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Analysis of fire development in a passenger car considering various insulation

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Abstract
This study is conducted on optimization of the structure of the insulating materials in the passenger wagon against the development of fire, with the aim of reducing the amount of fatalities in the event of an accident. After validating by an experimental model, by changing the insulation materials used in the wagon body and seats, new insulations of compressed polystyrene, expanded polystyrene, phenolic foam, stone wool and glass wool were simulated in wagon fire situation. Results showed that the wagon model with glass wool and stone wool insulation had a good performance in reducing the rate of fire development and maximum amount of heat release rate. Foams showed poor performance against fire and in addition to increasing the rate of heat release and flame temperature, they produced more smoke and combustion products. From the results of this analysis, it is recommended that for optimal control of fire development, it is better to use fiber insulation in the wagon and use phenolic foam insulation in the interior design of the seat for passenger comfort.

Keywords: Fire spread; passenger wagon; Heat release rate; Pyrosim.

1. Introduction

Today, the railway moves a huge amount of cargo and passengers around the world and to achieve this goal, it passes through structures such as stations, tunnels, urban and suburban spaces. Considering that the traffic of the rail transportation, like other means of transportation, can be affected by phenomena such as accidents, derailment, fire, etc., taking preventive measures and developing international standards to protect people and fleets are one of important aims of different countries. Therefore, there are many researches to modify the transportation safety and security. The topic under discussion is how much heat release rate, how much smoke, and what unfortunate events may occur in case of fire and wagon collision [1,2]. One of important railway collisions in Iran was occurred in 2016, with about 150 fatalities and injuries [3]. Peacock.et.al. studied the effect of wagon components on fire spread [4].

2. Methodology

In this work fire is simulated by a user graphical interface of Fire dynamics simulator (FDS). This software solves a specific form of the Navier-Stokes equations for low-speed flows, and the conservation of mass, momentum and energy equations numerically.

Conservation of mass:
$$\partial\rho/\partial t + \nabla.\rho u = 0 \qquad (1)$$

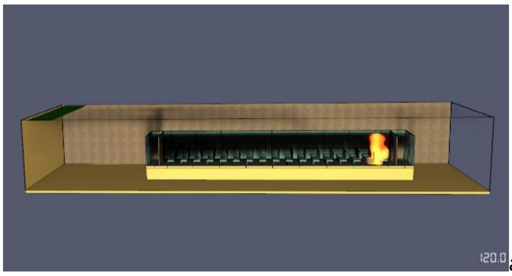
Conservation of momentum:
$$\partial/\partial t\,(\rho u) + \nabla.\rho uu + \nabla P = \rho f + \nabla.\tau\_ij \qquad (2)$$

Conservation of energy:
$$\partial/\partial t\,(\rho h) + \nabla.\rho hu = DP/Dt + q''' - \nabla.q + \Phi \qquad (3)$$

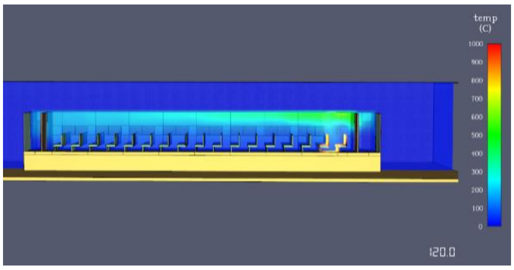
The wagon model was an intercity passenger carriage (bus) with dimensions of 23 meters in length, 3 meters in width and 3.7 meters in height, which was inside a 37.5 meters long tunnel with a fan output capacity of 132 cubic meters per second.

3. Results and Discussion

Temperature and smoke distribution in wagon are shown below for different conditions of fire in wagon. Fig.1 is shown the temperature and smoke distribution in wagon while the initial fire source conditions is fully developed.



