POSSIBILITIES OF COLLABORATIVE ROBOTS INTEGRATION IN AN INDUSTRIAL ORGANIZATION IN THE FIELD OF NONCONVENTIONAL TECHNOLOGIES

Gusan Vasile[1], Mircea Bădescu[2], Mihail Aurel Țîțu[3,4]
[1]Continental Automotive Systems SRL Sibiu, vasilegusan@yahoo.ro
[2]Lucian Blaga University of Sibiu, 10, Victoriei Street, Sibiu, România, mircea.badescu@ulbsibiu.ro
[3]Lucian Blaga University of Sibiu, 10, Victoriei Street, Sibiu, România, mihail.titu@ulbsibiu.ro
[4]The Academy of Romanian Scientists, 54, Spitalul Independenței, Sector 5, Bucharest, Romania

ABSTRACT: The scientific paper proposes a pragmatic perspective of presenting the most important theoretical and practical issues on the process of manufacturing by electrical erosion and integration of collaborative robots in an industrial organization, processes linked to the possibility of using new technologies in industry. Collaborative robots are an important viable alternative to new ways of streamlining process management in modern industrial organizations and in this article is presented the possibility of their integration in a processing flow based on electrical erosion. The research presents in an elegant way the possibilities of streamlining everything that means the process of manufacturing by electrical erosion using collaborative robots. The point of view presented is only a small part of what involves the implementation of such opportunities with a deep novelty. Through this scientific paper the authors are offering new opportunities to implement the concepts of efficiency and effectiveness in the process of manufacturing by electrical erosion in industry.

KEYWORDS: collaborative robot, nonconventional technologies, electrical erosion, manufacturing process, quality assurance

1. INTRODUCTION

The electric erosion is the unconventional technology used in the field of metal manufacturing. It is used to facilitate the processing of materials with a high or very high hardness. Also, this technology is used for processing materials that cannot be manufactured by the old conventional methods.

In present, it can be said that electrical erosion, although often referred to as an unconventional process, has disengaged from this category over time and has become a commonly used dimensional manufacturing process accepted by many industries. This technology can be used in many industrial applications, being able to meet all machinability requirements, starting with roughing and ending with superfinishing.

The history of the development of this unconventional technology begins in 1943, when the Lazarenko family proposed modifying the action of breaking electrical contacts and using the erosion of electrical contacts in order to process materials. Thus, the foundation of a processing technology that would revolutionize machinability was consolidated. In consolidating this base, other pioneers in the field of electrical erosion with scientific works on technology were noted: Germany (Hinuber, Opitz), Great Britain (Fefer, Rudorff), Switzerland (Pfau, Ullman), etc.

In the year 1954, during an exhibition in Milan in the field of machine tools, the first machine tools for processing by electrical erosion were presented. They were manufactured by valuable companies in Europe at that time: AGIE, SPARCATRON, CHRMILLES.

Following these actions, the process of manufacturing by electrical erosion begins an impressive and rapid development. Many countries have taken over this type of technology and started competing in perfecting this type of technology. Thus, this technology has such a high applicability that it can be integrated into any material manufacturing technology procedure.

Among the countries which entered in this competition, Romania is also listed in the early 50's. The results of research in Romania make it be positioned on the leading places in the European ranking between 70s and 80s, these results being recognized worldwide. The researches were performed in the field of manufacturing of electrical erosion processing systems and in the industrial usability of the electrical erosion process.

From a historical point of view, it is noted that the advent of electrical erosion processing technology is very similar to the emergence of the collaborative robots today.

The pioneer in launching these types of collaborative robots is the company Universal Robots. However, due to high demand, other competitors have appeared on the market, such as Techman Robots, ABB Robotics, Kuka and many others that offer this type of solution.

2. GENERAL THEORETICAL CONSIDERATIONS OF ELECTRICAL EROSION MANUFACTURING TECHNOLOGY

The electrical erosion manufacturing is the method of removing material by repeatedly caused impulse electrical discharges. These discharges take place between the processing object (part) and a transfer object (electrode - tool).

