ISSN : 0974 - 7494 Volume 4 Issue 2

Nano Science and Nano Technology
An Indian Journal

Trade Science Inc.

Full Paper

NSNTAIJ, 4(2), 2010 [92-95]

Experimental investigation of friction reduction in tubes caused by hydrophobic magnetite nano particles (HMNP) coating

Vali Kalantar*, Amir Javad Ahrar
Mechanical Engineering Department, Yazd University, Yazd, (IRAN)
Received: 20th August, 2010 ; Accepted: 30th August, 2010

ABSTRACT

In the present paper, reduction of friction coefficient caused by coating the tubes inner face with HMNP was investigated. At first, a thin layer of a mixture of compatible glow and HMNP was maintained on the tube inner wall while winding the tube and then water was fed into the tube. At the same time pressure difference between two ends of the tube was measured by two piezometers. Then friction coefficient of the tube was estimated via Bernoulli formula. The second part of the experiments was to measure the dynamic hydrophobicity of a HMNP coated surface via the sliding angle test. Then the results would be represented and compared together.

KEYWORDS

Hydrophobic magnetic nano particles;
Hydrophobicity;
Hydraulic table test;
Sliding angle.

INTRODUCTION

Wetting is the interaction of a liquid with a solid surface and is found in numerous natural processes as well as being of extreme importance to many industrial and engineering processes. Appliances like easy-to-clean anti-adhesion or anti-finger-print coatings are widely used[1-3]. In order to estimate the hydrophobicity of a surface, one can look from two different aspects: static hydrophobicity and dynamic hydrophobicity. The water-droplet contact angle is commonly used as a criterion for evaluating static hydrophobicity. To assess dynamic hydrophobicity, the sliding angles (the angle at which a water droplet of a certain mass begins to slide down an inclined plate) or contact-angle hysteresis (the difference between advancing and receding contact angles) has been commonly employed as a criterion. Usually the maximum achievable water contact angle is about 120°[4,5]. But neither of these criteria can represent water shedding properties. In addition, it is observed that usually expensive nano particles or techniques were used to produce a hydrophobic surface[6-8]. In this paper, a cheap nano particle (Fe_3O_4) was used as a coating on the tube. Then an experimental test was employed to measure the pressure downfall in a metal tube. In the second part the sliding angle test was employed to show the accuracy of the former technique, and also to be compared with it.

EXPERIMENTS

Hydraulic table experiment

The experiment was taken out on tubes made of black iron. Their diameter and their length were 20mm and 1m, respectively. First part of this experiment was to determine the friction coefficient of bare tubes (with-

Figure 1 : The joint with 2:3:1 ratio

Figure 2 : The hydraulic table

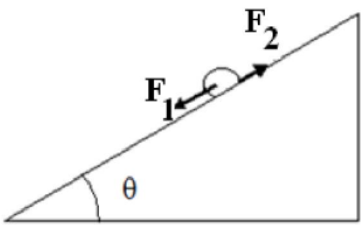

Figure 3 : The two forces on each droplet are F1 = mgsinθ and $F_2 = \mu_s$mgcosθ

out nano particles). Then as it was mentioned before, the hydrophobic nano particles were combined with a suitable glow. Later on the mixture was poured into a tube and the tube was winded at speed of 2000 rpm. So a thin layer of HMNP was coated inside the tube.

In order to determine the tube friction coefficient before and after coating, it was exposed to different flow velocities (different flow rates). Then two hydraulic piezometers were attached on two heads of the tube via a joint ratio of 2:3:1 (Figure 1). When water flows inside the tube the pressure difference between two heads of tube can be measured using the piezometers. The basic formula of this experiment is the Bernoulli equations:

$$\frac{p_1}{\rho g}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{v_2^2}{2g}+z_2+f\frac{L}{d}\frac{v_2^2}{2g} \qquad (1)$$

In the above equation P, v, z, f, d, ρ represent pressure, velocity, height, friction coefficient, tube diameter and the density of fluid, respectively. When there is no mass flow inside the tube terms which include velocity (v) are omitted and since there is no pressure difference due to change of height (z), the pressure difference is initially equal to zero ($p_1 = p_2$). So the heights of water in piezometers are equal at rest. The level of water can be changed by changing the air pressure above the water. The hydraulic table is shown in figure 2.

When water is pumped into the tube, the piezometers show a pressure difference which changes in case of different velocities. Therefore, this pressure difference was put in equation (1) and so the friction coefficient (f) can be estimated.

