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M. Abdel-Moneim
Department of Production Engineering., Faculty of Engineering & Technology Suez Canal University.

S. Ibrahim
Department of Production Engineering, Faculty of Engineering & Technology Suez Canal University.

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Some Experimental Investigations in the Performance of Electochemical Machining Process.

BY

M.Es. ABDEL MONEIM and S.M.IBRAHIM

Department of Production Engineering,
Faculty of Engineering & Technology
Suez Canal University.

Abastract:

A rigid abright drill provided the ratory motion for a brass disc employed as the tool having no embeded abrasive material. Sodium Chloride and Sodium Hydroxide having different concentrating rates between (10% - 50%) were employed as electrolytes covering the gab between the tool and workpieces. Mild steel, free machining -rass and pure aluminum in the as-received conditions were employed as workpieces.

Material removal rates were found to be greater for smaller gap widths, higher speed of revolution, greater gap voltage, higher percentages of electrolyte conceration and greater electrolyte velocity for all workpiece materials especially when using sodium chloride.

As the material removal rate increases, consequently workpiece surface temperature rises. Such temperature rises all-over the entire range did not exceed + 30°C.

Workpiece surface finish were found to improve for higher rates of material removal for mild steel and free machining brass only. No such improvements were noted after aluminum machining except at high tool speeds. Deep scatered scratchs in aluminum specimens were noted at lower tool speeds.

NOMENCLATURE

E	Applied voltage	volt
Wt	ATomic Weight	----
C	Concentration percentage	----
C.L.A.	Center line average height	μm.
ρ	Density	gm/cm^3
I	Electrolyzing current	amp.
K	Electrolyte conductivity at room temperature	ohm^{-1},cm^{-1}
R	Electrical resitance	ohm.
M	Equivalent weight of substance dissolved or deposited	gm.
V	Electrolyte Velocity	msec.$^{-1}$
γ	Electrochemical equivalent	----
η	Efficiency	----

F	Faraday's constant	amp.hr.
Y	Gap width	mm.
t	Machining time	min.
MRR	Material removal rate	gm/min
Zw	Materral removal by electrical action	gm.
Za	Material removal by abrasion	gm.
N	Tool speed	r.p.m.
v	VAlance of dissolution of anode metal	----
A	Workpiece cross-sectional area	cm^2

INTRODUCTION

Sodium chloride or sodium Hydroxide electrolytes may be pumped between the workpiece (anode) and the tool (Cathode) while a direct current is being passed across them.

The work material is, thus, removed by electrolytic dissolution of the anode workpiece. Metal removal rate in electrohcemical machining is dependent on current density, type and velocity of flow of the electrolyte, type of workpiece material and gap width.

The material removal in electrochemical machining is based on the simple laws of Faraday. Many theories have been advocated by research workers, e.g.[1-8] , in the field of electrochemical machining to explain the process.

ANALYSIS

The material removal in electrochemical machining is due to ion migration towards the tool, the cathode [6].The material removal rate [MRR] may be expressed as follows[7],

$$MRR = Zw + Za \quad \text{.....................[1]}$$

The value of Zw can be obtained from knowledge of the flowing current [I], the electrochemical equivalent of the workpiece material ψ and the current efficiency η (assumed to be 100%). The value Za which is the material removal rate by the abrasive material equal to zero in the current research since the tool has no embedded abrasive material. According to the first law of Faraday [9],[7], and [6];

$$M = \psi . I . t \quad \text{..............................[1]}$$

and $M = Wt/v$

then $$\psi = \frac{1}{F} . \frac{Wt}{v} \quad \text{..............................[3]}$$

Where F = Farday's constant = I.t.
= 96, 500 culombs = 26.8 amp.hours.

But

$$MRR = \frac{M}{A.\rho.t.} . \eta \quad \text{.....................} [4]$$

$$MRR = \frac{Wt.\ I.t}{F.v.A.\rho.} \ cm^3/min \quad \text{.................} [5]$$

or $$G = \frac{1}{F} \ \frac{Wt.\ I.t.}{v} \eta \ gm \quad \text{..................} [6]$$

Where G material removal, gm.

