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METHODS OF SURFACE ROUGHENING FOR SPHERICAL SOLID PARTICLES

Ahmed H. Hadi*, Hussein Y. Mahmood
* Ph.D. student, Mechanical Engineering Dept., Engineering College, Univ. of Baghdad, Iraq
Prof. Dr. Mechanical Engineering Dept., College of Engineering, Univ, of Baghdad, Iraq

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ABSTRACT
Five methods for surface roughening (Coarse emery papers, Pasting small glass spheres, Pasting sand, Chemical corrosion and CNC machining) were studied experimentally to choose the best method to produce three different grades of surface roughness for solid (Carbon steel) spherical particles of five diameters (10, 14, 18, 22 and 25) mm accelerated with rotation in Newtonian and non-Newtonian liquids. The results showed that coarse emery papers method gives irregular surface roughness and to measure the surface roughness it must be made of a plane sample so the devices of surface roughness measurement can predict the value of surface roughness and this is impossible to be produced with coarse emery papers (for the sphere and the plane sample with the same grade of surface roughness). Both pasting small glass spheres and sand gives regular and measurable surface roughness but they are irrelevant for the rotation of solid spherical particles because of the broking of roughened surface after a small period of time because of the liquid's resistance to the accelerated spheres motion. The chemical method gave one grade of surface roughness only and it is relevant and the surface roughness is measurable. The CNC machining method was the best method, it gave three different grades of surface roughness which were (74, 176 and 243) µm.

INTRODUCTION
Surface roughness is an important process in the fatigue strength, coefficient of friction and corrosion resistance of machined components [1, 2]. Achenbach (1972 and 1974) [3] and [4] studied experimentally the effect of smoothness [3] and surface roughness [4] on the flow past spheres at very high Reynolds number ($5*10^4 \leq Re \leq 6*10^6$), he determined the drag coefficient as a function of Reynolds number for five surface roughness. The rough surfaces were obtained by pasting glass spheres of different diameters onto the surface of the spheres and used coarse emery paper. Hadi and Ahmed (2006) [5] developed numerically an empirical model of surface roughness for high carbon steel (HRC40) as a function of feed, depth of cut and spindle speed based on factorial experiments on metal cutting results. Singh and Rao (2007) [6] predicted numerically and experimentally a surface roughness with the hard turning of bearing steel (AISI 52100) with ceramic tools. Their study showed that the feed is the dominant factor determining the surface finish followed by nose radius and cutting velocity. Mahmood (2012) [7] used a sand of three different grades to get three different surface roughness for spherical stainless steel accelerated particles in Newtonian and non-Newtonian liquids. Sharaf (2012) [8] studied the corrosion behavior of carbon steel in water media; he studied the effect of carbon's quantity in steel and different corrosion periods on corrosion rates. The aim of the present study is to choose the suitable methods of surface roughening of carbon steel spherical particles which are suitable for accelerating the spheres with rotation in Newtonian and non-Newtonian liquids and produce three different surface roughness degrees.

EXPERIMENTAL PROCEDURES
Solid Spherical Particles
Spherical particles of bearing carbon steel of five different diameters (10, 14, 18, 22 and 25) mm were used (the spheres properties were listed in table (1)).

Table 1. The spheres weights

Sphere diameter (mm)	10	14	18	22	25
Weight (gm)	4.162	11.8275	28.101	44.8157	66.6522

CHEMICAL CORROSION SURFACE ROUGHENING

The spherical particle was put as anode pole inside the corrosion medium. The cathode pole was made of two hollow copper hemispheres (see figure (1)) so a uniform corrosion can be made from sphere' surface. The sphere and the copper hollow hemispheres were welded each one with wire column (20 cm length and 1 mm diameter), the wires columns were insulated inside the corrosion medium.

Figure 1. Corrosion electrical cell

The Corrosion Media Preparation

The corrosion media were sea water and diluted Hydro Chloric acid (H Cl). The sea water was prepared by adding 35 gm of salt (Na Cl) to one liter of distilled water [8]. The diluted Hydro Chloric acid was prepared by adding 20 ml of laboratorial (H Cl) to 400 ml of distilled water.

HARD TURNING USING CNC MACHINE

A CNC router machine (DZQ 3040 - 4 axes- China) was used to roughen the spherical particles. The spherical particles were drilled from one side by making a hole of deep 0.5 mm and 1 mm diameter for the sphere of diameter 10 mm and 2 mm diameters for others spheres (see fig. 2). The spheres top holes were used to hold the sphere from top and the sphere was supported from down by a simple base with curvature surface which was in contact with the sphere so the sphere was supported well from top and bottom when it was machined by the CNC machine and the cutter (0.5 mm thickness) was perpendicular (i.e. rake angle 90°) on the sphere surface so as parallel lines of different feed and depths were produced on the sphere' surface.