For this experiment a series of tubes with length of 1 meter and diameter of 0.02 meter were used. Also for each tube, different velocities were tried. After computing the friction coefficient we can relate each tube with an enhanced tube roughness (ε′). To do this, the Colebrook formula is used:

$$\frac{1}{\sqrt{f}}=-2\log\left[\frac{\varepsilon'}{3.7D}+\frac{2.51}{Re\sqrt{f}}\right] \qquad (2)$$

where D is referred to the tube diameter, f and (ε′) are referred to the tube friction coefficient and tube roughness, respectively. This equation normally is used to determine f but since here we have estimated it from the Bernoulli equation here now we can compute (ε′) by the following equation:

$$\varepsilon'=3.7D\left[\exp\left(\frac{-1}{2\sqrt{f}}\right)-\frac{2.51}{Re\sqrt{f}}\right] \qquad (3)$$

The above equation is resulted from equation (2). As you can see f is changing by the Reynolds Number but in this equation, we have *f* and Re together, so for each tube we will reach to a fixed (ε′). This (ε′) is enhanced roughness because the effect of added HMNP was used in it.

The sliding angle test

This experiment is one of the most famous and usual experiment for measuring the friction coefficient of a water droplet on a solid surface. The basic concepts of this test are as follows:

As we can see in figure 3 if we place a droplet of water on a sloping surface, in static form two forces impose it: the force due to the gravity (downward the slop) and the second force is due friction (upward the slop). To determine each force you can see figure 3.

It is known that the droplet will start sliding down the slop at a specific angle in which the above forces

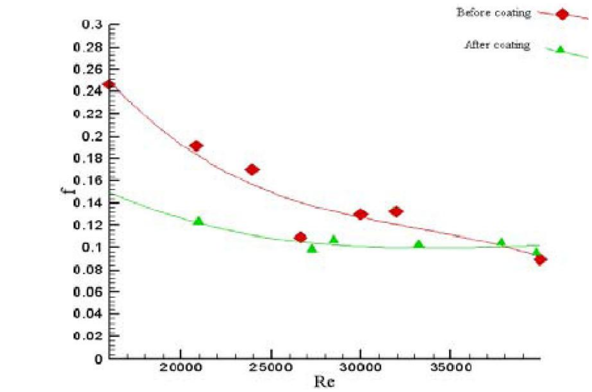

Figure 4 In this figure, the diamonds are belonged to the tubes before coating and the triangles are the points belonging to the tubes after coating with HMNP

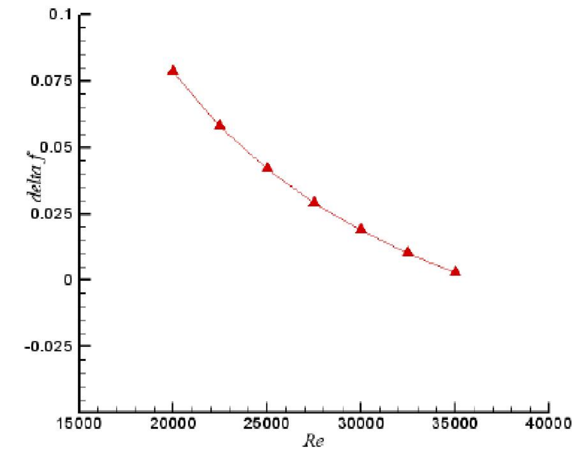

Figure 5 : Delta f plot refers to the changes in f versus Re

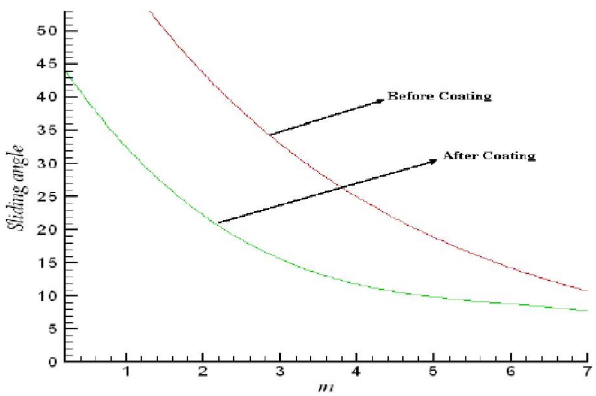

Figure 6 : The diagram of the sliding angle versus mass of droplets. Upper curve is related to the bare surface and lower one is related to the surface coated via HMNP

