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The experiences with the software Jet Fire thermal radiation modelling

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Zkušenosti získané při tvorbě software pro modelování tepelného toku z Jet Fire

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Abstract

The application for the theoretical calculations of Jet Fire based on Yellow book was developed on JAVA platform and tested in NetBeans IDE 7.4. Model calculates the size and shape of a jet for gaseous releases from pipelines, tanks and two-phase releases from tanks. Chamberlain empirical formulas for vertical and inclined burns in a horizontal wind are used to describe the geometry of the flame. The model returns the ground level distance for each of the heat radiation level of concern (tested for 5, 8, 10 kW/m^2). The model was used to calculate the heat radiation as a function of distance for a) C_nH_{2n+2} (alkanes, n = 1-4), b) C_nH_{2n} (alkenes, n = 2-4), c) $C_nH_{2n+1}OH$ (alcohols, n = 1-4) and hydrogen. The main benefit of presented model is that it allows a quick and fast estimation of the heat radiation from Jet Fire and could be further developed according to actual needs. It allows understanding the basic connections and the key parameters of Jet Fire phenomena from both the mathematical and physical point of view that make it primarily suitable for academic purposes.

Keywords: Jet-Fire model; heat radiation, alkanes, alkenes, alcohols

Abstrakt

Na základě Yellow book byla vytvořena aplikace k teoretickému výpočtu tepelného toku z Jet Fire založená na platformě JAVA a testována v prostředí NetBeans IDE 7.4. Modelem je možné spočítat velikost a tvar tryskového požáru pro úniky plynů z potrubí, zásobníků a dvou-fázové úniky ze zásobníků. K popisu geometrie plamene je použit Chamberlainův vztah pro vertikální a horizontální směr vanutí větru. Modelem lze vypočítat vzdálenost k cíli pro různé

hodnoty hustot tepelného toku (testováno pro 5, 8, 10 kW/m^2). Model byl použit k výpočtu hustoty tepelného toku jako funkce vzdálenosti pro a) C_nH_{2n+2} (alkany, n = 1-4), b) C_nH_{2n} (alkeny, n = 2-4), c) C_nH_{2n} (acetylen, n = 2), d) $C_nH_{2n+1}OH$ (alkoholy, n = 1-4) a vodík. Hlavním přínosem prezentovaného modelu je, že umožňuje rychlé stanovení hodnoty hustoty tepelného toku z Jet Fire a může být dále rozvíjen vzhledem k aktuálním inženýrským a výukovým potřebám. Model umožňuje porozumět základním vztahům a klíčovým parametrům jevu Jet Fire jak z matematického, tak z fyzikálního hlediska, což tento model primárně předurčuje pro akademické účely.

Klíčová slova: Jet-Fire model; hustota tepelného toku, alkany, alkeny, alkoholy

1. Introduction

A jet or spray fire is a turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction or directions. Jet Fires can arise from releases of gaseous, flashing liquid (two phase) and pure liquid inventories. Jet Fires represent a significant element of the risk associated with major accidents on offshore installations. The high heat fluxes to impinged or engulfed objects can lead to structural failure or vessel/pipework failure and possible further escalation. The rapid development of a Jet Fire has important consequences for control and isolation strategies. The properties of Jet Fires depend on the fuel composition, release conditions, release rate, release geometry, direction and ambient wind conditions. Low velocity two-phase releases of condensate material can produce lazy, wind affected buoyant, sooty and highly radiative flames similar to pool fires. Sonic releases of natural gas can produce relatively high velocity fires that are much less buoyant, less sooty and hence less radiative. The main objectives of this contribution are (1) to develop quick and fast estimation of the heat radiation from Jet Fire based on the Yellows book Chamberlain model [1]; (2) to initiate the need to increase knowledge and understanding in areas of Jet Fire effects evaluation for students of technical directions [2].

