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Effect of ultrasound power and frequency on the diameter of nickel microparticles produced by an ultrasound-aided electric discharge

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Abstract: The diameter of metal particles with nanometer or micrometer size are used in many different fields, such as pharmaceutical manufacturing, medicine, catalyst in the chemical industry, environmental industry, photovoltaic materials and invisible materials absorbing radar waves in the military. The manufacture of metal particles with nanometer or micrometer size are done research by many scientists and caried out by many different methods. The paper presents the models of producing the metal microparticles in combination electric discharge with ultrasound to carry out some of experimental investigation about the effect of electric discharge manufacturing (EDM) combined with ultrasound on diameter of nickel microparticles. Findings of paper show that while the ultrasound power is 400W and the ultrasound frequency is 28 kHz and 68 kHz, the diameter of nickel microparticles is less than 5µm even appearing nickel microparticles with nanometer size and hollow nickel microparticles. However, the diameter of nickel microparticles is more than 60µm while the ultrasound frequency is 120 kHz. Thus, the more the diameter of nickel microparticles is, the more the ultrasound frequency is at the same ultrasound power. Results of this study are potentials to design and fabricate the system of ultrasound-aided electric discharge in order to produce the microparticles applied to the paint manufacturing industry, cleaning the cylinder wall or machine parts and manufacturing emulsion fuel.

Keywords: *Ultrasound-aided electric discharge; EDM; ultrasound pamaters; micropartilcles.*

Introduction:

The process of fabrication and manufacturing the machinery products in general, we are mostly interested in the products but usually skipping the swarf machining, thus it is causing to waste the material and effect on the environment. There are many researchers [1],[2],[3] pointed out, while manufacturing by electric discharge combined with traditional ultrasound (forced main shaft), the ultrasound waves are generated separately, swarf machining is solid or hollow circle with the size of in diameter from dozens of nanometers to hundreds of micrometers. The properties of particles are lightweight, capable of absorbing electromagnetic waves, heating absorption, optical ... These particles are used in many different fields, such as pharmaceutical manufacturing, medicine, catalyst in the chemical industry, environmental industry, photovoltaic materials and invisible materials absorbing radar waves in the military [4]. Ultrasound waves are generated by many factors including friction, the vibration by high or slow speed, be impacted, electric discharge and the collisions between the matter particles of the gaseous or the liquid. The frequency of ultrasound waves using for manufacturing the machinery products is bigger than 40.000 Hz. The system of manufacturing by electric discharge aided ultrasound with ultrasound waves created separately is considered as a new method of processing, so the research only stops at analyzing the mechanisms of forming the hollow particles [5]. Further, it has not brought about the influence of technological parameters on particle size.

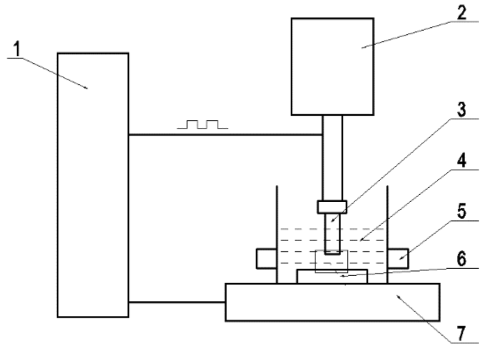
In this study, we focus on the effect of the ultrasound parameters on the diameter of nickel particles when processed by the system of ultrasound aided electric discharge with ultrasound waves are generated separately. From that results, the relationship between the distribution of the nickel particle size and the frequency and the power ultrasound is established.

Materials and Methods:

Digital controller machine - E46PM containing machining box made of stainless steel with 260mm x 190mm x 170mm in size is used to perform the experiments. The ultrasound systems of 40 kHz is mounted on the machining box, the machining tool with 10mm x 10mm in square and electrode are both of 99.99% nickel. Due to magnetic properties of nickel, magnetic magnets is use to absorb the nickel particles after processing. The nickel particles are cleaning by alcohol and checked under the SEM microscope.

