THE BLADES OF TURBINES PROCESSED BY ELECTRICAL EROSION.

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ABSTRACT: Processing by electro erosion EDM (Electric Discharge Machining) is a process that uses a series of electric discharges (sparks) to erode material from the work piece. Processing by electro erosion exploded. EDM (Electric Discharge Machining) has established itself as a precision technology chosen more for what can be done than for what they can not do conventional machines. EDM (Electric Discharge Machining) is a processing technology that enabled a multitude of new applications, the importance of increasingly high is placed on the graphite electrode material used. Although there are several methods to determine the correct material for an application, we believe that there are five factors that can mean the difference between success and failure, between profit and loss. These factors are: metal removal rate, wear resistance, surface finish, the processability, the cost of the material.

KEY WORDS: EDM (Electric Discharge Machining), metal removal rate, blades of turbines.

1. INTRODUCTION

The steam turbine is a rotary engine thermal machine that transforms the enthalpy of steam into mechanical energy available to the turbine coupling. The transformation is done by means of rotor blades mounted on a rotating joint. Currently, steam turbines completely replace steam engines mounted on a rotating joint. Currently, steam turbines completely replace steam engines due to higher thermal efficiency and a power / weight ratio better. Also, the rotation of the turbine is obtained without a translational mechanism parts, such as connecting rod-crank mechanism, is optimal for driving electric generators - approx. 86% of electric power produced in the world is generated using steam turbines. Steam with high pressure and temperature is expanded in the stator vanes, also called nozzles, to a lower pressure. Energy steam enthalpy characterized by kinetic energy is converted. High velocity steam flow direction is changed by means of blades, resulting in a force acting on the blades, which creates a force on the rotor time. It rotates at a certain rotational speed, torque delivering power as mechanical work per unit time. The turbines are classified according to different criteria:

1.1. After the thermodynamic principle of operation.

Turbines action- which all fall enthalpy of steam turbines available is converted into kinetic energy only stator vanes, rotor blades having only meant to transform the kinetic energy of steam into mechanical energy. Steam turbines action is characterized by diaphragms. Reaction turbines-with enthalpy drop is converted into kinetic energy partially stator blades, vanes called and the rest of the rotor blades.

As the steam expands in the rotor blades, the tangential force acting on both of the deviation is produced by the steam, and the reactive force due to the acceleration of the jet.

Turbine combined with action steps that have both (usually in the high-pressure) and speed of reaction (low pressure side). The fact that the steam is expanded fully, or not nozzles, that is, a stage action or reaction is strictly depends on the profile shape of the nozzles and blades, as illustrated in the figure.
1.2. After the number of steps.

Single-stage turbines - that are acting on the turbine enthalpy drop is converted in one step. An example is the Laval turbine. These turbines are simple and inexpensive, but can process only a relatively small enthalpy drop and can deliver low power at high speeds, sometimes more than 300 rev / s. The need for a gearbox limited practical applications.

Turbine overlapping - also known as turbine speed or turbine Curtis, which action turbine which fall enthalpy of the steam is transformed into kinetic energy in a single crown of nozzles (as a single-stage turbine), but the kinetic energy is converted into mechanical energy in two or three crowns fixed on the rotor blades. Between crowns are placed wreaths rotor blades fixed rectifiers, which conveniently orient the jet of steam coming out of the crown (step) before.

Curtis turbines can process enthalpy drop greater than single-stage turbines, but have a lower internal efficiency. Multi-stage turbines - also called pressure-stage turbine, where the enthalpy of the steam is converted in several steps arranged in series. They can be so acting, and with the reaction. Enthalpy drop per stage is lower resulting in lower engine speeds, when operating the preferred electrical generators, operating at 50 rpm / s and 25 rpm / s in Europe, namely at 60 rpm / s and 30 rpm / s USA. These turbines can process large enthalpy drop can be built for very high power and have higher effective yields. They, however, complicated construction, large masses are expensive and demanding operation and maintenance.

