TECHNOLOGICAL ANALYSIS OF FLAT SURFACE CONDITIONS BY MAGNETIC ABRASIVE FINISHING METHOD (MAF)

Dr. Ali H. Kadhum – Baghdad University – Al-Khawarizmi College of Engineering, Manufacturing Operations Department- Al-Jadriia, Baghdad (kadhumali59@yahoo.com).

Yahya M. Hamad - Baghdad University – Al-Khawarizmi College of Engineering, Manufacturing Operations Department- Al-Jadriia, Baghdad (yahya_m_hamad@yahoo.com.au)

Nazar K. Mohammad - Baghdad University – Al-Khawarizmi College of Engineering, Manufacturing Operations Department- Al-Jadriia, Baghdad

ABSTRACT

This study introduced the effect of using magnetic abrasive finishing method (MAF) for finishing flat surfaces. The results of experiment allow considering the MAF method as a perspective for finishing flat surfaces, forming optimum physical mechanical properties of surfaces layer, removing the defective layers and decreasing the height of micro irregularities. Study the characteristics which permit judgment parameters of surface quality after MAF method then comparative with grinding.

الخلاصة :

تم دراسة تأثير استخدام طريقة التشطيب بالنحت المغناطيسي (MAF) على السطوح المستوية حيث استخدمت ثلاثة متغيرات أساسية هي الحث المغناطيسي وسرعة القطع والخلوص وذلك لكون هذه العوامل لها تأثير كبير على تكوين شكل الفرشة المغناطيسية وتكوين الضغط على سطح المعدن المشغل. تم إجراء تجارب عملية بواسطة آلة مختبرية تعمل بمبدأ الحث المغناطيسي وباستخدام الطرق الإحصائية تم الوقوف على الحالة المثالية لقيم المتغيرات الثلاثة وتأثيراتها على حالة السطح ومقارنة النتائج مع طريقة التجليخ التقليدية واثبات أفضلية هذه الطريقة بالمقارنة مع طريقة التجليخ.

Keywords: Magnetic abrasive finishing (MAF), characteristic of roughness, flat surface, coefficients of parabola, ferromagnetic abrasive powder, magnetic induction, running clearance, cutting speed, support curve.

INTRODUCTION

At the present time, the magnetic –abrasive finishing method (MAF) is used in cleaning, grinding and polishing of flat surfaces in manufacturing engineering. The diagram of magnetic abrasive finishing of flat surface is represented in **(Fig. 1)**. The MAF method based on the principle that the work piece can be machined by the effect of ferromagnetic abrasive powder, this powder is densities by energy of external magnetic field; energy is supplied to running clearance between working surfaces and electromagnetic poles. Working motion is imported to the powder; the powder is pressed by magnetic field forces against working surfaces to finish it. The most important feature of this method is that the abrasive instrument has no bond; its function is performed by a magnetic flux in a working zone. These lead to arrange the cutting forces and also controlling the degree of elasticity by change of field strength [1-8] , via varying magnitude of the magnetic field in the machining zone, running clearance and the speed of rotation poles (cutting speed) .

The MAF method gives combined effects on work piece which influence to surface layers of parts is conditioned by abrasive cutting, plastic deformation, electromagnetic adhesive effect and chemical processes [5, 8, 11, 12].

The criteria of effective use the quality of surface of the parts after MAF and grinding methods defined by the parameters of roughness determined by formula (1):

R_a : arithmetic mean of profile declination.
R_z : height of profile roughness over 10 points.
R_{max} : the biggest height of profile unevenness.
S_m : the average pitch of profile unevenness.
r_1 : radius of top of micro roughness.
r_2 : radius of bottom of micro roughness.
t_p : relative support length of profile.

$$\left.\begin{aligned} R_a &= \frac{1}{n}\sum_{i=1}^{n}|y_i| ,\\ R_z &= \frac{1}{5}\left[\sum_{i=1}^{5}|y_{pmi}| + \sum_{i=1}^{5}|y_{vmi}|\right]\\ S_m &= \frac{1}{n}\sum_{i=1}^{n} S_{mi} ,\quad t_p = \frac{1}{L}\sum_{i=1}^{n} li\\ R_{max} &= \frac{y_{max} - y_{min}}{B_y} ,\ B_y = \frac{20000}{R_a} \end{aligned}\right\} \quad (1)$$

