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Numerical Analysis of Premixed Combustion in Heating Plate by T-type Ejector

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Abstract:* *A T-type ejector was developed to replace conventional spray nozzle in engineering. The gas of c_3h_8 and air gets a complete mixing in the T-type ejector. The mole fraction of c_3h_8 changes from 3.14% to 3.3% as the inlet pressures of c_3h_8 gas change from 20000 to 120000 Pa and it revealed that the mole fraction of c_3h_8 is not sensitive to inlet pressure. To evaluate the heat transfer performance, the premixed combustion of propane and air was studied by both of numerical calculation and experiment. The combustion is stable in the case of this article and the surface heat transfer coefficient of the paving plate is decreased gradually from time 100 s to 800 s. The temperature of paving plate shows gradual downward trend in 460-385 k after combustion heating 300 s. As a result, the numerical analysis model in this article can be used to predict the temperature of the paving plate of asphalt paver when using T-type ejector. This paper is supported by Hunan Provincial Natural Science Foundation of China (14JJ3149).

Keywords: Heating plate, T-type ejector, Partially premixed combustion, Numerical simulation

I. Introduction

The heat convection by combustion is widely used in heating plate in industry, such as the line heating abroad in ship engineering, and the combustion heating in steel manufacture, and the gas-cooker, ext. In conventional combustion heating study, the spray nozzle is customarily applied to heat the surface plate for its deeply research in experimental parameter. But it is obvious that the energy concentrates too much at the outlet of spray nozzle and the temperature uniformity which is important in industry cannot achieve quickly.

A new T-type ejector (Fig 1) is analyzed in this article. The ejector is fixed on the screed of asphalt paver which is used to pave highway. To avoid the damage to smooth paved surface from the cold asphalt mixture coagulated on paving plate, the paving plate temperature need to be heated up to 100 C° in 5 to 10 minutes considering the engineering efficiency that influence the cost of road construction seriously. The T-type ejector is made up of a traditional ejector and a side-by-side distributed nozzle. The gas of c_3h_8 and air were premixed in the T-type ejector. The premixed gas produced by the T-type ejector is ejected from nozzle in a form of plane and then burned in the combustion chamber (Fig2). The paving plate on the bottom side of screed heats up by convective heat transfer in the combustion chamber.

Using computational fluid dynamic, the premixed property of the T-type ejector in asphalt paver was analyzed in this article. To evaluate the heat transfer performance, the premixed combustion of propane and air was studied by both of numerical calculation and experiment.

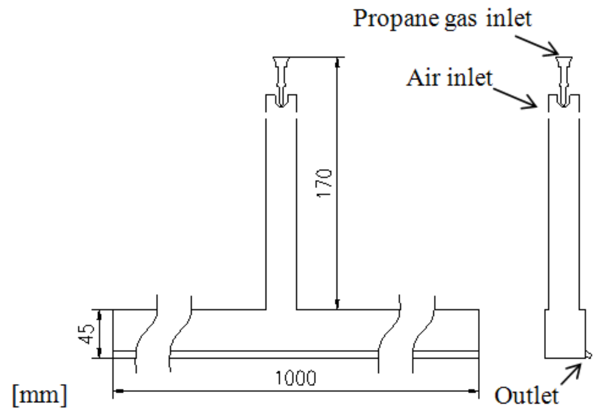

Fig 1: T-type ejector

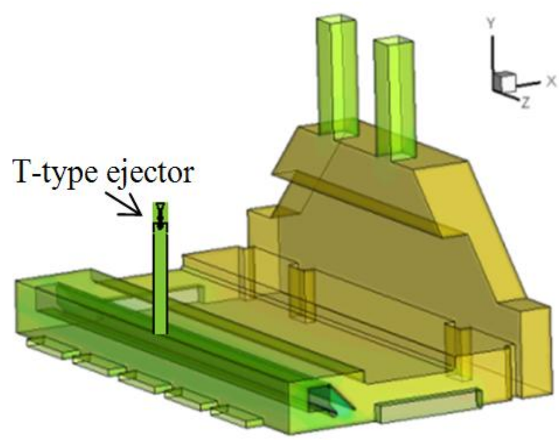

Fig 2: The combustion chamber of asphalt paver

II. Numerical Model

The heating process in this study was consisting of two stages respectively premix and combustion. At the first stage, there is physical mix between propane and air in the eject flow region. At the second stage, there is chemical combustion between the two species in the chamber flow region.