The electrical erosion manufacturing technology can be used in places where cutting manufacturing is outdated, or it is approaching the outdating or when cutting processing is not economically efficient.

The processing is performed by repeating with a very high frequency of the electrical supply pulses. This electric impulse discharge has in component many stages, but especially those of technological interest are:

- Spark unloading;
- Non-stationary arc discharge;

Both stages are located in the final area of the electric discharge period, having an own duration of approximately 10^{-4} seconds. Due to these aspects, the processing technology by electrical erosion has become a necessity, becoming at this moment one of the most used processing technologies in the field of concentrated energies.

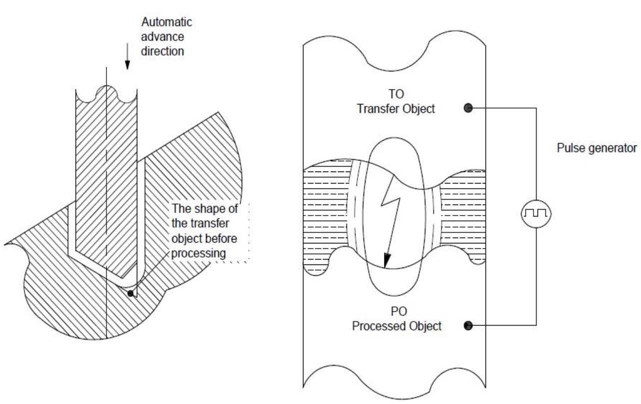

Figure 1. Principle of dimensional processing by electrical erosion

The tool and the processing object must be manufactured of materials with electroconductive properties. Between the electrode (tool) and the workpiece, arranged correctly from a spatial point of view of the tool, there will be an erosive space with a very small thickness filled with an electrical insulating environment. The electric discharge is performed following the penetration of the electrical insulating environment in case the electrical voltage is high enough and this facilitates the removal of small amounts of material. The removed material is located on the surface of the two interacting objects.

There are certain physical conditions that must be met so that dimensional processing by electrical erosion is possible and the system has a constant efficiency. These are:

1. Electrical energy must be introduced directly into the erosive space;
2. Electrical energy must be temporarily metered in pulse;
3. The polarized character of the electric discharges must be ensured;
4. The state of the erosive interspace must be continuously restored to its initial state;

Condition 1 can be fulfilled by constructing the electrode tool and the object from material with electroconductive properties or, if they do not have electroconductive properties, these properties will have to be applied to them during processing by electrical erosion.

In order for condition 2 to be fulfilled, it is necessary that the concentration of the effect energy to be found in the interaction area between the object to be processed, the erosive agent and the tool electrode. If this condition is achieved, the removal of the material occurs in the area of the interaction of the two objects. If the electricity were dosed in a continuous way, this situation will lead to the propagation of the thermal effect in the entire volume of the object destined for processing, and the removal of the material will no longer be observable. Due to this aspect, the electrical energy must be temporarily dosed by pulses, these being limited to time values below 10^{-1} seconds. This condition can be fulfilled by using a pulse generator or by relative movements that will facilitate the rupture of the electrical microcontacts between the two objects.

Condition 3 must be met to ensure the maximum productivity of the dimensional processing by electrical erosion in parallel with the minimum wear of the tool electrode. This condition can be achieved due to the choice of a suitable material for the construction of the tool electrode, but also by optimizing the electrical connections made by the pulse generator so that this optimization leads to the formation of protective layers.

Condition 4 is met by using a subsystem that automatically adjusts the erosive interspace or gap. The technological system of dimensional processing by electrical erosion must ensure the optimal conditions of discharge by using a system of

dielectric liquid circulation, this being necessary to fulfill the function of forced evacuation of material

accumulated with the appearance on the market of collaborative robots known as "COBOTS".