Experimental set-up:

The experimental model includes a system of ultrasound is placed on the table of machining by electric discharge and is shown in Fig 1.



1-Power source; 2-Main axis control system; 3-Electrode; 4- Machining liquid; 5-Ultrasound system; 6-Machine parts; 7- Machining table

Figure 1: The principle diagram of the machining process of ultrasound-aided electric discharge

Fig 1 shows the operation principle of the machining process of ultrasound-aided electric discharge, where the Electrode (3) and Machine parts (6) is connected to the Power source (1) through the Main axis control system (2). The Electrode (3) move downward and approach to Machine parts (6) till the gap between the Electrode and the Machine parts is small enough, the discharge phenomena occur through the Machining liquid (4).

The gap distance between Electrodes should be held constant for EDM processes focused on particle production. Variations in the gap distance change the rate at which the dielectric strength of the gap is recovered. If the gap is not held constant for successive discharges, the frequency of discharges can become erratic or the system may even short circuit. Thus, as material is removed from the Machine parts, it is necessary to feed the Electrode closer to the Machine parts. Manually, this would be problematic because the gap distance is often maintained at a value less than 100 microns. Instead, servo feed control systems are utilized which automatically control the tool electrode feed rate based on a measured resistivity across the gap. When the measured average gap voltage is higher than the servo reference voltage, the feed rate increases. Conversely, if the average gap is lower than the servo reference voltage, the electrode is retracted or the feed rate is decreased. By maintaining a constant working gap, servo feed control systems provide stable conditions, prevent short circuits, and increase the efficiency of the machining process. The discharge zone will create a very high temperature between the Electrode and Machine parts, thus it will appear the melting phenomenon and evaporation zone, and an air bubble zone. The evaporated metal with liquefied metal will overcome the vacuum to invade the liquid in order to form the metal particles.

The thermophysical properties of the Electrode material are responsible for the temperature profile across the electrodes and ultimately for the material removal conditions. Saito et al. found that although the melting point of copper is much lower than that of steel (1355 K vs.1800 K), the melted zone of copper is considerably smaller than that of steel due to its higher thermal diffusivity ($1.1x10^{-4}$ m^2/s vs. $2.0x10^{-5}$ m^2/s). In the case of copper, the melted zone may even resolidify during the discharge duration. Because the surface temperature drops rapidly in copper, the time needed for the plasma to be extinguished is short. This leads to stable machining and explains why copper is a popular choice for the Electrode in EDM. Besides, this process will heat up Machining liquid (4) till the decomposition to form the air bubbles and cooling substances. The evaporated metal with liquefied metal will create the corrosion of Machine parts (6). This corrosion process occurs very quickly, each pulse discharge takes place only a few dozen of µs to several hundred of µs.

Simultaneously with above process, the activity of the Ultrasound system (5) generated a large number of air bubbles accelerating the processes of releasing the liquefied metal out of the machining area. Air bubbles are also key factors to create the hollow material particles.

Results and Discussion:

Influence of ultrasound power

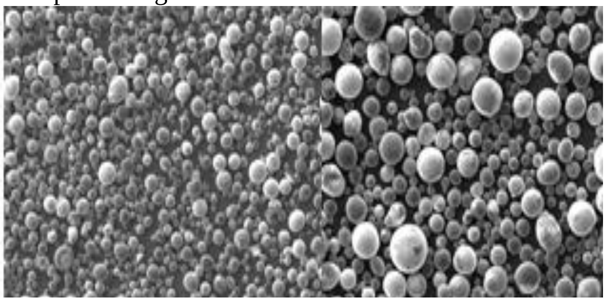
In the course of processing, specialized discharge processing oil is used as the machining liquid. The ultrasonic power (P) is changed corresponding 0W, 150W, 400W, 600W. However, the unchanged electric parameters such as 15A of amperage (I), 45V of electrical discharge voltage (U), 300 µs of the stretching value of the discharge pulse ($t_{i)}$, 28 kHz of ultrasound waves frequency (f) and 60 minutes of machining time (t).

Experimental parameters of the machining process of ultrasound-aided electric discharge while ultrasonic power (P) is changed is given in Table 1.

