Effect of a Diode Across the Spark Gap in Electric Discharge Machining

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Manuscript received 12 February 1970; revised manuscript received 30 [illegible] 1970

The effect of connecting a diode across the spark gap in electric discharge machining with a relaxation type generator is discussed. It is found that the reduction in tool wear increases with machining rate when the diode is used across the spark gap.

ELECTRIC discharge machining (spark erosion machining) has come into use as an effective tool for working on hard metals and alloys and machining complex shapes[1,2]. The most widely used circuit is of the simple relaxation typo known as the Lazarenko generator[3]. The circuit of the generator is given in Fig. 1. The capacitor C receives charge from a dc source V through a resistance R. The workpiece and the tool are immersed in a dielectric fluid, usually kerosene. Both are connected across the capacitor with a small gap between them, typically of the order of 20 µM. When tho voltage across C exceeds the breakdown voltage of the spark gap, dielectric breakdown occurs and a certain amount of material is removed from the workpiece and the tool. The capacitor is discharged and the operation repeats itself, resulting in the shape of the tool being eroded into the workpiece. Tho distance between the tool and the workpieeo is continuously adjusted by a ' feed control ' servomechanism as shown in Fig, 1. The voltage across the spark gap is averaged through a low pass filter and compared with a reference. Tho error is amplified and used to control the tool-feed mechanism, By changing the reference voltage tho rate of feed can be controlled.

For a given value of C the material removed per spark is proportional to the energy stored in the capacitor, which is given by $E = \frac{1}{2}CV^2$. If V and C are fixed and if there are N spark-overs per minute, the total material removed per minute is $\frac{1}{2}CV^2N$. Thus, the machining rate can easily be varied by varying N. This is accomplished through the variation of R.

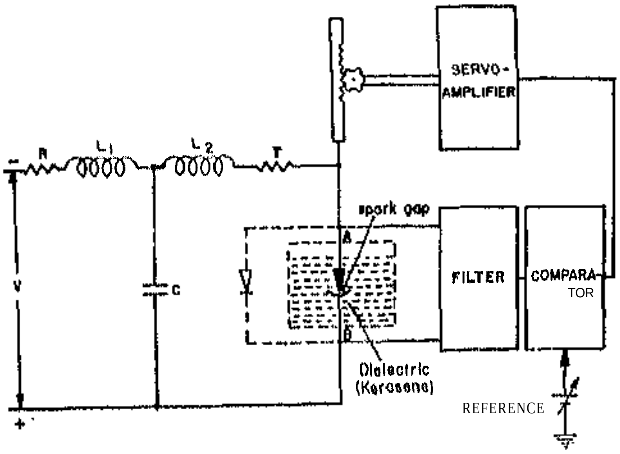

Fig. 1 Schematic diagram of the relaxation generator [(A) Tool, and (B) workpiece]

In Fig. 1, L_2 and r are the effective inductance and the resistance in the discharge circuit. Neglecting the effect of the charging circuit, the discharge current i follows the familiar LCR equation, As tho lead resistance is usually very small, the condition $r^2 < 4L/C$ is satisfied and the current is oscillatory[4]. The tool is normally held negative to reduce tool wear in machining due to the polarity effect[5]. Because of the oscillatory nature of the current, however, the roles of the tool and the workpiece are interchanged every half-cycle. This results in excessive tool wear while machining[6]. Many methods to obtain unipolar pulses are mentioned in the literature[7]. The idea of using a diode across the spark gap is one of them[8,9]. No quantitative results, however, seem to be available on the effect of using a diode across the spark gap. In view of the very high currents of the order of 1000 amp or more and the comparatively low voltages involved, only modern silicon rectifiers are suitable for this purpose.

