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EXPERIMENTAL STUDY ON THE EFFECTS OF SURFACE TENSION ON THE SPREADING RATIO DURING THE IMPACT OF MULTIPLE DROPLETS ONTO A HOT SOLID SURFACE

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Abstract

Multiple droplets are water droplets that are continuously dropped on a surface. The present study was conducted to investigate the dynamics of multiple droplet impact under various surface tensions. Here, the ethylene glycol with compositions of 0%, 5%, and 15% was injected through a nozzle onto stainless steel surface as the multiple droplet. The solid surface was heated at the temperatures of 170 ºC. To observe the dynamics of multiple droplets, a high speed camera with the frame rate of 2000 fps was used. A technique of image processing was developed to determine the maximum droplet spreading ratio. As the result, the surface tension contributes significantly to maximum spreading ratio. As the droplet surface tension decreases, the maximum spreading ratio increases. The maximum spreading ratio appears when the percentage of the ethylene glycol is 15% at the temperature of 170ºC. From the visual observation, it is shown that a slower emergence of secondary droplets (droplet splashing) is carried out under a lower surface tension.

Keywords*: multiple droplet, spreading factor, surface tension, stainless steel*

1. INTRODUCTION

The phenomenon of liquid droplet impact on a solid surface is one of the crucial processes one might be found in various practical applications. The dynamics of water impact (droplets) on a flat surface is one of the phenomena currently developed by many researchers for various uses. The impact phenomenon between droplets and solid surfaces can be found in various applications, such as in a cooling process. The cooling process is done with a number of water droplets and by spraying or commonly known as spray cooling to cool a hot surface.

During the interaction between droplets and hot solid surface, there will be several phenomena occurred: spreading, rebounding, and splashing (Chandra and Avedisian, 1991) due to an increasing temperature affect the surface tension of each material. Therefore, droplets behaviors observed in each different test specimen will have the different phenomena. Beside its colorless and odorless behaviour, ethylene glycol has low volatility

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and viscosity, and also hygroscopic fluid that can be mixed with water and other organic liquids.

2. METHODOLOGY

The experimental apparatus which is hired in this research is shown in Figure 1. An induction stove is used to heat the specimen. Furthermore, the heating temperatures are maintain at 100ºC, 150ºC, and 200ºC. The surface temperature was measured by utilizing a thermocouple. Droplets were dropped onto a heated surface by using a nozzle. The droplet size was considered constant at 3.1 mm. The droplet frequency was set with a control valve on 250/minute. The height between the nozzle and the heated surface was 70 mm, producing a moderate Weber number.

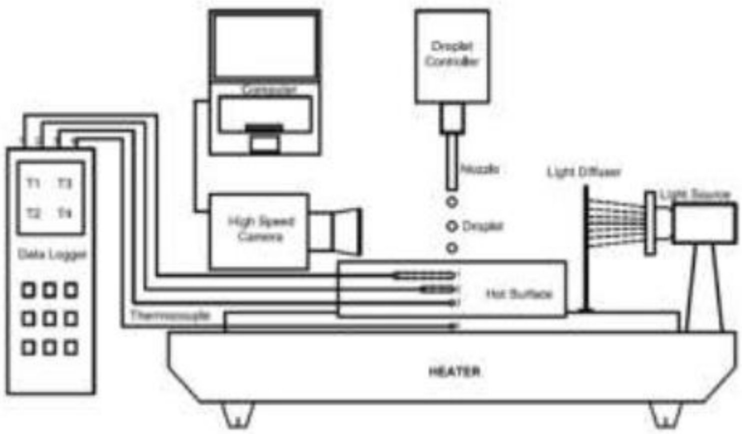

Figure 1 The schematic drawing of experimental apparatus (Wibowo *et al.*, 2018)

Behaviors of droplet impact were observed by using a high speed video camera with 2000 frame per second (fps) shooting speed. The technique of image processing was applied to process the data of pictures which are successfully captured by the high speed camera. Meanwhile, the data taken were the spreading factors (β).

$$\beta = d/d_0$$

where:

β = *spreading factor*

d = diameter of droplet wetting (m)

d_0 = initial diameter of droplet (m)

Materials used in this research were stainless steel with variations of ethylene glycol fluid.

Table 1. Surface Tension Test Results.

Liquid	Surface Tension
Water + EG 0 %	70,1 mN/m
Water + EG 5%	59,1 mN/m
Water + EG 15%	51,3 mN/m

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In the present study, the experimental conditions were as follows; water + ethylene glycol: 0%, 5% and 15%. Working fluids: water + ethylene glycol. As a result the values of surface tension varies. This indicates the concentration and distribution of surfactant in the test fluids are almost uniform. Consequently, the effect of dynamic surface tension in our experiments can be neglected. Variations of surface tension were proved based on visual observations and tests of surface tension with some variations of ethylene glycol, shown in the table of test results Tabel 1.