The difference between a collaborative robot and a

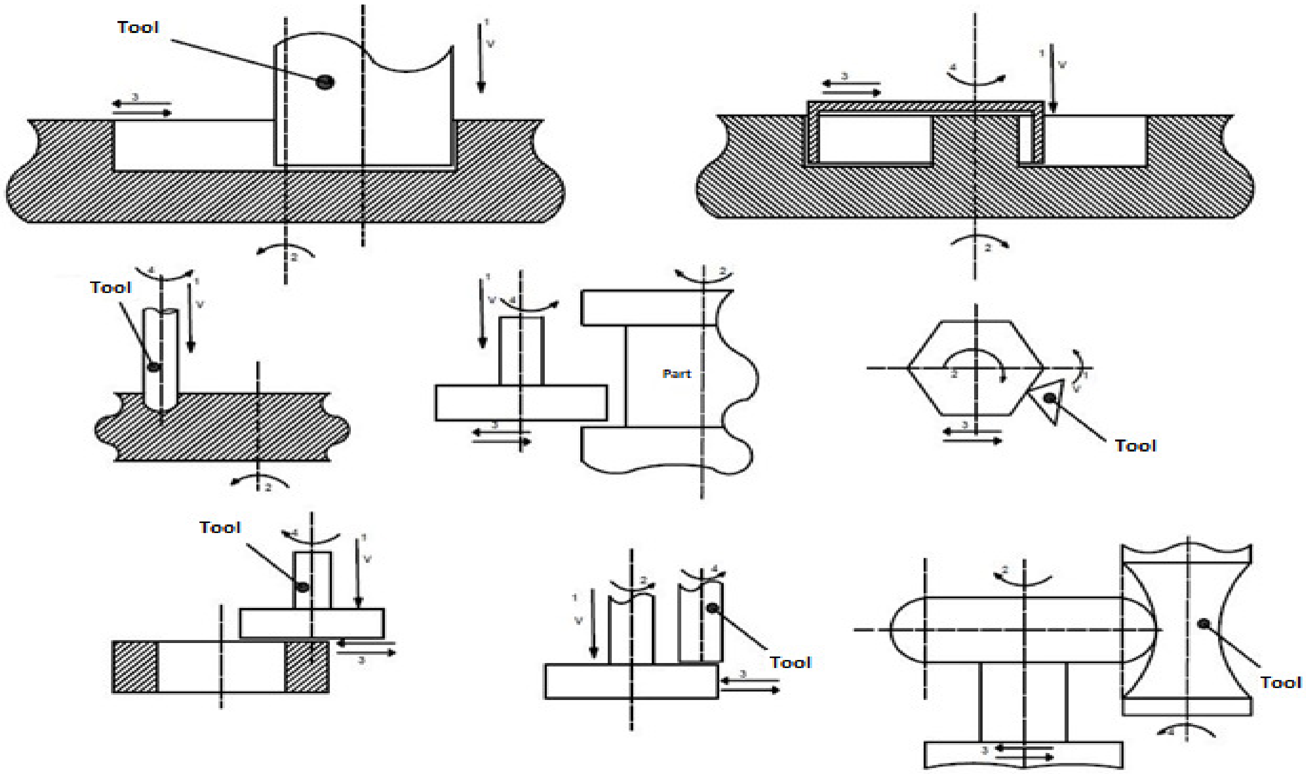

Figure 2. Manners of generating surfaces by electrical

resulting from processing by electrical erosion from the gap.

3. FUNDAMENTAL CONSIDERATIONS REGARDING THE USE OF THE COLLABORATIVE ROBOTS IN AN INDUSTRIAL ORGANIZATION

We are living in the century of speed, a century in which the manufacturer must be flexible and adapt to the market requirements as soon as possible. It must produce quickly, at the highest possible quality and at the lowest possible cost in order to continue to secure a competitive place in the market.