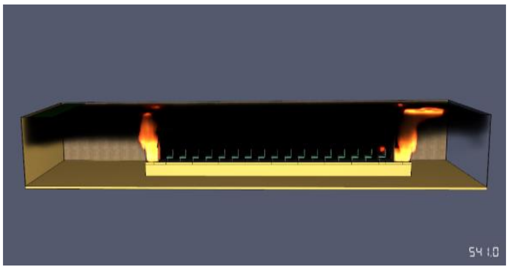
a. Smoke distribution in wagon



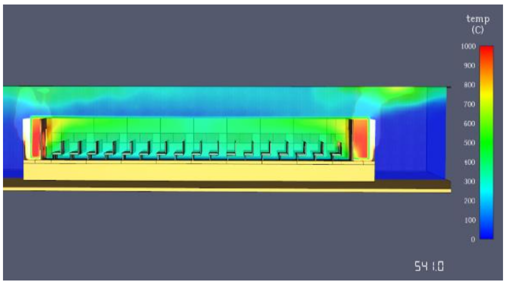
b. Temperature contour in wagon

Fig1. Initial fire source in fully developed status

In the following as shown in fig.2, the temperature is raised and leaded to first glass failure.



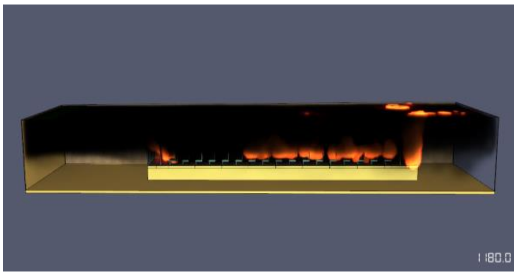
a. Smoke distribution in wagon



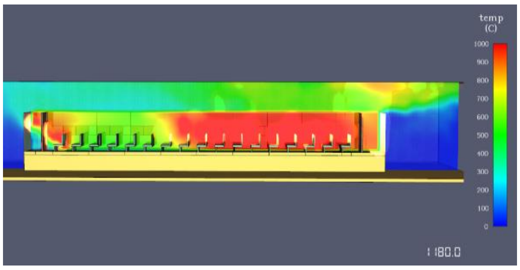
b. Temperature contour in wagon

Fig2. Failure of first glass in wagon

In fig.3 the temperature and smoke distribution are shown when the wagon fire was in fully developed mode, so the heat release rate was maximum.



a. Smoke distribution in wagon



b. Temperature distribution in wagon

Fig3. Wagon fire in fully developed, maximum HRR

In addition, the smoke distribution in different smoke detectors are shown in fig.4.

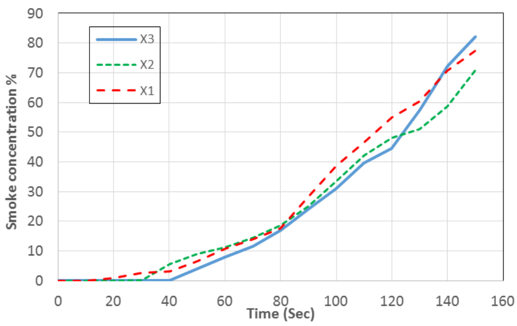


Fig4. Smoke distribution in different detectors

The heat release rate of new insulations used for wagon are shown in fig.5.