3. RESULT AND DISCUSSION

To simplify the explanation in this paper, we use some abbreviations for the surface tension characteristics as follows: EG 0%, EG 5% and EG 15%, shown in the table of test results Tabel 1.

a) Visualization of Multiple Droplet Impact at the surface Temperature of 170ºC

The phenomena occurring in the first droplet at the temperature of 170ºC are spreading, recoiling, and secondary droplet (Figure 4). The new phenomenon, split, occurs at this temperature. Droplets are split to be one main droplet and several smaller droplets, or the secondary droplets. The split occurs when $T_{wall} > T_{sat\ liquid}$, forming bubble boiling droplets. Bubbles generated by the heat transfer from the specimen surface will develop and lean towards the droplet surface, hence producing the secondary droplets as suggested by Cossali *et al.*, [7]. The fastest secondary droplet occurs at the surface tension of 70.1 mN/m or at t = 38 ms (Figure 4). It is because the higher the surface tension, the faster the emergence of secondary droplets. While the smaller the surface tension, the greater the spreading ratio (Figure 5).

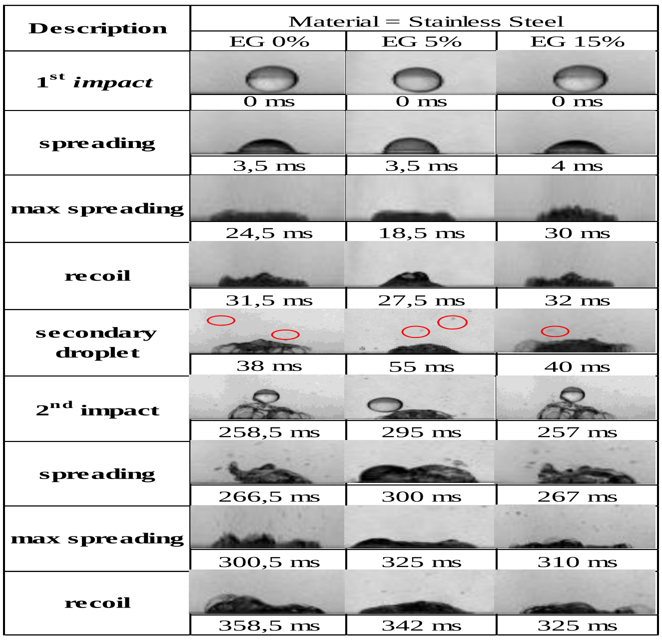

Fig. 4. The phenomena of spreading, recoiling, and secondary droplet at the multiple droplets with variation of ethylene glycol at the temperature of 170ºC

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Impacts between the second and first droplets of all surface tension variations have a similar pattern.

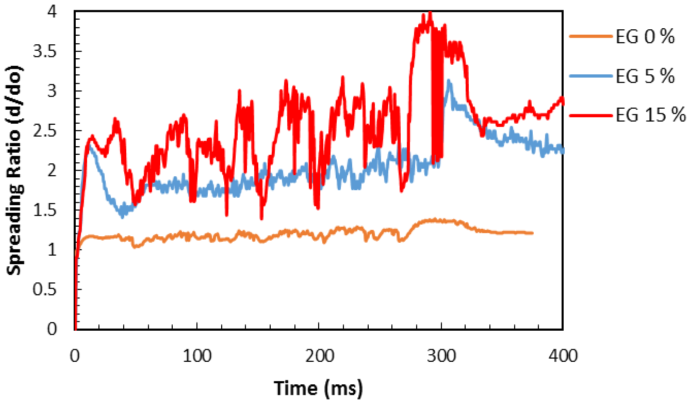

Fig. 5. The spreading ratio as a time function with variations of ethylene glycol at the temperature of 170ºC

4. CONCLUSION

The ethylene glycol concentrations of 0%, 5% and 15% on the dynamics behavior of successive multiple droplets is investigated experimentally. It is found that changes in surface tension at surface temperature resulted in different behavior than droplet collisions. The maximum spreading ratio appears when the percentage of the ethylene glycol is 15% at the temperature of 150ºC. It is clear that the present study has been conducted for all surface temperatures shows the effect of the same surface tension on the dispersion ratio, the smaller the surface tension, the greater the spreading ratio. Hence, surface tension plays an important role on the behavior of emerging secondary droplets.

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