperature of the springs were effected by a couple of thermic recordings with relevant potentialities, both for accuracy, where the uncertainty was of half degree C, and for range, which ranged between 0 and over 200 °C. The test was meant for measuring the maximum difference of temperature of the springs, so that it was measured at the beginning of the production, with the machine still, and after the machine had reached stability, with results that excluded the influence of the pressure variation on the total variability of the process: the temperature had maximum variations of 3°C and, once the production began, it remained constant. The next passage was to create a method to measure objectively the quality of the spot-welding, since we did not want to accept standard procedures or the tearing test effected by the people assigned to the machine. The problem was solved by means of a dynamometer, which was fitted to the dimensional needs of the magnetic group and it measured correctly the seal of the spot-welding; the only obstacle left was the necessity of shearing and folding the piece in order to permit the measurement: they were rather tiring operations, which, if they are not well made, could influence the validity of the measurement. Once the problem of the objectivity of the measurement was solved, another one arose, that is to correlate the various parameters to be controlled with the seal of the spot-welding. The current of spot-welding is variable and is controlled by the operators according to some parameters planned and optimized from experience, though still with some margin of improvement. The machine has its own control on the current of the spot-welding, and it itself rejects the pieces for which the current went out of a range of +/- 10%, but this happens very seldom, and besides, the value of current appearing on the display is not always reliable. The test we made concerned, of course, the current of spot-welding, and for this reason we used a very precise amperometer pliers with a certificate of gauging; it was more difficult to correlate the current measured to the seal of the spot-welding: the frequency of production of 50 pieces per minute and the fact that the piece for which we measured the current went out of the machine 19 pieces after measurement.

The tests of this type were 10 samplings with a number of samples variable from 30 to 100. The hypotheses on the current variability found verification in the type of supply given by the ENEL (The National Electricity Board). In fact, the company ensures the tension incoming with a variation of 10%, moderated by the adoption of a gas turbine cogenerator, which has partly stabilized the network tension. Entering into details, we find that the electric need of the company is covered for the 80% by the cogenerator, which weakens the changes of tension of the national network, thus reducing the changes inside the plant, which were before of 350 +/- 410 Volts. But there is still another problem unsolved: the location of the cogenerator which fulfils the needs of only two of the 4 sheds (C and D) of the plant, while only for a part, 60%, it satisfies A and B sheds and our process takes place in the A shed. For this reason it is still possible to find out changes of tension on the incoming current. The variability of the current is recordable both in a continuous way, and during the day, for the most part. Here below two diagrams show these variations (Figure 5a and 5b).

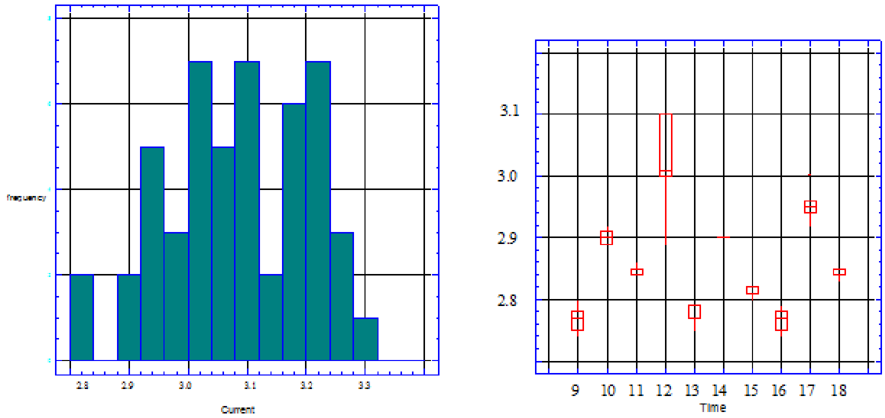


Fig. 5. a) Histogram Of Frequency Of The Currents Recorded In 50 Running Spot-Welding. b) Time Table Of Recordings.