The effectiveness of using MAF method can be determine by the effects to surface layer of parts and depend upon many technological parameters. Three technological parameters have been choose, which are magnetic induction or current force, running clearance and cutting speed (rotation of poles). They have combined effects on forming surfaces and the amount of pressure acting on work piece. Also they form the shape and nature of the brush of the ferromagnetic abrasive powder. According to experiments data obtained from references [1- 4, 7, 8, 11] the range of these parameters can be taken as following :

B = 0.2 ……… 0.8 TL (magnetic induction)
C = 1.0 ……..... 4.0 mm (running clearance)
V = 100 ……... 250 mm/min (cutting speed)

The ability of guiding these parameters to get the optimum values will help for finding the parameters of roughness (R_a, R_z, R_{max}, S_m,, r_1, r_2, t_p),, which influence for wear resistance under conditions of bounding and fluid friction, corrosion resistance, vibration resistance, heat reflection, contact rigidity and strength of surface connections. The most complex characteristic of roughness is the support curve, the analytical expression will be determined [6, 7, 8].

The most complex characteristic of roughness is support curve **Fig. 2**. the analytical expression of which is determined by formula (2)

$$Y = B_0 + B_1 Z_1 + B_2 Z_2^2 + B_3 Z_3^3 \qquad (2)$$

The mode construction of a support curve and the curve itself is represented in .Fig (2). On abscissa are laid off ration of sum of portions profile to studied length L; corresponded to distance y_i, measured from over hang height H laid off as ordinate (**See Fig.(5)**). In this case the height of profile levels is measured in absolute units.

The support curve is approximated by parabola:

$$\left.\begin{aligned} Y &= B_0 + B_1 f(z) + B_2 f(z) + B_3 f(z)\\ Z &= \frac{1}{L}\sum_{i=1}^{n} l_i \quad ,\quad Y = y_i \end{aligned}\right\} \qquad (3)$$

Coefficient of parabola B_o, B_1, $B2$, B_3, are determined by formula (4-7) :

B_o= [0.208y_o+0.196(y_1+y_2) +0.161(y_3+y_4) +0.103(y_5+y_6) +0.021(y_7+y_8)- -0.084(y_9+y_{10})] *(4)*

B_1= [0.065 (y_1-y_2) +0.111(y_3-y_4) +0.114(y_5-y_6)+0.006(y_7-y_8)-0.074(y_9-y_{10}) *(5)*

B_2= - [0.012yo+ 0.01(y_1+y_2) +0.007(y_3+y_4) +0.001 (y_5+y_6) – 0.007(y_7+y_8) - 0.017(y_9+y_{10})] *(6)*

B_3= - [0.003(y_1-y_2) + 0.004(y_3-y_4) +0.004(y_5-y_6)+0.001(y_7-y_8)-0.006(y_9-y_{10})] *(7)*

Then *Z* exchange within limit ±5 and t_p in limit ± 0.5

After correction, we get:

B_1= B_1 *10, B_2=B_2*$10^{2,}$ B_3=B_3* 10^3

$$Z = \frac{1}{L}\sum_{i=1}^{n} l_i - 0.5 \ ,\ Z = t_p - 0.5 \qquad (8)$$

EXPERIMENTAL METHOD AND MATERIALS

An experiment was conducted using MAF laboratory machine, it contains rotating magnetic poles, inside these poles there is an iron core made from ferromagnetic material. A running clearance (C) is filled with ferromagnetic powder. Magnetic poles rotate with powder over the work piece (which is fixed on the base (Fig.1)) by using variable speed electric motor and the axis of rotation is perpendicular to the work piece axis. Magnetic coils generate magnetic field and electric current which in turn gives the magnetic inductance (B). Variable values of electric current can be obtained by using current regulator. Running clearance value can be controlled by the work piece fixing base and its feed speed obtained from other electric motor with gear box.

The experiment executed according to the following steps:

1- Surface roughness test executed three times for each samples by using profile meter-profilograph.. Then the mean value of ΔR_a and other parameters obtained.
2- The experiment conducted according to the matrix factor plan (table 1).
3- Repeat the steps 1, 2 for each sample.

