The Steam Explosion Calculation Focused on the Mixing Particle Size

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1. Introduction

The reactor steam explosion calculations generally use the conventional approach, in which the code verification parameter is a pressure. This approach seemed not to give a consistent result; the explosion pressure by the new breakup model of TEXAS-V is quite different from that by the old breakup model of TEXAS-V even though these two models were tuned for the L-14 mixing pressure. The primary reason is that the verification by the pressure could distort the mixture condition. The explosion pressure generally is believed to be the function of the mixture condition such as the fuel particle distribution and void fraction, but tuning the code for the mixing pressure could not guarantee the rightness of the other mixture condition. A new approach to use the particle size distribution as the comparison parameter was suggested.

2. Conventional Approach to Explosion Calculations

2.1 The Evaluation of Mixing Model

The two breakup models implemented in TEXAS-V are used in the analysis. The new breakup model has a more mechanistic breakup mechanism including the RTI(eqn (1)), BLS(eqn (2)), and KHI(eqn (3)), while the old breakup model is based on the RTI(eqn (1)).

$$D_f^{n+1} = D_f^n(1 - C_0 \Delta T^+ We^{0.25}); C_0 = 0.11 - 0.0785\varepsilon \qquad (1)$$

$$dM_{BLS} / dt = \rho_f \int_R 2\pi U r dr \qquad (2)$$

$$dM_{KHI} / dt = C_0 \rho A [n\lambda]_{max} \qquad (3)$$

They do not show much difference for the simulation of FARO L-14[3] in Fig. 1.

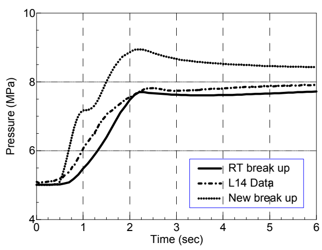

Fig. 1 Comparison of pressure for the L-14

2.2 Ex_Vessel Explosion Calculation

TEXAS-V computer code has a fragmentation model by Tang during the explosion presented as

$$M_f = C_{fr}\, m_p (P - P_{th})^{0.5} / (\rho_c R_p^2)^{0.5} g(\tau) F(\alpha) \qquad (4)$$

After two mixing calculations using the old breakup model and the new breakup model were done, the explosion calculation was done using the same explosion model. The explosion pressure behaviors of the two cases were quite different from each other. This means that the verification against the mixing pressure does not guarantee the rightness of the other parameter such as the particle size distribution and void fraction, which affects on the explosion pressure.

3. New Approach to Explosion Calculations

3.1 The Evaluation of Mixing Model

The particle size distribution was used for the verification of the mixing. The calculated distributions were quite different from each other for the simulation of the TROI-20. The old breakup model gave just one spectrum of the particle size, but it is a reasonable size comparing the TROI-20. The new breakup model gave a wide range of particle size distributions, but the value is far from the experimental results. This discrepancy might make the difference in the explosion calculation between the old breakup model and the new one.

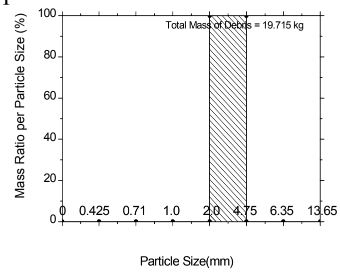

Fig. 2 Particle size distribution by old breakup

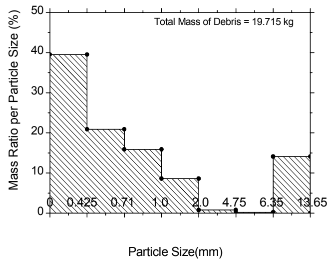

Fig. 3 Particle size distribution by new breakup model

A parametric study on the KHI breakup model of the new breakup model was done and modifications by 12*Co and 5* λ were suggested to fit the mixing particle size distribution of TROI-20. But, it is not sufficient when considering the TROI-20 result even though the pattern is closer than that by the original new breakup model. We note that TEXAS-V has two kinds of jet breakup model: KHI and BLS, and we just handled it with the KHI model.

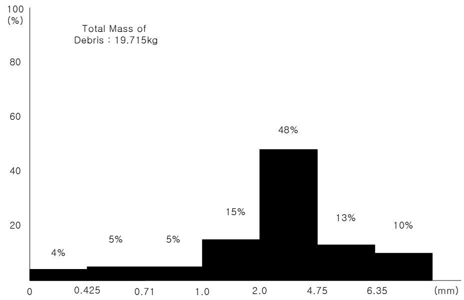

Fig. 4 Particle size distribution of TROI-20

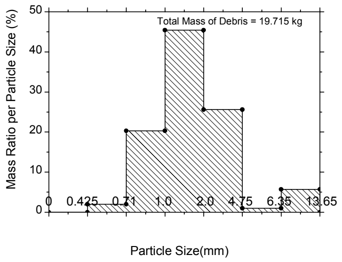

Fig. 5 Particle size by modified new breakup model

3.2 Ex_Vessel Explosion Calculation

Fig. 6~8 show that the explosion pressure by the modified new breakup model could become closer to that by the old breakup. The explosion peak pressure of Fig.8 is 70MPa, which is close to that of Fig. 6 and the pressure increase time is 2 ms, which is between 0ms of Fig. 6 and 4ms of Fig. 7. Thus, the explosion pressure profile by modified new breakup model has mean characteristics between that by the old breakup model and that by the new breakup.

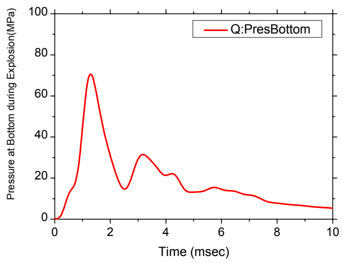

Fig. 6 Explosion pressure by old breakup model

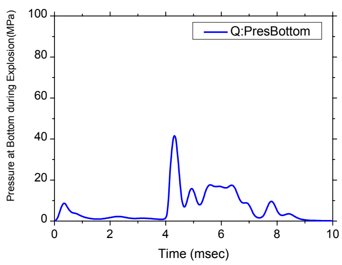

Fig. 7 Explosion pressure by new breakup model

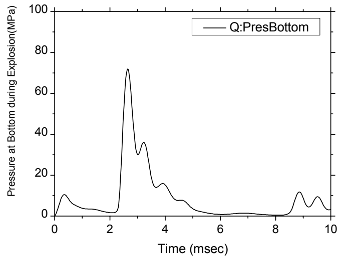

Fig. 8 Explosion pressure by modified new breakup

4. Conclusion

A new approach to use the particle size distribution as the comparison parameter was suggested because the conventional pressure verification method could not give a consistent result during a mixing and an explosion. The old breakup model and new breakup model of TEXAS-V could not give the realistic particle size distribution, so then the new breakup model was modified against the TROI-20 particle size distribution.

The modified new breakup model fitted for the TROI-20 particle size distribution data gave a closer explosion pressure to that by the old breakup model than the original breakup model. This means that we can simulate the mixing and explosion process more consistently.

ACKNOWLEDGMENTS

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