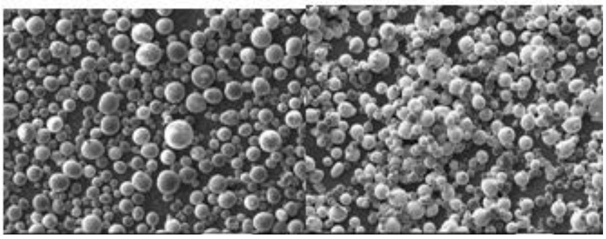
Table 1. Experimental parameters of the machining process of ultrasound-aided electric discharge

Experiment	P (W)	I (A)	U (U)	t_i (µs)	f (KHz)	t (min)
1	0	15	45	300	28	60
2	150	15	45	300	28	60
3	400	15	45	300	28	60
4	600	15	45	300	28	60

Fig 2 shows the size of the nickel particles obtained after processing



Experiment 1 Experiment 2



Experiment 3 Experiment 4

Figure 2. The size of the nickel particles under SEM microscope

The diameter of nickel particles (d_{Ni}) are numbered by Smile View & Origin software. The results of 4 experiments (Exp) are shown in Table 2 and Fig 3.

Table 2. Percentage of dispersion of nickel particle diameter with the change of ultrasound power

d_{Ni} (µm)	Exp 1	Exp 2	Exp 3	Exp 4
0-10	5.77	11.67	21.81	31.02
10-20	27.72	30.81	31.86	37.84
20-30	21.43	26.39	23.81	18.2
30-40	21.36	16.18	14.75	9.34
40-50	11.45	7.1	5.6	2.63
50-60	8.27	4.78	1.7	0.84
60-70	3	2.57	0.47	0.12
70-80	1	0.5	0	0

Table 2 and Fig 3 show that, the dispersion of nickel particle diameter is the most in about 10µ-20µm with the change of ultrasound power, 0 W, 150 W, 400W and 600 W. The bigger ultrasound power is, the larger the dispersion of nickel particle diameter is while the nickel particle diameter is smaller than 20µm, and otherwise the bigger ultrasound power is, the smaller the dispersion of nickel particle diameter is while the nickel particle diameter is larger than 20µm.

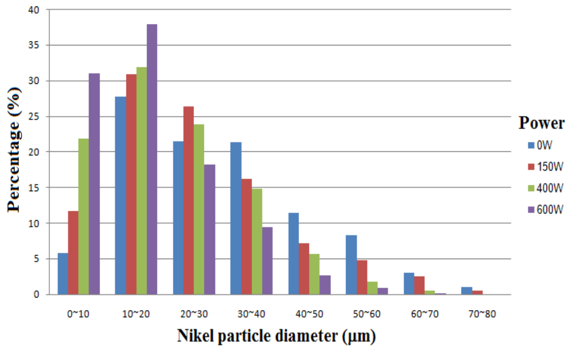


Figure 3. Dispersion percentage of nickel particle diameter with the change of ultrasound power

This matter happens is due to the appearance of ultrasound wave. The bubbles will be appeared inside the Machining liquid (so call: effect "Emptied"). The effects "Emptied" will increase the ability to break the metal particles and also limit the accumulation of evaporated metal atoms during freezing, thus it creates the particle metal with small diameter. Hence, the more increasing the ultrasound power is, the more increasing the intensity ultrasound is, the more intense the effect "Emptied" is and leading to the smaller diameter nickel particles are.

Influence of ultrasound frequency

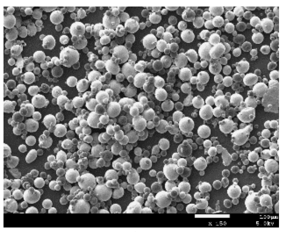
The method of carrying out the experiment to determine the influence of ultrasound frequency to nickel particle diameter is similar to the influence of ultrasound power. However, the frequency of ultrasound wave is changed corresponding 28 KHz, 68 KHz, 120 KHz in this case whereas ultrasound power (P) is unchanged with the value of 400 W.