The Following Data Used in The Experiments:

Test specimen shown in **Fig. 3** is a flat surface of dimensions : t × W × Le= 3,0 × 150 × 250 mm. Material of the specimen :Aluminum Alloys Number 2024, Hardness120 HB ; working conditions (constant) The magnetic abrasive powder-mass composition: Al= 0,2% to 16% ; c < 4% ; P= 1,5%; Si= 0,2% to 8% ; The rest is - Fe. Graininess of powder from 100 to 120 *µm*. working time= 30 sec; table feed= 340 mm/min; the volume of powder portion V_p= 20 cm^3

Ideal stress concentrators have been used for finishing the Aluminum alloy [11]. To test the effect of the three technological parameters on the effectiveness of the working operation and to specify the effectiveness relationships of the operation, experiments must be executed. Because the finished surfaces have more than one parameter at same time, a plan factors must be use to obtain the multifunction relationship which explain the combination between the main three technological parameters. To execute less number of experiments, statistical practical values used as listed in **Table 1**.

RESULTS AND DESCUSSION

Table 2 shows the values of final results, for the parameters of surface quality after MAF method. An example for obtaining the curve and the calculation of coefficients of the parabola is shown in **Fig. 4**

1- divide axis Z into ten steps 0, 1, 2, 3, 4, 5, -1, -2, -3, -4, -5 , then we can obtain ten values for *y* (obtained from Fig.(5)) as listed in **Table 3**
2- From these values , draw **Fig. 3** for the absolute value of $y=R_a$
3- Calculate the values of adding and subtracting.

$y_1+ y_2 = 0.288$ $y_1- y_2 = -0.038$

$y_3+ y_4 = 0.34$ $y_3- y_4 = -0.07$

$y_5+ y_6 = 0.34$ $y_5- y_6 = -0.1$

$y_7+ y_8 = 0.31$ $y_7- y_8 = -0.17$

$y_9+ y_{10} = 0.33$ $y_9- y_{10} = -0.21$

4- Calculate the coefficients of equation of support curves after MAF method B_o, B_1, B_2, B_3

$B_o= [0.0291+0.0564+0.0547+0.0350+0.0065 -0.0277] = 0.1541$

$B_1= [-0.00247-0.0077-0.0114-0.00102+0.01554] = -0.00712$

$B_2= - [0.00168+0.00288+0.00238+0.00034+0.00217-0.00561] = -0.00384$

$B_3= - [-0.000114-0.00028-0.0004-0.00017+0.00126] = - 0.000296$

5- Calculate the correction :

$B_1= - 0.00712\times10 = -0.0712$

$B_2= - 0.00384\times10^2 = - 0.384$

$B_3= -0.000296\times10^3= -0.296$

6- Then we get the following equation :

$y= 0.1541 - 0.0712Z - 0.384 Z^2 – 0.296 Z^3$

7- Divided by 0.4(the height of profile) to get :

$y= 0.385 – 0.178 Z - 0.96 Z^2- 0.74 Z^3$

The analysis of profile roughness by studying various model, showed that the maximum value for the relative support length of profile in the level 50% t_{p50}=68% (See **Fig. 4**). At the optimum technological parameters, from the best results of the support curve for model 10 (See **Table.2**), then:

*B= 0.96 TL , C=2.5 mm, V=175 mm/min. (*the optimum technological parameters)

At the best values, as following:

R_a=8 μm, R_z=0.14μm, R_{max}=0.2μm, S_m=15.5μm,

r_1=121μm, r_2=79.5μm, t_{p50}= 68%

By comparing these results with those obtained by grinding method from reference [6] as shown below:

R_a=0.32 μm, R_z= 1.2 μm, R_{max}= 1.7 μm, S_m=30.1 μm

r_1=36.6 μm, r_2=70.4 μm, t_{p50}= 53%

Topography of micro relief formed by MAF is more smoothing tops and bottoms of micro unevenness in comparison with grinding.

To assess the efficiency of the magnetic abrasive finishing method on flat surfaces and their edges, it has been a 15 technological system, by examining three parameters, affecting on the MAF method, by statistical method as **Table 1**.