1.3. After the direction of flow of steam.

Axial turbines - where the general flow of the steam is parallel to the axis of rotation of the rotor. They may be of any type described above. Acting axial turbines are called Rateau turbine and the turbine jet Parsons. These turbines have several advantages: they have a more favorable distribution efforts, construction, installation and adjustment simple and can be built to very high power advantages they provide most widespread. Radial turbines - the general flow of steam which is in a plane perpendicular to the axis of the turbine. Centripetal or centrifugal flow can be. They can be the action or reaction, single-stage or multistage. The best known is Ljungström turbine, which is a reaction turbine Multistage centrifugal flow, paddles mounted alternately on two rotors that rotate in opposite directions. Radial turbines have a very compact construction, but due to unfavorable schedule requests can not be constructed for very high power.

1.4. After the final pressure.

Condensing turbines, where steam is expanding to a pressure below atmospheric pressure achieved by a capacitor is discharged out of the steam turbine. Turbine emitted into the atmosphere from which the steam is discharged directly to the atmosphere, at a pressure slightly less than atmospheric pressure. These turbines have low thermal efficiency and are used only as auxiliary turbines to power very small. Back pressure turbine, wherein steam exhausted from the turbine is at a pressure greater than atmospheric pressure, to its use for technological purposes or heating (heating industrial).
1.5. After the sampling the steam outlets.

Turbine without sampling the entire amount of steam entering the turbine goes through all the steps. Unadjusted doses turbines, where some of the steam is taken of the stage and used for regenerative preheating boiler feed water. The pressure at the outlets is not necessary to have fixed values (to be controlled), where their name. Turbine socket set, where some of the steam is taken of the stage and used for technological purposes or for heating. The pressure at the outlet it is necessary to have fixed values.

1.6. The construction.

Nozzles are channels whose section varies continuously after a certain law to ensure desired speed of steam. Usually, these channels are made by joining a number of fixed blades, the space between each two blades forming a nozzle, resulting in a series of nozzles. If the speed that you need to reach the steam leaving the nozzle is subsonic, using convergent nozzle whose section decreases continuously from entry to exit.

If you need a supersonic speed, using convergent-divergent nozzles (Laval nozzles), whose section decreases to a minimum, in which section the speed of sound is reached, and further section increases, further increasing speed until desired value, the fact that corresponding channel section. The blades are parts that converts the kinetic energy of steam into mechanical energy. They consist of an active part of the blade and the blade disc clamping part (acting turbines) and the drum (the ones with the reaction), the foot of the blade. The blade of the blade serves to change the direction of the steam to extract energy from it. For this purpose blade is shaped aerodynamic profiles used are relatively thick and high curvature. And the blades profile shape depends on the desired flow.

The turbine blades action is needed in the channel inter color chart has a substantially constant section and those with reaction requires convergent-divergent or convergent channels. The speed of the steam (which is a vector) has a value that is related to the nozzle, which is fixed speed vector in this case the steam is denoted by \( c \), and another value if related to the blades, which move at the speed \( u \) velocity vector it being noted in this case steam \( w \). The three vectors: \( c \), \( w \), and \( u \) forms a triangle, called velocity triangles.

For a given speed in the speed \( u \) is proportional to the radius of the circle on which the moving section of the blade. Size speed \( c \) does not depend on radius, velocity triangles that form the radius changes. Blade profile shape is effective when input and output directions correspond to the directions of steam from the triangle of velocities. If the blades are not too long, radius does not vary much, either triangles do not differ much, so for simplicity technology, using constant-profile blades. However, if the blades are long and are intended optimal performance, the profile of the blades should vary with range, yielding the so-called variable profile blades (twisted blades).
Fig. 1. Single-stage turbine.

Fig. 2. Profile of turbine blade action.

Fig. 3. Profile of reaction turbine blade.

Fig. 4. Constant turbine blade profile.
2. THERMAL PHENOMENA OCCURRING IN THE ELECTRICAL EROSION.

The principle of spark erosion is simple. The work piece and tool are placed in the working position in such a way that they do not touch each other. They are separated by a gap which is filled with an insulating fluid. The cutting process therefore takes place in a tank. The work piece and tool are connected to a D.C. source via a cable. There is a switch in one lead. When this is closed, an electrical potential is applied between the work piece and tool. At first no current flows because the dielectric between the work piece and tool is an insulator. However, if the gap is reduced then a spark jumps across it when it reaches a certain very small size. In this process, which is also known as a discharge, current is converted into heat. The surface of the material is very strongly heated in the area of the discharge channel. If the flow of current is interrupted the discharge channel collapses very quickly.

