© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

The Active Fire Protection Prototype for Household-Scale Kitchen Based on Silica Gel from Rice Husk Ash

Himawan Hadi Sutrsino[1*]

[1]Fire Safety Engineering Department,
Universitas Negeri Jakarta, INDONESIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2022.14.03.005
Received 16 June 2021; Accepted 04 June 2022; Available online 20 June 2022

Abstract: This study aims to create a fire protection design in the kitchen with technology that is easily applied along with inexpensive extinguishing media using silica gel from rice husk ash. By using an experimental method, the active design of fire protection in the kitchen area uses compartmentalization equipped with a gas stove, kitchen equipment, as well as specially designed fire equipment components. The composition of the air in the compartment is calculated based on the volume of the compartment so that it can represent the coverage of oxygen and fuel in accordance with the conditions of free air, while the silica used as an extinguishing media from the extraction of rice husk ash using KOH 0,5M solvent. From the results of this study, the design of fire protection for silica gel-based kitchens made from rice husk ash is effectively used and easy to install in the kitchen area.

Keywords: Rice husk ash, kitchen, fire protection, prototype

1. Introduction

The development of fire prevention instruments aimed at protecting property and lives due to a fire disaster, where until the end of 2019 it took place in big cities, especially in Jakarta increasing. The incident is also likely to occur in other big cities. Besides having a complex population capacity, big cities are well known to have the characteristics of urban populations so that both in terms of the economic, social and habits of each population are very diverse.

From the cause, fires that occur especially for settlements in urban areas are much influenced by social habits, where bad habits such as electrical connection errors, semi-permanent houses made of wood can have the potential to fire [1]. From several events, an electrical short circuit that occurred in the settlement caused a fire, causing loss of property to death. It can also befall children as victims. As Harpur et al. [2] has observed, in his research, the incidence of fires that cause death in children has a large percentage even though the cause is not only due to adult activity but can also originate from dangerous children's toys. In addition to bad habits can cause a potential fire, many other causes are also found by some researchers. Yet, researchers who have found ways to prevent it from finding materials used for fire protection are also experiencing developments as published in the forensic engineering review [3]. So when fire prevention requires comprehensive handling, it also requires comprehensive management that involves all parties [4].

For fires that occur in residential areas, the development of equipment that can reach densely populated settlements continues and develops until now. Among them, the use of drones for fire extinguishing to the development of robotic devices installed in fire trucks so that they can control away from the scene of the fire [5, 6]. There is also Sutrisno et al. [7-10], by adding a centrifugal pump that is attached to the automatic scooter engine used as a fire engine for rapid reaction. This motor developed by reducing the difficulty of operating the fire extinguishing technique. Besides this vehicle also removes obstacles on fire trucks that are unable to enter the point of fire in densely populated settlements

*Corresponding author: himawan-hadi@unj.ac.id

due to narrow road access.

According to Wang et.al [11] the cause of fire, especially in residential area, some of them can originate from the use of fire in the manufacture of food, children's toys, adult cigarettes and the clutter of electric cables. So that in every residential area it is necessary to apply a home security system to a smart fire that is able to detect the potential for fire early [12]. Meanwhile, according to Arhur et al. [13], kitchen equipment that has a high potential for fire comes from equipment that uses electric power such as induction cookers. Although the probability of a fire from a kitchen is not as large as a fire caused by a number of other household appliances, the potential for this fire should remain a concern [14, 15].

To reduce the potential for fires that occur in the kitchen, Qin et al. [16] uses water mist to be applied in the prevention of fire in the kitchen where according to his research; the burning of oil used for cooking can be anticipated with water mist. However, the installation that is used for design using water mist requires high technology, so it is not easy to apply. In addition to water mist, widely available and inexpensive extinguish media can use silica. Some studies about silica can be used to increase the thermal conductivity of an object to increase material properties [17-19]. Besides silica material is also easily produced from rice husk ash so the costs used are relatively low [20, 21]. To developed a fire protection system in the kitchen by utilizing silica from rice husk ash, several studies have been carried out using this silica [22-24]., while in this study making prototypes to protection of fires in the kitchen will be explained as in the sub-chapter below.

2. Method

The fire protection prototype for silica gel-based kitchens as a burnout media is carried out by an experimental method, where the design of the fire protection system takes into consideration the actual kitchen conditions. The research stages are carried out as shown below.