If the applied voltage is equal to E_1 (voltage between electrodes) then for the working gap one can write;

$$I = \frac{E_1}{R}$$

$$R = \frac{Y}{K.E_1} \quad \text{..............................} [7]$$

$$I = \frac{E_1.\ K.\ A.}{Y}$$

EXPERIMENTAL DETAILS

Special set-up is designed and manufactured to conduct the needed electrochemical machining tests. (Fig.14) Workpieces in the as recieved conditions of mild steel (0.35% C, 0.03% Si, 0.006% Mn Rest Fe.), Free machining brass(56-59% cu, 37-42.5% Zn, 1.5-3% Pb) and Pure aluminum (96% Al, $% Mg.) are machined, in turn utilizing a vertical drilling machine. The employed tool, a free machining brass, is mounted on a chuck attached to the rotatory machine spindle. Workpiece specimen is held above the machine table and positive supply terminal.

The different electrolytes viz; sodium chloride (NaCL) or sodium hydroxide (NaoH) is pumped in the gap between the non-advancing tool and the workpiece.

The power supply is of up to 30 volts with current intensity ranging between 8 and 105 amp. Both tool and worpiece are well insulated.

EXPERIMENTAL OBSERVATIONS

Machining at a low cell voltage of 6 volts produces a dull white layer on the specimen surface for all employed workpiece materials.

As for brass and steel; voltages increase, cause higher electrolyte temperature and improvements in surface finish especially for brass.

Surface finish was found to improve for higher machining voltage due to the decrease in oxide film formation. However, the existance of gasses and water vapour at high machining voltages will lead to non uniformity in the electrical conductivity of the electrolyte deteriorating the surface finish. An optimum surface finish value was found to be at 24 volt.

Surface damage for aluminum was observed at voltages of 24 volts and higher where notable increases in surface roughness existed.

For small gap widths (less than 0.6 mm) crack formation were found to increase for aluminum specimens. Short circuit were noted for all specimens ast gap width less than 0.2 mm.

EXPERIMENTAL RESULTS AND DISCUSSION

Test Group No.[A]: Effect of working parameters on Material Removal Rate.

(a) Tool speed:

As the tool speed increase so do the material removal rate for all employed workpiece materials specially for sodium chloride electrolyte, (see Fig.2). Higher tool speeds lead to higher rates of oxide film removal. That results in more frequent surface generation and consequently, higher material removal rates.

(b) Gap width:

The rate of material removal was found to increase for narrower gap widths especially for sodium chloride (see fig.3). That increase is consistant was both Ohm and Farady's law.

(c) Machining Time:

As the machining time increased the rate of material removal was noted to get smaller, especially upon using sodium chloride as an electrolyte (see Fig.4).

(d) Electrolyte concentration Precentage:

For electrolyte having bigger concentration Precentage, the rate of material removal is conseuqently bigger especially for sodium chloride. That is consistant with Ohm's and Faraday's law (see Fig.5).

(e) Gap voltage:

As the gap voltage increase, the rate of material removal get higher for all comployed worpiece material especially for machining in presence of sodium hydroxide (see Fig.6). This is due to the more abusive action of sodium hydroxide.

(f) Electrolyte Velocity:

For higher electrolyte velocity, the rate of material removal increases for brass and steel (see Fig.7) especially for sodium chloride. This is logical since for higher electrolyte velocities there are fewer oxide films formation.

Test Group No. [B]: Effect of Working Parameters on the Surface Finish:

(a) Tool Speed:

As the tool speed increase the surface finish improve for all material employed in presence of sodium chloride at speeds ranging from 1150 to 2250 r.p.m. as indicated in Fig.(8).

(b) Gap Width:

The surface finish for all materials were found to deteriorate as the gap width increase between 0.6 to 1.0mm. (see Fig.9).

(c) Machining Time:

The surface finish varies with the machining time in a manner dependant on the type of the employed workpiece (see Fig.10).

