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Reliability Analysis of El Houareb Dam Kairouan – Tunisia – Case Study

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Abstract. The present paper deals with the reliability analysis of El Houareb earth dam (Tunisia). A conventional Three-dimensional limit equilibrium analysis has been performed for the dam using CLARA computer program. Also a simplified reliability associated with particular failure mechanism, is considered. The Spatial variability of soil properties is represented by a random field. The global probability of failure of El Houareb earth dam has been investigated.

***Keywords*:** Earth Dam, Reliability Analysis, Three-dimensional Limit Equilibrium Analysis

1. Introduction

Recently progress has been made in the application of probabilistic approach to geotechnical engineering problems. It appears that the probabilistic techniques offer the only systematic way of treating and reducing uncertainty within the design process. Moreover, it is only in terms of probability that the degree of uncertainty can be related quantitatively to the reliability of the engineering and geotechnical design of earth dam [1]. The correlation of mechanical and physical properties between two points in space within a dam exists [2].

Risk assessment of embankment dams must address both consequence of dam's slope failure and hazard or probability of failure (or reliability index), both require an understanding of the failure mechanism in order that the probabilities can be addressed.

2. Reliability Analysis of Earth Dams

Geotechnical engineering reliability analysis is concerned with finding the reliability or probability of failure (or reliability index) of structure or system. The benefit of reliability analysis in geotechnical engineering can be summarized in the few following points:

- to highlight the uncertainties in design of these structures. Reliability analysis plays a major role in considering the uncertainties influencing the design of earth structures. For example, an optimum procedure for design of an embankment can be discussed where there are uncertainties with regard to a stability problem.

- allow the geotechnical engineer to quantify the effect of various failure preventive measures on these structures in order to develop both, an inspection and maintenance programs.

The capacity-demand is the simplest and most utilized model for the reliability evaluation of most geotechnical structures, in particular existing earth dams. In this model, the question of interest is the probability of failure related to a load event rather than the probability of failure within a time interval. Reliability assessment methods are being adopted to develop the rigorous risk-management programs. Implementing the programs will ensure that the safety is maintained to a robust and acceptable level.

The reliability analysis typically includes the following steps:

- Establishing limit states,
- Identifying failure modes,
- Formulating limit state functions,
- Analyzing uncertainty,
- Evaluating reliability, and
- Assessment results.

The reliability index of earth dams is commonly taken as the value corresponding to the failure surface associated with minimum reliability index. The conventional factor of safety is defined as the ratio of limit capacity of soil to a demand in terms of loads, as follows:

$$F = \frac{R}{S} \tag{1}$$

in which:

R: The capacity (resisting force or resisting moment); and

S: The demand (driving force or driving moment).

In probabilistic modeling of safety, R and S are assumed to be random variables. Let $f_R(r)$ and $f_S(s)$ be the probability densities functions of variables R and S. The probabilistic measure of safety is the probability of failure, P_f in which should be smaller than certain reference values set a priori. The probability of failure is defined as (failure occurs if R<S):

$$P_f = P\left(\frac{R}{S} \le 1\right) \tag{2}$$

Assuming statistical independence between the variables R and S, the probability of failure can be expressed as:

$$P_f = \int_{-\infty}^{+\infty} f_S(s)\left(\int_{-\infty}^{r=s} f_R(r)dr\right)ds \tag{3}$$

The use of formulation (3) of probability of failure makes the simplification possible only for certain types of distribution of R and S such a normal distribution. In such case the notion of safety margin, MS=R-S (Cornell 1970) can be introduced. It is Possible to derive the density function $f_{MS}(MS)$ of the random variable MS and the risk of failure is given as:

$$P_f = \int_{-\infty}^{0} f_{MS}(MS)d(ms) \tag{4}$$

In general, the calculus of the integrals in the preceding equation is particularly cumbersome. In this case, the safety is defined by the reliability index, β, as [3]:

$$\beta = \frac{E\{MS\}}{\sigma_{MS}} \tag{5}$$

in which:

E{MS}: Expected value of MS; and σ_{MS}: Standard deviation of MS, p

Equation (5) provides a simple quantitative basis for assessing the risk i.e. probability of failure.

The advantage of reliability index is that it can be determined from two first statistic moments (mean value and variance) of probability density functions of R and S without any assumption on the specific shape of these functions.

However, embankments are considered as systems composed of several "infinite" number of possible failure surfaces associated with different reliability indices. Therefore, the global probability of failure of embankment is however, at least for the moment, a complicated problem to handle since correlation exists between different failure surfaces. Subsequently, the global probability of failure will be investigated in the case study of El houareb dam.

3. Case Study: El Houareb Dam

3.1 Description and Presentation

El Houareb dam (Central Tunisia) is selected as a case study to perform the reliability analysis. The main objective of this dam is to contain Merguellil Wadi Floods. El Houareb reservoir is a man-made water-body built on the Oued Merguellil, 35 km east of Kairouan, for flood-control and water-supply purposes. Where the river emerges from the Dorsale, the reservoir is bordered by higher land, but also has extensive flat shores. It retains the waters which once flowed into Sebkha Kelbia (Kairouan city, Tunisia). The average reservoir depth is nearly 20 m, but in periods of poor rainfall, it can remain completely dry for several years on end. The water plant grows commonly in the reservoir and provides the main food-source for wild fowl. The hydraulic characteristics of El Houareb dam are:

- Area of basin pouring: 1,120 km^2
- Total capacity: 95.3 x 10^6 m^3
- Yearly average contribution: 70 x10^6 m^3.

El Houareb dam is founded on a sedimentary basin. It is filled with a Triassic, Cretaceous; Tertiary aged marine and fluvial sedimentary rocks fractured rock mass on its right side. The dam has a height of 32 m and crest width of 8.5 m. A berm of 40 m long located at the downstream side. The clay core, which provides impermeable barrier within the body of the dam, has a sloppy upstream, 6 m wide at the top and 21 m wide at the foundation level. The compacted materials, Table (1), were evaluated according to their maximum dry unit weight (γ_{dmax}), optimum water content (w_{opt}), specific gravity (G_s), liquid limit (LL) and plasticity index (I_p), all the parameters except specific gravity indicated the desirable characteristic as an impervious fill material. Engineering analyses for the proposed dam were performed to evaluate a suitable dam section for the site conditions and available on-site construction materials, Figure (1).