Experimental parameters of the machining process of ultrasound-aided electric discharge while ultrasonic frequency (f) is changed is given in Table 3.

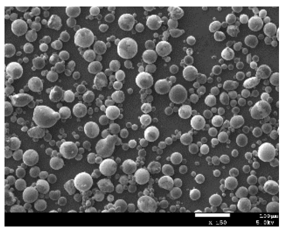
Table 3. Experimental parameters of the machining process of ultrasound-aided electric discharge

Experiment	f (KHz)	I (A)	U (U)	t_i (µs)	P (W)	t (min)
5	28	15	45	300	400	60
6	68	15	45	300	400	60
7	120	15	45	300	400	60

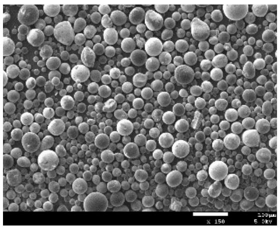
Fig 4 shows the size of the nickel particles obtained after processing in the case of changed frequency and unchanged power.



Experiment 5



Experiment 6



Experiment 7

Figure 4. The size of the nickel particles under SEM microscope

The diameter of nickel particles (d_{Ni}) are numbered by Smile View & Origin software. The results of 3 experiments (Exp) are shown in Table 4 and Fig 5.

Table 4. Percentage of dispersion of nickel particle diameter with the change of ultrasound frequency

d_{Ni} (μm)	Exp 5	Exp 6	Exp 7
0-5	2.87	2.17	0.16
5-10	28.14	21.84	8.24
10-15	22.75	27.69	20.76
15-20	15.08	15.7	22.19
20-25	10.3	9.75	16.16
25-30	7.9	9.31	12.04
30-35	5.51	4.51	9.98
35-40	3.83	3.43	4.75
40-45	2.16	2.71	2.54
45-50	0.6	1.99	1.43
50-55	0.48	0.54	0.79
55-60	0.38	0.36	0.48
60-65	0	0	0.32
65-70	0	0	0.16

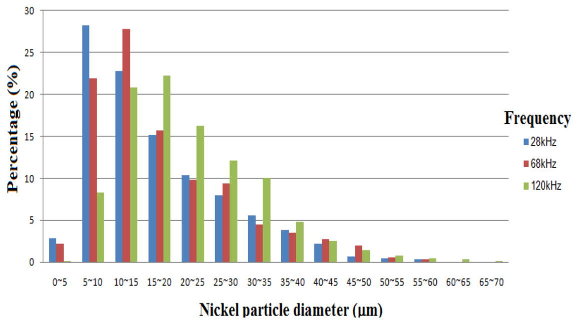


Figure 5. Dispersion percentage of nickel particle diameter with the change of ultrasound frequency

From Table 4 and Fig 5 show that, the nickel particles with diameter smaller than 5μm appear while the ultrasonic frequency is 28KHz and 68 KHz, especially there are nickel particles with nanometer in diameter. In contrast, there are not nickel particle with diameter less than 5μm, but there are nickel particle with diameter larger than 60μm while the ultrasonic frequency is 120KHz. The processing with 28 KHz of ultrasonic frequency makes up over 30% of the nickel particles in the range 0-10μm of diameter, whereas the processing with 120 KHz of ultrasonic frequency makes up only 8.4%.

Thus, the distribution of nickel particle diameter with 28 KHz, 68 KHz, 120 KHz of ultrasound frequency is respectively 5-10μm, 10-15μm and 15-20μm.
From here, it can be seen, when the frequency ultrasonic increases, the particle size increases too. The reason is that, the more increasing the frequency ultrasonic is, the weaker and the more difficult the effect "Emptied" occur.

Conclusion:
Paper give the models for manufacturing by spark in combination with ultrasound. Some experiments are performed to come up the influence of an ultrasound parameters such as power or frequency ultrasound to diameter nickel particles. Specifically, the effect of power and frequency ultrasound on nickel particle diameter is studied. The results show that, when the bigger the ultrasonic power is, the smaller diameter nickel particles are and the more increasing ultrasonic frequency is, the bigger the diameter of nickel particles are.