It is evident a remarkable leakage around the average value of about 3kW. In figure 6a is more evident the difference among the averages during a whole day of recordings. After stating the variability in the current of spot-welding, we have verified the influence of such phenomenon on the seal of spot-weldings, through a test on over 100 pieces. In figure 6b we show a histogram on the variability of the seal of the spot-welding.

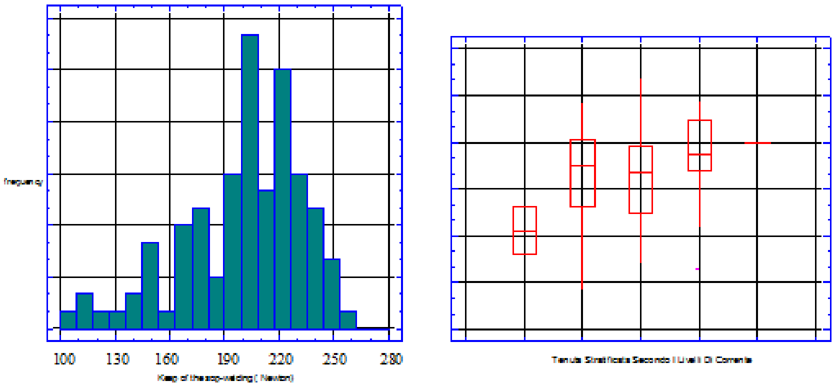


Fig. 6. a) Histogram on the variability of the seal of the spot-welding. b) Correlation between the seal of the spot-welding and the intensity of current.

As it is evident, most of the spot-weldings keep between 190 and 200 netwon, that is between 19 and 22 kg, which is a rather high value, considering the function of the spot-welding, which does not have bearing tasks inside the piece; however, there is a tail downwards that might cause problems, above all if it is not controlled. In order to find out the causes of this tail, we looked for a correlation between the seal of the spot-welding and the intensity of current (figure 6b). From Figure 6b it seems that there is a linear correlation between seal and current, which is confirmed also by the next graph (figure 7a).

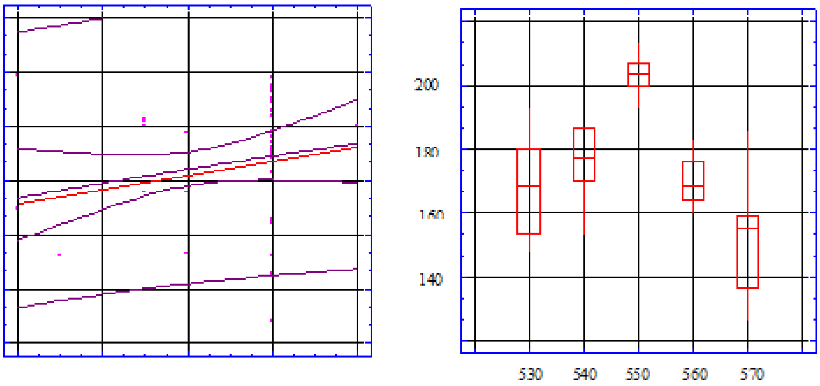


Fig. 7. a) Linear correlation between seal and current. b) Relation between seal and current.