To stand on the quality on surface and their edges from aluminum alloys was obtained practical results as **Table 2**, of the surface characteristics of previous of 15 technological systems, from profile of the surface **(Fig. 5)**.

It can obtained an equal elevation of surface roughness in deferent ways and from deferent technological conditions, so that it have been developed by backing the equation of support curve, showing the characteristics of surface roughness, so that can comparison with other technological process .

Study shows that the MAF method can access to the largest amount of micro profile proportion to the length of any profile, that mean, *tp50= 68%*. The grinding method give the value t_{p50}= 53% (9, 10) Magnetic induction affected on the supported curve value at B = 1TL get the best result.

CONCLUSIONS

1. The implementation of theoretical and practical test and established clear technological process for the operation of flat surfaces and their edges from aluminum alloys by MAF method.

2- An optimum technological system is achieved which would work to improve the roughness surface compared with grinding method. Thus obtaining practical advice to choose the most rational and technological uses of the area.

3- This method gives machining efficiency which is 1.5 to 2.5 times as great as that when using conventional grinding

4- The micro-irregularities can be reduced to 0.08mm

5- MAF method permits to increase the surface quality of machined parts

6- This method can be use to clean and polish the surface to create a situation before welding operations, without affecting the environment compared with the hazardous chemical method.

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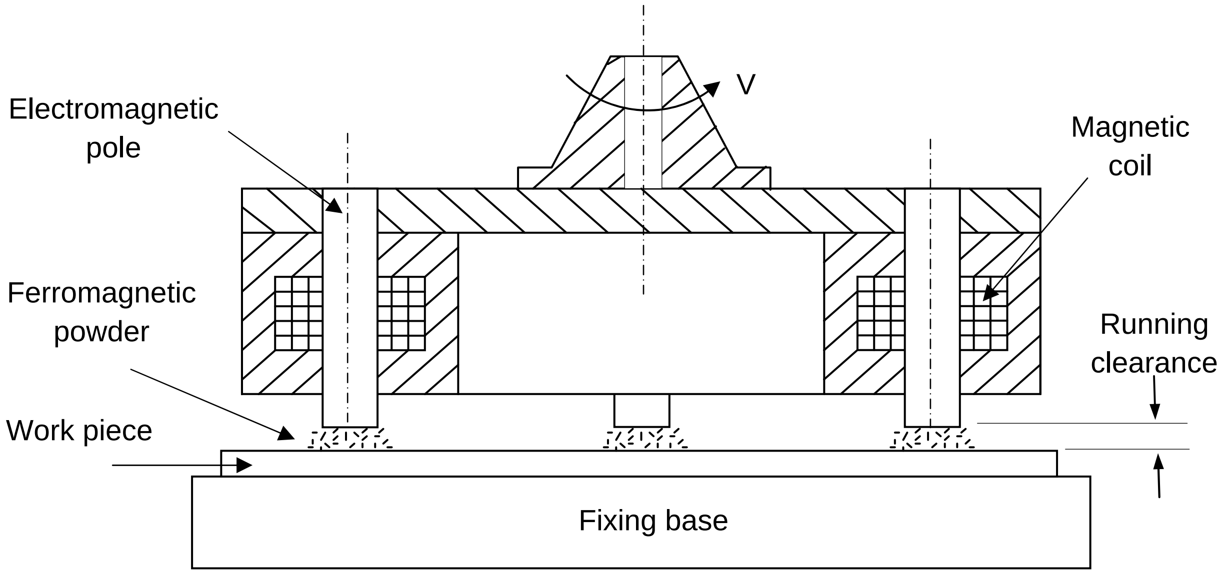