In the present study, the reduction in tool wear has been measured using a power diode across the spark gap as shown by dotted lines in Fig. 1. A 90 amp (I_{avg}) rectifier, 90RSD9, was used. With, this, it was possible to handle approximately 1000 amp of peak current which was encountered in the spark machine used. A 0·6 mm thick mild steel sheet was used as the workpiece. The amounts of tool wear in making a complete through-hole with and without the diode were measured and compared for various values of C and R. A 9·5 mm diameter brass rod was used as the tool and commercial kerosene as the dielectric. The tool wear was measured as the ratio of the loss of weight of the tool to that of the workpiece. Each experiment was repeated at least three times and the repeatability of the results was very good. The results were found to be the same with and without forced circulation of kerosene. This is easily explained in view of the small depth of penetration and large

TABLE 1 PERCENTAGE TOOL WEAR WITH AND WITHOUT A DIODE ACROSS THE SPARK GAP

Value of C µF	Voltage V	Value of R, ohms: 8·5		10		17		34		67		100	
		WOD	WD	WOD	WD	WOD	WD	WOD	WD	WOD	WD	WOD	WD
25	60	35	33	39	38	37	.15	40	36	*	*	*	*
	120	*	57	57	57	fiS	fit	60	53	60	53	58	52
	240	*	*	61	44	79	60	76	68	72	64	65	59
50	60	38	38	3.1	11	37	37	42	41	*	*	*	*
	120	67	66	68	68	65	65	66	65	67	66	62	59
	240	#	*	77	58	90	65	85	68	80	62	71	64
100	60	41	38	42	42	40	39	41	40	*	*	*	*
	120	69	65	67	65	67	66	67	62	67	60	65	60
	240	82	68	97	66	99	75	96	73	84	67	75	61

*Sparking unstable. WD = with diode, and WOD = without diode.

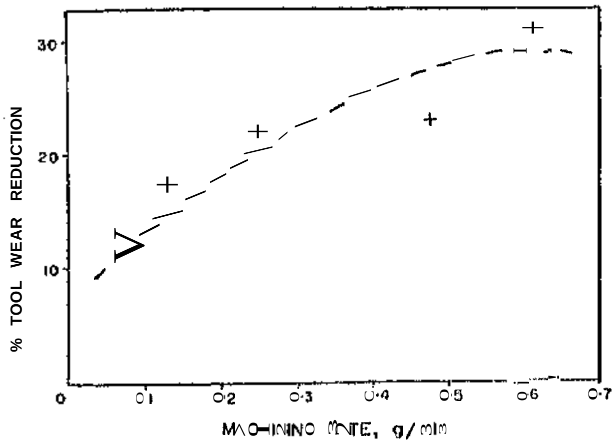

Fig. 2 — Tool wear reduction versus machining rate

volume of dielectric used. The results for various values of R and C are given in Table 1.

Discussion — At 240 V supply voltage the tool wear reduction is appreciable and increases with increase in the value of C (Table 1). At lower supply voltages, there is only a slight improvement with the use of the diode. This is to be expected, since at lower voltages, the reverse voltage built up is too low to cause any significant erosion of the electrodes.

Fig. 2 shows the reduction in tool wear against machining rate. The general pattern shows increasing improvement with increase in the machining rate. Because of the limitations of the relaxation type generator neither the sparking voltage nor the duration is the same for all the sparks[10]. So the absence of a perfect correlation between tool wear reduction and machining rate is not surprising.

No improvement in machining rate is noticed with the use of diode. Since an ordinary power diode is used there is a momentary reverse current through the spark gap for a period of approximately one micro-second before the diode starts conducting. To investigate the effect of this transient on tool erosion, a fast diode (a number of MOTOROLA MR 836's in parallel) with 'ON' time much less than 50 nsec was used in place of the 90RSD9. The results were identical with those obtained with the ordinary diode.

It follows that it is advisable to use a power diode across the spark gap as a regular feature in relaxation type generators. This adds very little to the cost of the machine and results in reduced tool wear under fast machining rates referred to as 'roughing'.

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