2. Previous studies

The Yellow book model has been generally accepted since 1997 as the semi-empirical model that provided the most accurate and reliable predictions of the physical hazards associated with Jet Fires, providing its application limited to the validation range of the model. This conclusion essentially remains valid today. The most important consideration when assessing the relevance and applicability of mentioned model is the range of data used in its derivation. This model has been developed in several years of research and has been validated with wind tunnel experiments and field tests both onshore and offshore. An in-depth description of the model is reported in Chamberlain [3]. Chamberlain's model was selected over the alternative point source model since the latter is known to be insufficient within one to two flame lengths for short-term radiation levels although sufficiently accurate in the far field. The Chamberlain better mimics the actual size and shape of a flare. In the literature [4],[5] could be identified two versions of the model, [3] and [6], both of which approximated the geometry of a flare as a frustum of a cone. While Kalghatgi's used small burners in a wind tunnel, the main focus of Chamberlain's work was on field trials at onshore oil and gas production installations. Both models used empirically fit equations to describe the flame shape. In fact, Chamberlain uses empirical equation to derive the flame length. Because Chamberlain's work was more recent and involved larger scale testing, the Chamberlain model was selected to describe thermal radiation hazards for Jet Fire.

3. Mathematical model

The model represents the flame as a frustrum of a cone, radiating as a solid body with a uniform surface emissive power. Correlation describing the variation of flame shape and surface emissive power under a wide range of ambient and flow conditions. The input parameters for chemicals are taken from DIPPR database [8].

3.1 Calculation of the flame dimensions

Steps 1-8 show the calculation of the exit velocity of an expanding jet. This exit velocity is an important parameter for the calculation of the flame length, lift-off and the widths of the frustum. First the properties of the flammable material are required for the calculation of the exit velocity of the gas, i.e.: molecular weight, the Poisson constant and the storage conditions of the gas, such as temperature and the pressure.

The mass fraction of fuel in a stoichiometric mixture with air:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (1)$$

where W = mass fraction of fuel in a stoichiometric mixture with air [-]; W_g = Molecular weight of gas [kg/mol].

Ratio of specific heat - Poisson constant:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (2)$$

where γ = ratio of specific heat - Poisson constant [-]; C_p = specific heat capacity at constant pressure [J/kg.K]; R_c = gas constant 8.314 [J/mol.K]; W_g = Molecular weight of gas [kg/mol].

For high pressure gas:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (3)$$

where γ = Poisson constant [-]; C_p = specific heat capacity at constant pressure [J/kg.K]; C_v = specific heat capacity at constant volume [J/kg.K]; R_c = gas constant 8.314 [J/mol.K].

The temperature of the expanding jet:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (4)$$

where T_j = temperature of the expanding jet [K]; T_s = initial temperature of the gas [K]; P_{air} = atmospheric pressure [N/m^2]; P_{init} = initial pressure [N/m^2]; γ = ratio of specific heat - Poisson constant [-].

The static pressure at the hole exit plane:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (5)$$

where P_c = static pressure at the hole exit plane [N/m^2]; P_{init} = initial pressure [N/m^2]; γ = ratio of specific heat - Poisson constant [-].

The Mach-number for chocked flow of an expanding jet:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (6)$$

where M_c = Mach-number for chocked flow of an expanding jet [-]; γ = ratio of specific heat - Poisson constant [-]; P_c = static pressure at the hole exit plane [N/m^2]; P_{air} = atmospheric pressure [N/m^2].

The Mach-number for unchocked flow of an expanding jet:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (7)$$

where M_j = Mach-number for chocked flow of an expanding jet [-]; γ = ratio of specific heat - Poisson constant [-]; m´ = mass flow rate [kg/s]; d_0 = diameter of the hole [m]; T_j = temperature of the expanding jet [K]; W_g = Molecular weight of gas [kg/mol].

The exit velocity of the expanding jet:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (8)$$

where u_j = exit velocity of the expanding jet [m/s]; Mach-number for (un)chocked flow of an expanding jet [-]; R_c = gas constant 8.314 [J/mol.K]; T_j = temperature of the expanding jet [K]; W_g = Molecular weight of gas [kg/mol].

By increasing the gas velocity, the fraction of heat released as radiation and the levels of heat radiation received radiation are reduced.

3.2 Calculation of the flame dimensions

In steps 9-22 position and dimensions of the flames are determined. These position parameters are required to calculate the lift-off and angle of the flame with respect to the object. This is important for the calculation of the view factor. The flame dimensions are used to calculate the surface area of the flame.

The ratio of wind speed to jet velocity:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (9)$$

where R_w = ratio of wind speed to jet velocity [-]; u_w = wind velocity [m/s]; u_j = exit velocity of the expanding jet [m/s].