Figure. (1) Machine

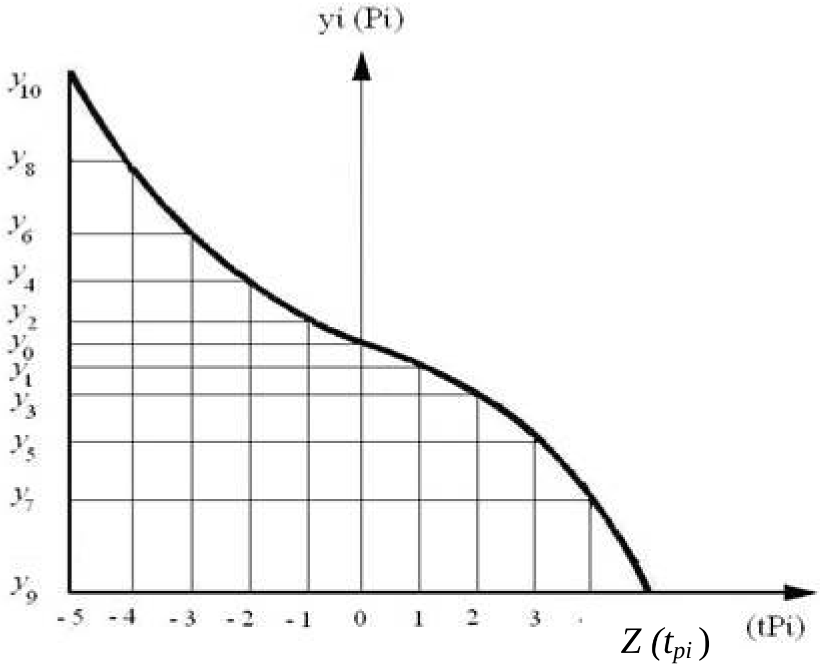

Figure. (2) Support Curve

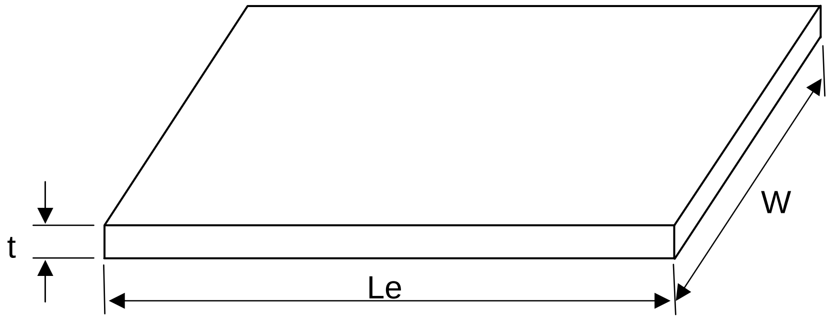

Figure. (3)

Table (1): Factor Plan Matrix

N=2^3+2.3+1

No. of experiments	Factor level					
	F.L.	(B) TL	F.L.	(C) mm	F.L.	V) mm/min
1	-1	(0.2)	-1	(1)	-1	(100)
2	+1	(0.8)	-1	(1)	-1	(100)
3	-1	(0.2)	+1	(4)	-1	(100)
4	+1	(0.8)	+1	(4)	-1	(100)
5	-1	(0.2)	-1	(1)	+1	(250)
6	+1	(0.8)	-1	(1)	+1	(250)
7	-1	(0.2)	+1	(4)	+1	(250)
8	+1	(0.8)	+1	(4)	+1	(250)
9	-1.2	(-0.96)	0	(2.5)	0	(175)
10	+1.2	(+0.96)	0	(2.5)	0	(175)
11	0	(0.5)	-1.215	(-4.86)	0	(175)
12	0	(0.5)	+1.215	(+4.86)	0	(175)
13	0	(0.5)	0	(2.5)	-1.215	(300)
14	0	(0.5)	0	(2.5)	+1.215	(300)
15	0	(0.5)	0	(2.5)	0	(175)

Note: -1 _ minimum value, +1 _ maximum value, 0 _mid value
Then we can get the relation:

$F = f\left(B, C, V\right)$, *F-The criteria* ($R_a$, R_z, R_{max}, S_m, r_1, r_2, t_p)