The idea that it might be possible to increase indefinitely the seal of the welding by simply increasing the intensity of current has left us doubtful. The results of the tests did not confirm what recorded at first, but they pointed out a relation between seal and current of the quadratic type, that is a parabola with a peak, an evident sign of the superim position of two opposite effects: 1) the necessity of high currents to reach temperatures sufficient to melt the materials and to end the welding; 2) the impossibility of the material to discharge a high intensity of current, and, therefore, a sudden increase in temperature which reveals itself with “sprinklings” and with burnt weldings. Here below there is a graph showing the above considerations (figure 7b). The axis of abscissae records the value of the parameter of the machine which controls the intensity of current, which has a suggested value of 545; we remember how during the test, with the value of the parameter fixed of 530, there was the separation of a terminal group from the bimetal inside the machine, with the consequent stop of the production, which dissuaded us from making further tests with so low levels of current. Among the parameters that can influence the variability of the process, there is the presence of oil on the materials to be welded, and therefore several tests have been made. As a matter of fact, the machine uses two different types of oil, a very viscous one to protect the gears of the machine, and a more fluid one to permit the sliding inside the guides of the lines of steel and bimetal. The oil used for sliding is a special oil for the weldings; it has the characteristic of evaporating rapidly, in order not to create insulting surfaces at the moment of welding; the other oil is of a commercial type and it should not be found on the materials to be welded. As a matter of fact, the position of the cams and levers does not allow to exclude certainly the presence of the "wrong" oil on the materials at the moment of the welding; so that it was considered to be useful to effect some tests to verify the effective influence on the quality of the spot-welding of the possible presence of oil. The influence of the oil (Figure 8) is proved by the next graph, and it is possible to associate some isolated points, that is some seals below the standard, in the accidental presence of oil.

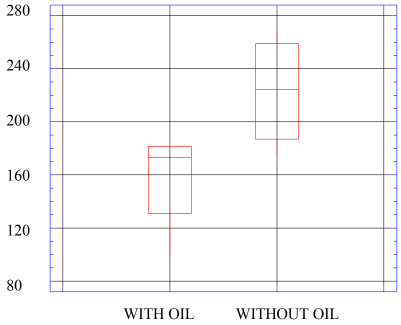


Fig. 8. Influence of the oil.

Another parameter taken into consideration in our analysis cause-effect was connected with the materials to be welded. The materials subjected to welding are a steel tape, with a constant thickness and, as a consequence, with welding characteristics constant, and a bimetal tape, with constant thickness, but whose welding characteristics might change owing to the different molecular structure.

However, it was not possible to point out remarkable variations in the resistivity of the bimetal, for instance, by means of the tools at our disposal, because the values to measure were by far below the minimum accepted by the instruments. Therefore, high precision instruments were used, and the results assured us about the real possibility that the variability in the bimetal might influence sensibly the seal of the spot-weldings. The last parameter we determined in the starting analysis, the electrodes, have had a greater importance during the development of the tests. Our initial hypothesis was based on the evident consumption due to the wear of the electrodes, that in fact, have a cycle of life equal to about 15,000 spot-welding before being checked up; and a wear electrode, since it trims off the point, it has a larger surface of contact with the piece to be welded, and a consequent leakage of current. This effect has been noted during the tests, and, in fact, the personnel appointed counterbalance with an increase of the intensity of current: practically, the process has a manual feedback; everything, however, is considered normal, and although it is not codified in the procedures, it is accepted praxis. But what we did not expect, appeared at the moment of the tests of the seal of the pieces, that is when broken, they might show different situations as regards the indentations:

1. both indentations separated. the seal of the spot-welding has been superior to the breaking load of the material, for which both indentations have

been sheared by the terminal group, where they are made: usually the seal is good.

2. both indentations attached: the seal of the spot-welding has been inferior to the breaking load of the material, probably because of a low tension of the spot-welding or too high: the seal is below the average.
3. Ashlar an indentation is separated and the other isn't: a strange situation which often occurred and which shows an irregular distribution of the current of spot-welding, above all if we consider that almost always it was the ashlar itself to separate, a sign of constancy in the performance of the machine.

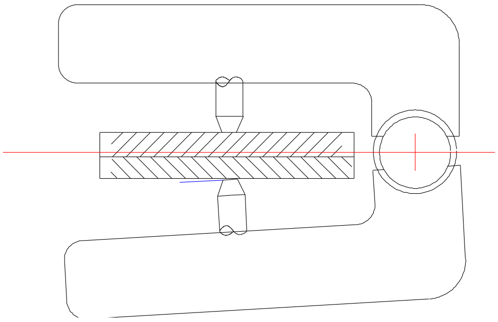


Fig. 9. Electrodes.