In this numerical model, the outlet of T-type ejector was set to pressure outlet for the flow region in chamber was connected to air environment. Both inlets of propane and air were set to pressure inlet. The inlet of air and outlet of T-type ejector were set to 0 Pa. The air was sucked into ejector by the negative pressure created by the propane gas flow. The two

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1 August 2016

species gases of propane and air were mixed in the turbulent area of the T-type ejector. Considering the pressure limits of gas cylinder in engineering, the numerical calculation of ejector was with varying pressures of inlet in 20000 Pa, 40000 Pa, 60000 Pa, 80000 Pa, 100000 Pa and 120000 Pa to evaluate the premixed property.

The premixed gas was ejected from nozzle and burnt in chamber. The burnt stream transferred heat to the steel paving plate by heat convection. In this combustion model, the species model of partially premixed combustion was used for the combustion process is neither purely premixed nor purely non-premixed. The premixed gas from ejector was set to be fuel and the air in chamber was set to be oxidizer. The reference temperature was set to 288.16 k. As the flow region in ejector and chamber is irregular, the RNG κ-ε model was used to calculate the turbulent flow.

III. Results and Discussion

Effect of inlet pressure on the species properties

In combustion theory, the mole fraction of c_3h_8 in theoretic complete combustion is 0.0403, and the burning condition of mole fraction of c_3h_8 is from 0.022 to 0.095. The combustion extinguishing takes place in other parameters.

Fig 3 shows the contours of mole fraction of c_3h_8 in condition of 40000 Pa in T-type ejector slices. On the bottom circle region of flow channel, the mole fraction of c_3h_8 comes to be a steady value in the range of 3%-3.5% after mixing. It means that the two streams gas of c_3h_8 and air get a complete mixing in the ejector.

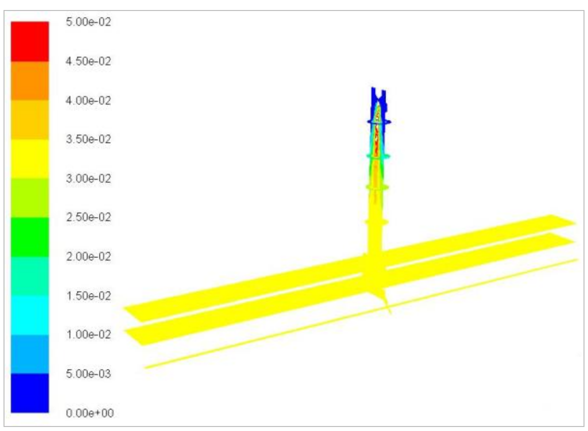

Fig 3: Contours of mole fraction of c_3h_8 in 40000 Pa in T-type ejector slices

Fig 4 shows the contours of velocity magnitude. The high pressure gas of c_3h_8 ejects from a tiny orifice in high speed and generates negative pressure zones where the air is inhaled, is slowed down in the expansionary circle channel. The completely mixed gas is transported to the flow region of the nozzle which is 1meter long and ejected to combustion chamber through the nozzle in velocity of 1-2 m/s.

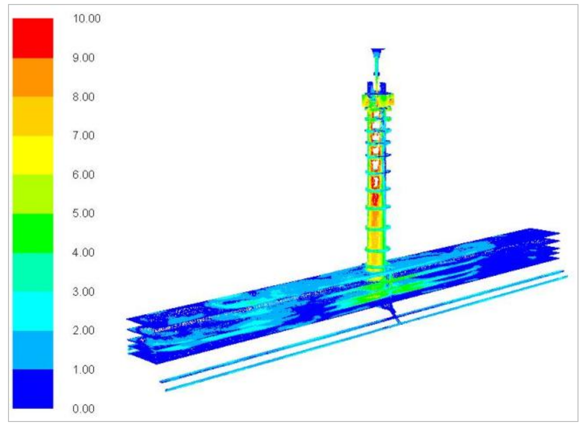

Fig 4: Contours of velocity magnitude in T-type ejector slices

The mole fraction of c_3h_8 in nozzle was calculated in different inlet pressures in 20000 Pa, 40000 Pa, 60000 Pa, 80000 Pa, 100000 Pa and 120000 Pa. As shown in fig 5, in a condition of determinate inlet pressure, the mole fraction of c_3h_8 in middle of T-type ejector is more than that were in two sides. But it also shows a harmonization that is less than 3% differences between the maximum and minimum. The mole fraction of c_3h_8 changes from 3.14% to 3.3% as the inlet pressures change from 20000 to 120000 Pa. As a result, this case reveals that the mole fraction of c_3h_8 in this T-type ejector is not sensitive to inlet pressure under these determinate pressure conditions. It means that the pressure control is not demanded much in precision and is low-cost in engineering when using this kind of T-type ejector.