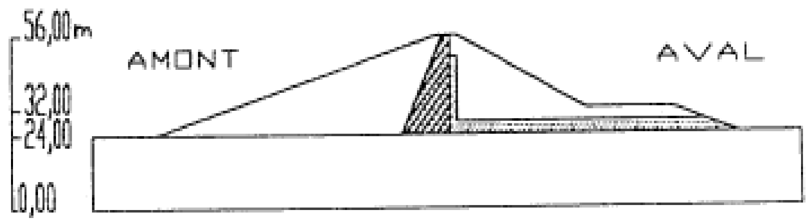

Fig. (1). Cross-section of El Houareb dam, Elevation is in meters

Table (1). Geotechnical properties of soils and earth dam materials. γ **=dry density, c= cohesive strength, Φ'=friction angle, E= Young's modulus, ν = Poisson ratio**

Nature of soils	γ (KN/m^3)	c (Mpa)	Φ' (°)	E (Mpa)	ν (-)
Clay	20	0.07	20	30	0.30
Sand	20	0.08	20	20	0.30
Filter	20	0.09	30	20	0.30
Clay Hard Core	20	0.08	25	50	0.30
Embankment compacted	25	1.00	40	100	0.25

3.2 Equilibrium Limit Analysis

The program CLARA, 2D/3D [4] may be used to conduct the Limit Equilibrium slope stability analysis in two or three dimensions. This program carries out the analysis of soil or rock slope stability both in static and seismic states. Moreover, different modes of failure, including circular sliding surfaces, ellipsoids, wedges and compound surfaces, could be implemented in CLARA. CLARA provides a choice of the method of analysis including the following:

- Fellenius's method,
- Bishop's method and uses 3D extensions of Bishop's Simplified,
- Spencer's method, and
- Janbu's method.

For the current study, the circular (Figure 2) and ellipsoid failure mechanisms have been considered:

Table (2). The Factor of safety corresponding to the different types of failure mechanism

FAILURE MECHANISM	Factor of Safety
Upstream slope failure 2D	1.6
Upstream slope failure 3D	2.01

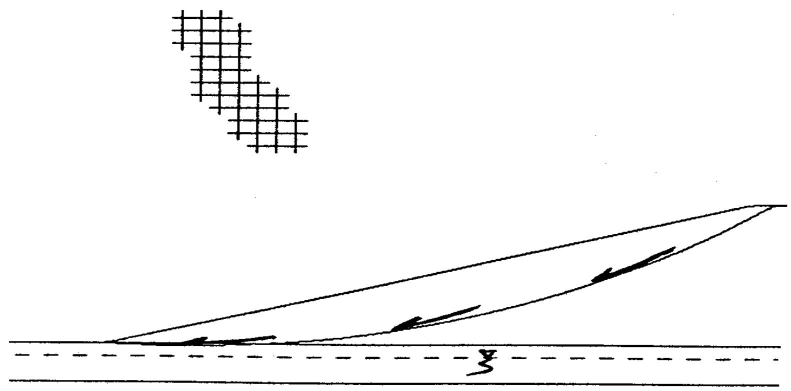

Fig. (2). Analysis of upstream slope of el Houareb dam using CLARA 2D to find the circular slip surface.

An example of CLARA 3D analyses of El Houareb dam is show in Figure (3). For the reliability analyses of El Houareb dam, only the ellipsoid failure mechanism will be considered.

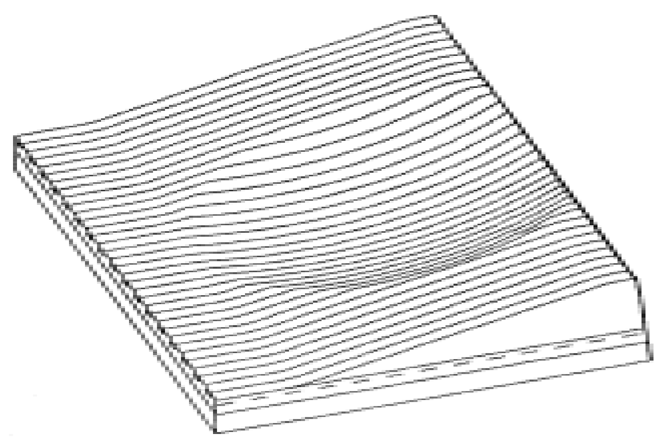

Fig. (3). Analysis of upstream slope of El Houareb dam using limit equilibrium to find the ellipsoid failure surface (3D extension of Bishop's simplified method, Clara 3D)

4. Reliability Assessment

4.1 Auto-Correlation Function

Spatial correlation has long been ignored in modeling variability of soil properties. However, the spatial dependency within the medium should be considered, particularly in a strongly compacted soil such as earth dams [5]. To take into account spatial correlation, it is possible to model the spatial variability of soil properties with a spatial stochastic process also known as random field [6]. In this process, the variable exhibits auto-correlation, the tendency for values of the variable at one point to be correlated to values at nearby points. Recently, special attention has been given to the role of spatial correlation. Some recent papers dealing with this concept include those by Mrabet and Giles [7].

Many studies stressed out the effect of existing auto-correlation on the results of probabilistic models of compacted earth slopes analysis. Ignoring auto-correlation is conservative and considerably more than desired [8]. The analysis that considers the typical auto-correlation distances results in reduction of probability of failure [9].

Extensive measurement program performed on earth dams such Mirgenbach and Vieux-Pre dams [10] and others led to the conclusion that, for such structures, a significant spatial correlation exists. The influence distance at which auto-covariance becomes negligible is sensitive to the construction procedure as well as the material nature, but is practically identical for all properties. A pronounced anisotropy of the auto-covariance exists; the vertical distance of influence is of the order of meters, while the horizontal distance of influence is of the order of tenth of meters [7, 8]. Similar pattern has been found for mechanical properties and the exponential auto-correlation function for two different points within the compacted soil of the El Houareb dam has been retained.