The performed tests showed that workpiece surface temperature increase are associated with higher gap voltage, narrower gap width, higher tool speed, higher concentration percentage, greater machining time, and lower electrolyte velocity. Such temperature increase are found to be within 30°C only.

CONCLUSIONS

1. No sparking existed for gab widths more than 0.40 mm. Such width yielded the largest material removal rate and the best workpieces surface finish.

2. Sodium chloride proved to a better electrolyte than sodium hydroxide. The former gave higher material rate and better surface finish.

3. Electrochemical machining process is capable of improving steel and free machining brass surface finish to reach 0.2-0.3 microns centre line average height. That result was obtained upon machining for 15 seconds starting with an intial surface finish of 2.5 microns.

4. Material removal rate increase linearly as the voltage and electrolyzing current rise. The last is affected by the applied gap voltage, gap width, electrolyte concentration precentage and the machined area.

5. Material removal rates were found to decay as machining last for longer periods.

6. Slight increases in workpiece surface temperatures were noted upon the increase of gap voltage and tool speed and for slower electrolyte flow rates and narrower gap width.

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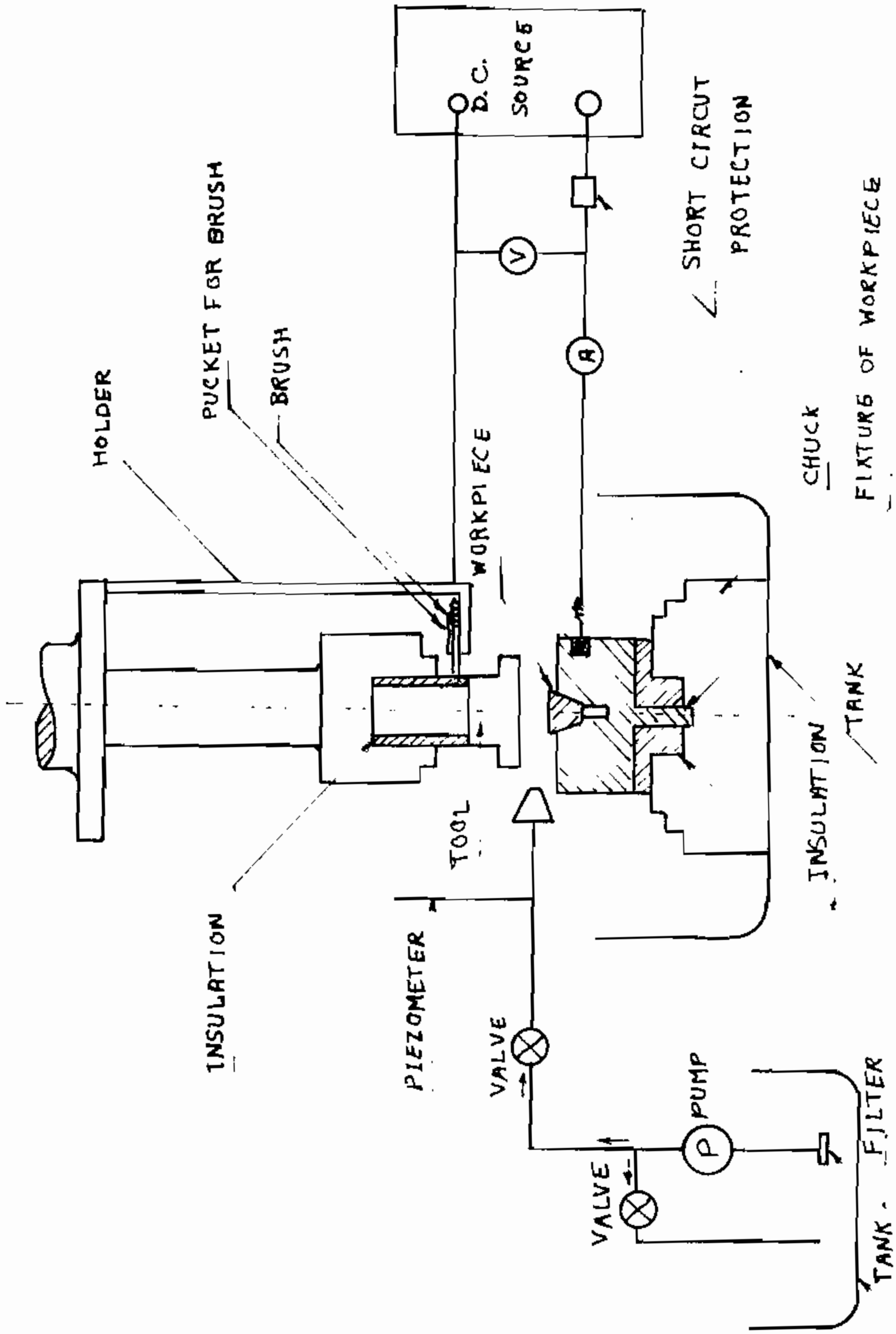
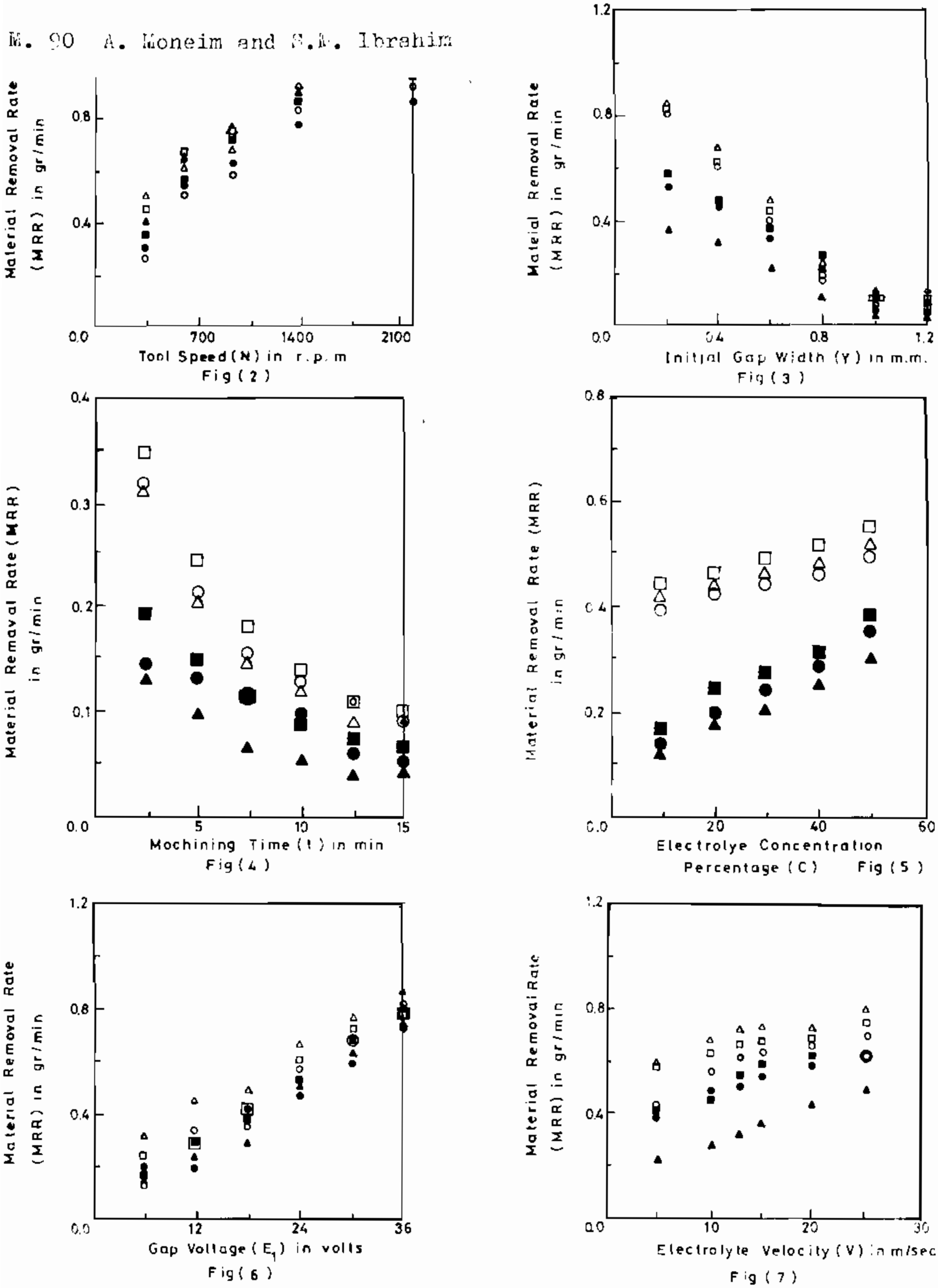