This is no exception in the automotive industry, where the manufacturer must be open and flexible, and at the customer's request be able to improve manufacturing quality, speed and reduce the cost of manufactured products.

Over time, this has led manufacturers to look for the best possible solutions in terms of increasing the quality of manufactured products, reducing product manufacturing costs, storing it and automating technological processes to ensure a more competitive place on the market.

This continuous requirement for improvement and flexibility of costs, qualities and speed have

classic robot is that the collaborative robot has been designed so that it can share the workspace with the operator or worker. If they accidentally collide with the operator or any other object they will instantly enter in a protective stop, which ensures a high safety of the operator.

The collaborative robots are easier to program, do not require great software knowledge or highly specialized training. This advantage can reduce a lot of costs in terms of qualified staff and also some changes will be able to be made by the responsible staff without resorting to other suppliers who will bring additional costs to any change.

The program can also provide information that the operator must take into account, situations in which the operator can make a decision due to the fact that the interface is friendly to humans. This type of robot has several types of options through which it can communicate with the environment or other equipment. It can communicate through electrical input/output signals or can use industrial communication protocols such as MODBUS or Profinet.

Cobots will be able to easily to take the jobs in dangerous areas or with repetitive character.

The movement of collaborative robots in a continuous technological manufacturing flow is fast and flexible.

Thus, they will be able to adapt very easily to the numerous manufacturing changes.

The ergonomics of the operator workplace will be improved, the collaborative robot being able to take over the non-ergonomic activities of the man easily. In this way, it will be possible to reduce work accidents and the operator and the worker will be able to be take over more important roles in the decision on product quality, supply, etc.

These cobots are able to perform various processes of dispensing on the product, screwing, pressing, sanding, packaging and palletizing, integration into a electrical erosion enviroment, plastic injection, taking over and placing the parts on the technological flow.

Visual control applications can also be implemented using a camera system that will communicate with these robots.

The price is low compared to traditional robots, while ensuring high accuracy, a large range of the robot reach and a satisfactory weight that can be handled by the cobot.

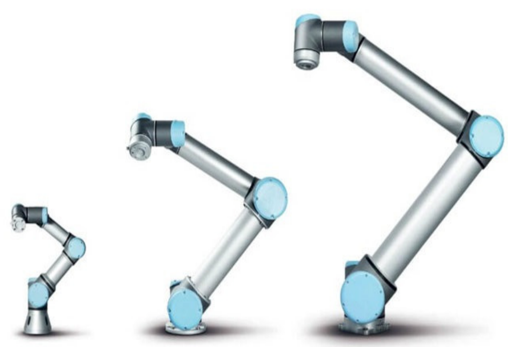

Figure 3. Collaborative robots known as Cobots

The conclusion is simple, the collaborative robots have the advantage of easy integration, with zero maintenance costs and high productivity, the benefit is in the economic field, product quality, workplace ergonomics and high productivity.

4. THE TECHNOLOGICAL SYSTEM OF PROCESSING BY ELECTRICAL EROSION AND POSSIBILITIES OF INTEGRATION OF COLLABORATIVE ROBOTS

The advent of collaborative robots has had an impact similar to the emergence of electrical erosion, an impact that has revolutionized the global industry.

Due to this aspect, the authors considered it necessary for these two technologies to meet in an industrial application in a medium series or large series production. In order to demonstrate the integration benefits of collaborative robots, it is necessary to present the system or the way of working before integrating them.

The data of the initial application are the following:

1. The processing time of a part on an electric erosion processing machine is 60 minutes;
2. In the production hall there is an island with 10 identical machines that produce the same part;
3. The machines are running in four shifts, on each shift being an existing man who operates the entire line. The operator is only deals with loading and unloading machines, without having a direct impact on product quality, performing the same repetitive movements.;

The economic analysis was made based on the payback period method. The study will have to economically bring improvements in costs per year. In two years, if the study fails to bring back the money invested, it is considered not feasible.