Due to the lack of data concerning the horizontal auto-correlation function, Anderson's work (1981) is utilized to establish one. Therefore, the following function is obtained:

$$\rho_{hor9x)} = \exp(-0{,}065x) \qquad (6)$$

4.2 Global Probability of Failure

The reliability index of earth dam is commonly taken as the value corresponding to the failure surface associated with minimum reliability index. However, embankment dams are investigated as systems composed of several infinite number of possible failure surfaces associated with different reliability indices. Therefore, the global probability of failure of an embankment dam is however, at least for the moment, a complicated problem to handle since correlation exists between different failure surfaces. In practice, the reliability of the whole system may be governed by a few subsystems or components. The calculated probability associated to the critical failure surface constitutes a lower limit of the global probability of failure of El Houareb dam. Subsequently, we calculate the global probability of failure in respect to the following conditions:

- Ceros-section of El Houareb dam as considered in the above analysis (figure 1)
- Horizontal auto-correlation distance =60 m
- Vertical auto-correlation distance =3.1 m

- Coefficient of variation of the cohesion of the El Houareb dam= 0.35

The dam is divided into a series of ellipsoids, which are vertically independents and separated by 3 m.

Table (3): Failure Probability

H_i (m)	**F_i**	β_i	**P_{fi}**
0 m Contact Dam-Foundation	2.01	3.45	0.025
3	2.63	4.00	0.00013
6	2.95	4.23	0.0003
9	3.50	4.55	0.00002
12	3.78	4.80	0.000003
15	5.14	5.23	0.0000023
18	7.02	5.40	0.0000001
21	9.04	5.63	0.000000025
24	15.02	5.90	0.000000004
27	18.3	6.13	0.0000000032
30	25	6.23	0.0000000005

H_i = depth of the ellipsoid regarding the interface dam-foundation (or the bottom of the dam)
F_i = Factor of Safety corresponding to the ellipsoid failure Surface number i.
β_i = Minimum Reliability index corresponding to the ellipsoid failure surface number i.
P_fi = Failure probability corresponding to the ellipsoid failure surface i,
The global failure probability is calculated using the following equation:

$$P_{global} = 1 - \prod_{i=1}^{n} \left(1 - P_{fi}\right) \tag{7}$$

Which is found to be = 0.02. This value is close to the value associated with the critical ellipsoid failure surface shown in Table 93). This calculation shows that the concept of global probability is coherent; and should be considered, later, as the global probability of the project.

In reality, these results show that other sources of uncertainty should be taken into account including, but not limited to:

- Mechanisms of failure
- Properties of materials
- Entire history of dam behavior
- Ignorance of the auto-correlation function.

5. Conclusion

The rational way to managing uncertainty in evaluating the safety and reliability of El Houareb dam is to reduce it. The reliability analysis should include all sources of uncertainty.

Similar reliability analysis could be performed using conditional random field to evaluate the uncertainty related to spatial variation of the material properties within the dam based on quality control.

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التحليل الإحصائي لسد الهوارب بوسط الجمهورية التونسية

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ملخص البحث. هذا البحث يهتم بالتحليل الإحصائي لسد الهوارب بوسط الجمهورية التونسية. لأجل القيام بالتحليل التوازن الحدي ثاني و ثالث الأبعاد تم الاعتماد على برنامج كلارا (CLARA). كذلك تم إبراز دور النموذج الإحصائي في فهم الانزلاق الأرضي في منحدرات الجانبية للسد. للأخذ بعين الاعتبار المتغيرات المكانية لخصائص التربة تم إدراج الحقل العشوائي في هذا البحث. من خلال هذا البحث توصلنا إلى حساب إمكانية الانزلاق الأرضي للمنحدرات الجانبية لهذا السد وفقا للتحليل الإحصائي العشوائي المجمل.

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Superconducting Generator Stability Enhancement Using a Facts Device

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Abstract. Stability of the superconducting generator (SCG) is a key concern in developing this machine. The paper here presents a method for enhancing stability of a SCG connected to an infinite-bus system using one of FACTS devices. In this method, a static VAR compensator (SVC)-based stabilizer is designed in coordination with a governor controller (GC) to effectively damp the mechanical oscillations which arise in the system when subjected to a major disturbance. A time response-based objective function is defined and the design problem of an SVC-based stabilizer and GC is formulated into an optimization problem. Particle swarm optimization (PSO) technique is employed to find out an optimal set of parameters for the SVC-based stabilizer and GC. Simulation results and damping torque analysis show that the proposed PSO-based control scheme provides more damping to the SCG, and enhances its stability over a range of operating conditions.

Keywords: Superconducting generator, FACTS, Transient stability, Particle swarm optimization

List of Symbols

p : derivative operator
ψ : flux linkage
ω_o : synchronous speed (rad/s)
ω : rotor speed deviation from synchronous speed (rad/s)
V : voltage
i : current
R : resistance
δ : rotor angle with respect to infinite bus
H : inertia constant
T_m : mechanical torque
T_e : air-gap torque
P_t , Q_t : active power and reactive power at generator terminal
P_o : boiler steam pressure
Y : output of a turbine or reheat stage
τ : time constant of stage
G_M , G_I : main and interceptor valve positions
F : fractional contribution of the turbine stage into T_m
U_G : governor actuating signal
T_1 , T_2 : time constants of governor controller
G_s : gain of governor controller
u : stabilizing signal generated by governor controller
B : susceptance of the SVC
K_{svc}, T_s : gain and time constant of the SVC
K_v, T_3, T_4 : SVC-based stabilizer parameters
u_{SVC} : stabilizing signal generated by SVC-based stabilizer
K_s , K_d : synchronizing and damping coefficients

Subscripts

a : armature winding
f : field winding
d,q : d and q axis circuits of stator winding
$D1,Q1$: d and q axis circuits of outer screen
$D2,Q2$: d and q axis circuits of inner screen
HP : high pressure stage
RH : reheat stage
IP : intermediate pressure stage
LP : low pressure stage

