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Development and Experimental Study of Powder Mixed EDM for Cemented Carbide Work piece

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***Abstract*— This paper presents the study of a development and experimental study of powder mixed EDM. Powder mixed electric discharge machining (PMEDM) is a relatively new technique for the enhance the capabilities of Electric discharge machining (EDM) process. In powder mixed EDM, there is the addition of fine powder particles in the dielectric fluid. The addition of powder particles in dielectric fluid change some process characteristics and created the condition for achieving optimum machining performance. In this research work, the workpiece material is taken as cemented carbide workpiece. For the purpose of machining, the copper tool is used. Graphite powder is used for the addition in the dielectric. The experiment is performed on the self-develop set-up of powder mixed EDM. The peak current, pulse on time, duty factor and the concentration of powder are considered as process parameters. In this research work, the effect of these process parameters on the performance parameters such as MRR and surface roughness are investigated. From the study it is shown that peak current and the concentration of powder have great effect on the material removal rate (MRR) and surface roughness.**

Keywords*— Powder mixed EDM, Graphite powder, MRR and Surface finish.

I. INTRODUCTION

There has been rapid development of harder materials during last three decades. The machining of such materials such as ceramics, composite material and super alloy is not only difficult but also costly by using conventional methods. The degree of accuracy and surface finish are poor by using conventional methods. To avoid these problems, there have been developing numbers of machining methods are known as modern machining methods or non-conventional machining processes. Material removal does not occurred due to formation of chips and plastic deformation in modern machining process [1].Among all the AMPs, the electrical discharge machining process is going popularities in manufacturing in modern industries. But the efficiency of electric discharge machining is very low when high precession and smooth surface are required. The working principle of powder mixed electric discharge machining (PMEDM) are based on the working principle of electric discharge machining but the mechanism is different from the electric discharge machining (EDM).To avoid the problem of low machining efficiency, there are the latest technique which are known as powder mixed EDM. Powder mixed EDM is the improvement in electric discharge machining. Fine powder particles are mixed in to the dielectric in PMEDM. In powder mixed EDM, a suitable material in powder form is mixed into dielectric fluid of EDM. When a voltage of 80-320v is applied to both of electrode, an electric field in the range of 10^5-10^7 v/m is created. The spark gap is filled with additives particles and gap distance set-up between tool and work piece increased from 25-50 to 50-150μm.The powder particles are get energized and behave in zigzag fashion. The grains come to closer each other under sparking area and gather in cluster. The interlocking between different powder particles due to different shape and size. They arrange themselves in form of chain at different palace under sparking area .due to bridging effect, the gap voltage and insulating strength of dielectric fuel decreases. The easy short circuit take place which causes early explosion in gap. as a result, The series discharge start under electrode area due to increase in frequency discharge. The faster sparking within a discharge takes place which cause faster corrosion from work piece surface. At the same time, added powder get modify the plasma channel .the plasma channel gets enlarged. The electric density decreases hence sparking is uniformly distributed among powder particles. This result in improvement in surface finish [1,2].Ojha.et.al [2011] studies the effect of chromium powder mixed in the dielectric on powder mixed EDM set-up. Material removal rate are increased with increased in concentration of powder and tool wear rate increase with lower range of powder concentration but decrease with increase in powder concentration. Kansal et.al [2005] have carried out the study has been made to optimize the input parameters of powder mixed electric discharge machining (PMEDM). The combinations of high peak current and high concentration of powder produce more material removal rate and small surface roughness. More surface roughness is expected at higher concentration of silicon powder.

II. DESCRIPTION OF EXPERIMENTS

In this research work, the experiments are performed on a self-develop set-up of powder mixed EDM. The set-up of powder mixed EDM is install on the S 50 ZNC EDM made by Sparkonix india Pvt. Ltd. The tank of powder mixed EDM is made transparent Acrylic sheet of 6 mm thick. The tank is made of transparent sheet so we can see the mechanism of machining. It can contains 64 liter oil. A pump (power 18 watts, lifting height-1.3 m) is installed in this tank for the purpose of discharge of powder mixed dielectric in to the discharge gap between the workpiece and the electrode. For the proper mixing of powder particles, a motor of power 80 watts is installed on a tank. Two permanent magnets are kept at the bottom of the tank for separate the debris which are produced due to the machining. The figure 1 shows the set-up of powder mixed EDM.

