Analysis of fire rate on paper coated with the silica gel from rice husk ash

H H Sutrisno*, R Wirawan, A Febriani and D Ambarwati

Fire Safety Engineering Department, Universitas Negeri Jakarta, Indonesia

*Himawan-Hadi@unj.ac.id

Abstract. Silica element can be used as one of additional elements in a material. It is good to improve the thermal properties so it can stabilize the heat resistance of a material. The silica gel resulted from the extraction process of rice husk ash can also do the stabilization of heat resistance. This element is known to be able to reduce the fire rate in a material. In this research, the fire rate on a paper is analyzed from the result of paper coating by using the silica resulted from the extraction of rice husk ash. It is done by using the flammability test device. The silica gel used to coat the paper is obtained from variety of time during the extraction process, so it will give a difference toward the fire rate on the paper. From the research result, the paper coated by the silica gel sourced from the extraction of rice husk ash with the shortest amount of heating time has the lowest fire rate compared to other samples. It means that the percentage of silica gel obtained from the extraction of rice husk ask with various time variety is in line with the reduction of fire rate.

1. Introduction
The increase of needs for the composite material used for airplane or vehicle materials nowadays demands the researchers to always improve the performance of the developed composite material [1-5]. It is related to certain needs in meeting the material specification of a product, it is common for the engineers to modify the material properties so that it will be in accordance with the desired material properties. For example, the addition of element to the silica gel on the material of polymethyl-vinyl silicone rubber composite, modifying this material results in a material model that has the enhancement on the thermal conductivity compared to the material prior to modification[6].

The element of aerogel silica is known as one of the elements that has transparent color but with a high thermal conductivity[7-10]. When the silica element is used on fiber yarn or fabric, the change of thermal properties from the main element shows a significant improvement. Some techniques in material engineering using the aerogel silica are by way of coating, this model was developed by Hu-Zhang et al. [10]. From the addition of aerogel silica on the utilized fiber, it can result in the improvement of thermal conductivity of a material. It is proven by the spectral extinction coefficient of fiber or opacifier from the fiber that has been added by the silica element by using FTIR device[10]. In line with the research regarding the aerogel silica, the influence of heat treatment on the microstructure of a material increases the thermal isolation property from the material added by the aerogel silica. However, the result of measurement depends on the pores resulted during the thermal treatment when the device is prepared [4, 11]. Similar to the research conducted by Lee et. al [3], the mesoporous silica is used as the
coating material. Since this material is as thin as thin film, such coating model can be utilized to reduce the thermal conductivity on a material. Therefore, it becomes a good coating material.

One of the materials that can produce the aerogel silica is the extraction of rice husk ash. The research that uses the basic material of silica gel from the rice husk ash was conducted by many researchers [12-15]. According to Blisset et. al. [16], in the process of rice husk ash utilization in order to produce the silica, the TORBED reactor becomes one of the furnaces that burns the rice husk so that it produces quality ashes. These ashes give an impact toward the silica obtainment. Of the silica resulted from rice husk ash, according to Junaidi et. al [17], it can be utilized as nanoparticle for the super-hydrophobic coatings of a material. By utilizing the similar technique in modifying a material for the purpose of increasing the fire rate of a material, the silica gel from rice husk ash will be utilized as the additional material in this research, in which the experiment result will help improve the fire resistance of a coated material and also complete the previous researches that the extraction of rice husk ash by using KOH solvent with various heating times also generates a different percentage of silica [18]. In order to see the phenomenon of paper coatings by using the silica gel as the coating’s material, the research procedure is conducted as explained the sub chapter below.

2. Research method

In order to discover whether there is an impact in the coatings of silica gel resulted from rice husk ash, then the research procedure is conducted by applying the following procedure (figure 1):

![Figure 1. Method.](image)

From the procedure above, the device and material preparation are as follows:

2.1. Flammability test

The device used for the flammability test is a box equipped with scales. Inside the box, the oxygen consumption is endeavored to be stable by providing air to the inside which is set by using an air regulator. In normal condition, the air percentage in the oxygen is 20%. Therefore, during the burning
process in a closed space, the oxygen level that must be provided inside the box is 20% of the box volume in every unit of time. The air is resulted from the air compressor that at any time provides air to the box. In order to measure the magnitude of fire rate, a number of masses that has been tested is connected to the scales. When being burned, every mass residue from the burning process in every unit of time can be measured. The device used for the flammability test can be seen in Figure 2.

![Figure 2. Flammability test equipment.](image)

2.2. The making of silica gel

The silica gel used is the one that was produced by the extraction of rice husk ash with KoH solvent. Before producing ash from rice husk, the rice husk used is the one that has the same level of water. To prepare the same water level, the rice husk is dried in an open space for 48 hours. On the next day, the dried rice husk is burned in a furnace with 800° of temperature. After all husks are burned and become ashes, the resulted ashes are filtered in order to obtain a similar size of husk ash. This process will ease the process of husk ash extraction in order to produce the silica gel. In the making process of silica by using the KoH extraction method, generally it requires 60 minutes of heating time. In this research, the applied heating time process is 15 minutes, 30 minutes, 45 minutes and 60 minutes. The making process of silica from husk ash until it produces the silica can be seen in the following Figure 3.

