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Performance Experiment of the Quenching Mesh at High Velocity Flame

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1. Introduction

According to the domestic and foreign regulations, a DDT (deflagration to detonation transition) should not occur in the containment during severe accidents and the major equipment in the containment should also perform their functions during/after severe accidents [1, 2, 3]. The possibility of a DDT occurrence in the IRWST of the APR-1400 [4,5,6] still remains an issue.

A quenching mesh can be a means to arrest the flame acceleration by installing it at an appropriate distance from the ignition source. The provision of a quenching mesh can be used to prevent a DDT through arresting flame acceleration. In addition, a quenching mesh can play the role of protecting the equipment if it is installed around the equipment. At a low flame velocity, it was shown that a quenching mesh could arrest the flame when it is installed between compartments and a quenching mesh could protect the equipment [7].

The objective of this paper is to test the performance of quenching meshes at a high flame velocity because the flame velocity in severe accidents can be higher than that at a laminar flame.

2. Performance test of a quenching mesh

2.1.Test Facility

The test facility consisted of a visualization system, a combustion chamber, a data acquisition system and a electric spark igniter system. The flame acceleration is achieved by providing an expansion vessel attached to the combustion chamber, as shown in Fig. 1. The ignition node is installed at the end-center of the first compartment. All the tests were carried out at a 9% hydrogen concentration at an atmospheric pressure.

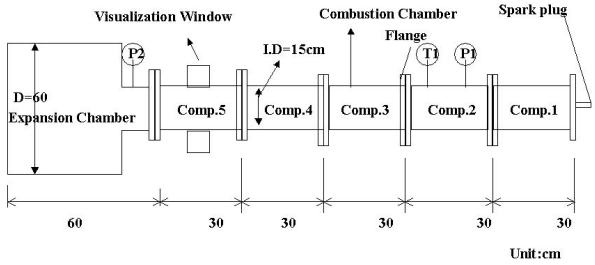

Fig. 1 Combustion chamber

2.2.Test Results

The quenching mesh's performance between compartments is tested first. Two kinds of plastic vinyl are used between the fifth compartment and the expansion vessel to accelerate the flame. Without a burn, the first type of thin plastic vinyl (Type 1) and the second were ruptured at a 0.15Bar and a 0.4Bar pressure difference between the fifth compartment and the expansion vessel, respectively. Table 1 shows the test series for the quenching mesh's performance. In Tests 1 and 5, the flame speed reached about 25m/s with rupture of the plastic vinyl due to a pressure build-up during the combustion period. However, the flame speed reached about 3m/s because the plastic vinyl was ruptured at the instant of a combustion in Test 3. The quenching mesh could not arrest the flame for the high flame speed of Test 2, but it could arrest the flame for the low speed of Test 4.

In Test 6, two sheets were used. The quenching mesh could arrest the flame even though the flame speed reaches about 25m/s with a rupture of the plastic vinyl. The gas temperature at the behind the mesh was less than 100 °C. It was seen that the flame could not pass through the two sheets from the Shadow high-speed image.

Table 1. Test Cases between Compartments

Test No	Visualization Location	Mesh With/Without (Between Comp.)	Vinyl Type
1	Comp 4	Without	2
2	Comp 4	With(3,4)	2
3	Comp 5	Without	1
4	Comp 5	With(4,5)	1
5	Comp 5	Without	2
6	Comp 5	With (5, Exp) Two sheets	2

The quenching mesh's performance for protection of the model equipment is also tested. Figs. 2 and 3 show the model equipment (5cmx5cmx5cm) and the mesh which surrounds the model equipment. Four different meshes are used to investigate the distance effect from the surface of the model equipment to the mesh.