The distance between powder mixed dielectric suction point and nozzle outlet is kept as short as possible (10 inch) in order to ensure the complete suspension of powder in discharge gap. A holding assembly is provided in the machining tank for holding the workpiece properly.

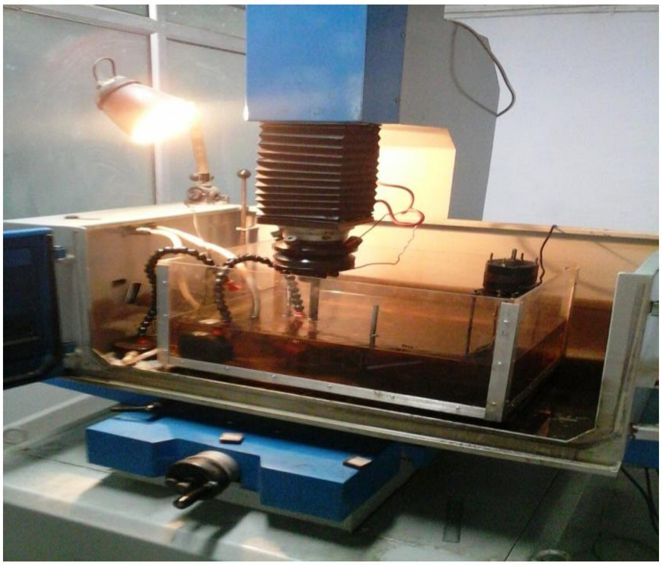

Fig 1: Set-up of powder mixed EDM

When conducting the experiment on powder mixed dielectric, some important points are kept in mind given following.

- The powder particles should not entered in to the main dielectric tank and the filtering tank of electric discharge machine.
- Proper conductive must be maintained between electrode and the work-piece.
- For avoiding the wastage of dielectric, the machining should be performed in to the smaller tank
- To prevent the settling of powder particles, the dielectric should be continuously stirred.

III. MATERIALS AND METHODS

A. Selection of workpiece

EDM machine have the capability of machining of hard material component such as composite, super alloys, heat treated steel, carbides etc. the higher carbon grades are typically used for such applications stamping dies, metal cutting etc. in this experiment we used tungsten carbide of grade H10F. The properties and combinations of material are given below.

TABLE 3.1:PROPERTIES OF WORK-PIECE

Sl. No	Properties	Values
1	Tensile Strength	4300 MPa
2	Compressive Strength	6250 MPa
3	Corrosion Resistance	4
4	Density	14.45 $/cm^3$

The tungsten carbide material is composition of cobalt and tungsten carbide. We can vary the percentage of cobalt according to the requirements. In H10F grade, there are 10% cobalt and 90% tungsten carbide.

B. Selection of tool

In this experiment we use circular copper tool of diameter 12.5 mm. so the cavity produced on the surface of the work-piece are same as the tool. The copper tool is selected because it is good electrical conductor and its cost is low.

TABLE 3.2: PROPERTIES OF TOOL

Sl.NO	Properties	Values
1	Melting Point	1084.6^{o}c
2	Thermal Conductivity	$401WM^{-1}K^{-1}$
3	Young,s modulus	110-128 GPa
4	Bulk modulus	140 GPa
5	Heat of vaporization	$300.4KJMol^{-1}$
6	Poisson ratio	0.34
7	Electrical resitivity	16.78

C. Selection of powder

The selection of powder is important because the different powder have different-different properties. From the study of the literature review, we take graphite powder as a additives. The additives are mixed into the dielectric for increasing the machining efficiency. The size of the particles are also important because the fine powder particles are not so effective for enhance the machining process. We used graphite powder as a additives in the dielectric fluid. The size of the powder particles are 35-45µm.

TABLE 3.3: PROPERTIES OF GRAPHITE POWDER

Sl. No	Properties	Values
1	Density	1.95 g/cm^3
2	Modulus of elasticity	8-15 GPa
3	Thermal conductivity	30 W/M.K
4	Specific heat capacity	710 J/Kg.K

D. *Experimental Design*

The objective of these research work are to study the effect of powder mixed dielectric upon material removal rate, tool wear rate and wear ratio through material transfer from powder mixed in the dielectric by varying various input machining process parameters.