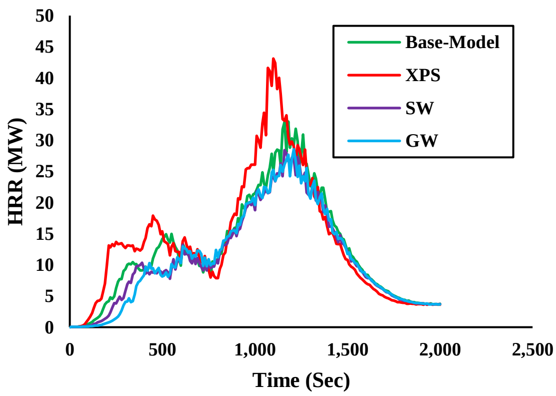
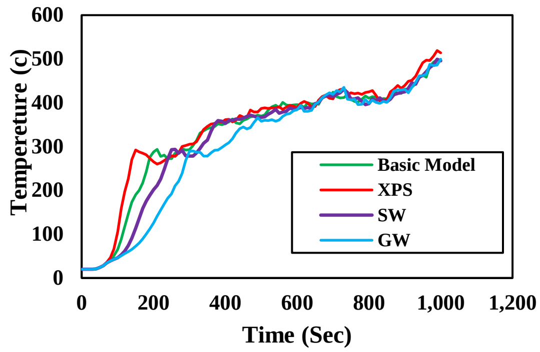
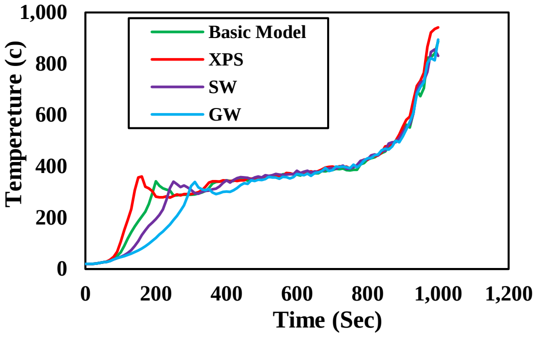


Fig5. Heat release rate of new insulations

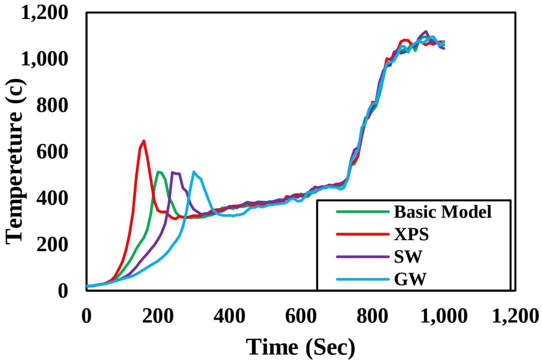
As discussed in the text, there are some thermocouples to measure the temperature in different points in the wagon. For each new insulant, the results are shown in fig.6.



a. Measured temperature by X1



b. Measured temperature by X2



c. Measured temperature by X3

Fig6. Thermocouples time history in wagon for different insulations

4. Conclusions

It was concluded that compressed polystyrene insulation has the highest heat release rate despite its good density and low thermal conductivity coefficient (good insulation) due to its high flammability property. These factors caused the fire development rate to be higher and the temperature distribution in wagon and the production of combustion products to be higher and also to reach the critical range faster. In contrast, glass wool insulation with low heat capacity and good density has the lowest heat emission rate due to non-flammability. These factors cause the rate of fire development to be low, and temperature distribution in wagon and the production of combustion products will reach the critical range in a longer time, and the passengers will use this break to escape from wagon.

5. References

[۱] بلبل امیری، نجمه و نصیرزاده، فرناد، ۱۳۸۸، کاربرد رویکرد FMEA فازی برای ارزیابی ریسک خرابی‌های مربوط به سیستم سیگنالینگ، علائم، کنترل و مخابرات مترو، *دومین کنفرانس بین‌المللی پیشرفت‌های اخیر در مهندسی راه‌آهن*

[۲] فکور، ارغوان، ۱۳۹۵، آنالیز ریسک حریق ناشی از سوختگیری قطار مسافری حین جابجایی مسافر مطالعه موردی: ایستگاه راه‌آهن سیرجان، *کنفرانس ملی محافظت ساختمان‌ها و سیستم‌های حمل و نقل در برابر آتش*، تهران

[۳] اقتصاد آنلاین (۱۳۹۵). حادثه قطار هفتخوان. https://www.eghtesadonline.com

[4] Peacock, R. D., & Braun, E. (1984). Fire tests of Amtrak *passenger rail vehicle interiors (No. NBS/TN-1193).*