1. Introduction

Superconducting generators (SCG) have several potential advantages such as small size, light weight, high efficiency and increased steady state stability limit [1-2]. The advantages of SCG have drawn more interest in industrial countries since 1970's, such as in USA, UK and Japan where many R&D projects on SCGs have been conducted at utility companies, power plant manufacturers and other organization toward a 200 MW class pilot-machine [3-7]. However, superconducting generators are also characterized by low inertia and low inherent damping, each of which adversely affects the transient performance of these machines. Moreover, the very long field winding time constant and the shielding effects of the two rotor screens make the achievement of acceptable dynamic performance very difficult using excitation control. Governor control hence becomes the only technique feasible for stability enhancement of superconducting generators. The availability of electro-hydraulic governors and fast operation of steam valves has now made it possible to obtain very fast turbine response. Research work reported in Ref. [8-9] has shown that the SCG stability can be improved by introducing a phase advance network (conventional stabilizer) in the governor feedback loop, activated by the speed error signal. The conventional stabilizer parameters are fixed to ensure a good performance at a specific operating point. However, because of the high nonlinearity of the machine/power system combination, the stabilizer's performance tends to be degraded whenever the system operating conditions move significantly away from the specific point. Therefore, the conventional stabilizer should have some degree of robustness to be able to stabilize the system over a wide range of operating conditions. Many attempts along with comprehensive analysis have been made to improve matters a) by retuning the conventional stabilizer, b) by utilizing adaptive control technique and c) by adopting a fuzzy logic stabilizer [10]. In all these attempts, stabilizer parameters were selected using a genetic algorithm (GA) technique.

Recently, the flexible AC transmission systems (FACTS) have been introduced, in which various power electronics-based controllers are used to maximize the utilization of transmission assets efficiently and reliably [11-12]. In addition, FACTS devices regulate power flow and, through rapid control actions, can mitigate low frequency oscillations and enhance power system stability [13-14]. A literature survey on the work done on the application of FACTS devices along with the excitation control to enhance damping of conventional generator oscillations is given in the introduction of Ref. [14].

Early investigation on the dynamic performance of a superconducting generator when equipped with static VAR compensator at its terminal was reported in Ref. [15]. In that study, the stabilizing signal was not optimized. Moreover, the governor role in damping the machine oscillation was not considered. However, no or little efforts have been made towards stability enhancement of superconducting generator using coordinated governor controller and FACTS device-based stabilizer. Here, enhancement of SCG stability using coordinated design of a governor controller (GC) and a static VAR compensator (SVC)-based stabilizer is studied.

The optimal parameters of SVC-based stabilizer and GC are sought by utilizing the particle swarm optimization (PSO) technique [16]. Non-linear simulation is carried out to investigate the effectiveness of the proposed scheme.

2. System under Study

The system considered is a single superconducting generator (SCG) connected to an infinite bus power system as shown in Fig. (1). The SCG has superconducting field winding in the rotor, surrounded by two separate screens. The inner screen, which has a relatively long time constant, shields the superconducting field winding from external, time varying magnetic fields. The outer screen serves as a damper and has a substantially shorter time constant than that of the inner screen [17]. The SCG is driven by a three-stage steam turbine with reheat between the high pressure and intermediate pressure stages. The turbine is controlled by fast acting electro-hydraulic governors fitted to the main and interceptor valves, which are working in unison. The system is equipped with a controller in the governor loop and an SVC at the terminal of the SCG. The exciter voltage, U_e , of the SCG is kept constant during transients.

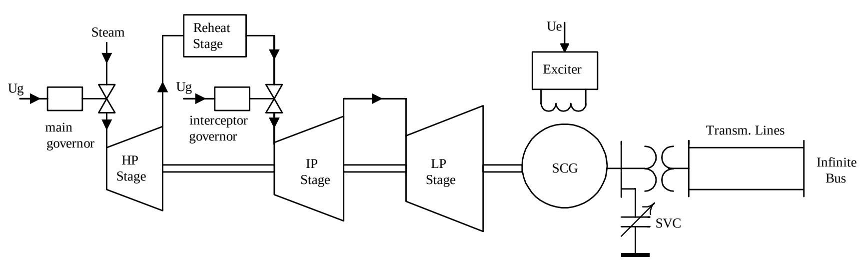

Fig. (1). SCG system under study with SVC

3. Mathematical Model

The mathematical models for SCG, turbine and governor are shown below, while the parameter values and physical constraints are given in Appendix A. All the state variables used in the mathematical models for the system under study is in per unit except δ is in radian and δ is in radian/s.

3.1- Superconducting Generator Model

Based on Park's *d-q* axis representation, seven non-linear differential equations are used to represent the mathematical model of the SCG's electric circuits. These equations along with the mechanical equations of motion give the flux linkage model of the SCG [9] as follows:

$$p\psi_d = \omega_o[V_d + i_d R_a + \psi_q] + \psi_q \omega \quad (1)$$

$$p\psi_q = \omega_o[V_q + i_q R_a - \psi_d] - \psi_d \omega \quad (2)$$

$$p\psi_{D1} = -\omega_o i_{D1} R_{D1} \tag{3}$$

$$p\psi_{Q1} = -\omega_o i_{Q1} R_{Q1} \tag{4}$$

$$p\psi_{D2} = -\omega_o i_{D2} R_{D2} \tag{5}$$

$$p\psi_{Q2} = -\omega_o i_{Q2} R_{Q2} \tag{6}$$

$$p\psi_f = \omega_o [V_f - i_f R_f] \tag{7}$$

$$p\delta = \omega \tag{8}$$

$$p\omega = \frac{\omega_o}{2H}[T_m - T_e] \tag{9}$$

$$T_e = \psi_d i_q - \psi_q i_d \tag{10}$$

3.2- Turbine and Governor Model

The mathematical model of the turbine and governor system is represented by six non-linear differential equations [18] as follows:

$$pY_{HP} = (G_M P_o - Y_{HP}) / \tau_{HP} \tag{11}$$

$$pY_{RH} = (Y_{HP} - Y_{RH}) / \tau_{RH} \tag{12}$$

$$pY_{IP} = (G_I Y_{RH} - Y_{IP}) / \tau_{IP} \tag{13}$$

$$pY_{LP} = (Y_{IP} - Y_{LP}) / \tau_{LP} \tag{14}$$

$$pG_M = (U_G - G_M) / \tau_{GM} \tag{15}$$

$$pG_I = (U_G - G_I) / \tau_{GI} \tag{16}$$

The output mechanical torque is given as:

$$T_m = F_{HP} Y_{HP} + F_{IP} Y_{IP} + F_{LP} Y_{LP} \tag{17}$$

The main and interceptor valves are conventionally actuated by a normalized speed error signal incorporating a droop, typically 4%. Constraints are imposed on valve positions and rates of movement. The rate constraint is based on complete opening or closing time for the valves of 150 ms. The rate limits correspond to the fastest valve operation reportedly available in literature [18].