The design variable can be categorized below:

1. Min and max levels of peak current are used.
2. Min and max levels of pulse on time are used.
3. Min and max levels of duty factor are used.
4. One powder is used for mixing in the dielectric with different concentration at different-2 input parameters.

TABLE 3.4: MACHINING PARAMETERS AND THEIR LEVELS

Machining Parameter	Symbol	Unit	Range		
Current	I_p	Ampere	6	9	12
Pulse on time	T_{on}	μs	90	120	150
Duty factor	D.F	%	0.67	0.89	0.95
Concentration of powder	Con	g/l	0	1	2

IV. RESULTS AND DISCUSSION

A. *Response table*

After the experimentation on self -developed set-up of powder mixed ZNC electric discharge machining. The range of all input parameters has been selected and the experimental results are shown in table.

B. *Effect of current on MRR and surface roughness*

The fig 4.1 shows the effect of current on material removal rate for different concentrations of powder which are mixed in to the dielectric. Pulse on time and duty factor are constant at 90 μs and 0.67 respectively. So the effects of current are show in following graph.

The fig 4.1 shows that the material removal rate is increased with the increase in the current value. This is due to that when we increases current, more discharge energy is released and the work-piece is thermally soft and more material removal is take place. It is also observed that when we increases powder concentration in the dielectric, the material removal rate is increased at particular current level.

TABLE 4.1 RESPONSE TABLE

Exp.no	Current (A)	Pule on time(μs)	Duty factor (%)	Con of powder (g/l)	MRR(mm^3/ min)	R_a(μm)
1	6	90	0.67	0	0.121	4.47
2	12	90	0.67	0	0.633	5.45
3	6	150	0.67	0	0.167	6.67
4	12	150	0.67	0	0.802	7.37
5	6	90	0.95	0	0.367	4.787
6	12	90	0.95	0	1.608	5.73
7	6	150	0.95	0	0.242	7.29
8	12	150	0.95	0	0.657	6.67
9	6	90	0.67	1	0.145	5.047
10	12	90	0.67	1	0.744	6.035
11	6	150	0.67	1	0.180	5.51
12	12	150	0.67	1	0.882	6.647
13	6	90	0.95	1	0.487	5.12
14	12	90	0.95	1	1.467	6.282
15	6	150	0.95	1	0.256	6.205
16	12	150	0.95	1	0.830	5.702
17	6	90	0.67	2	0.224	3.695
18	12	90	0.67	2	0.878	4.622
19	6	150	0.67	2	0.245	5.507
20	12	150	0.67	2	0.892	6.072
21	6	90	0.95	2	0.615	4.34
22	12	90	0.95	2	1.190	5.062
23	6	150	0.95	2	0.335	6.307
24	12	150	0.95	2	1.083	6.055

It is due to that on mixing of powder particles, the powder particles are get energized and behave in zigzag fashion. The grains come closer to each other under sparking area and gather in cluster. It forms chain like structure under sparking area .Due to bridging effect, the gap voltage and insulating strength of dielectric fuel decreases. The easy short circuit take place which causes early explosion in gap. The series discharge start under electrode area due to increase in frequency discharge. The faster sparking within a discharge takes place which cause faster corrosion from work piece surface.

