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ESTIMATION OF THE HEAT RELEASE RATE OF COMPARTMENT FIRES USING INVERSE FIRE MODELING WITH GENETIC ALGORITHM

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ABSTRACT:-
A sudden accident or a natural catastrophe that causes great damage or loss of life. From these hazards fire incidents are the major accidents that hamper the progress and well being of mankind. Inverse Fire Model (IFM) is one of them, it can estimate the average heat release rate inside a building in an attempt to aid fire fighting operations. In this article, one separate compartments was made to represent an office that a fire may occur. Size of compartment was 10m x 10m x 3m. IFM are used to estimate the fire size in compartment. The IFM model describes the intensity of fire, fire conditions, inside a building. This model also tries to evaluate the fire conditions by employing the GA. The GA can use multiple parameters like MLR, vent dimensions, HRR etc. Another advantage of GA is that one can arrive at the ideal solution by giving different values of parameter in algorithms. This would result in getting a situation that it is very much near to the real values.

Keywords: MLR, HRR, IFM, GA

1. Introduction:-

A sudden accident or a natural catastrophe that causes great damage or loss of life. From these hazards fire incidents are the major accidents that hamper the progress and well being of mankind. By experience mankind know that total prevention of unwanted fire is not possible. However there has been every effort to reduce the loss incurred due to such 'unfriendly fire'. With the progress of science and technology the knowledge about factors that are responsible for accidental fire and protection against fire has been increased.

From various fire accidents here we consider the fire accidents which occurs in compartments. Generally a compartment fire has two layers namely upper layer and lower layer. In the upper layer there are hot products like CO_2,CO etc. These products are collected in the area below the ceiling. In the lower layer there is ambient air that is in contact with the base of the fire.

There are many models provided by fire engineering, physics, chemistry and mathematics. Since the inverse mathematical model can be used to detect fire source and measure it.

Inverse Fire Model (IFM) is one of them, it can estimate the average heat release rate inside a building in an attempt to aid fire fighting operations. It provides the profile of the upper layer temperature, from which an estimate can be made of the average heat release rate inside a building. The recorded upper layer temperature is used as inputs into the IFM to find the average fire.

2. Methodology

This study uses genetic algorithm, and two layer fire model. This model will provide an estimate of the HRR (heat release rate). The genetic algorithm uses a fitness function. This evaluation function minimizes the error between estimated values and reference temperature. A number of estimates will be done to minimize the error. The genetic algorithm will subsequently give population generated from initial population that will help arrive at fitness. In this, it is assumed that HRR is an average value.

2.1 Fire modeling

To predict the behavior of fire in a compartment, physical equations must be made in terms of fire. Such a model is an idealization of the compartment phenomenon. Consider a fire, which starts at some point below the ceiling & which releases energy and products of combustion. The hot products of combustion reach the ceiling and spread out to form a hot gas layer. On reaching the ceiling, the hot product of combustion turn into a near-ceiling horizontally outward flow. A layer of hot gases is soon formed in the upper portion of the compartment. There is a sharp interface between the hot upper layer and the layer in the lower part of the compartment. It is assumed that the distribution of temperature and other properties are uniform throughout each layer.

One separate compartments was made to represent an office that a fire may occur. Size of compartment was 10m x 10m x 3m. The wall materials are flexible fiber board. It had a single door to the outside, sized at 1mx2m.

2.2 Compartment test procedure

The set of test focused on estimating the heat release rate as a single parameter. The test is focused on estimating the heat release rate as a single parameter.

The genetic algorithm was tested to estimate the fire size of a reference B R I. If the genetic algorithm proved that it could successfully estimate the average heat release rate with reasonable certainty, the proof of concept can be validated.

2.3 Genetic Algorithm

It is one of the widely used functional optimization tools in engineering and mathematical problems. It is capable of solving problems related to many local minima and maxima. The important plus point of this tool is its capacity of handling multiple parameters.