Consequently the molten metal on the surface of the material evaporates explosively and takes liquid material with it down to a certain depth. A small crater is formed. If one discharge is followed by another, new craters are formed next to the previous ones and the work piece surface is constantly eroded.
2.1. Spark gap

The voltage applied between the electrode and work piece and the discharge current have a time sequence which is shown under the illustrations of the individual phases. Starting from the left, the voltage builds up an electric field throughout the space between the electrodes. As a result of the power of the field and the geometrical characteristics of the surfaces, conductive particles suspended in the fluid concentrate at the point where the field is strongest. This results in a bridge being formed, as can be seen in the centre of the picture. At the same time negatively charged particles are emitted from the negatively charged electrode. They collide with neutral particles in the space between the electrodes and are split. Thus positively and negatively charged particles are formed. This process spreads at an explosive rate and is known as impact ionization. This development is encouraged by bridges of conductive particles.

Fig. 8. The evolution thermal phenomenon and graph electric voltage and the intensity.

Here again we see what in fact is invisible. The positively charged particles migrate to the negative electrode, and the negative particles go to positive. An electric current flows. This current increases to a maximum, and the temperature and pressure increase further. The bubble of vapors expands, as can be seen.
2.2. Connection between the path of electrical power and heat.

The model shows how the supply of heat is reduced by a drop in the current. The number of electrically charged particles declines rapidly, and the pressure collapses together with the discharge channel. The overheated molten metal evaporates explosively, taking molten material with it. The vapour bubble then also collapses, and metal particles and breakdown products from the working fluid remain as residue. These are mainly graphite and gas.

By means of the model we will now try to demonstrate the relationship between the flow of current and heat. In a detail enlargement below we see the negative electrode surface, and above it a part of the discharge channel.
3. RESEARCH OBJECTIVES.

We want to process turbine blade erosion by electric. For this we need to be selection electrodes to obtain the desired roughness.

3.1. Key factors in the selection electrode

EDM (Electric Discharge Machining) has established itself as a precision technology chosen more for what can be done than for what they can not do conventional cars. EDM (Electric Discharge Machining) is a processing technology that enabled a multitude of new applications, the importance of getting more water is put graphite electrode material used. Although there are several methods to determine the correct material for an application, we believe that there are five factors that can mean the difference between success and failure, between profit and loss.

3.1.1. Metal removal rate – MRR

Metal removal rate is usually expressed in cubic millimeters per hour or cubic inches per hour but can be expressed as realistic and $ / hour. Achieving an efficient MRR rate is not just a matter of correct settings of the car. It involves also direct energy dissipated in the EDM process. Graphite is generally more efficient than metal electrodes but, however, metal removal rates vary widely depending on the particular graphite. With the right material chosen MRR rate can be maximized.

3.1.2. Wear resistance – WR

There are four types of wear: volumetric, from corner to end and side. Of the four, we believe that corner wear is the most important since the contours of the final cut are determined by the electrode to resist erosion of its corners and edges. This means that if a electrod successfully resist erosion in its most vulnerable points, then overall wear will be minimized and maximizes the life of the electrode. Electrode erosion can not be prevented, but can be minimized by choosing the correct electrode / right combination of metal and optimal settings. Electrode capacity to produce and maintain detail is directly related wear resistance and processing capacity. Minimizing corner wear requires the choice of an electrode material that combines high strength with high temperature resistance.
3.1.3. Surface finish – SF.
A good finish is achieved through a combination of correct electrode material, good condition washing and supply the correct settings. High frequency, low power and orbiting produce the best finish, as these conditions produce smaller craters less defined metal. Final finish will be a mirror image of the electrode surface, thus angstro-fine and ultrafine graphite with high strength are the best choices for finishing electrodes.

3.1.4. Processability.
Any operator who knows machined graphite cuts very easily. Just because it is able to process, does not mean that the material is the ideal choice for an electrode. It should be strong to resist damage after handling and in the process of electro itself. Strength and small size of particuleelor are important because small tolerances can be achieved. The hardness of the material is also a factor in graphite machinability, as tougher materials is much faster chipping during the machining process.