In order for a feasible comparison to be made, an economic calculation had to be made between the way of working with operators and the way of working with cobots. Given that the line in the past was serviced by an operator, the calculations will be made only for the operator who will be replaced by a collaborative robot. Prices are estimated in EURO.

The economic calculation of working with operators method:

On the existing line, the line is able to run with with one operator on each shift. Given that the line has 4 shifts, then the calculation shows that we will need 4 operators.

N = O x S = 1 x 4 = 4 operators;

O – number of operators per shift;

S – number of shifts;

N – number of total operators needed.

The salary for each operator is approximately 820 Euros per month. A monthly total will be calculated for each operator serving the line.

TS = N x € = 4 x 820 = 3280 de Euro / month;

TS – total salaries received by all shifts / month;

N – number of total operators needed;

€ – the salary received per month by an operator.

It will calculate the annual salary that the company pays for all operators.

TA = TS x L = 3280 x 12 = 39360 Euro / year.

TA – The annual salary received by all operators;

TS – total salaries received by all shifts / month;

L – the number of months existing in a year.

Economic calculation for investing in robot method:

Safety system (Ss): 5000 EURO for the entire line.
BUFFER or automated conveyors (B): 10000 EURO / piece;
Support with electric axis (Sea): 15000 EURO / piece;

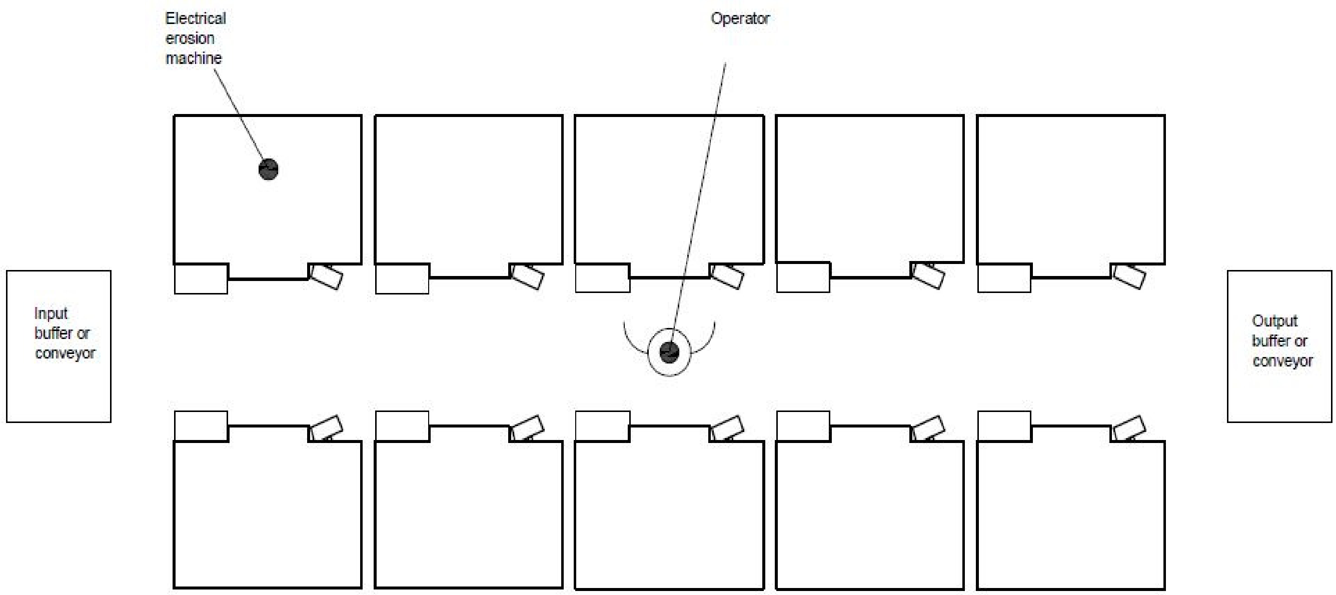

Figure 4. The situation before the implementation of the collaborative robots

The robot consumes electricity. First of all, a consumption calculation was made.