Figure 2. Spheres top holes

PLANE SAMPLES FOR SURFACE ROUGHNESS MEASUREMENTS

The devices of measuring surface roughness can't measure spherical shapes [7] so plane samples of aluminum were produced by the same operation conditions of the spheres surfaces (see fig. 3). A microscopic of Carl Zeis Jena Ltd. 8052-GDR was used to measure surface roughness [1].

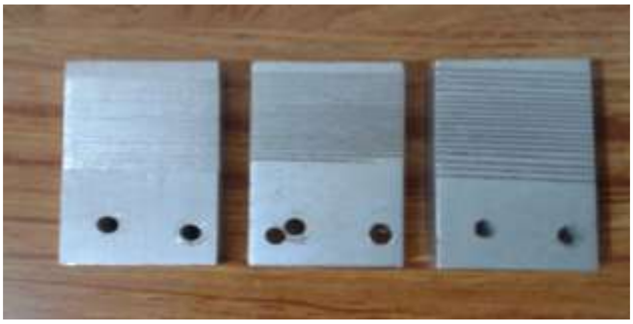

Figure 3. Flat samples for surface roughness measurements

RESULTS AND DISCUSSION

Chemical Corrosion Results

Four chemical experiments were done on the sphere; the details are listed in table (2). At all the experiments and after a period of time from the beginning of the reaction a carbon layer displayed on the sphere surface which reduced the electrical current of the reaction and it prevented the sphere's corrosion so one degree of surface roughness was gained from this method (see fig.4).

Figure 4. Roughened surface by corrosion

Table 2. Chemical corrosion results

No.	Voltage (volt)	Current (ampere)	Time (min)	Corrosion medium
Exp. 1	5	3	4	Sea water
Exp. 2	5	3	8	Sea water
Exp. 3	5	3	10	Diluted H Cl
Exp. 4	5	3	10	Diluted H Cl

CNC HARD TURNING PROCESS RESULTS

Three different surface roughnesses were resulted from the CNC machining process. The operation parameters are listed in table (3) and the roughened spheres are shown in figure (2). The top hole of the sphere was filled with cold Argon welding to keep the spherical shape of the solid particles.

Table 3. Operation parameters

	µm	Feed mm /rev	Rake angle°	Cutting velocity rpm	Nose radius mm
Ra1	74	0.4	90	11000	0.5
Ra2	176	0.5	90	11000	0.5
Ra3	243	0.6	90	11000	0.5

OPTIMUM SURFACE ROUGHENING METHOD FOR SOLID PARTICLE'S ROTATION

Coarse emery papers method gives a random surface roughening method [4] which is difficult to produce a plane sample which is roughened by the same way of the spherical particle. So the coarse emery papers method is unmeasurable of surface roughness for spherical particles. Pasting small glass spheres method [4] and pasting sand method [7] on the sphere surface can be produced plane samples with the same roughening method in which the surface roughness measurements can be made by the surface roughness measurements devices, but in rotation of solid particles in Newtonian and non-Newtonian liquids (like polymers solutions) is irrelevant because of the broking of the surface roughness layer of sand or glass after a few period of time as a result of liquid's resistance on the accelerated spherical particles. The chemical corrosion method gave one grade of surface roughness only. The CNC machining process can produce a regular surface roughness in which plane samples can be made to measure the surface roughness, and this method is relevant for surface roughening of solid spherical particles. The summary of the previous methods are listed in table (4).

Table 4. Surface roughness methods

Surface roughness method	Regularity of surface roughness	Relevant for sphere's rotation application	Surface roughness measurements possibility
Coarse emery papers	Irregular	Irrelevant	Impossible
Pasting small glass sphere	Regular	Irrelevant	Possible
Pasting sand	Regular	Irrelevant	Possible
Chemical corrosion	Irregular	Relevant	Possible
CNC machining	Regular	Relevant	Possible

CONCLUSION

1. The coarse emery paper method gives irregular surface roughness and making of a plane sample for surface roughness measurement with the same roughness degree of the spherical particle is difficult.
2. The pasting of small glass sphere method or pasting sand method gives regular surface roughness and the measurement of surface roughness possible but these methods are irrelevant for solid spherical particles rotation in Newtonian and non-Newtonian liquids because of the broking of the roughened surface after small period of time because of liquids resistance to the particles motion.
3. The chemical corrosion method gave one degree of surface roughness only.
4. The CNC machining method gave three different grades of surface roughness and it is measurable and relevant for accelerating spherical particles with rotation in Newtonian and non-Newtonian liquids.

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