3.1.5. The cost of the material.
Electrode material cost is generally only a small part of the total EDM. What is often neglected but is that electrode material cost calculated out of the total application is devoid of meaning. Fabricarre time, working time, labor, electrode wear - all these factors depend on the electrode material more than any other factor. Thus, it is crucial to know the characteristics of available materials for electrodes peerformanta because they affect metals processing. Only with this information you can make an analysis of the cost / performance to determine the actual cost of EDM application.

4. RESEARCH METHODOLOGY AND DATA COLECTION.

4.1. Spezial solutions for processing the turbine blades.

We are specialists in development and construction of spezial machines. You provide us with your requirements - we develop solutions and produce the machine according to your request and needs.
Work piece diameter 2,000 mm. Work piece weight 1 T. Electrode diameter 2.8 mm. Drilling up to center axis with max. electrode length of 1,150 mm.

4.2. Novick technology orbit ii pro.

EDM machines with orbit - or vectorization - mostly used in a single electrode rough and finish machining of workpieces, eliminating the need for different electrodes. The result is a significant reduction of time polishing and finishing as cavity walls kept longer smooth and perpendicular to the workpiece, and a cost reduction recorded with electrode materials through the use of smaller electrodes in fewer. Technology orbit - which basically uses a head electrode orbit to rotate around its center point to the desired radial cavity - allows an easier and more precise control of the workpiece. Cavity size can be adjusted independently of the electrode size and Novick Orbit II Pro technology lets you make 95% of all CNC machining operations at a fraction of the cost of other CNC EDM machines. A normal burning a conventional EDM machine / NC or CNC requires that you know the exact size of the cut excess wash to have perfect conditions and requires the use of multiple electrodes - generally one to two raw processing and finishing - and still does guarantees the elimination of taper. The same burning carried out with a machine with orbital uses fewer electrodes - usually one for raw processing and one for finishing. The machine offers the ability to perform combustion Z axis and orbit to the desired size. Heun is able to drill around the corner. A special process enables us, to machine the work piece at points difficult to access, with bended and rotating electrodes.

![Fig. 14. Graphic form of turbine blades using electrical erosion.](image)

In the manufacture of turbine blades, coolant holes are required in extremely steep entry and exit angles. Even though the material thickness is not known, the breakthrough of the drilling without damage of the close rear panel has to be guaranteed.
Travel 2,100 x 900 mm. Electrode length up to 1,150 mm. Work piece weight up to 8 T. Heun is able to drill around the corner. A special process enables us, to machine the work piece at points difficult to access, with bended and rotating electrodes.

4.3. Applications.

Winbro Group Technologies has developed a comprehensive range of application solutions for aerospace and industrial cooling hole and form generation. These are often tailored to fulfill the specific requirements of a particular engine design. The primary areas where Winbro’s High Speed EDM, Laser and ECM technologies are applied include:

- Holes for wall cooling and effusion cooled combustors.
- Film cooling holes in HP blades, vanes segments.
- Laser drilling, cutting and ablation of various engine components.
- Shaped holes for blades and vanes.
- Cooling hole re-opening ECM forming of compressor blades.
- Creep-Feed grinding of forms and features in blades, vanes segments.

Additional applications and machine systems are continually being developed to meet the specific needs of our customers, ensuring that we always provide the most appropriate solution to any individual application.
4.3.1. Small hole drilling edm is used in a variety of applications.

On wire-cut EDM machines, small hole drilling EDM is used to make a through hole in a work piece in through which to thread the wire for the wire-cut EDM operation. A separate EDM head specifically for small hole drilling is mounted on a wire-cut machine and allows large hardened plates to have finished parts eroded from them as needed and without pre-drilling. Small hole EDM is used to drill rows of holes into the leading and trailing edges of turbine blades used in jet engines. Gas flow through these small holes allows the engines to use higher temperatures than otherwise possible. The high-temperature, very hard, single crystal alloys employed in these blades makes conventional machining of these holes with high aspect ratio extremely difficult, if not impossible. Small hole EDM is also used to create microscopic orifices for fuel system components, spinnerets for synthetic fibers such as rayon, and other applications. There are also stand-alone small hole drilling EDM machines with an x–y axis also known as a super drill or hole popper that can machine blind or through holes.