The density of air:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (10)$$

where ρ_{air} = density of air [-]; P_{air} = atmospheric pressure [N/m^2]; W_{air} = Molecular weight of air [kg/mol]; R_c = gas constant 8.314 [J/mol.K]; T_{air} = air temperature [K].

Combustion effective source diameter:

In combustion modeling the effective source diameter is widely used concept, representing the throat diameter of an imaginary nozzle releasing air of density at mass flow rate m.

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (11)$$

where D_s = effective source diameter [m]; m´ = mass flow rate [kg/s]; ρ_{air} = density of air [-]; u_j = exit velocity of the expanding jet [m/s].

Combustion effective source diameter in case of a chocked flow:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (12)$$

where d_j = diameter of the jet at the exit hole [m]; P_c = static pressure at the hole exit plane [N/m^2]; W_g = molecular weight of gas [kg/mol]; ρ_{air} = density of air [kg/m^3]; R_c = gas constant 8.314 [J/mol.K]; T_j = temperature of the expanding jet [K].

The jet expands to atmospheric pressure at a plane downstream of the exit hole with the plane acting as a virtual source of diameter.

It can be assumed that the diameter of the jet fire about equal as the diameter of the hole.

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (13)$$

where Y = variable coefficient calculated by iteration [-]; D_s = effective source diameter [m]; u_j = exit velocity of the expanding jet [m/s]; W_g = molecular weight of gas [kg/mol].

The length of the Jet Fire in still air:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (14)$$

where L_{b0} = flame length in still air [m]; Y = variable coefficient calculated by iteration [-]; D_s = effective source diameter [m].

For a tilted jet, Kalghatgi [6] showed in laboratory experiments that the flame length reduces as the jet is tilted into the wind. Chamberlain [3] uses Kalghatgi's empirical fit equation to determine the flame length, L_b. Extending from the center of the hole to the flame time, L_b, is calculated.

The length of the Jet Fire measured from the tip of the flame to the center of the exit plane:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (15)$$

where L_b = length of the Jet Fire measured from the tip of the flame to the center of the exit plane [m]; L_{b0} = flame

length in still air [m]; u_w = wind velocity [m/s]; Θ_{jv} = angle between hole axis and the horizontal in the direction of the wind [°].

The Richardson number of the flame in still air:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (16)$$

If $R_w \leq 0.05$, then the flame is dominated, the tilt angle is given by:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (17)$$

where α = the tilt angle [°]; Θ_{jv} = angle between hole axis and the horizontal in the direction of the wind [°]; $R_i(L_{b0})$ = Richardson number [-], R_w = ratio of wind speed to jet velocity [-].

If $R_w > 0.05$, then the flame tilt becomes increasingly dominated by wind forces:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (18)$$

where α = the tilt angle [°]; Θ_{jv} = angle between hole axis and the horizontal in the direction of the wind [°]; $R_i(L_{b0})$ = Richardson number [-], R_w = ratio of wind speed to jet velocity [-].

The lit-off of the flame by the following empirical relation:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (19)$$

where b = lit-off of the flame [m]; L_b = length of the Jet Fire measured from the tip of the flame to the center of the exit plane [m]; R_w = ratio of wind speed to jet velocity [-].

In still air (α = 0°), $b = 0.2 \cdot L_b$. For flames pointing directly into the high winds (α = 180°), $b = 0.015 \cdot L_b$.

Length of frustum (flame):

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (20)$$

where R_l = length of frustum [m]; L_b = length of the Jet Fire measured from the tip of the flame to the center of the exit plane [m]; b = lit-off of the flame [m]; α = the tilt angle [°].

Ratio between air and jet density:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (21)$$

where ρ_{air} = density of air [-]; ρ_j = density of jet [-]; T_j = temperature of the expanding jet [K]; W_{air} = molecular weight of air [kg/mol]; T_{air} = temperature of air [K]; W_g = molecular weight of gas [kg/mol].

Richardson number based on the combustion source diameter, used for the calculation of the frustrum base width:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (22)$$

where $R_i(D_s)$ = Richardson number based on the combustion source [-]; D_s = effective source diameter [m]; uj = exit velocity of the expanding jet [m/s].

Constant for calculation the frustrum base width:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (23)$$

where C = constant for calculation the frustrum base width [-]; R_w = ratio of wind speed to jet velocity [-].

