RELATIONSHIP DIAGRAM AND TREE DIAGRAM APPLIED AT INCREASING FLEXIBILITY OF ULTRASONIC ELECTRODISCHARGE MACHINING TECHNOLOGY

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Abstract: The paper deals with improving the performances of ultrasonic aided EDM micromachining (μEDM+US) through using some quality management instruments like relationship diagram and tree diagram. Some characteristics of these instruments are presented and opportunities to combine them in order to solve the same problem aiming at improving the obtained results by synergy. The mix application of these instruments is achieved in order to increase the flexibility of μEDM+US through identification and removing the causes of this main disadvantage of this combined nonconventional technology.

Keywords: electrodischarge machining, ultrasonics, flexibility, quality improvement methods.

1. INTRODUCTION

The quality management instruments as Relationship Diagram and Tree Diagram are considered new instruments able to solve problems belonging to management system but they are also applicable to operational management due to their versatility [1]. In this case, a problem or process improvement is addressed, i.e. the flexibility of electrodischarge machining aided by longitudinal vibrations of electrode-tool in micromachining mode (μEDM+US).

The EDM micromachining process is characterized by very narrow working gap, which frequently causes short-circuits and therefore instability of material removal process, which affects the output technological parameters: surface quality, precision and machining rate [2]. Ultrasonic assistance of microEDM is capable to improve these technological performances. Only one main disadvantage remains to be solved: the time consume during manufacture preparation, which makes μEDM+US low efficient at individual and short series production.

Practice of quality management confirms that more complementary methods / instruments - as it is the case of the mentioned instruments - are used to solve the same problem, more the results are better, based on their synergy.

2. RELATIONSHIP DIAGRAM METHODOLOGY

The relationship diagram also called interrelationship diagram or network diagram shows cause-and-effect relationships between issues. This quality management instrument helps the work team to understand the natural links between different aspects of a complex group of factors that affects the solving of a problem.

Some recommendations for relationship diagram application are [3]:

- When trying to understand the links between cause-and-effect relationships, in order to identify the most important factors of quality improvement;
- When the problem to deal with consists in a great complex of elements and it is analyzed for causes identification;
- When a complex solution, device or process is being implemented; this is the case of μEDM+US flexibility improvement;
- After application of an affinity diagram, cause-and-effect diagram, if the work team wants to explore more the relations between ideas.

The methodology of relationship diagram application comprises the following steps:

Step 1. A statement defining the problem that the relationship diagram will try to solve is written on a card or post-it and place it at the top of the work surface (chart pack, panel etc.). The moderator must be ensured that every member of the work team perfectly understands the problem in discussion [4].

Step 2. A Brainstorming within the working team is used to generate ideas about the problem to be solved. These ideas are written on cards, notes or post-its or even in text boxes on a computer screen (it is easier to modify or move text boxes). If the Relationship Diagram is used after related instruments like Affinity Diagram or Fishbone Diagram the ideas could be taken from there, respectively from the most detailed stage of these diagrams. It is also possible to use these previous ideas as a basis and just use Brainstorming for additional ideas.

Step 3. The team members analyze all the emitted ideas, group the identical or similar ideas and also check for omissions [4]. Thus a definitive panel of ideas is obtained.

Step 4. In order to find the relations between ideas, the following procedure could be adopted: place one idea at a time on the work panel asking if the respective idea is related to others already analyzed. If yes, the idea is placed near the one related to it. Some space must be kept to draw arrows between them, in the next stage. The procedure is repeated until all the ideas from the work panel are analyzed.

The ideas (cards or post-its) are placed in the proximity if they are connected. Nevertheless, a perfect order as in case of Fishbone Diagram cannot be achieved. Only a structure that shows the interrelations complexity is aimed at. As it is possible that the ideas are grouped considering the categories they are belonging to as in case of Fishbone Diagram. Therefore it is possible to discover subcauses if the identified ideas are studied more [4].

Step 5. Other order relations between ideas are emphasized. Therefore, for each idea, the team has to answer to the question: "Has this idea any influence on others?" Then arrows are drawn from each idea to the others that influences them (arrow sense from the cause to effect). In the same way as in previous stage, the question is repeated for each idea from the work panel.

Step 6. The diagram is analyzed from the following points of view:

○ The ingoing and outgoing arrows for each idea box are counted. The determined number is written next to each box. The ideas associated with great number are considered the key ideas (factors).

○ The ideas that have mainly outgoing arrows are regarded as basic causes.

○ The ideas that have mostly ingoing arrows are considered final effects. These could be critical to be addressed.

The idea boxes with fewer arrows must be checked if they are key ideas. The number of arrows is only an indicator, not an absolute rule. Finally, when all the key ideas are identified the team draws bold lines to emphasize them.

Sometimes it could be interesting and useful in solving the problem to highlight the chains of relationship rather than identify the main ideas [4].