The problem was soon solved. the asymmetry in the welding of the ashlar depends on the working of the pliers making the weldings. As it is evident from the figure 9, between the electrodes there is not a perfect parallelism of the surfaces of contact, therefore there is a difference in the pressures of contact and consequently in the distribution of the current. What is much pointed out in the figure, as a matter of fact, it is a difference in level between the ends of the inferior electrode of about a tenth of millimetre, that is why too complex and expensive solutions have been avoided, such as, for instance, to move the centring of the pliers or even to move the guides of the tapes to be welded; the solution suggested is simple and effective at the same time: to modify the lower electrode, modelling it according to the need of making the surfaces of contact parallel.

4 Dimensional parameters

The dimensions that constitute the specification of the piece are three and all are referred to the terminal group, that becomes the referring base for the remaining part of the whole magnetic group. The dimensions considered are: height of the bimetal, position of the bimetal, position of the electrode. Among these only the first two have a real influence on the functionality of the piece, while the third one is necessary to allow the piece to get into the plastic hole without problems, even if the tolerance margins are very short. The height of the bimetal and its position are fundamental, since the functioning of the magnetic group is based just on the deformation of the bimetal, that, bending, releases a mechanism which interrupts the current flow. Since these parameters are very important, the tolerances on the dimensions are extremely limited, and, besides, there is a continuous control by means of control charts on all the dimensions. In order to determine the parameters which influence the critical dimensions, we analyze them one by one, without considering the position of the electrode, which cannot give remarkable problems and which is exactly within the margins of the specifications. The height of the bimetal depends on the method with which the tape of the bimetal is sheared: after the last spot-welding, the one with the electrode, the tape is blanked with a blanking-punch, whose frequency is obviously equal to the spot-welding one. Practically, the height of the bimetal depends on the speed of progress of the band of bimetal, which in its turn, is predefined and not alterable at the moment of the adjustment: the total height of the bimetal is practically fixed. On the contrary, the position of the bimetal is modifiable as to the electrode and the terminal group. That is, it is possible to let out a part of the bimetal in the back part of the spot-welding, in order to reduce the dimension called "height of the bimetal", as it is shown in the next figure 10.

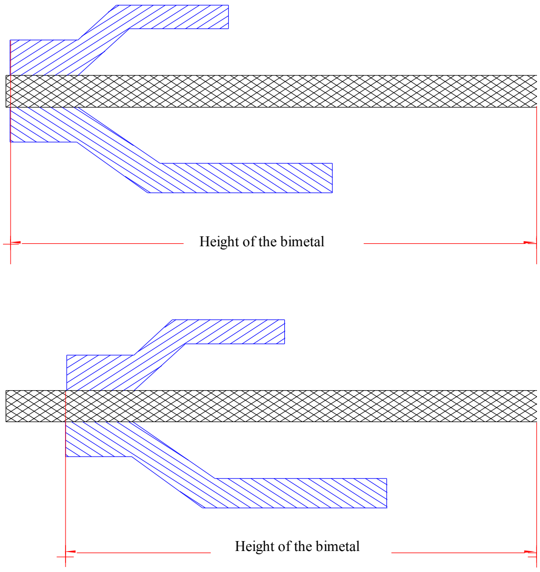


Fig. 10. "Height of the bimetal".

It is necessary to have recourse to this device, because the bimetal is some tenth of millimetre longer than necessary, on account of the frequency of cutting and the speed of progress. The dimensional specifications were very narrow: 6.15 cm (-0.35, +0.2) mm. On this base the verification with the control charts and the Cp and Cpk indexes did not give valid results. However, the pieces were accepted all the same, since they worked perfectly. In this temporary phase of production, we provided for enlarging the tolerance margins, in order to codify what was already happening; the new measures became: 6.15 cm (-0.35, +0.35) mm. For both we show the historical data going back to eight months of production, both without distinction and stratifying as to the amperage, particularly recording the production of 10A. Let us start with the control charts (Figure 11) for all the production and then for the production of only 10 Ampere.

