EFFECT OF THE RATE OF EROSION ON THE FATIGUE STRENGTH OF A 0.7% C. TOOL STEEL

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ABSTRACT.

Spark erosion process is becoming a powerful tool in shaping tools and dies and other mechanical elements made of hard steels. However there is not sufficient information regarding the effect of the process on the mechanical properties of such steels.

The object of the present investigation is to find out the effect of the rate of erosion on the fatigue strength of a 0.7% C tool steel compared with that of grinding, as well as, to furnish the tool and die makers with useful information regarding the amount of improvement on the fatigue strength as a result of a stress relieving of spark eroded specimens.

It was found that the decrease of the fatigue strength due to spark erosion process amounted to 40 % for roughing rate of erosion and 23.5 % for fine rate of erosion.

The gain due to stress relieving amounted to about 18%.

The relation between the surface finish parameters for the used tool steel were verified and those between the fatigue strength of the used steel and the free polishing depth were established.

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CHAPTER I

SPARK EROSION AND SCOPE OF PRESENT WORK .

A - SPARK EROSION:

1 - Spark erosion process compared with conventional mechanical processes:

Today technical progress is characterised by ever-increasing utilization of materials displaying poor machine-ability such as cemented carbides, heat resistant steels and materials resistant to aggressive media.

During machining by conventional mechanical methods the requirement that the material of the cutting tool to be harder than that of the workpiece must be observed. This requirement often forced the designers to avoid the above mentioned materials in the construction of machines and equipment.

The spark erosion process which is becoming an integral part of engineering technology overcomes this difficulty since in this process it is possible to machine materials regardless of their mechanical, physical and chemical properties. The only pre-requisite of this process is the electric conductivity of the material to be machined. It is particularly effective in working metals or alloys of great hardness such as nimonic, hardened steel, brittle materials and other materials that are not machineable by ordinary cutting tools, and for complex shapes in soft materials. It is used for:

* Cut and polish various metals and alloys.
* Cut blind and through holes of various diameters.
* Produce press-tool dies.
* Carry out copying and engraving operations.
* Sharpen tool fitted with cutting edges of hard alloys.
* Machining of forging dies, extrusion and drawing dies and of die casting moulds.
* Machining materials for which deformation due to the cutting force can not permitted, it is either extremely difficult or entirely impossible to shape materials in conventional machine tools.
* Complex dies, plastic moulds, wire-drawing dies as well as slots and holes of various shapes and of a size from several hunderdths to several tenths of a millimetre.

In this process erosion occurs in both workpiece and tool electrode while in the conventional mechanical processes the rate of metal removal of the tool is negligible compared with that of the workpiece. A specific feature of the electro sparking method is the absence of every mechanical force acting at the working area as this is a contactless method.

The surface produced by spark erosion is completely covered by roughly spherical shape craters and is therefore non-directional, thus different from surfaces produced by the conventional mechanical methods.

2 - Principle of operation:

A series of sparks is passed between a workpiece and an electrode while the area around the spark is immersed in a suitable dielectric fluid, a small amount of the material of both electrode and workpiece is eroded by each spark. In the practical electro-sparking method of working the discharges are usually produced with close contiguity of electrodes (anode, cathode) by a general arrangement that ensures the required form of non-stationary discharge. During the drawing together of the electrodes, at some predetermined gap between them the potential intensity of the electrical field increases so much that individual electrons begin to break loose from the surface of the cathode and are impelled towards the anode under the influence of the field forces. In their movement in the inter-electrode space the electrons will collide with neutral molecules and will ionize them, which is the necessary condition for producing a discharge.

At some time such ionization of the interspace between the electrodes becomes sufficient to form a narrow channel of continuous conductivity. At that moment there is a considerable flow of electrons along the channel thus formed towards the anode producing by such movement a momentary current impulse or discharge. The liberation of energy accompanying the discharge leads to the production of extremely high temperature causing fusion and partial vapourization of the metal. Thus each discharge creates its own heat impulse, causing breakdown of electrode material. These momentary heat impulses in periodical sequence produce deep physico-chemical transformation in the surface layer of the workpiece.

As the material of both is eroded the tool electrode is fed forward to maintain a small constant gap through which the spark will pass, then the shape of the electrode will be cut into the workpiece.

A spark erosion machine therefore consists essentially of an electric circuit capable of generating a series of sparks. This circuit is composed of condensers arranged in parallel to the electrode and is periodically charged from a direct current supply as in (Fig. 1). It includes also a servo-system and drive to maintain a constant spark gap and a work tank to hold the dielectric liquid as in (Fig. 2).

3 - Hypotheses of spark erosion:

Four main hypotheses have been forwarded to explain the phenomenon of erosion by electric sparking. These are the hypotheses of Flares(1), of mechanical action,(2) of thermal action(3) and of shock waves.(4)

Concerning the hypothesis of flares, erosion is supposed to take place by the action of metallic vapour jets streaming between the electrodes. While this could be accepted in the case of high tension discharge in a gas dielectric, however, this fails to explain the erosion in liquid dielectric which occurs at such low voltages.

As for the hypothesis of mechanical action, it assumes that the space charge caused by the sudden flow of electrons upsets the equilibrium in the electrodes and the resulting electrostatic forces tear off the material. This hypothesis fails to explain the experimental results which show that the rate of erosion of mild steel and of hardened steel is the same despite the big difference in tensile strength.

Regarding the hypothesis of thermal action, it assumes that the stream of electrons is braked in the anode (workpiece) and its energy is converted into heat. The same applies to the stream of ions emerging from the anode and striking the cathode (tool electrode) and erosion of the workpiece as well as tool electrode occurs. Since there is some delay between the impact of electrons and the arrival on the cathode of ions generated by that impact, tool erosion should be expected to depend on the duration of the discharge. Very short discharge show a ratio of tool to workpiece erosion of only a few percent, while with the increase in the duration of the discharge the ratio increases too and eventually approaches unity. A detailed study of the thermal phenomena in connection with spark machining was carried out by Solotych who concluded that the electromagnetic forces inside the spark channel and just underneath the eroded surface produce an upward directed tension of 2-3 Kg/cm^2 which is sufficient to lift the molten metal.

The shock waves hypothesis assumes that, at each electrical discharge a focussed stream of electrons flowing at a high velocity from one electrode to the other, produces compression shock waves on the surface of the electrodes. The formation of the compression shock wave is accompanied by a local increase in temperature and a certain deformation of the surface layer. The mechanical stress occuring in the metal spreads at a definite velocity in all directions including the one from which the shock wave was propagated. When it reaches the initial surface it is reflected as a tensile stress of a magnitude many times more than the tensile strength of the material. As a result particles of metal are torn off in the direction facing the compression shock wave.

4 - Factors governing the spark erosion process:

The technological characteristics of electro-spark working which are: high efficiency, good surface finish and accuracy depend on: -

a - Parameters of the electrical circuit.

b - Precision of adjustment of feed control.

c - Electrode material.

d - Liquid dielectric.

e - Electrode tool design.

In the present investigation the important parameter of rate of erosion (which depends mainly on the parameters of the electrical circuit) was the only variant.

Brass electrode and kerosene dielectric were chosen as they are the most commonly used. The shape of the electrode conformed to the required circular notch of the standard fatigue test specimen.