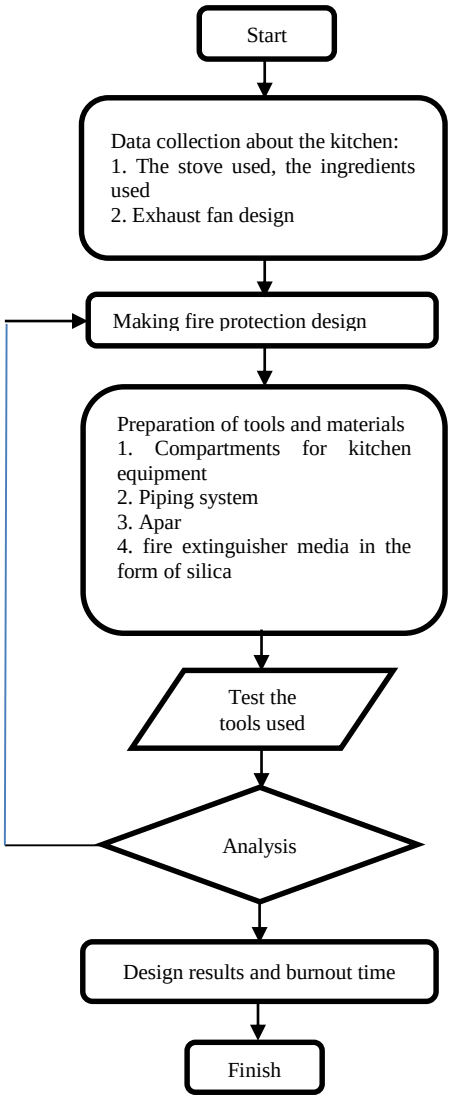

Fig. 1 - The flowchart of research

According to the figure above, to get the optimal design of a fire protection prototype for a domestic kitchen can be done by:

1. *The information on kitchen equipment that has the fire potential*

Generally, there is always a kitchen stove for cooking in the stove both for electric stoves and gas stoves are as a source of heat, while fuel cooked or oil used for frying food. It is well known that cooking oil has a low flash point compared to other ingredients in the kitchen. Besides heat sources and fuel in the kitchen, oxygen sources are often obtained from the exhaust mounted on the stove that exhales fresh air from outside for the combustion process. However, this system is different when the stove used is in the form of an electric induction cooker, where the exhaust only serves to collect and release the combustion air.

2. *Preparation of tools and materials*

In the fire protection design that will be made, the tools used are active fire protection devices. Where this means the fire protection device in the design is made to work when there is a fire. In this design, the tools used are a pendant type sprinkler with an optimum temperature of around 70 C and connected to a fire extinguisher with a size of 1 kg. The tool used to make a fire protection prototype for the kitchen is shown in Figure 2.

Fire extinguisher pipe sprinkler

Fig. 2 - The tools used for fire protection prototypes

The media used in a fire extinguisher is silica gel derived from rice husk ash whose silica content and mass percentage of extraction results have been studied in previous studies [1, 2]. The variation in silica levels used is the result of differences in the heating time during the extraction process (as figure 3), wherewith 15 minutes, 30 minutes, 45 minutes and 1 hour produces different percentages of silica. To prove that the results of extraction of rice husk ash using KOH solvent, the gel mass measured by looking at the structure of the content using Scanning Electron Microscopy - Energy Dispersive Spectroscopy (SEM / EDS). From the results of previous studies, images of the silica content in the gel, and the number of mass processes measured are found in Figures 3a and 3b.

a. Rice husk ash resulted from the burning process

b. Filtering process of rice husk that has been added with KoH and heated with 85° of temperature