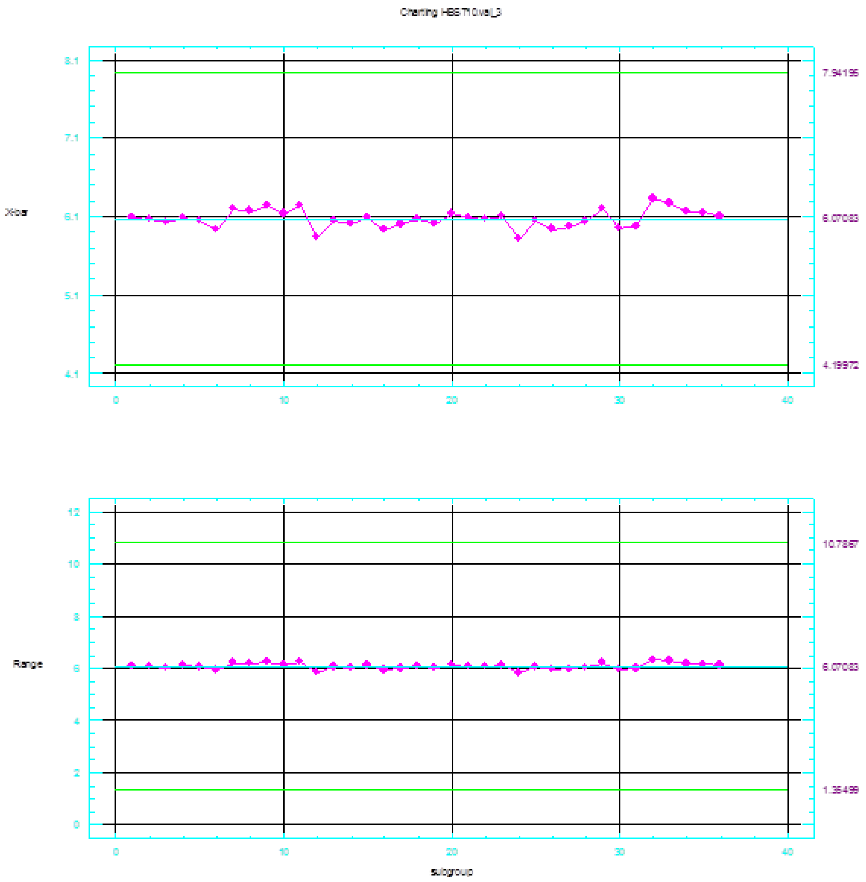


Fig. 11. Control charts.

Now, we show the histograms with the values of process capability concerning all the production and the production of only 10 A, recording both the initial specifications (figure 12a) and the derogated ones (figure 12b).

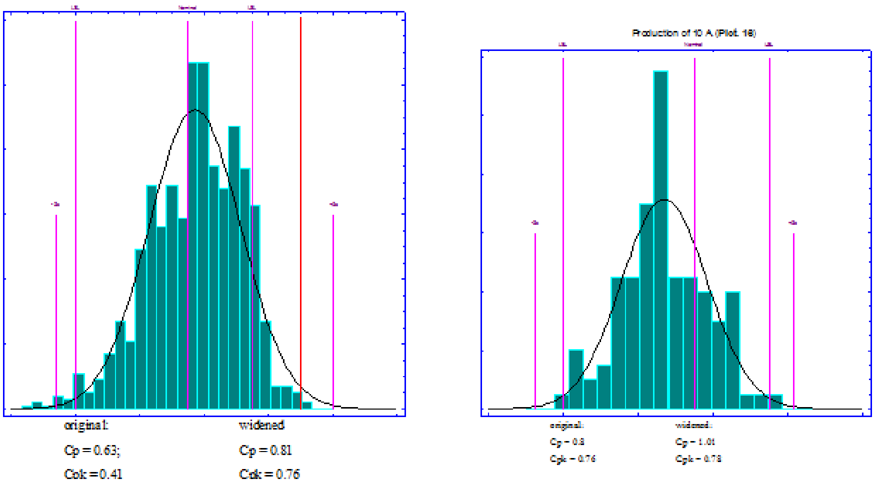


Fig. 12. a) Process capability - initial specifications. b) Process capability - derogated specifications.