The frustrum base width:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (24)$$

where W_1 = width of frustrum base [m]; D_s = effective source diameter [m]; R_w = ratio of wind speed to jet velocity [-]; P_{air} = atmospheric pressure [N/m^2]; P_j = jet pressure [N/m^2].

The frustrum tip width:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (25)$$

where W_2 = width of frustrum tip [m]; L_b = length of the Jet Fire measured from the tip of the flame to the center of the exit plane [m]; R_w = ratio of wind speed to jet velocity [-].

The surface area of frustrum, including end discs:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (26)$$

where A = surface area of frustrum including end discs [m^2]; W_1 = width of frustrum base [m]; W_2 = width of frustrum tip [m].

3.3 Calculation of the surface emissive power

The surface emissive power can be calculated with the net heat released from combustion of the flammable gas, the fraction of that part of the heat radiated and the surface area of the frustrum.

The net heat per unit time released:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (27)$$

where Q = combustion energy per second [J/s]; m´ = mass flow rate [kg/s]; ΔH_c = heat of combustion [J/kg].

The fraction of heat radiated from the surface of the flame:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (28)$$

where F_s = fraction of heat radiated from the surface of the flame [-]; u_j = exit velocity of the expanding jet [m/s].

The surface emissive power:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (29)$$

where SEP_{max} = maximum surface emissive power [J/m^2.s]; F_s = fraction of heat radiated from the surface of the flame [-]; Q = combustion energy per second [J/s]; A = surface area of frustrum including end discs [m^2].

3.4 Calculation of the view factor:

Coordinate transformation to X´, Θ´ is required before a model for the calculation of the view factors can be used.

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (30)$$

where X´ = distance from the center of the bottom plane of a lifted-off flame o the object [m]; b = frustrum lift-off height [m]; Θ_j = angle between the centerline of a lifted-off flame and the object [°]; X = distance from the center of the flame without lift-off to the object [m].

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (31)$$

where Θ´ = angle between the centerline of lifted-off flame and the plane between the center of bottom of the lifted-off flame and the object [°]; Θ_j = angle between the centerline of a lifted-off flame and the object [°]; α = angle between hole axis and the flame axis [°]; b = frustrum lift-off height [m]; X = distance from the center of the flame without lift-off to the object [m].

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (32)$$

where x = distance from the surface area of the flame to the object [m]; X´ = distance from the center of the bottom plane of a lifted-off flame o the object [m]; W_1 = width of frustrum base [m]; W_2 = width of frustrum tip [m].

3.5 Calculation of atmospheric transmissivity

Partial vapor pressure of water in air at a relative humidity:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (33)$$

where p_w = partial vapor pressure of water in air at a relative humidity RH [Pa; N/m^2]; RH = relative humidity of air [%rel/100]; T_a = absolute temperature of ambient air at standard conditions [K].

Calculation of the atmospheric transmissivity (valid for $10^4 < p_w \cdot x < 10^5$) if absorption coefficient of water vapor and absorption coefficient of carbon dioxide is not known:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (34)$$

where τ = atmospheric transmissivity [-]; p_w = partial vapor pressure of water in air at a relative humidity RH [Pa; N/m^2]; x = distance from the center of the Fire Ball to the radiated object [m].

Calculation of the atmospheric transmissivity if absorption coefficient of water vapor and absorption coefficient of carbon dioxide is known:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (35)$$

where τ = atmospheric transmissivity [-]; α_w = absorption coefficient of the water vapor for an average flame temperature [-]; α_c = absorption coefficient of the carbon dioxide for an average flame temperature [-].

3.6 Calculation of the heat flux at a certain distance

With the dimensions of the flame and the view factor the thermal heat flux at a certain distance x from the heat source can be calculated:

$$W = \frac{W_g}{15.816 \cdot W_g + 0.0395} \quad (36)$$

where q´´= thermal heat flux at a certain distance x from the heat source [J/m^2.s]; SEP_{max} = maximum surface emissive power [J/m^2.s]; F_s = fraction of heat radiated from the surface of the flame [-]; τ = atmospheric transmisivity [-].