![Figure 3. Extraction process of the silica gel from rice husk ash.](image)

From the extraction result by using time variety, it will produce the different amount of silicon content by using SEM device which will be explained in the sub chapter below.
2.3. Paper immersion

The paper immersed is the one with the size of (L x W) 24cm x 7cm with the number of samples on every variant of the silica gel is 3. The immersion process is conducted by using a large container as the silica container. Each paper is immersed for 24 hours in room temperature. Next, each of the immersed paper is dried in an open space with direct sunlight for 48 hours. Such process is conducted simultaneously for every paper in order to obtain the uniformity of water content in every sample. Paper sample used for the flammability test can be seen in figure 4.

![Paper immersion with the silica gel resulted from rice husk ash](image)

**Figure 4.** Paper immersion with the silica gel resulted from rice husk ash (a) The silica gel and paper as the sample tested with the flammability test, (b) Paper immersion, (c) Result of paper immersion from various silica gel.

2.4. Flammability test Paper burning by using the flammability test device

Having fulfilled the number of samples and the immersion level toward the silica gel until the water level resulted from the drying process with the same amount of time is met, next, every sample’s fire rate is tested by using UL94 standard test. On every sample, the mass residue is measured from every burning process whose result will be compared with every variant of silica gel used. The paper burning process on the flammability test device can be seen in Figure 5.

3. Result and discussion

Difference in heating time during the extraction of silica from rice husk ash gives a difference in the extraction result characteristics. Every composition of silica extraction result with different heating time by using KoH solvent has different characteristics. In order to prove that the extraction result has a difference, the material composition test by using Scanning Electron Microscope (SEM) is conducted. In this process, in every sample which is the husk ash extraction result, the percentage of silicon and other elements contained in it can be measured. Figure 5 is the SEM and EDS result and the percentage of element contents contained in the silica gel for the extraction process with 60 minutes of heating time.
Figure 5. EDS result of element contents in the extraction result of rice husk ash with 60 minutes of heating time.

Meanwhile, the different percentage of every heating time difference can be seen on the Table 1 below.

| No. | Heating Time | Acquisition Parameter | Si   | C    | Cl   | K    | O    |
|-----|--------------|------------------------|------|------|------|------|------|
| 1   | 15 minutes   | 6510(LA)               | 24.73| 18.69| 22.82| 28.54| 17.91|
|     |              | Acc. Voltage : 20.0 kV |      |      |      |      |      |
|     |              | Probe Current: 1.00000 nA|    |      |      |      |      |
|     |              | PHA mode : T3          |      |      |      |      |      |
|     |              | Real Time : 18.48 sec  |      |      |      |      |      |
|     |              | Live Time : 15.00 sec  |      |      |      |      |      |
|     |              | Dead Time : 18 %       |      |      |      |      |      |
|     |              | Counting Rate: 3315 cps|      |      |      |      |      |
|     |              | Energy Range : 0 - 20 keV|    |      |      |      |      |

| 2   | 30 minutes   |                        | 11.58| 20.58| 19.39| 20.41| 28.05|
|     |              |                        |      |      |      |      |      |
| 3   | 45 minutes   |                        | 10.39| 29.50| 15.86| 16.11| 28.14|
|     |              |                        |      |      |      |      |      |
| 4   | 60 minutes   |                        | 9.81 | 24.04| 17.99| 18.75| 29.42|

Of the table above, it can be seen that the rice husk ash extraction by using 15 minutes of heating time contains the highest level of silica, while the longer heating time is in fact produces the lower percentage of silicon level. Next, in order to test the difference of fire rate on a paper, the material immersed by using the silica gel extracted from rice husk ash is compared from one to another. The following is the paper test result without immersion (Figure 6).

Figure 6. Test result of fire rate on a paper without immersion with the silica gel extracted from rice husk ash.
Meanwhile, for the paper that has been immersed from the extraction of rice husk ash with various heating times can be seen in Figure 7.

![Mass changes in every unit of time](image)

**Figure 7.** Mass changes in every unit of time.

Of the chart above, it can be seen that the paper that experiences immersion by using the silica gel with 15 minutes of heating time, from the first minute until the 12th, has a higher number of mass residue resulted from the burning process compared to the mass residue on a paper immersed with the silica gel with time variant of 30 minutes, 45 minutes and 60 minutes. Meanwhile, the paper immersed with the silica gel with 60 minutes of heating time has a smallest number of mass residue resulted from the burning process. On the 12th second, the difference of mass residue resulted from the burning process of paper that has been immersed with the silica gel has a significant value. In addition, it can be seen that the immersion with the silica gel for 15 minutes has a higher number of mass compared to the others. It means that the fire rate is reduced on the paper immersed by using the silica gel for 15 minutes.