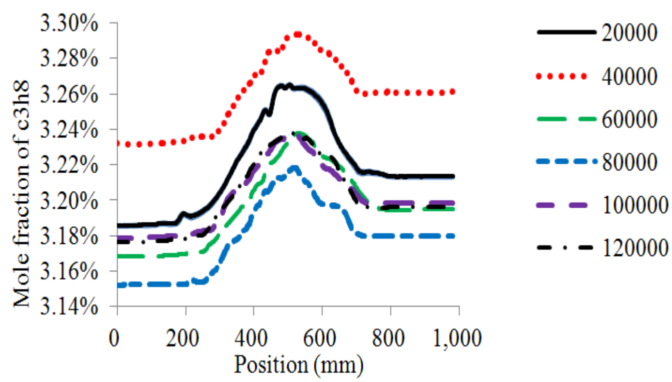

Fig 5: Mole fraction of c_3h_8 in different inlet pressure

In another combustion index, the over-fire air ratio calculated is about 1.344-1.152. It also means that the combustion should be complete as the inlet pressures change from 20000 to 120000 Pa.

The distribution of surface heat transfer coefficient

Fig 6 shows that the surface heat transfer coefficient of the paving plate. The paving plate region in width between -0.15 m to 0.05 m is the major combustion region where the flow has higher speed, and thus makes the surface heat transfer coefficient in this region greater than others. At the beginning 100 s, the surface heat transfer coefficient is mostly above 500 w/m-2k which is greater than that in other times. The surface heat transfer coefficient is decreased gradually from time 100 s

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to 800 s as the subtracter between the paving plate temperature and the reference temperature decreased gradually. The fig 6 also shows that there exists a region that is relatively poor in heat transfer ability./

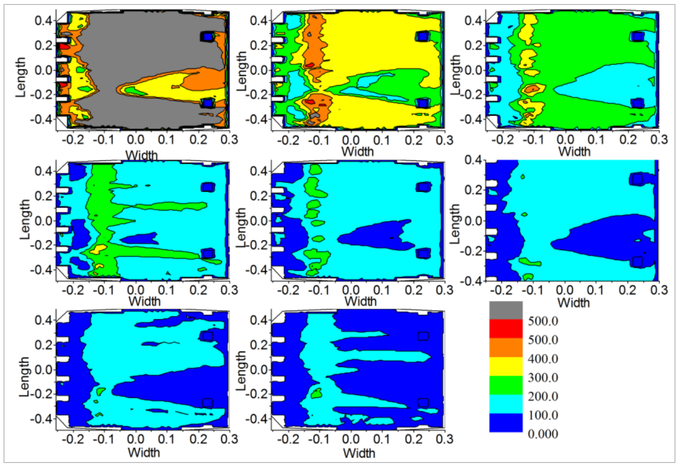

Fig 6: Distribution of the surface heat transfer coefficient in times from 100 s to 800 s

The flow field of combustion

Fig 7, the premixed gas ejected from the nozzle was completely burned in the combustion chamber. The flame temperature reached to 2000 ℃ or above. The combustion gas flowed along the paving plate to the two outlets, and transferred heat to the paving plate by convection. The gas flow temperatures showed a gradual downward trend along the direction from the nozzle to the outlet where it dropped from 2000 ℃ to 1000℃.

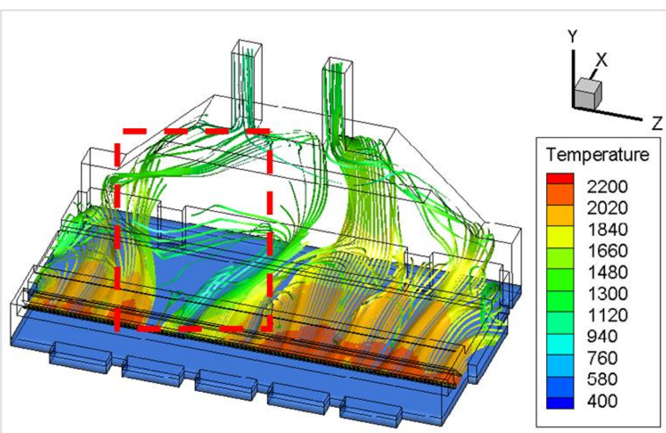

Fig 7: Streamtraces of nozzle colored by temperature

In the red rectangle zone of the combustion region, the flow shows an eddy flow with low temperature. This eddy obviously took effect in bringing lower temperature gas from the outlet side to the nozzle, making low temperature gas staying too much time upon the saddle, thus decreasing the temperature difference of heat transfer between combustion gas and the paving plate. The temperature distributing in paving plate is comparable to that in gas flow. As a result of these phenomena, there is a distinct temperature saddle on the paving plate compare with the eddy in combustion region.