4. Results and discussions

In the following calculation example the heat radiation was calculated as a function of distance for an object at a certain distance i.e. 150 m from the surface of the jet flame. Data from [1], [8] has been used as the input values for the calculation example of chocked flow through the 0.1 m hole diameter in high pressure pipeline. We calculated heat radiation as a function of distance for hydrogen and we compared calculated results with a) C_nH_{2n+2} (alkanes, n = 1-4); b) C_nH_{2n} (alkenes, n = 2-4); c) C_nH_{2n-2} (acetylene, n = 2); d) $C_nH_{2n+1}OH$ (alcohols, n = 1-4). From chemical point of view we investigated chemicals (hydrocarbons) with a) different number of carbon atoms; b) and c) different bonds order; d) hydroxyl chemical functional group. The results of calculations are illustrated in Figures 1-2.

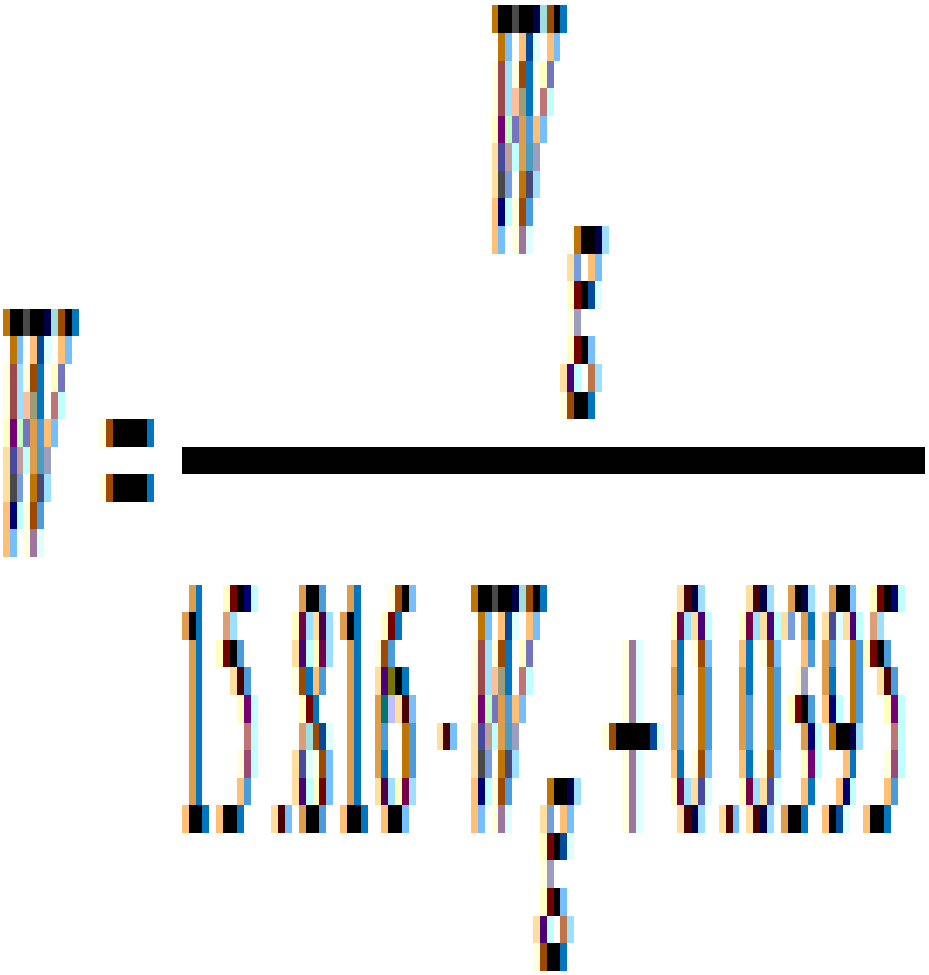

Figure 1: Heat radiation as a function of distance for hydrogen and a) C_nH_{2n+2} (alkanes, n = 1-4); b) C_nH_{2n} (alkenes, n = 2-4).