4. Proposed Approach

4.1. Control Objective

The control objective is to generate two stabilizing signals using the speed error signal. The first control signal is produced via a conventional controller and then introduced into the governor loop of the SCG system as shown in Fig. (2). The control signal, *u*, generated by the conventional controller is given as:

$$u = G_s . \frac{(1+T_1 s)}{(1+T_2 s)} .\omega \tag{18}$$

where ω is the speed error signal, G_s , T_1 and T_2 are the controller parameters, which have to be designed properly to achieve a satisfactory performance.

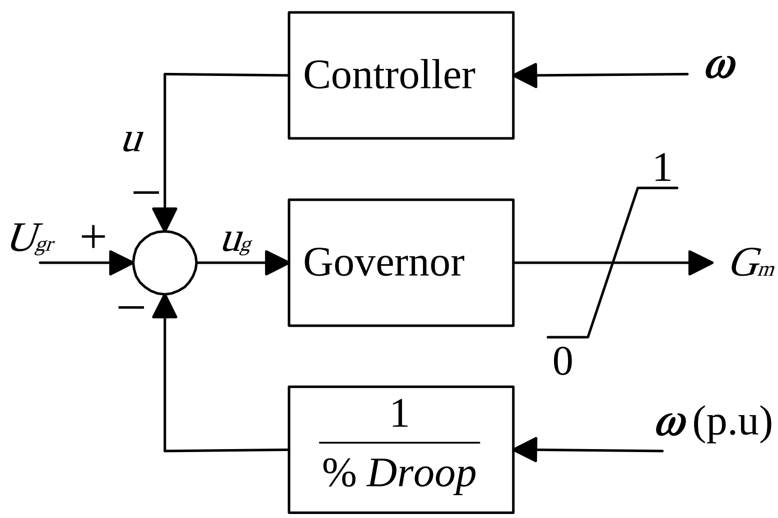

Fig. (2). The governor control system

4.2 SVC-Based Stabilizer

The block diagram of an SVC with a conventional lead stabilizer is shown in Fig. (3). Functionality, the SVC is thought of as an adjustable shunt susceptance that can be varied with sufficient rapidity. Elaborated model for SVC can be seen in Ref. [19]. However, the susceptance, *B*, of the SVC can simply be expressed as [14]:

$$pB = (K_{svc}(B_{ref} + u_{SVC}) - B) / T_s \tag{19}$$

where K_{svc} and T_s are the gain and time constant of the SVC. B_{ref} is the reference susceptance of the SVC and u_{SVC} is the stabilizing signal generated by the conventional stabilizer installed in the feedback loop of the SVC as shown in Fig.3.

$$u_{SVC} = K_v . \frac{(1+T_3 s)}{(1+T_4 s)} .\omega \tag{20}$$

where K_v , T_3 and T_4 are the SVC-based stabilizer parameters, which need a careful selection to enhance the system stability. Both of u and u_{SVC} has upper and lower limits, i.e.

$$u_{\min} \le (u, u_{SVC}) \le u_{\max} \tag{21}$$

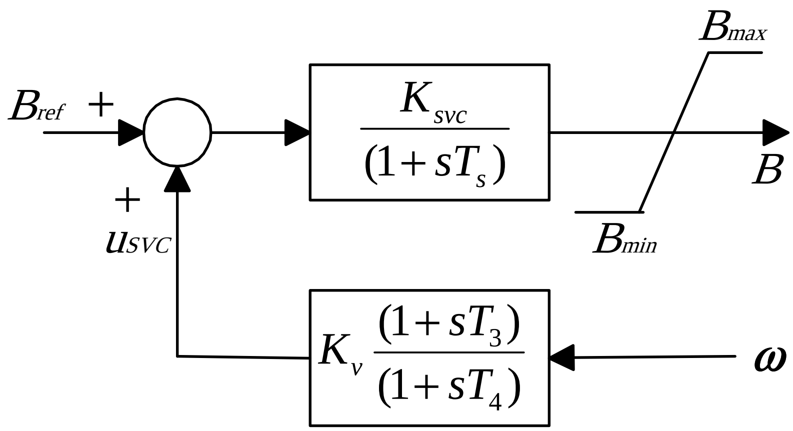

Fig. (3). SVC with lead stabilizer

5. Stabilizer Parameters Selection Using PSO

Recently, a heuristic search method called *particle swarm optimization* (PSO) has been introduced [20]. PSO is characterized as a simple concept, easy to implement, and computationally efficient. Theses features make PSO technique able to accomplish the same goal as genetic algorithm (GA) optimization in a new and faster way. A number of very recent successful applications of PSO on various power system problems have been reported in literature [16].