c. Extraction result of rice husk ash in the form of the silica gel

Fig. 3 - The making process of silica from husk ash

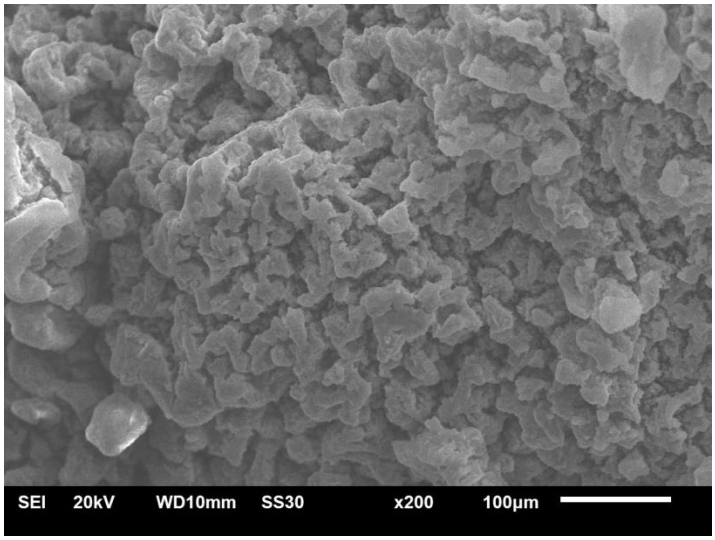

Fig. 3 – (a) The scanning Electron Microscopy result of silica from rice hush ash with 30-minute heating time

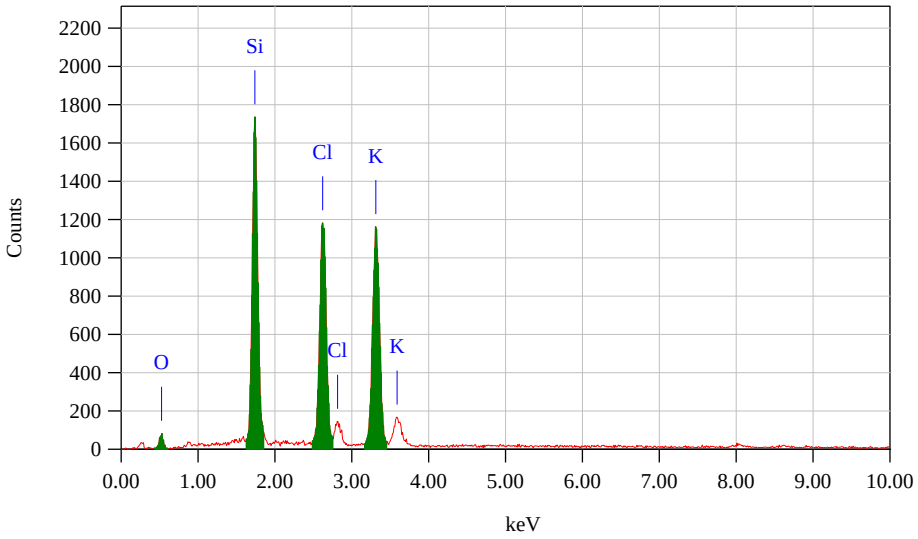

Fig. 3 – (b) Energy Dispersive Spectroscopy result of silica from rice hush ash with 30-minute heating time

From Figure 3 above, there is silica content in each gel mass-produced from the extraction of rice husk ash. Further, when there is a difference in the heating time at the time of extraction, the mass concentration of silica produced is also different. This can be seen in table 1 below.

Table 1 - the silica gel composition of each time difference

No.	Heating Time	Si	C	Cl	K	O
1	15 minutes	25.73	18.69	22.82	28.54	17.91
2	30 minutes	20.58	20.58	19.39	20.41	28.05
3	45 minutes	16.39	29.50	15.86	16.11	28.14
4	60 minutes	9.81	24.04	17.99	18.75	29.42

3. Results and Discussion

The fire triangle is a chain reaction consisting of fuel, material, and heat as shown in Figure 3 below. If there are 3 criteria in the reaction, then a fire will occur. This means if one of the factors contained in the reaction eliminated or cut off then the fire does not occur. This is the basis for making fire protection prototypes in the kitchen by utilizing rice husk

ash as a breaker reaction material from the fire triangle. The results of rice husk ash extraction using KOH solvent tested using TGA (thermogravimetric analysis), where the TGA test results will be identified how many masses are burning and not burning masses at a certain temperature. From the results of production, each variation of the heating time at the time of extraction gives the characteristics of different mass residuals. This can be proven from the results of TGA silica gel with a heating time of 15 minutes (figure 4) and silica gel from rice husk ash with a heating time of 60 minutes (Figure 5).