EDM drills bore holes with a long brass or copper tube electrode that rotates in a chuck with a constant flow of distilled or deionized water flowing through the electrode as a flushing agent and dielectric. The electrode tubes operate like the wire in wire-cut EDM machines, having a spark gap and wear rate. Some small-hole drilling EDMs are able to drill through 100 mm of soft or through hardened steel in less than 10 seconds, averaging 50% to 80% wear rate. Holes of 0.3 mm to 6.1 mm can be achieved in this drilling operation. Brass electrodes are easier to machine but are not recommended for wire-cut operations due to eroded brass particles causing "brass on brass" wire breakage, therefore copper is recommended.

![Fig. 17. A turbine blade with internal cooling as applied in the high-pressure turbine.](image1)

![Fig. 18. Small hole drilling EDM machines.](image2)
4.3.2. Turbine blades high pressure.

Winbro manufactures machine systems which are used to create the miniature holes required to cool aero and industrial gas turbine high pressure blades. These holes are critical in allowing internal airflow to cool parts and prevent overheating during engine operation. Effective cooling improves component efficiency leading to reduced fuel consumption and NOx emissions on today’s generation of lightweight, low noise, jet engines. Cooling holes shield components from temperatures that are often higher than their melting point, making their precise design and manufacture a critical feature of the engine. Components are often cast from high nickel and high cobalt alloys to enhance performance and longevity. Winbro uses different processes to produce cooling holes – EDM, Laser Drilling, Laser Ablation or a combination of these. The choice of these technologies can be influenced by the particular coating applied to the part (Ceramic or Metallic), metallurgy / productivity requirements or component / feature access. Winbro Group Technologies has become recognised as a world leader in the development and implementation of these technologies for the production of cooling holes.

![Fig. 19. High Speed EDM single point drilling of a HP Aero Turbine Blade.](image)

![Fig. 20. Industrial gas turbine blade with (thermal barrier coating).](image)

![Fig. 21. Typical HP Turbine Blade.](image)
Now with the addition of the FGC 2 creep-feed grinding machine manufactured at Winbro we offer multi axis grinding of features such as fir-tree root forms.

Vollmer Werke, based at Biberach, Riss, Germany, are known worldwide as an eminent Manufacturer of an extensive range of machines for sharpening of Band, TCT HSS blades Erosion machines for rotary diamond tools. Accredited as a privately held family owned company, we have carved ourselves a position amidst the acknowledged manufacturers, suppliers and exporters of an exhaustive collection of Saw Sharpening Machines for Band Saws, Circular Saws (TCT HSS) Erosion Machines for Rotary Diamond Tools. These machines are valued by our clients for their superior technology, durability, reliability and sturdy structure. With an experience of over 103 years, we have earned the respect and sincerity of our customers world-wide. We have employed a team of highly qualified professionals that works relentlessly to cater to the growing demands of our clients. Products we offer are manufactured using superior quality raw materials that are procured from the most trusted vendors of the industry. Our team of quality controllers keeps a stringent check on each step of the entire production processes in order to delivery a top quality product to our customers.
4. THE INFORMATICS PROGRAMS ANSYS PROCESSING BY ELECTRICAL EROSION OF TURBINE BLADES.

Fig. 23. Informatics programs applied to turbine blades.

Fig. 24. Informatics programs applied to turbine blades.

Fig. 25. Informatics programs applied to turbine blades.

Fig. 26. Informatics programs applied to turbine blades.
Fig. 31. Informatics programs applied to turbine blades.

Fig. 32. Informatics programs applied to turbine blades.

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Fig. 41. Informatics programs applied to turbine blades.

Fig. 42. Informatics programs applied to turbine blades.

Fig. 43. Informatics programs applied to turbine blades.
5. A CASE STUDY.

The electrical erosion processing parameters turbines, for the case study, we used the following parameters of electrical erosion values in the chart below.

Ra - The surface roughness of turbine blade.
Uz - The tool electrode the wear.
T_p - The pause time between two impulses.
T_i - The impulse time.
Q_p - The productivity of realized.
Or You realized 10 experiments processing electrical erosion of turbine blades values below.
Fig. 48. Table containing the values parameters of electrical erosion.