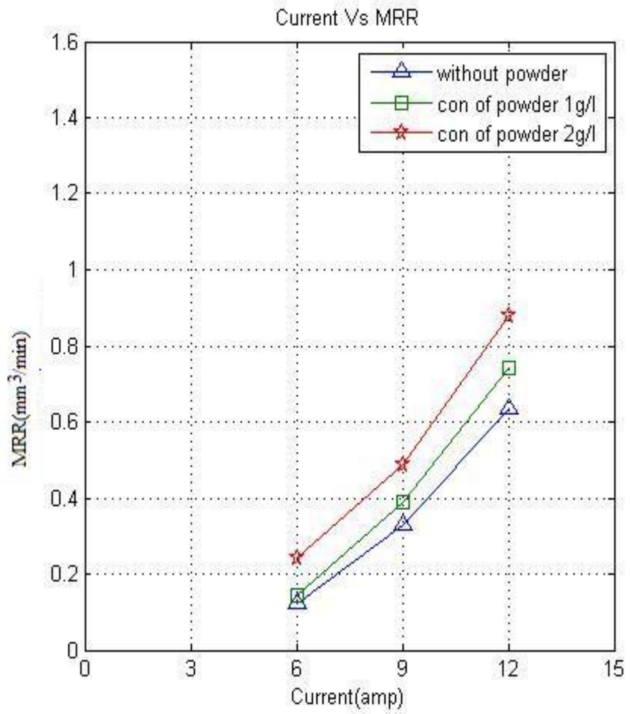

Fig 4.1: Effect of current on MRR for different powder Concentration at pulse on time 90μs and duty factor 0.67

The fig 4.2 shows the effect of current on surface roughness for different powder concentration. Duty factor and pulse on time are kept constant at 0.67 and 90 μs respectively. The graph shows that the surface roughness is increased with increasing current value. This is due to the fact that on increase in the spark energy, which leads to large impulsive forces which are removing more molten material and creating deeper and larger craters, increases the surface roughness. The surface roughness is decreases with increases powder concentration. This is due to the fact that the sparking becomes uniformly distributed among the powder particles so as a result even and uniform shallow craters are produced resulting better surface finish of machined surface.

C. Effect of pulse on time on MRR and surface roughness

The fig 4.3 shows the effect of pulse on time on the material removal rate for different concentrations of powder which are mixed in to the dielectric. Current and duty factor are constant at 6 amp and 0.67 respectively. So the effects of pulse on time are show in graph 4.3,

The graph shows that MRR are increases with the increases on pulse on time. This is due to that enough time is available for conduction of heat in to interior of the work-piece, so as a result larger volume of the work-piece is softening. Since MRR is related with the depth of penetration. So it increases with increases pulse on time.

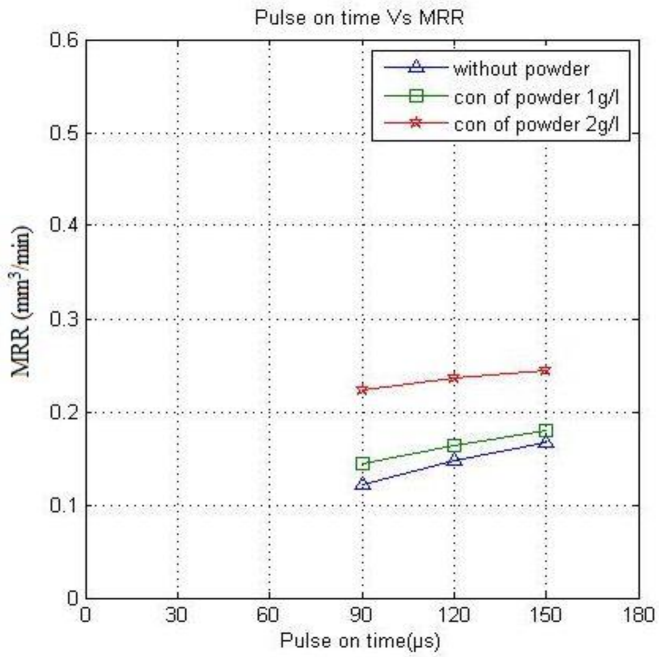

Fig 4.2: Effect of current on Ra for different powder powder con at pulse on time 90 μs and duty factor 0.67

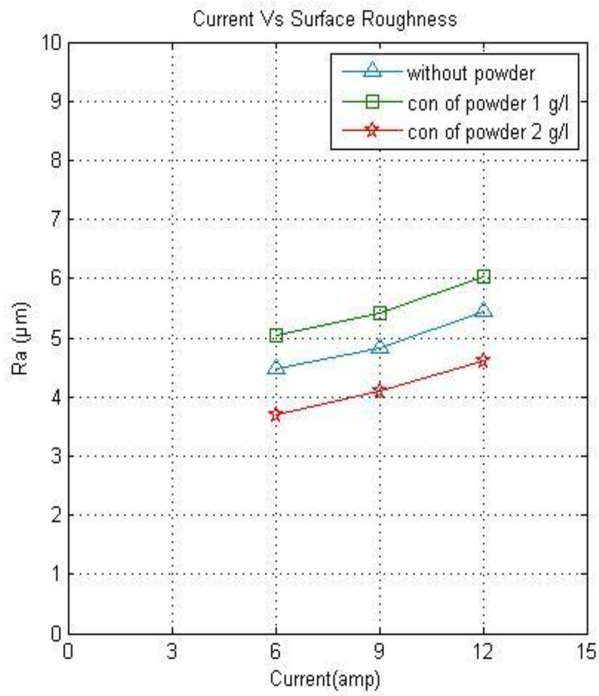

Fig 4.3: Effect of pulse on time on MRR for diff powder Con during machining at 6 amp current and 0.67 duty factor

