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Short communication

# A correlation to estimate the velocity of convective currents in boilover

Fabio Ferrero [a,*], Bulent Kozanoglu [b], Josep Arnaldos [a]

[a] *Centre d'Estudis del Risc Tecnològic (CERTEC), Chemical Engineering Department, Universitat Politècnica de Catalunya, Diagonal 647, 08028 Barcelona, Catalonia, Spain*

[b] *Mechanical Engineering Department, Universitat de las Américas, Puebla, 72820 Santa Catarina Mártir, Cholula, Puebla, Mexico*

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**Abstract**

The mathematical model proposed by Kozanoglu et al. [B. Kozanoglu, F. Ferrero, M. Muñoz, J. Arnaldos, J. Casal, Velocity of the convective currents in boilover, Chem. Eng. Sci. 61 (8) (2006) 2550–2556] for simulating heat transfer in hydrocarbon mixtures in the process that leads to boilover requires the initial value of the convective current's velocity through the fuel layer as an adjustable parameter. Here, a correlation for predicting this parameter based on the properties of the fuel (average ebullition temperature) and the initial thickness of the fuel layer is proposed.

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## 1. Introduction

Boilover has a major bearing on fire safety assessment and has been studied for many years, but is as yet not totally understood [1–3].

Recently, Kozanoglu et al. [4,5] developed a model that predicts with good accuracy the temperature distribution in the fuel layer during combustion in hydrocarbon mixtures, both for experiments performed *ad hoc* with diesel-oil and gasoline by Centre d'Estudis del Risc Tecnològic (CERTEC) of Universitat Politècnica de Catalunya and for previous data [1–3]. The adjustable parameter of the model, which helped to predict the possibility and type of boilover, was the initial value of the convective currents.

This paper attempts to correlate the initial value of the convective currents as a function of the fuel properties and the operating conditions (initial fuel thickness and pool diameter), in order to offer an initial value for the simulation of different hydrocarbon mixtures.

* Corresponding author. Tel.: +34 93 401 66 75; fax: +34 93 401 71 50.
*E-mail address:* fabio.ferrero@upc.edu (F. Ferrero).

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## 2. Results

Table 1 summarizes the values of the initial velocity of the convective currents ($V_{a,0}$) in the experiments analyzed. As mentioned in [4,5], the dependence on the type of fuel and on the initial thickness of the fuel layer is clear. Furthermore, pool diameter effect seems negligible in this range. As suggested in previous studies, the average ebullition temperature of the fuel significantly affects boilover type. It may be reasonably assumed that the initial velocity of the convective currents is influenced by this parameter. In Fig. 1, this influence is studied for two different initial fuel layers. It should be pointed out that the average ebullition temperature values shown in Table 2 were calculated as averages based on the distillation curves of the fuels.

The lines in Fig. 1 clearly show the trend for $V_{a,0}$ to decrease with the average ebullition temperature. The curves vary according to the initial fuel thickness. Eqs. (1) and (2), where $T_e$ is in °C and $V_{a,0}$ in mm/s, are the correlations that best fit the experimental data for these two thicknesses:

$$V_{a,0} = 7185 T_e^{-2,23}, \qquad \text{for } h_0 = 15\,\text{mm} \tag{1}$$

$$V_{a,0} = 1778 T_e^{-1,92}, \qquad \text{for } h_0 = 20\,\text{mm} \tag{2}$$

**Nomenclature**

| | |
|---|---|
| $h_0$ | initial layer thickness of fuel (mm) |
| $T_e$ | average ebullition temperature (°C) |
| $V_{a,0}$ | initial velocity of the convective currents (mm/s) |

As indicated above and confirmed by Fig. 1, the initial layer of fuel influences the initial velocity of the convective currents. Thus, all the experimental data should correlate with a single equation that expresses their dependence on both $T_e$ and $h_0$. The correlation selected was of the type established by the following equation:

$$V_{a,0} = a(h_0)^b(T_e)^c \quad (3)$$

By minimizing the following objective function:

$$\sum((V_{a,0})_{experimental} - (V_{a,0})_{predicted})^2 \quad (4)$$

Eq. (5), which presents a regression coefficient of 0.97, is obtained. The accuracy of the correlation is also shown in Fig. 2.

$$V_{a,0} = 267.34(h_0)^{0.94}(T_e)^{-2.09} \quad (5)$$

Eq. (5) can be used to estimate the initial values of the convection currents of hydrocarbons that differ from the ones employed in this study. These values may be used to evaluate the possibility and type of boilover, by means of the analysis of the Fourier and Prandtl numbers shown in [5].