In this, the G.A (Genetic Algorithm) application is centered on a reference curve given by BRI (building related illness). G.A will be needed to determine the accuracy of potential solution estimates in relation to the reference curve. In this model the ventilation inside a compartment, and the size of fire are unknown parameters. The G.A allows one to use many simulation with different compartment size. The Genetic algorithm begins its process with an initial population of individual candidates. Each individual candidate contains parameters i.e.; mass loss rate, door width, door height, window width depending on the problem. This initial population can either be manually inputted to the genetic algorithm. In the genetic algorithm it is specified that each parameter be maintained between user specified bounds. For example the mass loss rate can be specified to be between 200-6,000 kw for the entire simulation, and the door width between 0-2m.

After the generation of initial population, each individual candidate is assigned fitness. The fitness function measures the error between the upper layer temperature of the reference curve and the upper layer temperature created by an individual. The fitness function is a least square function. The fitness function is in the form of

$$f = \left(\sqrt{\frac{\sum_{n=1}^{N} \left(T_{ref}(t_n) - T_{try}(t_n) \right)^2}{N}} \right)^{-1}$$

Where **{Neviackas, A. W. (2007)}**

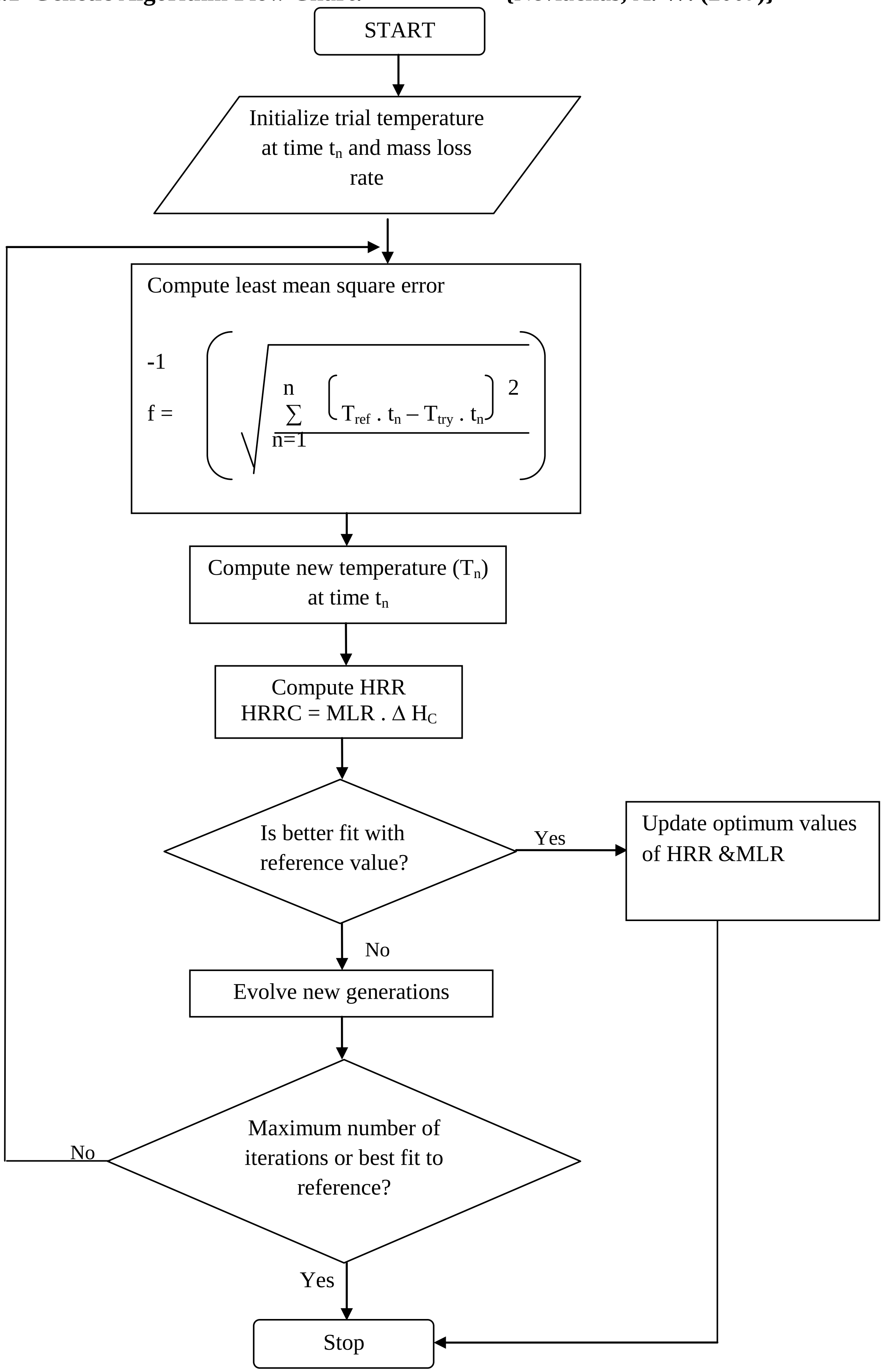
T_{ref} → Reference temperature from BRI