Table (2): Experimental Results

No. of experiments	R_a µm	R_z µm	R_{max} µm	S_m µm	r_1 µm	r_2 µm	t_p %
1	0.34	1.12	1.6	30.2	32.2	63.7	55
2	0.27	0.91	1.4	20.3	48.1	85.7	54
3	0.19	0.22	0.29	17.0	123.4	59.2	60
4	0.105	0.21	0.28	11.85	55.5	130.1	62
5	0.09	0.19	0.18	10.6	171.2	129	65
6	0.24	1.12	0.85	22.6	70.5	78.4	57
7	0.30	0.95	1.30	27.3	50.1	61.2	54
8	0.21	0.82	1.55	18.4	86	70.1	60
9	0.09	0.19	0.23	17.7	98.4	88.2	67
10	0.08	0.14	0.2	15.5	121	79.5	68
11	0.11	0.2	0.25	16.8	87	90.2	66
12	0.07	0.16	0.19	16.6	99.1	87	67
13	0.19	0.22	0.24	17.5	123	145	65
14	0. 28	0.16	0.208	25.3	263.7	205	61
15	0.17	0.20	0.26	16.63	124.0	59.0	60

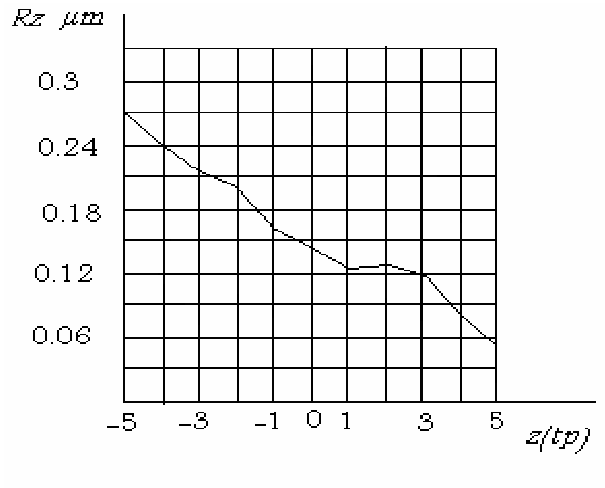

Figure.(4) Graph of Support Curve by MAF

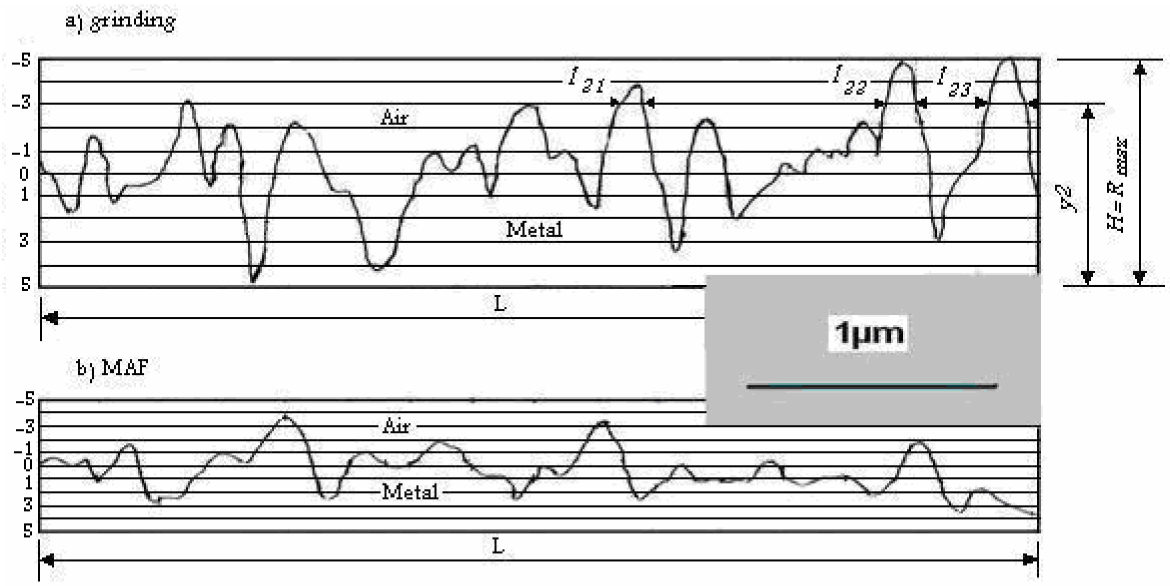

Figure.(5) Surface Profilogram Formed by MAF and Grinding.

Table (3)

	y_0	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}
y (µm)	0.14	0.125	0.163	0.135	0.205	0.12	0.22	0.07	0.24	0.06	0.27
Z	0	+1	-1	+2	-2	+3	-3	+4	-4	+5	-5