4.1 Position Of Bimetal

The other very important parameter is the position of the bimetal, calculated at its free end, perpendicularly to its length as to the terminal group, which, as said before, acts as reference. The importance is obvious, since a bimetal more or less shifted towards the terminal, determines a time of working, that is of starting of the opening mechanism of the contact, more or less long owing to the greater distance that the bimetal must run bending. The causes involving this different form of the bimetal are to be found in the bimetal itself, that can have different bendings, called slashings, which influence evidently: for this reason, when the tape enters the machine, there is a calender which puts the bimetal straight.

The problem is that during the unrolling of the tape, therefore during the production, the slashing of the bimetal varies, and it often changes direction. The problems caused by these anomalies are shown in the following graph, concerning the collection of data for the position of the bimetal.

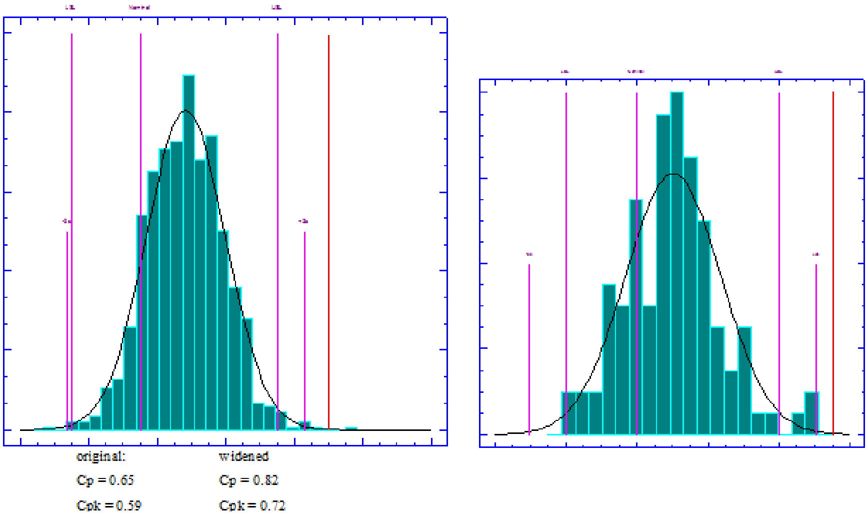


Fig. 13. a) Collection of data for the position of the bimetal. b) Process capability - whole production.

After the control charts referred only to the total production, we show the histograms with the values of the process capability both for the original specifications and for the ones widened by the planning so as to make acceptable a greater number of pieces produced. Figure 13a is referred to the whole production, and the next one, figure 13b, refers to the only production of 10 A. Also in the case of the production of the 10 A, the widening of the specifications has allowed an improvement of the values of the process capability, which passed from Cp=0.74 to Cp=0.93 and from Cpk=0.73 to Cpk=0.74. The series of graphs shown has pointed out the centering of the processes on the specifications; in fact, the middle of the products is just in the centre of the margins; but it pointed out also that the best quality had not been reached yet, which is proved by the remarkable tails outside the specifications.

4.2 Analysis of the data

For the homologation of the process a Cpk objective has been determined, which, opportunely increased according to the numerosity of the test sample, becomes the Cpk of decision, the lower limit for the success of the operation. The Cpk objective, in order to be able to work under a system of security, must be at least 1.33, that is a value that can be found in the table enclosed; as numerosity of the sample a number of 100 elements has been considered valid. Here below is a part of the table which adapts the Cpk objective to the finished number of samples and which defines the Cpk of decision.

Table 1. Cpk Decision.