4. **Conclusion**

From variety of heating conducted during the extraction process of silica gel from rice husk ash, it produces the characteristics with different percentage of silica. Form 4 types of heating, the husk ash that experiences 15 minutes of heating has the highest percentage of silica mass compared to other heating times. If the silica gel experiences the reduction of fire rate, the best fire rate is obtained from the immersion by using the silica gel which was heated for 15 minutes. It is in line with the percentage of silica in every variant of heating process during the extraction of rice husk ash. The larger number of silica content used to immerse the paper will reduce the fire rate.

**References**

[1] Z A A Halim, M A M Yajid and M H Idris 2018 Physiochemical and thermal properties of silica Aerogel-Poly vinyl alcohol/ Core-Shell structure prepared using bed coating process for thermal insulation applications *Material Chemistry and Physics* 215 8.

[2] Y Kim, M Kim, H-G Seong, J Y Jung, S-H Baeck and S E Shin 2018 Roles of silica-coated layer on graphite for thermal conductivity, heat dissipation, thermal stability, and electrical resistivity of polymer composites *Polymer* 148 8.

[3] J Lee, J Kim, B J Lee, J Lee, H W Lee, M-H Hong et al. 2018 Characterization of mesoporous silica thin film for application to thermo; isolation layer *Thin Solid Film* 660 5.

[4] Y Lei, X Chen, H Song, Z Hu and B Cao 2017 Improvement of thermal insulation performance of silica aerogels by AL2O3 powders doping *Ceramics International* 43 6.

[5] S M, J R, R N P and R Jose 2018 Thermal and structural micro analysis of micro silica blended
fly ash based geopolymer composites. *Journal of Non-Crystalline Solids* **499** 14.

[6] X-W Zhao, L-Y Song, X-D Zhu, K-G Liu, C-G Zang, Y-Q Wen et al. 2018 One-step enrichment of silica nanoparticles on milled carbon fiber and their effect on thermal, electrical, and mechanical properties of polymethyl-vinyl siloxone rubber composites *Composites Part A* **113** 11.

[7] S D Pooter, S Latre, F Desplenter and D Seveno 2018 Optimized synthesis of ambient pressure dried thermal insulating silica aerogel powder from non-ion exchanged water glass *Journal of Non-Crystalline Solids* **499** 10.

[8] S Shafi, R Navik, X Ding and Y Zhao 2019 Improved heat insulation and mechanical properties of silica aerogel/glass fiber composite by impregnating silica gel *Journal of Non-Crystalline Solids*.

[9] Y Xu, H Ye, L Zhang and Q Cai 2017 Investigation on the effective thermal conductivity of carbonized high silica/phenolic ablative material *International Journal of Heat and Mass Transfer* **115** 7.

[10] H Zhang, W-Z Fng, X Wang, Y-M Li and W-Q Tao 2017 Thermal conductivity of fiber and opacifier loaded silica aerogel composite *International Journal of Heat and Mass Transfer* **115** 11.

[11] Yaofei-Lei, X Chen, H Song, Z Hu and B Cao 2017 The influence of thermal treatment on the microstructure and thermal insulation performance of silica aerogels *Journal of Non-Crystalline Solids* **470** 6.

[12] Y-Y Hsieh, Y-C Tsai, J-R He, P-F Yang, H-P Lin, C-H Hsu et al. 2017 Rice husk agricultural waste-derived low ionic content carbon-silica nanocomposite for green reinforced epoxy resin electronic packaging material *Journal of the Taiwan Institute of Chemical Engineers* **78** 7.

[13] M M Younes, H A Abdel-Rahman and M M Khattab 2018 Utilization of rice husk ash and waste glass in the production of ternary blended cement mortar composites *Journal of Building Engineering* **20** 9.

[14] J Prasara-A, S H and Gheewala 2017 Sustainable utilization of rice husk ash from power plants: A review *Journal of Cleaner Production* **367** 9.

[15] E Menya, P W Oluput, H Storz, M Lubmawa and Y Kiros 2018 Production and performance of activated carbon from rice husk for removal of natural organic matter from water: A review *Chemical Engineering Research and Design* **119** 26.

[16] R Blisset, R Sommerville, N Rowson, J Jones and B Laughin 2017 Valorisation of rice husk using a TORBED combustion process *Fuel Processing Technology* **158** 9.

[17] M U M Junaidi, N N R Ahmad, C P Leo and H M Yee 2016 Near superhydrophobic coating synthesized from rice husk ash: Anti-fouling evaluation *Progress in Organic Coating* **99** 7.

[18] R Wirawan, H H Sutrisno, D Ambarwati and A Febriyani 2019 Characteristic of Silica Level (SiO3) Resulted from the Extrac-tion of Rice Husk Ash with KOH Solvent towards the Amount of Heating Time *International Journal of Engineering & Technology*.