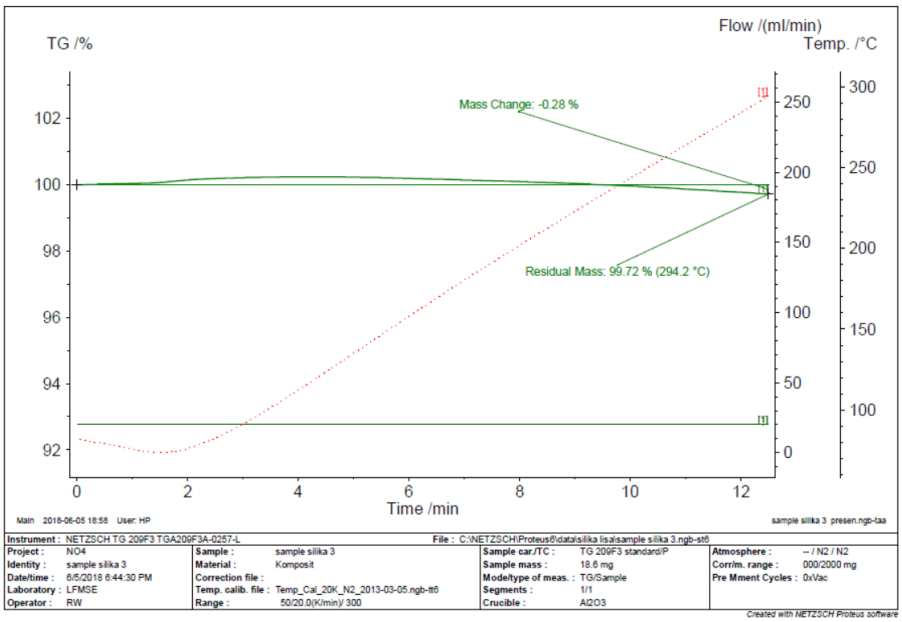

Fig. 4 - Results of the TGA from silica gel produced with a heating time of 15 minutes

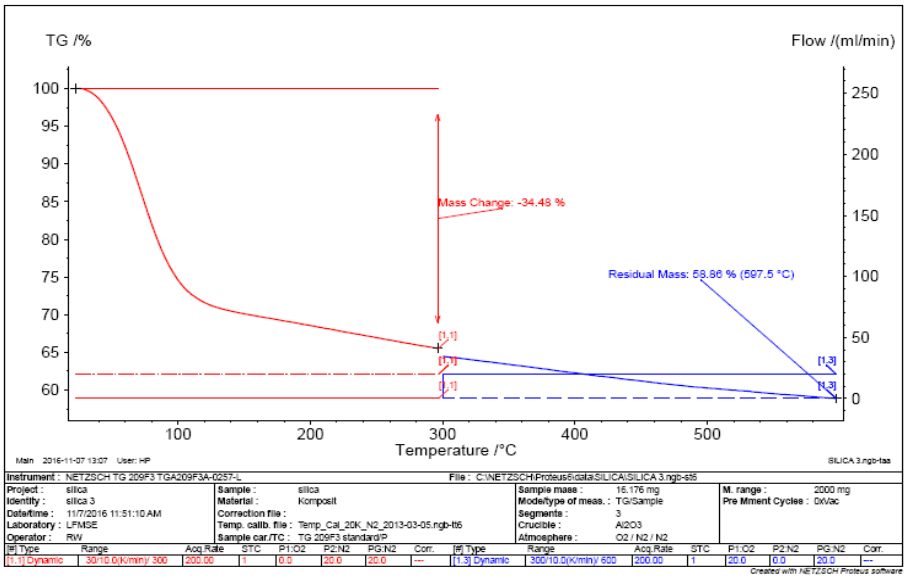

Fig. 5 - TGA results from silica gel produced with a heating time of 60 minutes

Based on the TGA results above, both silica gel with a variation of heating time of 15 minutes and 60 minutes, there is a residual mass of combustion at a temperature of 300 C. This means that when silica gel completely covers the burning material to the surface temperature of the material 300 C, silica does not burn perfect. This can be used as a basis for breaking the chain of fire triangles so that oxygen cannot interact directly with the fuel and heat in the burning material.

For silica gel heating results 15 minutes at the time of extraction, the material burned less than 1%. This means that at that temperature the material is almost non-combustible, or in other words that the material is resistant to temperatures of 300^0 C. So the TGA test results on this material can be used as an indication of the material that can decide the fire

triangle reaction. While for each variation of the heating time during extraction can be seen as in table 2 below and the chart in Figure 6.