The following were considered:

- The price is 0.27 Romanian Lei KW / hour;
- Each robot consumes 2 KW per hour;
- The day has 24 hours;
- 1 collaborative robot will be used;
- They will not stop and will work continuously 365 days a year;

According to the above aspects, the formula for calculating the consumption of robots per year (CRy):

CRy = 0.27 Romanian lei KW / hour * 2kw per cobot * 24 h* 1 cobot * 365 days / year = 4730 de Romanian lei / year.

Converting to EURO results in a consumption of about 1000 EURO per year.

The following investments to be made for integration were considered:

- Collaborative robot price is 25000 EURO per piece from where it results:
PRt = 25000 x 1 = 25000 EURO
PRt – the total price of the purchased cobot.

In order for the line to become COBOT friendly certain costs were estimated:

Therefore, once the above data has been collected, a calculation can be made for production line reengineering (RLP):

RLP = Ss x 1 + B x 1 + Sea + Sr x 1 = 5000 + 10000 + 15000 = 30000 de EURO;

To this calculation (RLP) will be added both the consumption of the robots per year (CRy) and the total price of the purchased robot (PRt) to obtain a total investment cost (CTI):

CTI = RLP + CRy + PRt = 30000 + 1000 + 25000 = 56000 EURO.

In conclusion, according to the calculations, the following results were obtained:

- Working mode with operators (TA): 39360 Euro / year.;
- investment in the working with robot method (CTI): 56000 EURO investment.

Every year, the working method with operators will cost the company 39360 Euro each year, while the price of the robot integration is paid only once.

According to the calculation below we can see that in that year the company will invest 16640 EURO (I) more than the company would do if we continued working with operators, but in 2 years (Y) the company will recover the following amount (RT):

CTI - TA = 56000 – 39360 = 16640 EURO
RT = TA x Y = 39360 * 2 = 78720 EURO in two years.

According to the RT index, 78720 Euros will be recovered in two years, and the investment of 56000 Euros will be payed off.

The final conclusion was that the project will make a profit right from the beginning of the second year of use, the project is feasible and has been approved for implementation.

The collaborative robot will be integrated on an electric axis, and it will be positioned in a horizontal position, being oriented downwards.

If the access on the line will be required for maintenance, it will rise above the axis to clear the area.

The collaborative robot will precisely execute the loading of parts on each electrical erosion machine. Both the robot and the equipment will be introduced in the company network.

The cobot will communicate through the MODBUS protocol with the electrical erosion machine.

The robot will control the electric axis to be able to reach, depending on the need, each electrical erosion equipment, as well as the automatic storage equipment or conveyors for entering the parts in the manufacturing and output flow.

The robot will receive signals from the conveyors or the storage equipment, the conveyor or the equipment for storing the incoming parts will notify the robot when it has a ready part, and the storage equipment or the conveyor for leaving the parts in the manufacturing flow will notify the robot. when it can receive the piece.

The electrical erosion processing equipment will notify the robot when they have finished processing the part and are ready to receive new parts.

The robot will have 6 minutes free time to move between the equipment, to take a part from the input conveyor, to feed an electrical erosion equipment and to unload the part from the equipment and then to position the processed part on the output conveyor from manufacturing flow.

If it is necessary to implement a safety system, due to the company strict requirements, it is possible to install perimeter laser scanners, emergency buttons or the system can be surrounded by a fence with an access door The system will stop the collaborative robot and the axis so that no work accident will not take place.

The robot itself will stop if it enters in collision with a person or anything else.

5. CONCLUSIONS

The scientific paper offers from a theoretical and applied point of view some important basic notions about the process of processing by electrical erosion of surfaces, from a technical and economic point of view the benefits that can be obtained by integrating these collaborative robots in a system for processing surfaces by electrical erosion.