Size Sample	*Cpk objet.*	*1.0*	*1.1*	*1.2*	*1.3*	*1.4*	*1.5*	*1.6*	*1.7*	*1.8*	*1.9*
250	1.07	1.17	1.28	1.39	1.49	1.60	1.70	1.81	1.91	2.02	2.13
200	1.08	1.18	1.29	1.40	1.50	1.61	1.72	1.82	1.93	2.04	2.14
150	1.09	1.20	1.30	1.41	1.52	1.63	1.74	1.84	1.95	2.06	2.17
125	1.10	1.21	1.32	1.42	1.53	1.64	1.75	1.86	1.97	2.08	2.18
100	1.11	1.22	1.33	1.44	1.55	1.66	1.77	1.88	1.99	2.10	2.21
90	1.12	1.23	1.34	1.45	1.56	1.67	1.78	1.89	2.00	2.11	2.22
80	1.13	1.24	1.35	1.46	1.57	1.68	1.79	1.90	2.02	2.13	2.24

As it is evident, the value of Cpk to be obtained is at least equal to 1,44. Here is (Figure 14a) the histogram of the test concerning the height of the bimetal with the relative values of process capability.

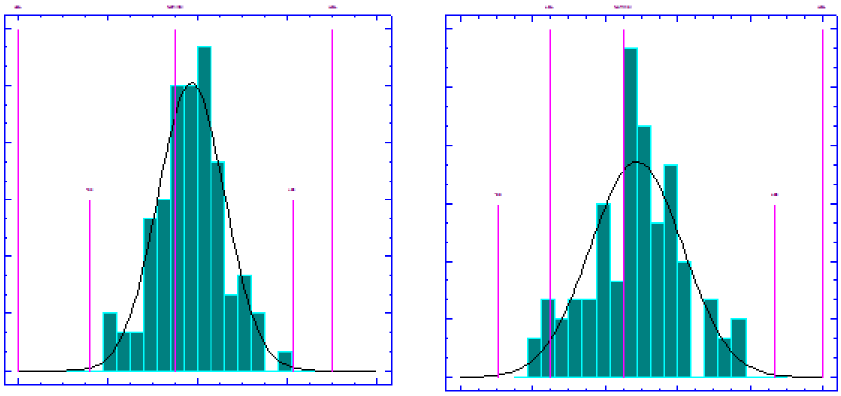


Fig. 14. a) Histogram of the test concerning the height of the bimetal with the relative values of process capability. b) New Histrogram.

As it is evident, leaving aside a small tail higher than scheduled, but, anyway, within the tolerance margins, the production is very well centred as to this critical dimension; in fact, we obtain values of Cp = 1,65 and of Cpk=1,51 which go over the minimum scheduled. As to the position of the bimetal the problem is more complex. Here below you will find the histogram (figure 14b).As you can see (figure 14b), in this case, the curve of distribution has a percentage outside the tolerance limits, and, in fact, we obtain Cp=0,98 and Cpk=0,62, which are values insufficient for the stability of the process.

5 Conclusion

From the analysis of the above graphs referred to the dimensional parameters of the terminal group, in spite of the solutions propose, there are still anomalies in the behaviour of the position of the bimetal. In fact, while we succeeded in satisfying the requisites for the homologation regarding the height and position of the electrode, the position of the bimetal is still a problem.

Anyway, the solutions implemented have allowed "to plug" the problem, as is it possible to understand from the previous diagrams, and thus to obtain the homologation of the process. However, the present condition can only be considered temporary, since the present trend of the Company is to completely change the approach to the process capability, in the attempt to follow Dr. Taguchi's suggestions. With regard to this, some "pilot processes" have been identified for the starting implementation of the Design of Experiment. However, in this first phase, the improvements have been obtained by the techniques of Problem Solving which allowed to reach the aim proposed, that is the qualification of the process besides a remarkable improvement of the quality of the product and the consequent reduction of the costs, which is not less important.

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