Table 2 - The differences in the heating time variation of silica extraction to mass residuals from the TGA test

Time/Period (minutes)	*Mass Change* at temperature 300ºC (%)	*Residual Mass* (%)
15	0,35	99,65
30	6,37	83,24
45	24,09	75,81
60	31,09	63,21

From the table above, the highest mass burned in silica gel extracted from rice husk ash with a heating time variation of 60 minutes, where when a temperature of 300 C has achieved the mass loss of burning results reaches 35% percent, while for the other 2 variations, with a heating time of 30 minutes and 45 minutes respectively provide data that the mass burned at 30 C is 24% and 15%. This means that the variation of heating during the extraction of rice husk ash provides resistance to the burning temperature of 300C which is different and above 63% residual mass.

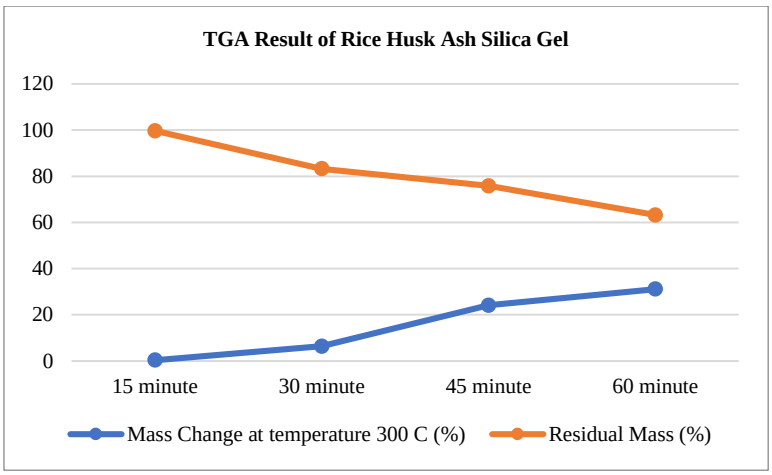

Fig. 6 - Residual mass at every heating time extraction of rice hush ash

From the above data, the process of making an active fire protection prototype in a silica gel-based kitchen from rice husk ash uses the following data:

a. Compartments, in the form of a box with walls made of 5mm thick GRC, box dimensions 60cm x 60cm x 110 cm
b. 0.5-inch pipe
c. Sprinklers mounted on the ceiling box
d. Stove, gas, deep fryer and vegetable oil
e. Fire extinguisher with silica gel from rice husk ash

All the components above installed with the following design **(Figure 7)**

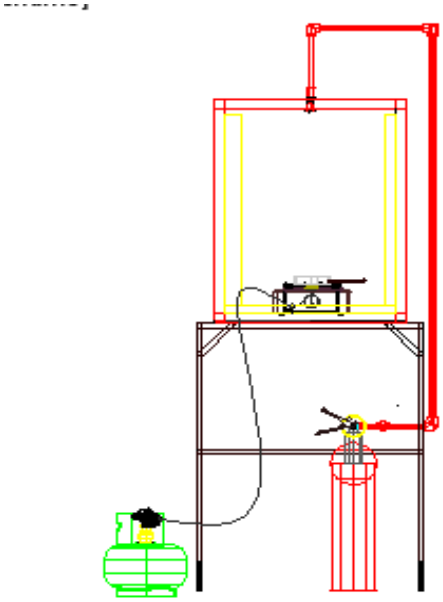

Fig. 7 - The fire protection design in the kitchen

Placement of the stove is in the box and when the experiment has given vegetable oil in accordance with the volume of the fryer used. When the heat of the vegetable oil reaches the flashpoint, the oil burns, at that time the temperature of the burning vegetable oil reaches up to 300 C (as figure 8). Sprinkler above the ceiling box intended as a sensor and spraying extinguishing media when there is excessive heat in the deep fryer, where the distance of the stove and sprinkler is 100 cm in accordance with the distance of the installation of the exhaust hood that is generally installed in the kitchen. If the heat of the ceiling fulfilled 70 C then the sprinkler will split and release the extinguishing media.

Pipe installation in the sprinkler connected directly with fire extinguisher which has been filled with extinguishing media in the form of silica gel extracted from rice husk ash, where in each tube is filled with a composition of 70% extinguishing media and 30% in the form of nitrogen which serves to put pressure on the tube so that it can deliver media silica comes out covering the burning vegetable oil. At optimal pressure conditions, the contents of the cylinders in the form of silica can be dispersed completely so that the oxygen for the reaction in the fire triangle becomes cut off and causes the fire is off.