Comparing the numerical result with experiment

As shown in fig 8, the experimental setup was assembled in an asphalt paver which was composed of machine frame and several 0.5-1.5 m screeds. A gas cylinder was fixed on one of the screeds. The T-type ejector was bolted in the combustion chamber of the screed. The propane in gas cylinder was supplied to the T-type ejector by the pipe and set to 40000 Pa by an adjustable throttle valve. The temperatures on the paving plate of one 1 m screed were measured using an infrared thermal imager which has an infrared rays sensor in size 120×160. The accuracy of temperature measurements is 0.1 k.

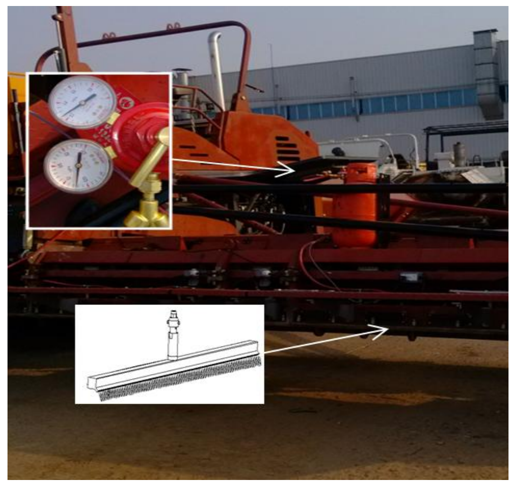
Fig 8: Experimental setup

Fig 9 shows that the flame is similar in 5 minutes and 10 minutes. It indicates that the combustion is stable in this case. The blue colour of the flame also shows that there is a complete combustion near the nozzle as is predicted by the numerical result. It is obviously that the flame extended from the nozzle to the 2/3 paving plate.

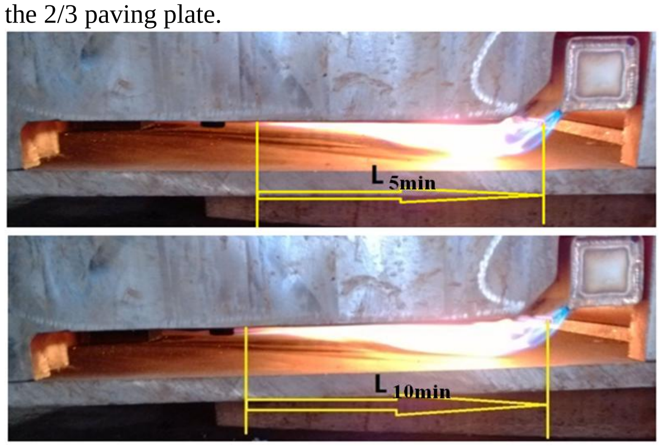

Fig 9: The flame in 5 minutes and 10 minutes

As shown in fig 10, the temperature of paving plate in 5 minutes was measured comparing with simulation. The contours of temperature field shows gradual downward trend in 460-385 k. The temperature in the region near the nozzle is higher than that in others as compared to the distribution of surface heat transfer coefficient.

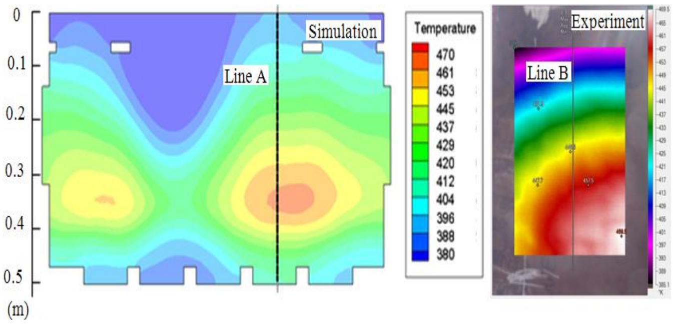

Fig 10: Comparing the simulation with experiment in temperature of paving plate

As a statistical result, the correlation coefficient of line A and line B in Fig 11 is 0.985. The value of mean, standard deviation, min and max of line A are 440.5 k, 20.99 k, 395.11 k and 463.91 k, and the value of mean, standard deviation, min and max of line B are 440.45 k, 12.24 k, 418.37 k and 457.24 k. It indicates that the numerical analysis model in this article can be used to predict the temperature of the paving plate of asphalt paver when using T-type ejector.