The tuning parameters in the proposed approach are G_s , T_1 and T_2 for the controller in the governor loop, and K_v , T_3 and T_4 for the SVC-based stabilizer. Usually, T_2 and T_4 are pre-specified leaving the other four parameters, G_s , T_1 , K_v and T_3 to be tuned [14, 21]. Here, the degree of freedom in the design problem is increased by letting T_2 and T_4 be freely selected as well as the other four tuning parameters. This addition is intended to enhance the effectiveness of the proposed stabilizer. Therefore, we have now six parameters to be optimally chosen. This task is achieved using the PSO technique. To do so, the following quadratic performance index, *J,* is first defined.

$$J = \sum_{k=1}^{N} \{[kT.\omega(k)]^2 + [\Delta\delta(k)]^2 + [\Delta G_M]^2\} \qquad (22)$$

where $\Delta\delta(k)=(\delta(k)-\delta_o)$ denotes the deviations (in radians) of the instantaneous rotor angle from its steady state value, δ_o , and $\Delta G_M(k)=(G_M(k)-G_{Mo})$ is the deviation of the instantaneous governor valve position $G_M(k)$ from its value in the steady state, G_{Mo}. This choice of performance index seeks to minimize the mechanical-mode oscillations of the SCG system with minimum governor valve movements. As is seen, the speed deviation, $\omega(k)$, is weighted by the elapsed time *kT*. Thus, a low value of *J* corresponds to a small settling time, a small steady state error, and small overshoots in rotor speed, rotor angle and valve position. The performance index is minimized subject to the following constraints:

$$G_{S,\min} \le G_S \le G_{S,\max} \tag{23}$$

$$T_{1,\min} \le T_1 \le T_{1,\max} \tag{24}$$

$$T_{2,\min} \le T_2 \le T_{2,\max} \tag{25}$$

$$K_{v,\min} \le K_v \le K_{v,\max} \tag{26}$$

$$T_{3,\min} \le T_3 \le T_{3,\max} \tag{27}$$

$$T_{4,\min} \le T_4 \le T_{4,\max} \tag{28}$$

The PSO algorithm iteratively updates the velocity of each particle using its current velocity and its distance from "global best position" (g_{best}) and from "personal best position" (p_{best}) according to the following equation:

$$v_i^k = w^k v_i^{k-1} + c_1 r_1 (p_{best,i} - x_i^{k-1}) + c_2 r_2 (g_{best,i} - x_i^{k-1}) \tag{29}$$

where:

i = 1, 2, 3, …………..m

v_i^k is the velocity of particle i at iteration k

x_i^k is the position of particle i at iteration k

r_1, r_2 are uniformly distributed random numbers in the range [0, 1]

c_1, c_2 are positive constants

w^k is the inertia weight at iteration k, decreasing as $w^k = \alpha w^{k-1}$

m is the number of particles in a swarm, and α is a decrement constant

PSO itself has a number of parameters to be properly specified. The main PSO parameters are the initial inertia weight, w^0, and the maximum allowable velocity, V_{max}. w^0 is set at 1, and V_{max} at 12.5% of the search space for each variable. The swarm size is chosen to be 60 particles. Other parameters are set as decrement constant α=0.98, and $c_1 = c_2 = 2$.

6. Simulation Results

The author examined a number of alternatives in developing the proposed scheme. The performance index was evaluated, in all cases, in response to a three-phase to ground fault of 120-ms duration with the operating point (P_t=0.8 p.u, Q_t=0.6 p.u). The first attempt was individual design for the SVC-based stabilizer; considering no governor controller, i.e. u=0. Then, the optimal set of (K_v , T_3, T_4) for SVC-based stabilizer was searched for; considering governor controller with G_s=0.1 T_1,=0.5s and T_2=0.01s [8, 22]. Finally, coordinated design for best combination of (G_s , T_1, T_2) for GC, and (K_v , T_3, T_4) for SVC-based stabilizer was sought.

Variation of the performance index J with the number of iterations is shown in Fig. 4. The optimal coordinated values selected by PSO for (G_s , T_1, T_2) and (K_v , T_3, T_4) are (0.065, 1, 0.01) and (1.142, 0.183, 0.063) respectively. Performance of the SCG system with the proposed scheme following a 3-phase short circuit fault, at [(P_t, Q_t) = (0.8, 0.6), (0.9, 0), (0.7, -0.2) p.u] is shown in Figs. 5 to 7. Figures 8 to 10 show the system response to a temporary (100-ms long) 10% step increase in the governor set point at the previous loading conditions.

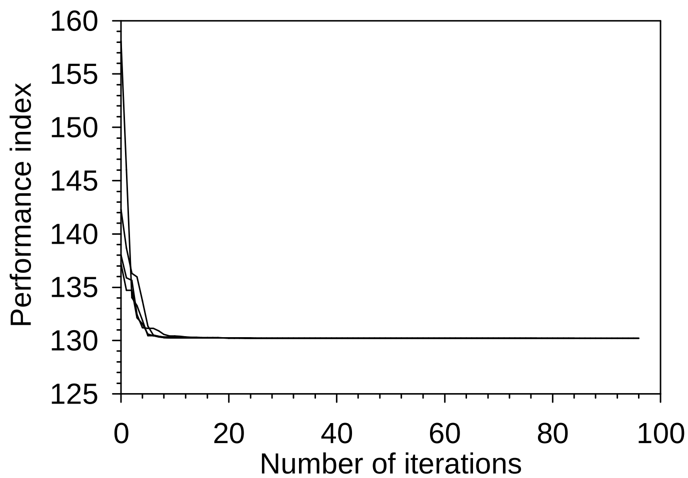

Fig. (4). Convergence of performance index with iterations At different seed values