Next research, the application of spark in combination with ultrasound to manufacture the hollow particles will presented. This new result can carry out the unity between the different atoms such the additives and biofuel or the additives and paint.

References:

[1] Annadurai, A., Nandakumar, A. K., Jayakumar, S., Kannan, M. D., Manivel Raja, M., Bysak, S., Gopalan, R. and Chandrasekaran, V. “Composition, structure and magnetic properties of sputter deposited Ni–Mn–Ga ferromagnetic shape memory thin films”, J. Magn. Magn. Mater, Vol. 321, pp. 630–634, 2009.

[2] Atli, K. C., Karaman, I., Noebe, R. D., Garg, A., Chumlyakov, Y. I., Kireeva, “Shape memory characteristics of Ti49.5Ni25Pd25Sc0.5 high-temperature shape memory alloy after severe plastic deformation”, Acta Materialia, Vol. 59, pp. 4747-4760, 2011.

[3] Ayuela, A., Enkovaara, J., Ullakko, K. and Nieminen, R .M. “Structural properties of magnetic Heusler alloys”, J. Phys. Condens. Matter, Vol. 11, pp. 2017-2021, 1999.

[4] Banik, S., Rawat, R., Mukhopadhyay, P. K., Ahuja, B. L., Aparna Chakrabarti, Paulose, P. L., Sanjay Singh, Akhilesh Kumar Singh, Pandey, D. and Barman, S. R. “Magnetoresistance behavior of ferromagnetic shape memory alloy Ni1.75Mn1.25Ga”, Phys. Rev. B, Vol. 77, pp. 224417-8, 2008.

[5] Berkowitz, A.E., Harper, H.,Smith,D. J.Hu, H.,Jiang,Q., Solomon, V.C. et al. “Hollow metallic microspheres produced by spark erosion”. Applied Physics Letters, 85, pp 940–942, 2004,

[6] Carrey J, Radousky H.B., Berkowitz A.E., “Spark-eroded particles: Influence of processing parameters”. Journal of Applied Physics, pp823-929, 2004.

[7] Kuppan P, Rajadurai A and Narayana S, “Influence of EDM Process Parameters in Deep Hole Drilling of Inconel-718”, Int. J. Manuf. Tecnol., 38(1-2, pp. 74-84, 2008.

[8] Kunieda M., Lauwers B., Rajurkar K.P. & Schumacher B.M., “Advancing EDM through fundamental insight into the process”, CIRP AnnalsManufacturing Technology 54, pp. 64-87, 2005.

[9] Liu Yifan, Li Xianglong, Bai Fushi, et al. “Effect of system parameters on the size distribution of hollow nickel microspheres in ultrasonic-aided electrical discharge machining process”[J]. Particuology, pp. 36-41, 2014.

[10] R.H. Kodama, A.E. Nash, F.E. Spada, A.E. Berkowitz, in: G.C. Hadjipanayis, R.W. Siegel (Eds.), Nanophase Materials, Kluwer Academic Publishers, Dordrecht, pp. 101, 1994.

[11] Saito N., Kobayashi K., “Machining Principle and Characteristics of Electric Discharge Machining”, Mitsubishi Denki Giho 41, pp. 1222-1230, 1967.

[12] Song Hongwei, Li Xianglong, Zhang Chu. “Technical study and analysis of hollow micro-nano spheres produced by EDM”. Modern Manufacturing Engineering, pp 90-92, 2011.

[13] Vineet Srivastava, Pulak M. Pandey, “Effect of process parameters on the performance of EDM process with ultrasonic assisted cryogenically cooled electrode”. Journal of Manufacturing Processes, pp. 393–402, 2012.

[14] Y. Uno, A. Okada, Y. Hayashi, and Y. J. J. S. E. M. E. Tabuchi, "Surface integrity in EDM of aluminum bronze with nickel powder mixed fluid," J. Jpn. Soc. Elec. Mach., (32), pp. 24-31, 1998.