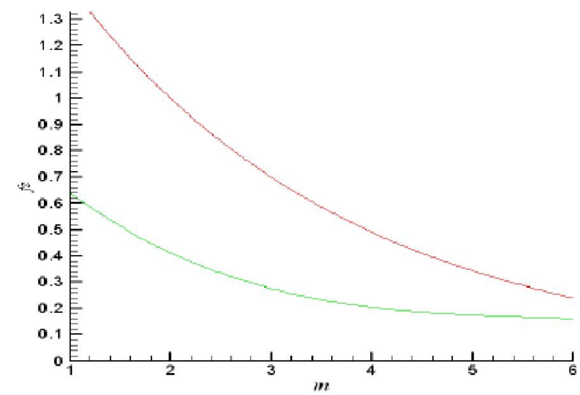

Figure 7 : The friction coefficient related to the diagram of figure 6. Upper curve is related to the bare surface and lower one is related to the surface coated via HMNP

are equal, so we can write:

$$F_1 = F_2 \Rightarrow mg \sin\theta = \mu_s mg\cos\theta$$

$$\mu_s = \tan\theta \qquad (4)$$

In above equations m, g, θ and μ_s are referred to mass, gravity acceleration, sliding angle and friction coefficient, respectively. Regarding to equation (4), we can estimate the static friction coefficient between water droplet and the solid surface by measuring the sliding angle of the droplets. This was done for a bare solid and an HMNP coated surface. In order to show the result, the mass of droplets were changed and for each case, the sliding angle was measured.

RESULTS AND DISCUSSION

For each part of the experiments, a certain diagram was plotted. The test was done for the tubes once before coating with HMNP and once after. The results for the first experiment (Hydraulic table experiment) are presented in figure 4.

In order to estimate the difference in the friction coefficient the delta *f* plot is presented.

It is understood that not only the friction coefficient is reducing due to Reynolds number increase, but the difference between friction coefficients also decreases in high Reynolds numbers.

In the next part of the experiment a water droplet was placed on a smooth metallic surface, then the angle at which the droplet started to move down was measured. This is the angle on equation (IV), which was concluded: its tangent is equal to the static friction coefficient (μ_s).

Figure 6 shows the diagram related to the sliding angles, in this diagram m is a dimensionless character, which refers to the mass of droplet divided by the minimum mass of the droplets (0.04 gr). The sliding angle here is in degrees.

We can estimate the friction coefficient of the surfaces in this test by equation (4). The result is demonstrated in figure 7. As we can see, although they have different operating conditions, the results of the later test are in a good agreement with figure 4.

CONCLUSION

The hydrophobic effect of HMNP (Fe_3O_4) was investigated via two experimental tests. It was seen that the dynamic friction coefficient of the fluid moving through a pipe was reduced by adding the HMNP. Also for the second test, there was a significant decrease in the sliding angle caused by adding the HMNP on an inclined plane. Regardful the static friction coefficient decreases.

For the later test, we should note that in case of a solid-solid interface, the static friction coefficient is a fixed number so the lines in figure 7 should have a fixed slop, But as we can see here the slop is changing by increasing the mass of droplets. Although by increasing the number of droplets, changes of the slop will become more fixed but one assumption for this phenomenon can relate it with the cohesive properties of fluids.

ACKNOWLEDGMENTS

Hereby, we take this chance to thank the Karafarini center of Yazd University. The authors are also thankful to the Science and Technology Park of Yazd.

REFERENCES

[1] S.Kamps, W.Ensinger, F.Eder, A.Berndt, H.Zeininger; Applied Surface Science, **256S**, S92 **(2009)**.

[2] O.I.Vinogradova; International Journal of Mineral Processing, **56**, 31-32 **(1999)**.

[3] J.C.Eriksson, U.Henriksson, A.Kumpulainen; Colloids and Surfaces A, **79**, 282-283 **(2006)**.

[4] W.Xi, Z.Qiao, C.Zhu, A.Jia, M.Li; Applied Surface Science, **255**, 4836 **(2009)**.

[5] H.K.Christenson, P.M.Claesson; Advances in Colloid and Interface Science, **91**, 391-393 **(2001)**.

[6] J.Kijlstra, K.Reihs, A.Klamt; Colloids and Surfaces A, **206**, 521 **(2002)**.

[7] S.Suzuki, A.Nakajima, K.Tanaka, M.Sakai, A.Hashimoto, N.Yoshida, Y.Kameshima, K.Okada; Journal of Magnetism and Magnetic Materials, **254**, 1797-1798 **(2008)**.

[8] K.Sefiane, J.Skilling, J.MacGillivary; Advances in Colloid and Interface Science, **138**, 102 **(2008)**.