We can see at Figure 1a that there is a simple increasing trend going from the C1 to the C4 species (24.0 kW/m^2, 26.4 kW/m^2, 30.2 kW/m^2, 33.7 kW/m^2). The calculated theoretical values of heat radiation curve have its maximum at approximately 9.7 m as a distance of the flame to the object. The lethal value of radiation taken as 10 kW/m^2 corresponds to 31.5 m (C1), 34.5 m (C2), 38.2 m (C3) and 42 m (C4), respectively. Similarly, we can see at Figure 1b that there is also a simple trend going from the C1 to the C4 species (26.4 kW/m^2, 25.3 kW/m^2, 32.8 kW/m^2). The calculated theoretical values of heat radiation plot have its maximum at approximately 5.2 m as a distance of the flame to the object. The lethal value of radiation taken as 10 kW/m^2 corresponds to 31.5 m (C1), 34.5 m (C2), 38.2 m (C3) and 42 m (C4), respectively. For further comparison we divide the plots from Figures 1a,b into two parts from the point of view of distance. First part will be from 0 mto 5.2 m and the second part will be from 5.2 mto approximately 60 m. If we compare the theoretical calculated results for the first part we can recognize that the line for C_nH_{2n+2} (alkanes, n = 1-4) is less increasing than that for C_nH_{2n} (alkenes, n = 2-4). If we compare the theoretical calculated results for the second part for both tested systems we can see that the line for C_nH_{2n+2} (alkanes, n = 1-4) is less decreasing than that for C_nH_{2n} (alkenes, n = 2-4). As a conclusion both results show that the profile shape factor of C_nH_{2n+2} (alkanes, n = 1-4) is more sharp than that of C_nH_{2n} (alkenes, n = 2-4). These basic facts concerning the heat radiation as a function of distance for the species with different bonds orders could be recognized and could be further

analyzed by comparing them with the species substituted by hydroxyl chemical functional group. In both cases, the theoretical calculations of hydrogen heat radiation as a function of distance (denoted by the red color in Figures 1a,b) have been used for scaling (from 0 m to 150 m). As in the case of alkanes and alkenes, we can see at Figure 2a the value of acetylene heat radiation (24.7 kW/m^2). The calculated theoretical value of heat radiation curve has its maximum at approximately 5.2 m as a distance very similar to that obtain for alkenes. The lethal value of radiation taken as 10 kW/m^2 corresponds to approximately 24.7 m which is slightly lower than 25.3 kW/m^2 for C_2H_4. For further comparison we divide the plots from Figures 1a,b into two parts from the point of view of distance. We can see at Figure 2b that there is also a simple trend in alcohol substituted species going from the C1 to the C4 species (11.2 kW/m^2, 17.8 kW/m^2, 22.8 kW/m^2, 24.3 kW/m^2). This may be related to the fact that the molecular structure of the OH· moiety change under substitution heat radiation value much more than in C_nH_{2n+2}, as shown by presented theoretical calculation, confirmed by results of experimental studies $C_nH_{2n+1}OH$. Apart from the trends investigated in different number of carbon and different bonds order aspects, the study of calculated jet, fire and heat flux parameters and for calculation used constants are of importance.