In particular, studies have been conducted on the role, advantages and conditions of collaborative robots.

A special interest was applied to collaborative robots marketed by Universal Robots, with the aim of a light introduction to research.

The many options that an integrator can opt for and the benefits brought were presented.

The research can bring real benefits to any company that performs electrical erosion processing: reduced product manufacturing costs, improved capacity on the production line, improved delivery time, reduced scrap, improved workmanship and ergonomics.

It was also demonstrated in the research that the implementation of collaborative robots in a production process can have real benefits in addition

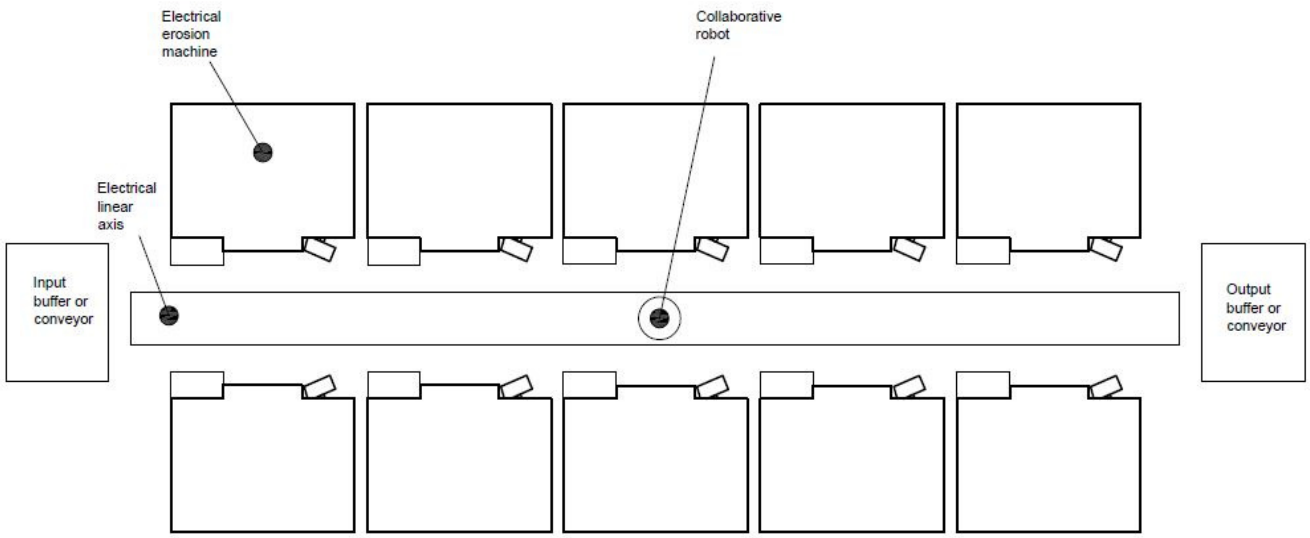

Figure 5. Situation after the collaborative robot implementation

terms of quality, but also by reducing the high number of scraps and improving the manufacturing process itself.

The economic calculation has been transposed in accordance with the prices currently existing on the industrial market. The situation before the implementation and the situation after the implementation of the collaborative robot were presented.

From an economic point of view, the scientific paper has demonstrated the feasibility of integrating collaborative robots in any field, not just in the field of electrical erosion processing.

Through this study, an unconventional technology met with a technology from the field of robotics. The study demonstrated that collaborative robots can be integrated into a technological flow in which surface processing technology by electrical erosion is predominant.

There were presented possibilities of integration, depending on the need, of a line safety system after the integration of collaborative robots.

The study presented a single point of view regarding the transformation of the line into a line operated by a collaborative robot, the possibilities of improving this manufacturing flow being unlimited.

The electrical erosion processing technology can be easily combined with collaborative robots. The final advantage are: an easy integration, zero maintenance costs and high productivity, and the benefit is in the economic field, product quality, workplace ergonomics and increased productivity.

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