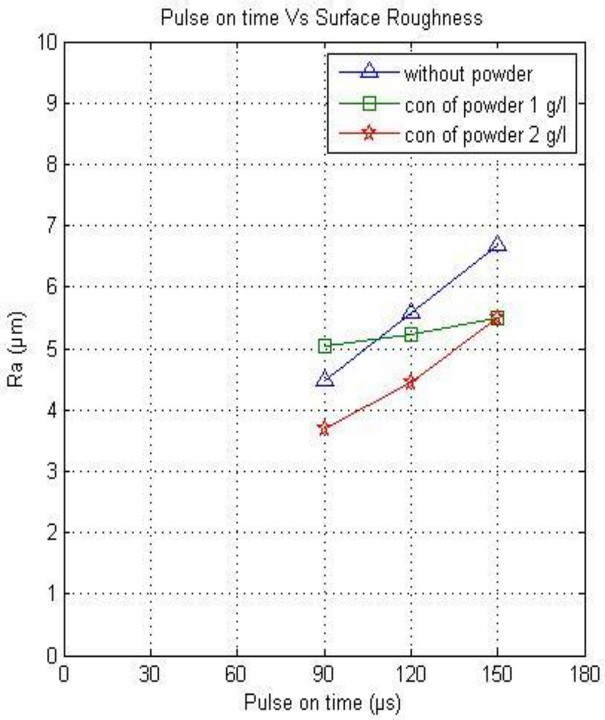

Fig 4.4: effect of pulse on time for diff powder con at 6 amp current and 0.67 duty factor

The fig. 4.4 shows the effect of pulse on time on surface roughness for different powder concentration. Duty factor and current are kept constant at 0.67 and 12 ampere respectively. The graph shows that the surface roughness is increases with increases pulse on time.This is due to the fact that at constant current setting an increase in pulse on-time results in a proportional increase in spark energyand consequently the melting boundary becomes deeper and wider, and hence increases the roughness value. It is also observed that with the increase in powder concentration the surface roughness are improved. This is due to the fact that the sparking becomes uniformly distributed among the powder particles so as a result even and uniform shallow craters are produced resulting better surface finish of machined surface.

D. Effect of duty factor on MRR and surface roughness

The fig. 4.5 shows the effect of duty factor on MRR for different powder concentration. Current and pulse on time are kept constant at 6 amp and 90 µs respectively.

The graph shows that the MRR increases with increases duty factor. This is due to the fact that when we increased duty factor there are more time and energy available for conduction of heat. So there are more material are removed from the surface of the work-piece.It is also observed that the material removed is also increased on increasing powder concentration. This is due to the fact that powder particles forms chain like structure and insulating strength of dielectric fluid are reduced.The easy short circuit take place which causes early explosion in gap. So the MRR is increases on increases of powder concentration.