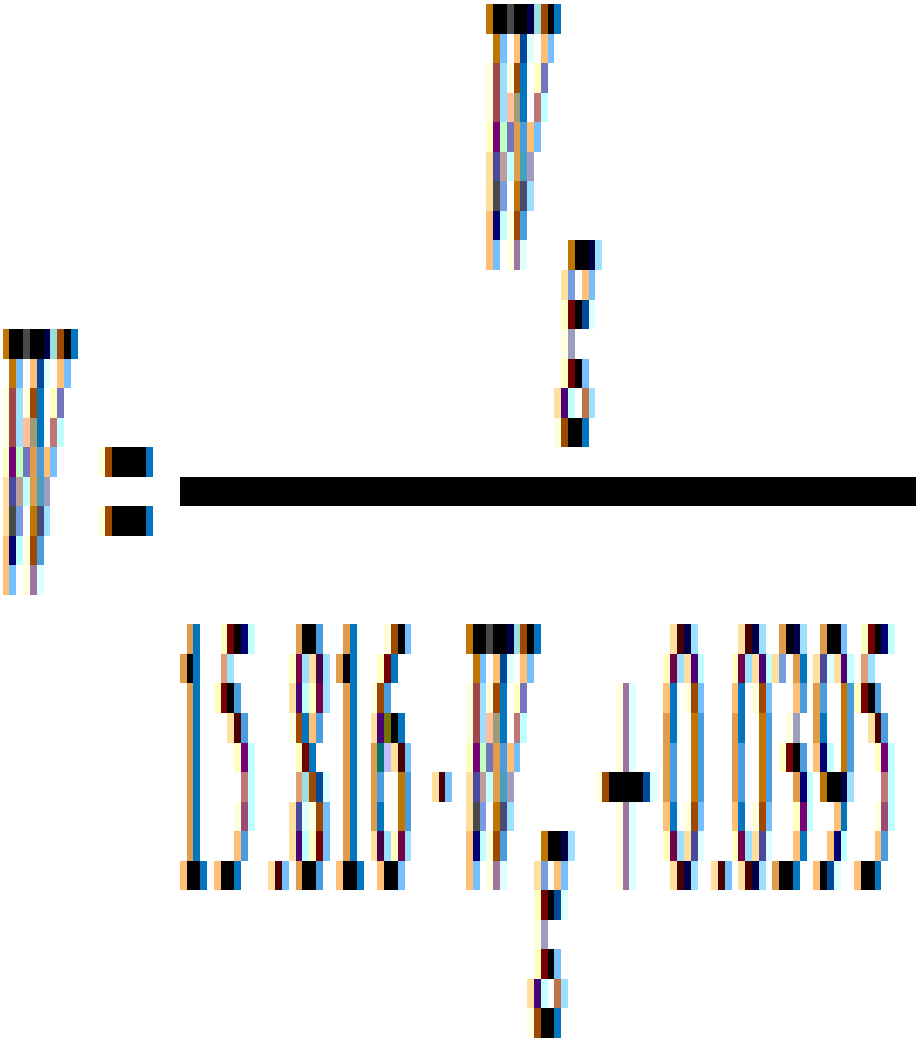

Figure 2: Heat radiation as a function of distance for hydrogen and a) CnH2n-2 (acetylen, n = 2); b CnH2n+1OH (alcohols, n = 1-4).

All jet, fire and heat flux parameters used for calculation of the heat radiation as a function of distance were established during the present investigation for the first time, and the values of alkanes, alkynes and acetylene could be compared with those of their alcohols analogues. The present gas phase (alkanes, alkenes, alkynes) and two-phase (alcohols) investigation has started the series of studies by mathematical modelling of the substituted hydrocarbons. The calculated values of parameters characterizing the jet, fire and heat radiation have been accurately determined for methane, and they compare well with the theoretical calculations listed in [1]. These values are typical of the hydrocarbons of non-multiple bonds. The mass fraction of fuel in a stoichiometric mixture with air, W, together with gas constant, R_c, and specific heat capacity, C_p, was effectively transformed into ratio of specific heat - Poisson constant, γ. The value of Poisson constant γ = 1,306 has been of comparable value with the value γ^Y = 1,307 published in [1]. The Mach-number, M_j ,for chocked flow of an expanding jet has been determined in this investigation. The Mach-number is estimated from the temperature of the expanding jet, T_j, and the static pressure, P_c, at the hole exit plane [N/m^2]. The value of the Mach-number M_j = 3,95 has been of slightly higher value than the value M_j^Y= 3,55 published in [1]. The further parameters values are in good agreement with the values published in [1].

5. Conclusion

(1) exit velocity of expanding jet [m/s]; (2) angle between hole and flame axis [°]; (3) frustum lift-off height [m]; (4) width of frustum base [m]; (5) width of frustum tip [m]; length of frustum (flame) [m]; (6) surface area of frustum [m^2]; (7) maximum surface emissive power [kW/m^2]; (8) atmospheric transmissivity [%] and view factor [-]. Further parameters could be implemented based on actual needs. In the near future we are planning to compare the results of the C_nH_{2n+2} (alkanes, n = 1-4), C_nH_{2n} (alkenes, n = 2-4), C_nH_{2n-2} (acetylene, n = 2), $C_nH_{2n+1}OH$ (alcohols, n = 1-4) calculations with the results obtained by procedure Jet Fire (Chamberlain model) implemented as a part of the program Effects version 9.0.8 that will be possible to use a tour department. This model could be further developed according to present engineering knowledge and can make a contribution towards solving the problems facing the flammable liquefied fuels in industrial practice in assessment of jet fire hazards comprises (1) identification of areas of uncertainty in the characterization of jet fires; (2) identification where the jet fire hazard is significant in relation to other hydrocarbon hazards; (3) initiation of research to increase knowledge and understanding in ill-defined areas of Jet Fire evaluation and (4) promote the use of a consistent methodology for evaluation of jet fire hazards. Furthermore, the model application and development could support the practice of the Department of Major Accidents Prevention of Occupational Safety Research Institute.

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