Fig. 49. Table containing the values parameters of electrical erosion.

Fig. 50. The form 2D graphics parameters electrical erosion.
Fig. 51. The reporting parameters electrical erosion to roughness.

Fig. 52. The connection between electrical erosion parameters.

Fig. 53. The shape 2D the electrical erosion parameters and their values.
**Fig. 54.** The form 2D graphics parameters electrical erosion.

**Fig. 55.** The shape 2D of the electrical erosion parameters and their values.

**Fig. 56.** Table containing the values parameters of electrical erosion.
**Fig. 57.** The form 2D graphics parameters electrical erosion.

**Fig. 58.** The shape 2D the electrical erosion parameters and their values.

**Fig. 59.** Table containing the values parameters of electrical erosion.
Fig. 60. The reporting parameters electrical erosion to roughness and wear.

Fig. 61. Table containing the values parameters of electrical erosion.

Fig. 62. The shape 2D the electrical erosion parameters and their values.
Fig. 63. Table containing the values parameters of electrical erosion.

Fig. 64. The connection between electrical erosion parameters.

Fig. 65. Table containing the values parameters of electrical erosion.
**Fig. 66.** The shape 3D the electrical erosion parameters and their values.

**Fig. 67.** The form 2D graphics parameters electrical erosion.

**Fig. 68.** Table containing the values parameters of electrical erosion.
Fig. 69. The shape 2D of the electrical erosion parameters and their values.

Fig. 70. Table containing the values parameters of electrical erosion.

Fig. 71. Representation of process parameters of electrical erosion.
Fig. 72. Representation of process parameters of electrical erosion.

Fig. 73. The right equation parameters erosion electrical.

Fig. 74. The right equation parameters erosion electrical.
Fig. 75. The right equation parameters erosion electrical.

Fig. 76. Form 2D graphics and equations of lines.

Fig. 77. The form 2D graphics parameters electrical erosion.
6. RESULTS AND DISCUSSIONS.

The electric erosion machining of turbine blades note that the results obtained by the equations straight lines and the graphics in the form of balls the results are the same.

**Fig. 78.** The right equation parameters erosion electrical.

**Fig. 79.** The right equation parameters erosion electrical.

**Fig. 80.** Form 2D graphics and equations of lines.
When productivity is \( Q_p = 19 \) and the momentum is \( T_i = 3 \) results in surface roughness \( R_a = 2.8 \). And when productivity is \( Q_p = 78 \) and momentum is time \( T_i = 25 \) have a roughness of \( R_a = 4.85 \). Maximum value of surface roughness is when \( T_i = 400 \) and \( Q_p = 59 \) and result \( R_a = 7.85 \)

**Fig. 82. The reporting of parameters electrical erosion roughness.**

**7. CONCLUSIONS.**

Orbital (radial movement) or trace (angular movement) to the electrode ensures better wash, removes the wall cavity conicity and allows you to control the size you want. During electro-erosion, the material is removed by electrical discharge, leftover (Particles and electrode-wool molten Board) traveling Towards the upper edge of the wall of the secondary cavity Creating That produces a conical effect, known as the bell-mouth, as you leave the cavity. Once Reached the desired Z-depth, movement of the blind or tracing allows you to remove the secondary discharge Produced conicity. Spindle taper Will Be removed Using the same settings used in the processing of the raw. Once the spindle taper is removed, dazzling Until the desired finish by decreasing the power settings. The movement of the blind or tracing also creates a vacuum: pushing the dielectric liquid cleaner into the hole and drag-forcing molten out of Spain, The which provides a much better finish. The movement of the blind and tracing is programmable on each axle U and V or V and W or U and W.
The biggest advantage of EDM technology orbit from Novick is the ability to make electrodes uniform size. Normally, an EDM machine without orbital positions, start with a much smaller electrode for raw processing, then choose a larger electrode to finish, because we have the ability to rotate. With the Pro-II orbit can make an electrode-sized - no need to get the exact dimensions immediately if you have a wall orbital cleaner and straighter, a more efficient and cheaper.

8. REFERENCES.