Fig. 8 - The burning kitchen utensils

The fire extinguisher canister used with a capacity of 1 kg so that in each experiment the silica gel used on the jar was 700 grams. In each variation of silica gel based on the difference in heating time at the time of extraction, the process of extinguishing the fire in a fryer that has been burned can be seen like in Figure 9 with the time needed when the sprinkler starts to burst until the fire extinguished completely as shown in the picture

Fig. 9 - The outbreak of a sprinkler that sprays the extinguishing media

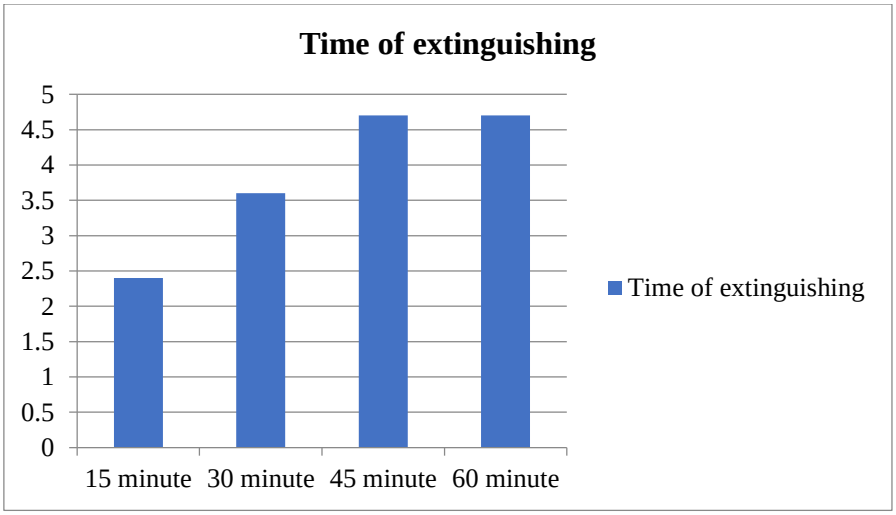

Fig. 10 - The outbreak of a sprinkler that sprays the extinguishing media

From the picture above, the extinguishing time after the sprinkler rupture occurs in the second of each variation of silica gel used as figure 10, where silica gel is produced from the extraction of rice husk ash with a heating time of 15 minutes to get the fastest extinguishing time compared to extinguish in the other three variations that is equal to 2.4 seconds. While silica gel from the extraction of rice husk ash using 60 minutes heating time has a long extinguishing time of 4.7 seconds. At the heating time variation of 30 minutes, the silica element in the resulting silica gel has a tendency to be less than the heating time of 15 minute, this applies to the heating time of 45 minutes to 60 minutes. The difference in mass of elemental silica has a contribution to the speed of fire extinguishing time.

4. Conclusion

From the experimental results, the fire protection design that was designed can work well. Where the average percentage of extinguishing until it can decide the fire reaction can be done with the longest time 4.7 seconds. This means that when there is a fire with temperatures reaching more than 70 degrees in the kitchen, the sprinkler will automatically break and the fire extinguisher containing the extinguishing media can work. This will automatically happen without additional instruments. While silica gel media from rice husk ash based on the results of the experiment in the form of 4 variations can be used perfectly. In this case, evidenced by the extinguishing of the fire after a fire and breaking the sprinkler so the fire extinguisher works. The fastest time during the extinguishing process of extracted silica gel with a heating time of 15 minutes, where by giving silica gel the extinguishing time only takes 3 seconds after the sprinkler breaks

Acknowledgment

This research was funded by the BLU funds of the State University of Jakarta in accordance with the decision of the Chancellor of the Universitas Negeri Jakarta number 291/UN39/PT.01.02/2021.