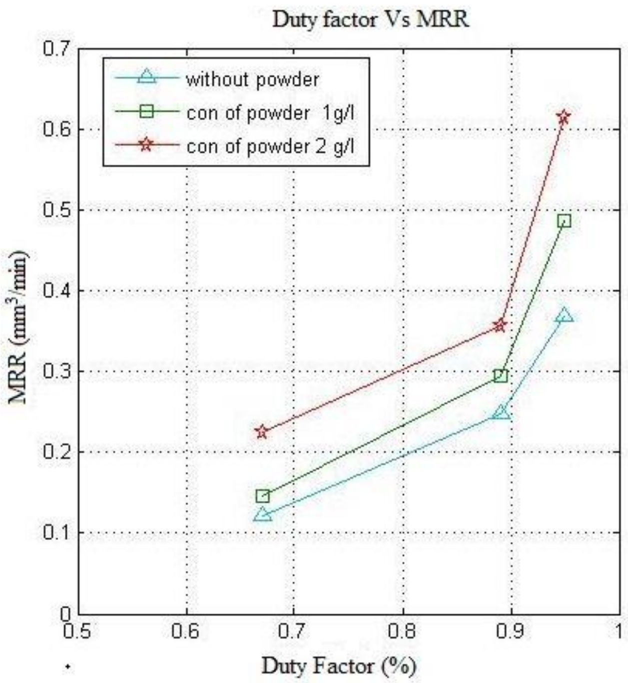

Fig 4.5: Effect of duty factor on MRR for diff powder Concentration at current 6 amp and pulse on time 90 µs

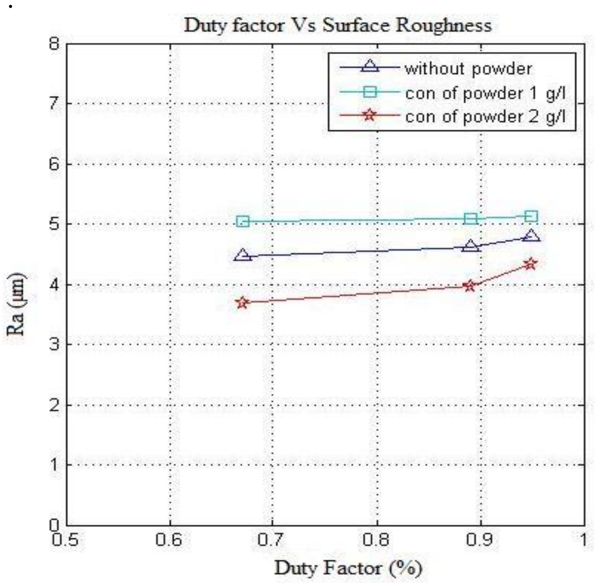

Fig 4.6: Effect of duty factor for diff powder con At current 6 amp and pulse on time 90 µs

The fig. 4.6 shows the effect of duty factor on surface roughness for different powder concentration. Pulse on time and current are kept constant at 90µs and 6 ampere respectively. The graph shows that the surface roughness is increases with increases duty factor. This is due to the fact that when we increases duty factor there are more time and energy available for conduction of heat. So there are more material are removed from the surface of the work-piece.

Due to more energy and time is available at the surface of the work-piece; there is the creation of high and deeper cavities. So the surface roughness is increased at the surface of the work-piece. It is also observed that the surface roughness is increases at the concentration of powder 1g/l but for the powder concentration of 2 g/l, the surface roughness value are improved. This is due to the fact that much loss of discharge energy in the discharge gap and reduction of ejecting force on the melted material. So the surface roughness is smaller in powder mixed electrical discharge machining.

V. CONCLUSIONS

From the study, it has been concluded that powder mixed electric discharge machining have significant effect on the material removal rate and surface properties like the surface finish. From the mixing of the powder in the dielectric the material removal rate is increased at a great extent and the surface finish are improved. Graphite powder gives better result in terms of material removal rate as well as surface finish. The experiments were conducted under various parameters setting of Current (Ip), Pulse On-Time (Ton), duty factor (%) and concentration of powder (g/l) are selected as process parameters. After the experiments, the performance parameters are measures in terms of material removal rate (MRR) and surface roughness (SR). all the performance parameters are compared at the same parameters for without powder and with the concentration of the powder using the graph draw on MATLAB. The following conclusions are given below:

1. The MRR is increases with an increase of peak current for both without powder and with the concentration of powder. The MRR are also increases with increases in the powder concentration.

2. The surface finish are increased with increased in peak current for both without powder and powder concentration but the surface roughness are improved with increased in powder concentration.

3. The MRR are increases with increases pulse on time for both without powder and powder concentration. The material removal rate is also increased with increased in powder concentration.

4. The surface roughness is increased with increased in value of pulse on time for both without powder and with powder concentration. But it is improved with increased in powder concentration.
5.
6. The material removal rate is increased with increased in duty factor for both without powder and with concentration of powder. The material removal rate is also increased with increased in powder concentration.
7. The surface roughness is increased with increased in value of duty factor for both without powder and with concentration of powder. But the surface finish is improved with increased in powder concentration.

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