T_{try} → Trial temperature

T_n → Time at n second.

N → Number of generations

2.1.1 Genetic Algorithm Flow Chart:- {Neviackas, A. W. (2007)}



3. Result and Discussion:-

Results analyzing the ability of IFM to estimate the fire size for either a single parameter (HRR) is described. Mass loss rate is the corresponding fire size in kw that is input into BRI. Heat Release Rate is the fire size in kw that actually burns inside a compartment based on the mass burning rate.

3.1 Temperature rise at fire accident:-

Curve of fire temperature with respect to time is plotted for different parameters.

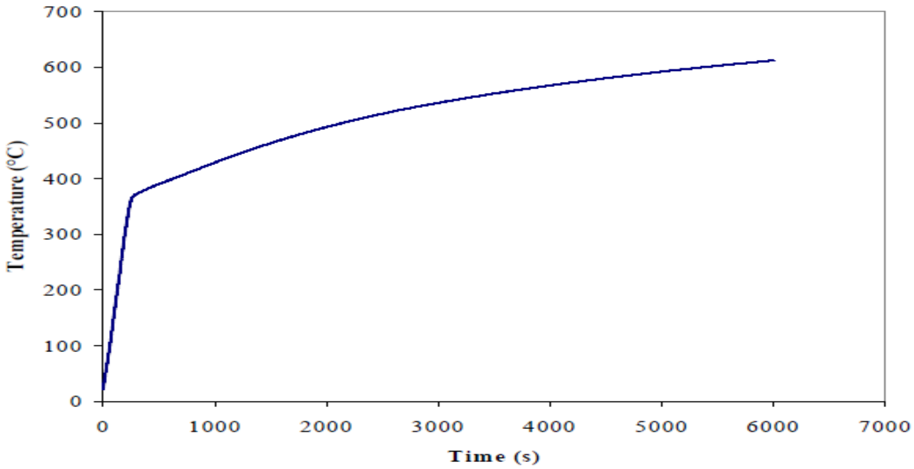


Figure:- 1 Temperature curve from 1-6000s

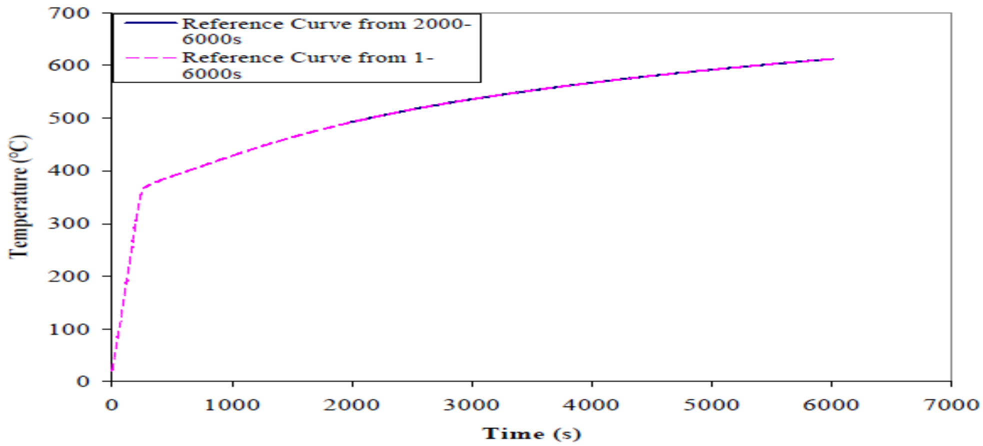


Figure:- 2 Temperature curve from 2000-6000s

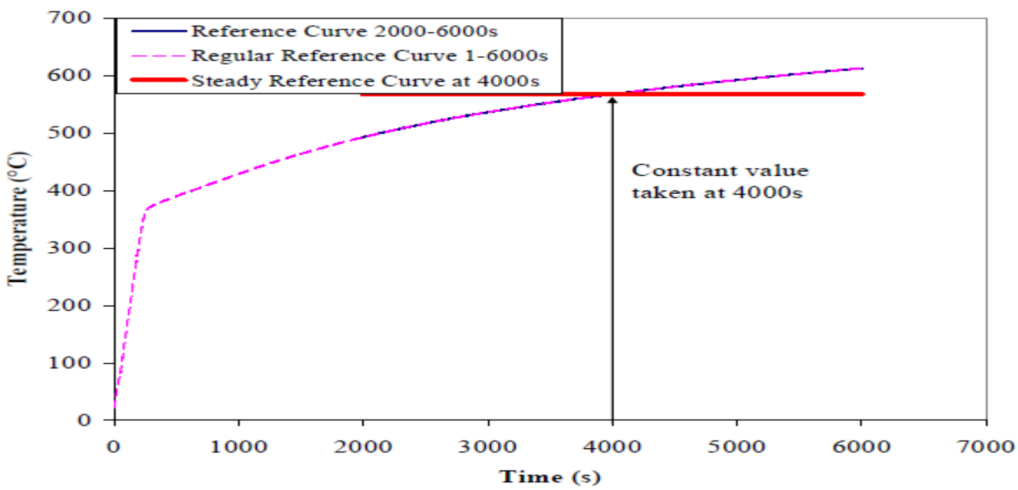


Figure:- 3 steady Temperature curve at 4000s

From the above graph, it is observed that after the fire accident, initially the temperature rises rapidly but after passes of time at t=4000s, the rise in temperature is steady.

3.2 HRR (Heat Release Rate)

HRR (Heat release rate) is calculated with the help of genetic algorithm which is discussed above (Content 2.2).

Sl. No.	Reference MLR	Reference Average HRR (0-6000 s)	GA best MLR	GA best average HRR (2000-6000 s)
SC 10mx10mx3m Fb a1	1920kW	1406kW	1917kW	1408kW
SC 10mx10mx3m Fb a2	2400kW	1485kW	2423kW	1489kW
SC 10mx10mx3m Fb a3	2400kW	1485kW	2402kW	1486kW

Table 1:- HRR as per GA and BRI

It can be seen from the table that best results are produced. For example there is a difference of only 3 kW between G.A best and reference MLR (Reference: MLR 1920 kw and GA best 1917 kW).

In the following figure two temperature profiles are shown. These temperature profiles are upper layer temperature reference curve and GA best estimate. As seen in the figure they are identical.