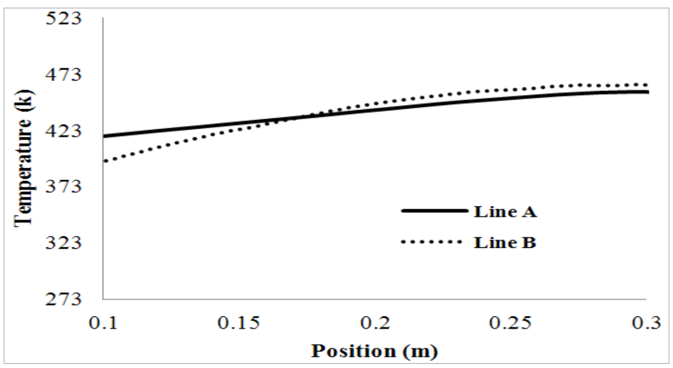

Fig 11: Comparing the temperature of line A and Line B in Fig 10

IV. Conclusion

Based on the CFD analysis and the experimental investigations presented in this paper, the conclusions are follows

1. The two streams gas of c_3h_8 and air get a complete mixing in the T-type ejector.
2. The mole fraction of c_3h_8 changes from 3.14% to 3.3% as the inlet pressures of c_3h_8 gas change from 20000 to 120000 Pa. The pressure control is not demanded much in precision and is low-cost in engineering when using this kind of T-type ejector.
3. The surface heat transfer coefficient of the paving plate is decreased gradually from time 100 s to 800 s. The combustion flow temperatures show a gradual downward trend along the direction from the nozzle to the outlet where it dropped from 2000 ℃ to 1000℃.
4. The combustion is stable in the case of this article. The blue colour of the flame also shows that there is a complete combustion near the nozzle as is predicted by the numerical result. The flame extended from the nozzle to the 2/3 paving plate.
5. The numerical analysis model in this article can be used to predict the temperature of the paving plate of asphalt paver when using T-type ejector.

References

i. Bernard S. Kim, Stanlryl. Stoy, and Herschel J. Fivel. "Arc heater nozzle heating test with hydrogen combustion products", Journal of Thermo physics and Heat Transfer, Vol. 6, No. 3 (1992), pp. 439-444.

ii. L.L. Dong, C.W. Leung, C.S. Cheung. "Heat transfer and wall pressure characteristics of a twin premixed butane/air flame jets", International Journal of Heat and Mass Transfer, Vol. 47(2004), pp. 489-500.

iii. Paolo Blecich, Kristian Leni’c, Anica Trp and Bernard Frankovi’c. “Heat Transfer Analysis of Heating Plate with Multiple Heat Sources”, Strojarstvo, Vol. 52, No. 3 (2010), pp. 549-557.

iv. J.W. Mohr, J. Seyed-Yagoobi, R.H. Page. “Heat transfer characteristics of a radial jet reattachment flame”, Journal of Heat Transfer, Vol. 119 (1997) , pp. 258–264.

v. L.L. Dong, C.S. Cheung, C.W. Leung. “Heat transfer from an impinging premixed butane/air slot flame jet”, International Journal of Heat and Mass Transfer, Vol. 45 (2002), pp. 979–992.

vi. J. Wu, J. Seyed-Yagoobi, R.H. Page. “Heat transfer and combustion characteristics of an array of radial jet reattachment flames”, Combust. Flame Vol. 125 (2001), pp. 955–964.

vii. A. Milson, N.A. Chigier. “Studies of methane and methane-air flames impinging on a cold plate”, Combust. Flame, Vol. 21 (1973), pp. 295–305.

ix. M. Fairweather, J.K. Kilham, A. Mohebi-Ashtiani. “Stagnation point heat transfer from turbulent methane-air flames”, Combust. Sci. Technol, Vol.35 (1984), pp.225–238.

x. D.G.Norton，D.G.Vlachos, “Combustion characteristics and flame stability at the microscale: a CFD study of Premixed methane/air mixtures”, Chemical Engineering Science, Vol. 58, No. 21(2003), pp. 4871-4882.

xi. Gardon R, Akfirat J C. “The role of turbulence in determining the heat transfer characteristics of impinging jets”, International Journal of Heat Mass Transfer, Vol. 8, No.10(1965), pp.1261-1272.

xii. O’Donovan T S, Murray D B. “Fluctuating fluid flow and heat transfer of an obliquely impinging air jet”, International Journal of Heat and Mass Transfer, Vol.51, No.25/26(2008), pp. 6169-6179.