The Main Components of the Mechanical System and Typical Electrical Circuit For Electrochemical Machining.



For NaCL: ○ BRASS, □ STEEL, △ ALUMINUM

Figs (2 _ 7)

For NaOH: ● BRASS, ■ STEEL, ▲ ALUMINUM

The Relation-Ships Between Working Parameters and Materials Removal Rate (MRR) In gr/min For Br; Al, and St. For NaCl and NaOH

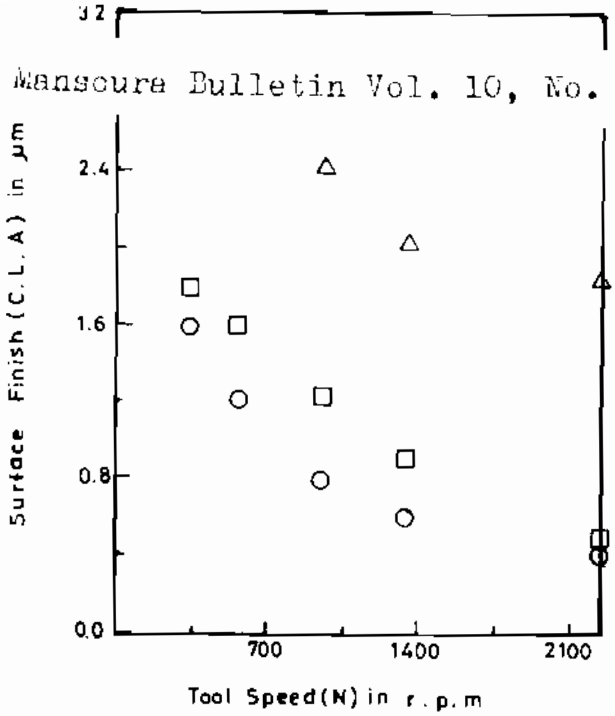


Fig (8)

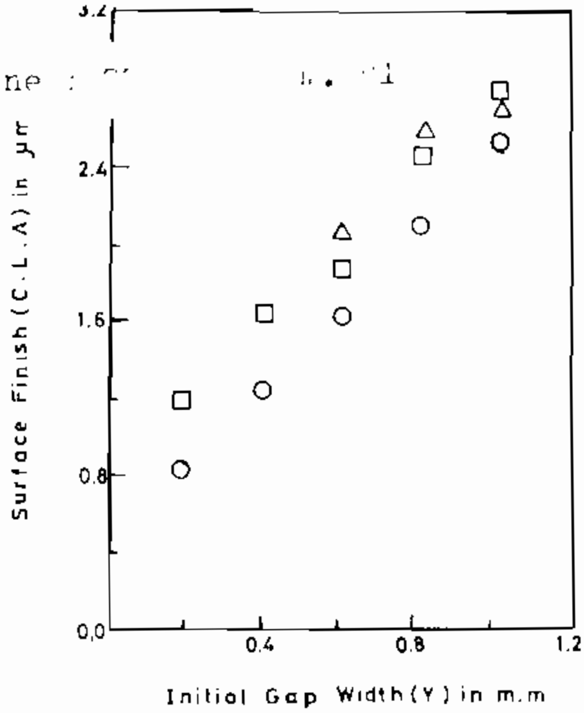


Fig (9)