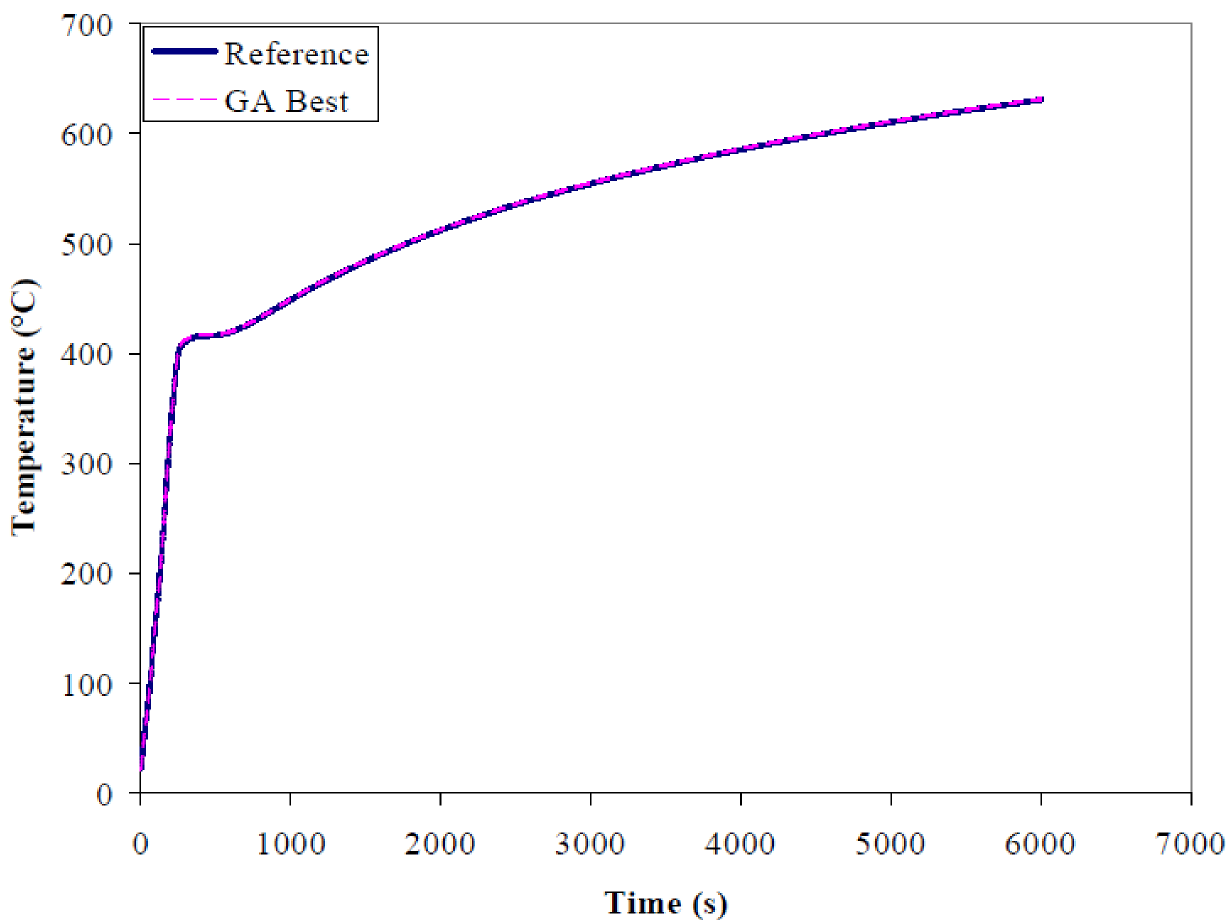


Figure 4:- The upper layer temperature of the reference simulation and the GA best simulation

3.3 MQH Correlation:-

MQH correlation is an alternative to IFM model that relates fire size to upper layer temperature and compartment configuration.

MQH correlation is defined as

$$\dot{Q} = \left[\left(\frac{\Delta T_g}{6.85} \right)^3 * \left(A_0 \sqrt{H_0} h_k A_T \right) \right]^{1/2}$$

IFM estimate	MQH Correlation
1408kW (4000s)	1423 kW
1489kW (4000s)	1495 kw
1486kW (4000s)	1490kw

Table 2:- MQH estimate vs. IFM estimate

As can be seen for a steady 1408 Kw fire was calculated in IFM, the MQH correlation estimates a fire size of around 1423 Kw at a corresponding temperature value taken at 4000s. For the 1489 kw fire as calculated in IFM, the MQH correlation estimates a fire size of 1495 kw for a corresponding temperature value at 4000s.

4. Conclusion

In this particular model a comprehensive attempt is made to implement a methodology that would help analyzing a real situation. For that purpose an IFM model is employed. The IFM model describes the intensity of fire, fire conditions, inside a building. This model also tries to evaluate the fire conditions by employing the GA. The GA can use multiple parameters like MLR, vent dimensions, HRR etc. Another advantage of GA is that one can arrive at the ideal solution by giving different values of parameter in algorithms. This would result in getting a situation that it is very much near to the real values.

The immediate advantage of this is for fire fighters. Most often their life is in rich, merely because of the lack of understanding of the intensity of fire inside the building. But the HRR help them to measure the heat inside the building. On the basis of this information, they can productively put out the fire. Thus this mechanism saves the life of the fire fighters and reduces the cost of fire fighting. It also save the building by controlling the fire that may develop into a big one to destroy the entire building.

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