Table 2
Average ebullition temperature of the studied hydrocarbon mixtures

| Fuel | $T_e$ (°C) |
|---|---|
| Crude-oil | 385 |
| Diesel-oil | 278 |
| Mixture (50% diesel-oil–50% gasoline) | 200 |
| Gasoline | 123 |

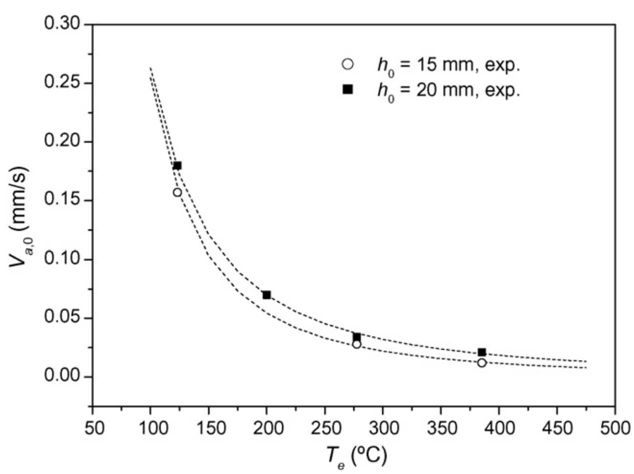


Fig. 1. Initial velocity of the convective currents as a function of the average ebullition temperature of the fuel.

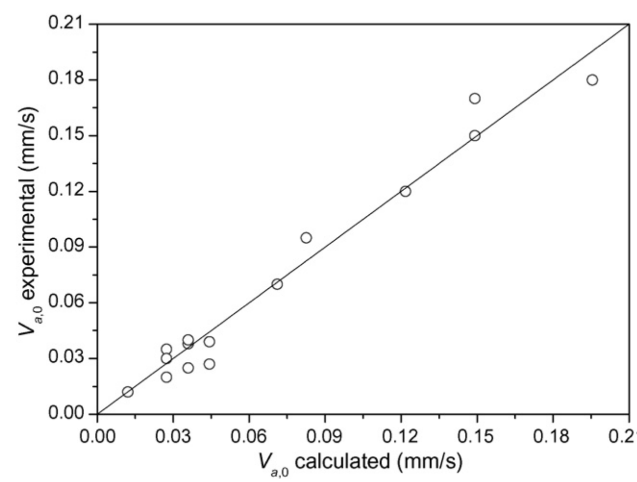


Fig. 2. Comparison between the predicted and experimental data of $V_{a,0}$.

Table 1
Initial velocity of the convective currents in the analyzed experiments

| Experiment | Fuel | $D$ (m) | $h_0$ (mm) | $V_{a,0}$ (mm/s) |
|---|---|---|---|---|
| This work (CERTEC) | Diesel-oil | 3.0 | 15 | 0.035 |
| This work (CERTEC) | Diesel-oil | 3.0 | 20 | 0.038 |
| This work (CERTEC) | Diesel-oil | 3.0 | 25 | 0.039 |
| This work (CERTEC) | Diesel-oil | 4.0 | 15 | 0.020 |
| This work (CERTEC) | Diesel-oil | 4.0 | 20 | 0.025 |
| This work (CERTEC) | Diesel-oil | 4.0 | 25 | 0.027 |
| This work (CERTEC) | Diesel-oil | 5.0 | 15 | 0.030 |
| This work (CERTEC) | Diesel-oil | 5.0 | 20 | 0.040 |
| This work (CERTEC) | Gasoline | 3.0 | 20 | 0.180 |
| This work (CERTEC) | Gasoline | 3.0 | 15 | 0.170 |
| This work (CERTEC) | Gasoline | 4.0 | 15 | 0.150 |
| This work (CERTEC) | Gasoline | 5.0 | 15 | 0.150 |
| This work (CERTEC) | Mixture (50% diesel-oil–50% gasoline) | 3.0 | 20 | 0.071 |
| Garo et al. [2] | Crude-oil | 0.15 | 13 | 0.012 |
| Broeckman and Schecker [1] | Crude-oil | 1.0 | 151 | 0.120 |
| Koseki [3] | Crude-oil | 1.0 | 100 | 0.095 |

## 3. Conclusions

An equation to predict the initial velocity of the convection currents during the process of combustion in hydrocarbon mixtures was proposed. The correlation depends on the initial thickness of the fuel layer and on the average ebullition temperature. The values given by this correlation may help future analyses for predicting the type of boilover and the likelihood for it to occur.

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