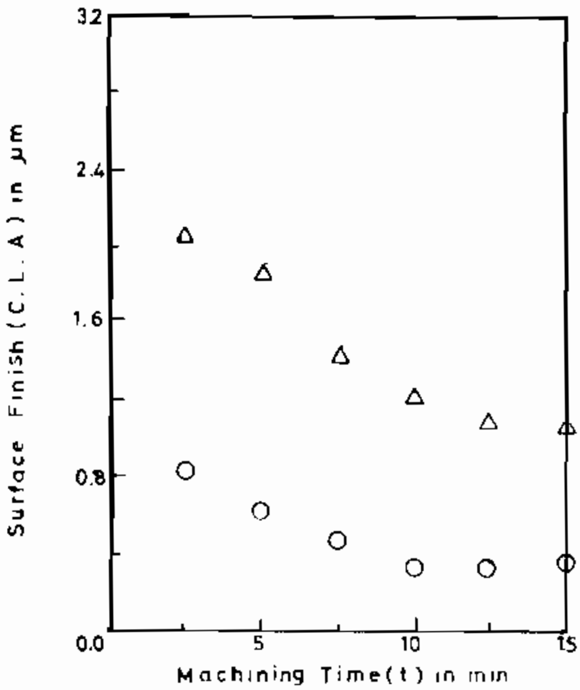


Fig (10)

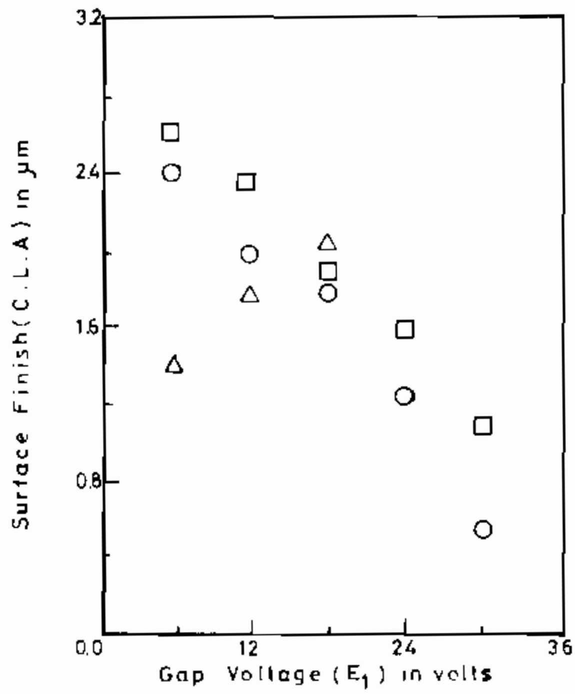
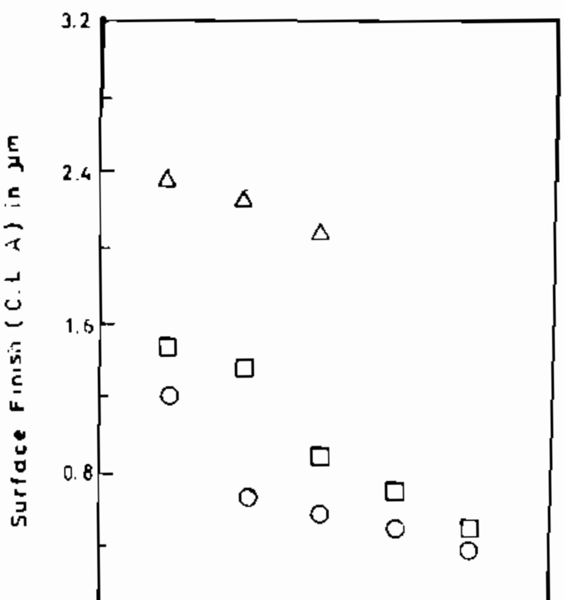


Fig (11)



Figs.(8 _ 12): The Relation-Ships Between Working Parameters and Surface Finish (C.L.A) In µm. For Br; AL; and St . For NaCL Electrolyte.