References

[1] Peng, K.-w., l.-w. Chu, and j. Li, *Research and countermeasures of fire protection in southwest rural areas.* Procedia Engineering, 2016. **135**: p. 10.
[2] Harpur, A.P., K.E. Boyce, and N.C. McConnell, *An investigation into the circumstances surrounding fatal dwelling fires involving very young children.* Fire Safety Journal, 2013. **61**: p. 11.
[3] Staufer, E., *Interpol review of fire investigation 2016-2019.* Forensic Science International; Synergy, 2020. **xxx**.
[4] Villani, E., P.J.I. Kaneshiro, and P.E. Miyagi, *UNCERTAINTY IN HYBRID SYSTEMS AND THE FIRE MANAGEMENT SYSTEM DESIGN.* 16th Triennial Word Congress, Prague, Czech Republic, 2005. **16**.
[5] Gea, W., J.I. Yong-xing, and S. Yao-zong, *The 3rd Generation Fire Truck and its Spraying Technique.* Procedia Engineering, 2011. **11**: p. 424-430.
[6] Watanabe, K., et al., *Stabilization of a Fire Truck Robot by an Invariant Manifold Theory.* Procedia Engineering, 2012. **41**: p. 1095-1104.
[7] Sutrisno, H.H. and Triyono, *Designing a Firefighter Motorcycle as an Effort to Provide an Early Response to Fire Disaster: A Study Case in Jakarta Special Capital Region.* Journal Of Mechanical Engineering, 2017. **SI**: p. 12.
[8] Sutrisno, H.H., *The selection of flying roller as an effort to increase the power of scooter-matic as the main power of centrifugal pump for fire fighter motor cycle.* Materials Science and Engineering Conference Series, 2018. **324**.
[9] Sutrisno, H.H. and Triyono, *Improvement of Performance and Design on Firefighter Motorcycle as a Fast Response to Decrease Fire Disaster in a Densely Populated Area.* International Journal of Mechanical Engineering and Robotics Research, 2019. **8**(4): p. 5.
[10] Triyono and H.H. Sutrisno, *Implementation of VDI 2221 Method for Firefighter Motorcycle Design.* International Journal of Innovative Technology and Exploring Engineering (IJITEE), 2019. **8**(6s): p. 5.
[11] H, W.J., et al., *Statistical Analysis on the Temporal-spatial Characteristics of Urban Fires Under Typical Urbanization Features.* Procedia Engineering, 2011. **11**: p. 437-444.
[12] Kumar, K., et al., *A Fuzzy Decision in Smart Fire and Home Security System.* Procedia Computer Science 2017, 2017. **105**: p. 6.
[13] K, A., K. Wong, and N.K. Fong, *Experimental Study of Induction Cooker Fire Hazard.* procedia Engineering, 2013. **52**: p. 10.
[14] Jutras, I. and B.J. Meacham, *Development of objective-criteria-scenario triplets and design fires for performance-based Fire Safety Design.* Journal of Building Engineering, 2020. **xxx**.
[15] Beasley, M.G., et al., *cuases, Consequences and Prevention of Refrigeration Fires in Residential Dwellings.* Fire Safety Journal, 2018: p. 28.
[16] Qin, J., B. Yao, and W.K. Chow, *Experimental study of suppressing cooking oil fire with water mist using a cone calorimeter.* hospitality Management, 2014. **23**: p. 12.
[17] M, S., et al., *Thermal and structural micro analysis of micro silica blended fly ash based geopolymer composites.* Journal of Non-Crystalline Solids, 2018. **499**: p. 117-130.
[18] Shafi, S., et al., *Improved heat insulation and mechanical properties of silica aerogel/glass fiber composite by impregnating silica gel.* Journal of Non-Crystalline Solids, 2018. **in press**.
[19] Shen, C., et al., *Silica coating onto graphene for improving thermal conductivity and electrical insulation of graphene/polydimethylsiloxane nanocomposites.* Journal of Materials Science & Technology, 2019. **35**(1): p. 36-43.
[20] Carmona, V.B., et al., *Nanosilica from rice husk: Extraction and Characterization.* Industrial Crops and Products, 2013. **43**: p. 6.
[21] Hsieh, Y.-Y., et al., *Rice husk agricultural waste-derived low ionic content carbon–silica nanocomposite for green reinforced epoxy resin electronic pac*
[22] H. H. Sutrisno, B. Wibawa, T. Triyono, J. Amiruddin, C. S. Kusumohadi, P. Setyadi, *et al.*, "The identification of fire potentials in oil mining area on Minas Sumatera Operations-Indonesia by manual assessment method," *IOP Conference Series: Materials Science and Engineering*, vol. 1098, p. 062093, 2021.
[23] H. H. Sutrisno, R. Wirawan, A. Febriani, and D. Ambarwati, "Analysis of fire rate on paper coated with the silica gel from rice husk ash," *Journal of Physics: Conference Series*, vol. 1402, p. 044052, 2019
[24] H. H. Sutrisno, "The full scale fire extinguisher test for silica gel from rice husk ash," *Journal of Critical Reviews*, vol. 7, 2020.