Fig. 2 Model Equipment

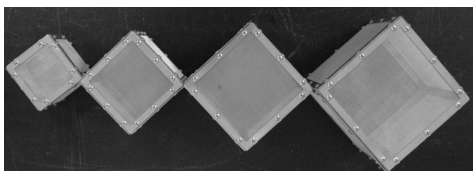

Fig. 3 Mesh Type 1,2,3,4

The dimensions of the Type 1, Type 2, Type 3 and Type 4 are 7cmx7cmx7cm, 9cmx9cmx9cm, 11cmx

11cmx11cm, 13cmx13cmx13cm, respectively. The distances from the thermocouple tip to the mesh are 15mm, 35,mm, 55mm, and 75mm for Type1, Type 2, Type 3 and Type4, respectively. Table 2 shows the test series for the quenching mesh's performance. Test No.1 was carried out to observe the temperatures at the model equipment for a hydrogen combustion without the mesh. The flame velocities were about 25m/s except for Test No. 3 when the plastic vinyl was ruptured at 0.4Bar.

Table 2. Test Cases and Flame Velocities

Test No	Mesh Types	Vinyl Type	Flame velocity [m/s]
1		1	2.17
2	1	2	25
3	2	2	8.33
4	3	2	25
5	4	2	25

Figs. 4 and 5 show the Shadow images passing the model equipment during the burn. Even though the flame speed was high, the flame did not propagate into the mesh. The flame with this speed propagated to the mesh when the mesh was installed between the compartments. It is thought that the flow at the back of the mesh can play an important role in the flame propagation.

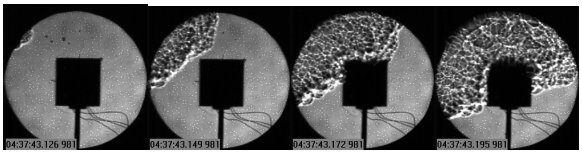

Fig. 4 Flame Images without Mesh
(Test No.1 of Table 2, Time Period: 23ms)

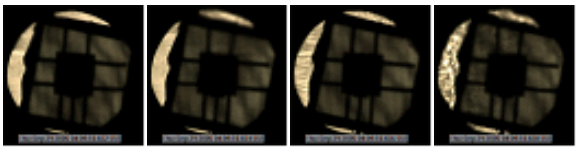

Fig. 5 Flame Images with Mesh
(Test No.5 of Table 2, Time Period: 2ms)

The pressure rise in the combustion chamber and the expansion vessel are about 0.2Bar and about 0.3Bar, respectively, as shown in Fig. 6. The pressures in the combustion and expansion chambers are equalized after a rupturing of the vinyl.

For test No.1 without the mesh, the temperatures in the combustion chamber are about 300 °C and the temperatures at the surfaces of the model equipment are about 200 °C. However, the temperatures at the surfaces of the model equipment when the mesh surrounds the model equipment are less than 100 °C even though the flame velocity is 25m/s, as shown in Fig. 6. They are almost the same for all the surfaces of the model equipment. The distance from the mesh to the surface of the model equipment did not affect the temperatures at this flame speed.

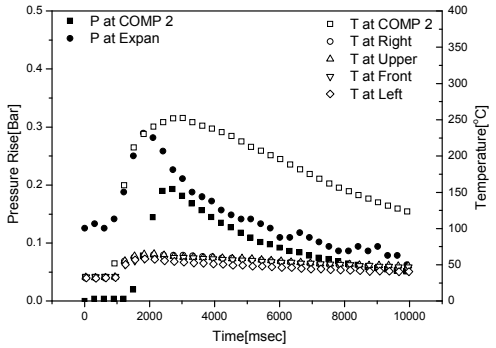

Fig. 6 Pressure and Temperatures for Test No. 5

3. Results and Discussions

The function of quenching meshes was tested with high flame speeds. All the tests were carried out at a 9% hydrogen concentration at an atmospheric pressure. The quenching mesh could not arrest the flame with a 25m/s flame speed. However, it could arrest the flame with a 25m/s flame speed when two sheets were used between compartments. The effects of the flame velocity and the distance from mesh to the surface of the model equipment were investigated The temperatures at the model equipment surfaces were less than 100 °C even with a high flame velocity with about 25m/s. In addition, the distance from the mesh to the surface of the model equipment had no effect on the temperatures at the model equipment surfaces.

The performance of the quenching mesh on the obstacles, flame velocity and initial gas temperature is going to be carried out.

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