3. RELATIONSHIP DIAGRAM APPLICATION

The relationship diagram steps to solve the problem in discussion are presented:

Step 1. The defined problem to be solved is: lack of flexibility of μEDM+US technology. More precise, this acts mainly in the stage of manufacturing preparation, related chiefly to the technological system adjustment to work under the resonance condition.

Step 2. The initial ideas related to the problem to be analyzed are taken from a previous Affinity Diagram [5]. Additional ideas are brainstormed within the work team. All the ideas are presented in fig. 1:

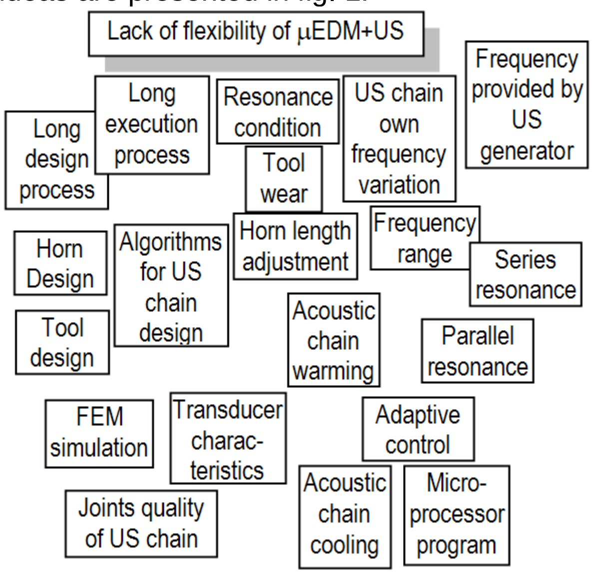

Fig.1. The ideas related to lack of flexibility of μEDM+US technology

Step 3, 4. The ideas including previous omissions are placed appropriately taking into account the relations between them as it is presented in fig. 2:

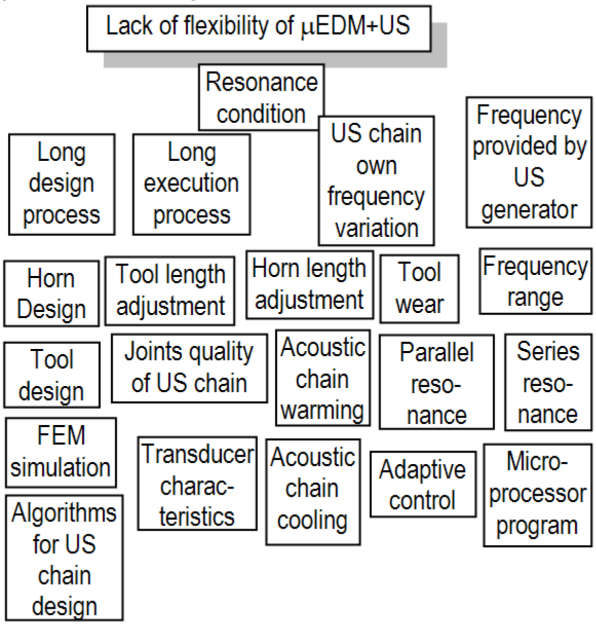

Fig.2. The ideas placement determined by their relations

Step 5, 6. The relations between ideas are displayed through ingoing and outgoing arrows respecting cause-effect determination. The obtained structure is presented in fig. 3:

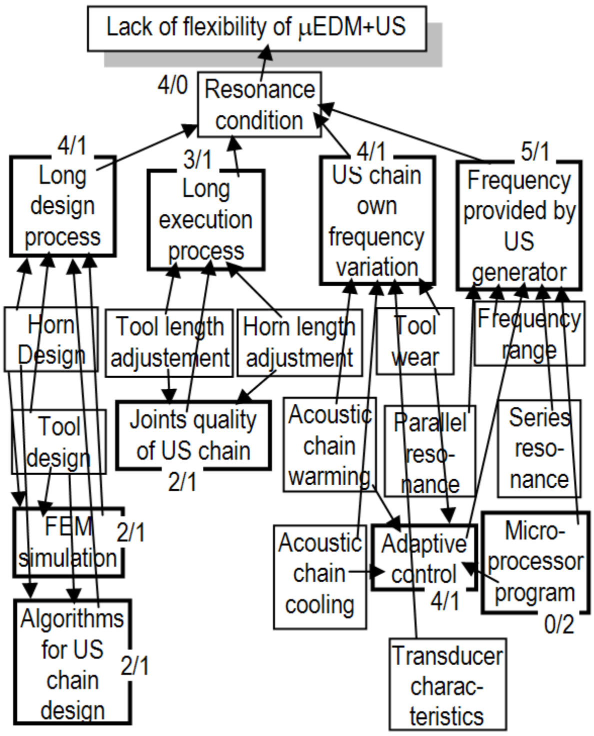

Fig.3. The structure of Relations Diagram for lack of flexibility of μEDM+US

The counting of ingoing and outgoing arrows corresponding to each idea was used to establish the key-factors. Only ideas high numbers were displayed in fig. 3. The key-factors boxes were represented by bold lines. It can be noticed that for obtaining resonance condition strongly related to lack of flexibility, some factors (key-ones) play an important part as causes (with high number of outgoing arrows). Finite Element Method (FEM) Simulation and Calculation Algorithms of acoustic chain can decrease the time for getting resonance condition. The precision of joint surfaces are essential to stable work of acoustic chain. Especially, the frequency provided by US generator, which must equal the own frequency of acoustic chain, is a critical issue. In this respect, the adaptive control is essential based on microprocessor programming. The last issue is considered a key idea even with only 0/2 [ingoing/outgoing] because it can generate flexibility.

3. TREE DIAGRAM METHODOLOGY

The tree diagram - also called tree analysis, analytical tree, or hierarchy diagram - is used to find finer and finer levels of detail of a complex issue. It helps to shift step by step from generalities to specifics. The diagram is developed until the desired level of detail is reached [7].

Some recommendations for using tree diagram are:

- Defining actions specific to 'real-world' to solve a complex problem;
- When analyzing complex processes in detail; this the case of achieving in short time the resonance condition;
- When the work team has to investigate if the root cause generates a certain effect, respectively the problem to be solved;
- When evaluating several potential solutions in order to implement them;
- When an affinity diagram or relations diagram has not broken in detail for some key issues;
- When monitoring the progress of complex activities;
- When assign responsibilities to team members for removing the undesired effect.

A step-by-step procedure to achieve the tree diagram is presented below [3], [4]:

Step 1. The statement of the goal or the problem to be solved is written at the left (in case of a horizontal tree);

Step 2. The next detail level is achieved answering to the questions like: What tasks must be done to accomplish this?" "What causes this?" or "Why does this happen?

"What are the components?" The corresponding answers are identified through Brainstorming or could be provided by previous Affinity Diagram or Relationship Diagram. These first ideas are written in a line to the right (for a horizontal tree).

Step 3. Check the omissions on the first level by asking „Are all the items at this level necessary to accomplish the level above?"

Step 4. Each idea previously identified now becomes the subject to be achieved with the means from the inferior level. So, for each item, ask again the questions from above to determine the next level of detail. As previously, a necessary and sufficient check is performed by the work team.

Step 5. The process is continued to determine for each new idea the inferior level elements until the real elements are reached. Specific actions can be carried out on these, components that are not divisible any more.

Step 6. A final check is performed to find out if all the items necessary for the initial objective (problem) are presented on the entire diagram.

3. TREE DIAGRAM APPLICATION

A step-by-step application of the instrument is presented below in relation with fig. 4.

Step 1. The goal (the problem to be solved) is lack of flexibility of μEDM+US.

Step 2, 3. To improve the flexibility, one can act through making faster the processes of US chain design and execution and achieve an US generator more adaptive to US chain working characteristics.

Step 4, 5. The detailing process continued addressing the design associated with CAE techniques and also algorithms to determine the acoustic chain components. The fast and precise CNC machining of US chain components is considered followed by resonance test. The US generator based on adaptive control is the key-solution of the problem.

Step 6. A final variant of the Tree Diagram is achieved which included the real measures to adopt. The improvement of CAE simulation (FEM results) is based on previous experimental results and computerized transfer of information to CNC machine through a CIM system. The US generator can be accomplished using a microprocessor and an implemented appropriate program.

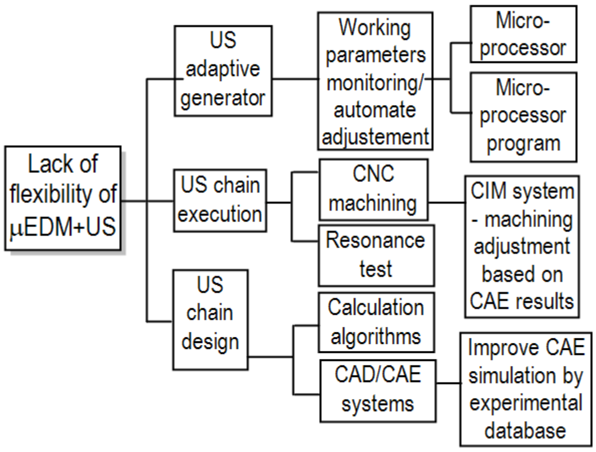

Fig.4. The structure of Tree Diagram for lack of flexibility of μEDM+US

4. CONCLUSIONS

Relationship Diagram and Tree Diagram succesively applied to improve lack of μEDM+US flexibility emphasized gradually some practical (real world) possible solutions, focused on FEM simulation of resonance condition integrated in an acoutic chain CIM. The adaptive control US generator is a key factor that could be achieved using a microprocessor and a performing program aiming at maintaining the frequency within an optimum range.

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