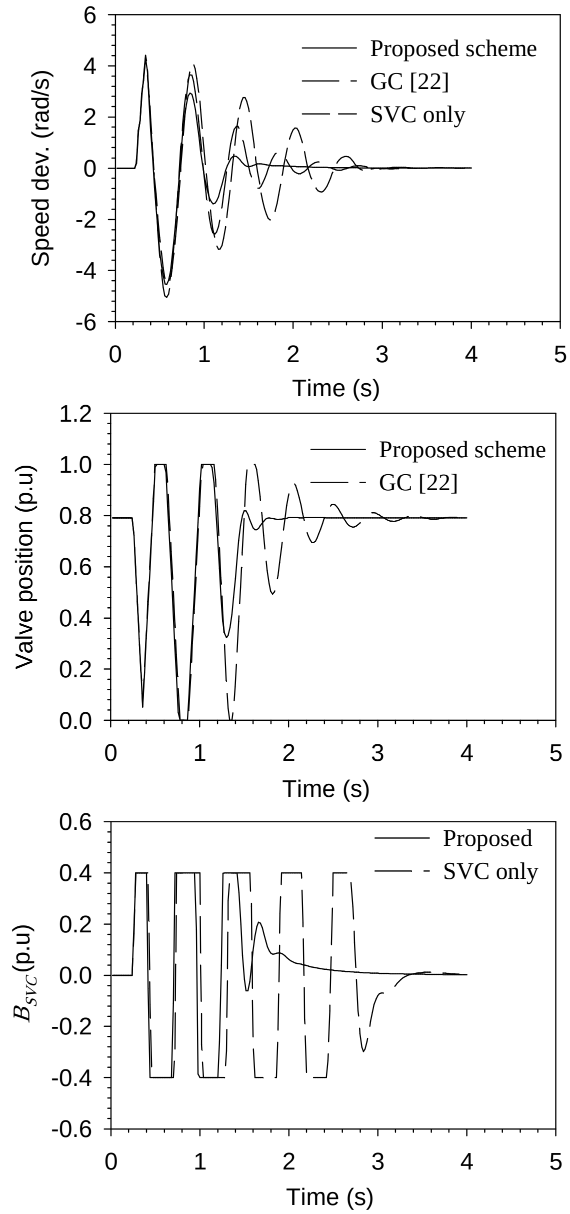

Fig. (5). Response to a 3-phase SC at P_t=0.8 p.u, Q_t =0.6 p.u

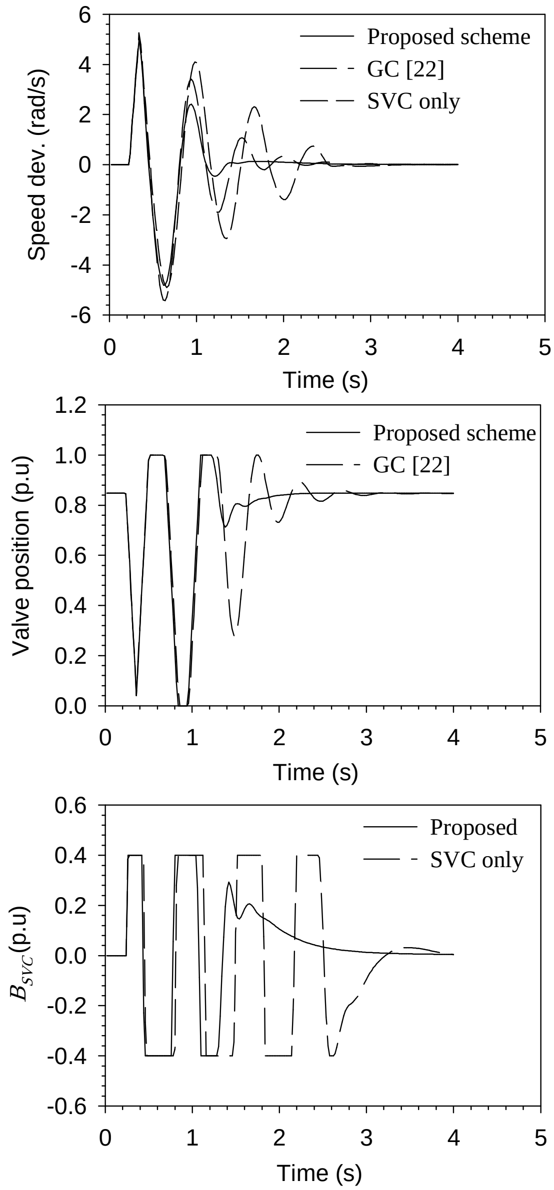

Fig. (6). Response to a 3-phase SC at P_t=0.9 p.u, Q_t =0 p.u

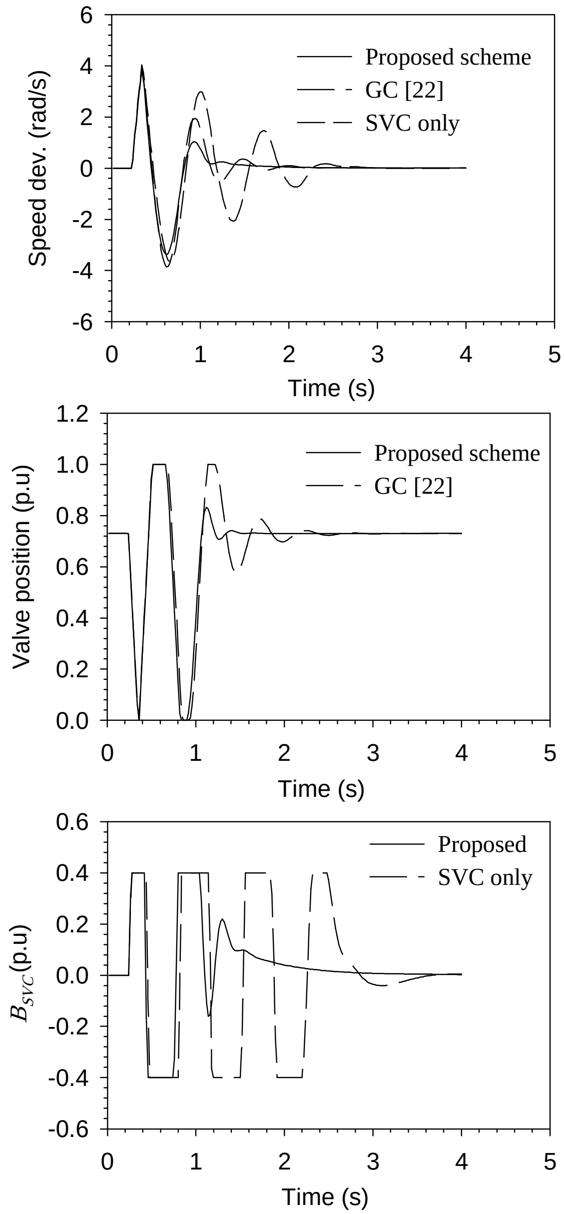

Fig. (7). Response to a 3-phase SC at P_t=0.7 p.u, Q_t =-0.2 p.u

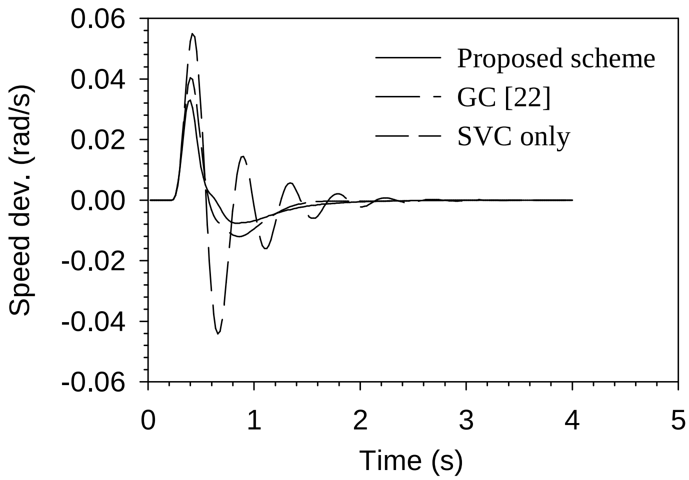

Fig. (8). Response to a 10% pulse in U_{gr} at P_t=0.8 p.u, Q_t =0.6 p.u

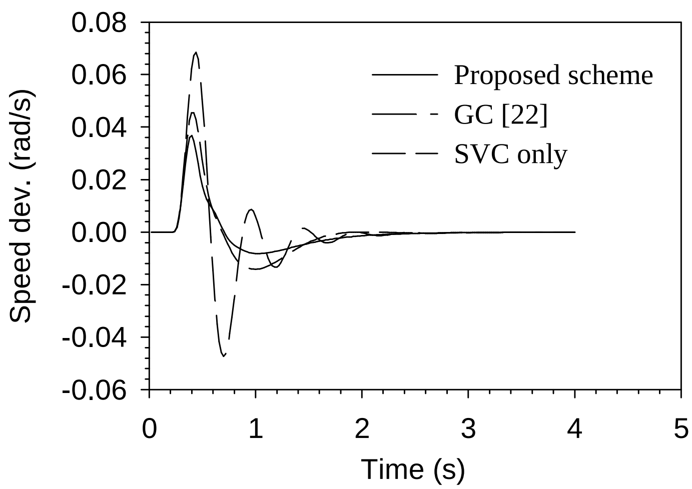

Fig. (9). Response to a 10% pulse in U_{gr} at P_t=0.9 p.u, Q_t =0 p.u

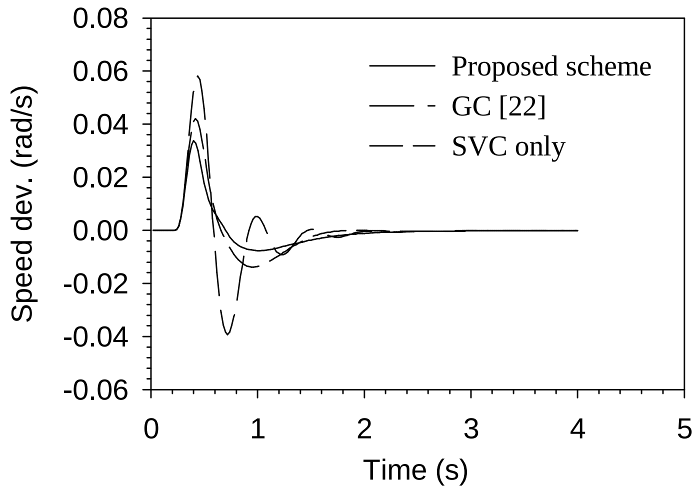

Fig. (10). Response to a 10% pulse in U_{gr} at P_t=0.7 p.u, Q_t =-0.2 p.u

The results show that the proposed control scheme results in a significant improvement in the SCG transient performance and a considerable reduction in the rotor oscillations with acceptable valve movements.

7. Damping and Synchronizing Torques Analysis

The object of this section is to investigate the effects of the proposed control scheme and other schemes on the SCG dynamic performance using the concept of damping and synchronizing torques, which was initially introduced by Demello and Concordia [23]. This concept indicates that, at any given frequency of rotor oscillations, there exists oscillatory electrical torque acting on the rotor which has the same frequency and whose amplitude is proportional to the amplitude of the oscillations. The change in this torque ΔT_e can be divided into two components: one is in time phase with, and proportional to the rotor angle deviation $\Delta\delta$. This is called the “synchronizing torque”. The other, which is in time phase with and proportional to the rotor speed deviation ω is called the “damping torque”. Therefore, the change in electrical torque can be written as follows:

$$\Delta T_e = K_s \Delta\delta + K_d \omega \tag{30}$$

where K_s and K_d are the synchronizing and damping coefficients respectively. It is now well recognized that machine stability is highly degraded if there is lack of either or both of synchronizing and damping torques. The values of K_s and K_d are determined from the time responses of electrical torque, rotor angle and rotor speed, using the technique explained in [24-25]. In that technique, the error between the actual torque deviation and that obtained by summing the damping and synchronizing torque components is defined as:

$$E(t) = \Delta T_e(t) - [K_s \Delta\delta(t) + K_d \omega(t)] \quad (31)$$

The error squares can be summed over the simulation time period. Minimizing this summation with respect to K_s and K_d yields the following dependent algebraic equations:

$$\sum_n \Delta T_e \Delta\delta = K_s \sum_n (\Delta\delta)^2 + K_d \sum_n \omega\Delta\delta \quad (32)$$

$$\sum_n \Delta T_e \omega = K_d \sum_n (\omega)^2 + K_s \sum_n \omega\Delta\delta \quad (33)$$

Solving the equations (32) and (33) gives the values of K_s and K_d, where n is the discrete-simulation time. A summarized comparison of the proposed scheme and other schemes (viz. GC [22] with SVC, and GC [22] only) is shown in Table (1).

Table (1). Comparison of the proposed scheme and other schemes

(P_t, Q_t) p.u	**(0.8, 0.6)**			**(0.7, -0.2)**	
	J	K_d	k_s	K_d	k_s
Coordinated GC with SVC	130.2	0.231	1.941	0.212	1.184
GC [22] with SVC	138.4	0.166	1.836	0.142	1.11
GC [22] only	261.7	0.014	2.011	0.016	1.251

From this table, it can be finally concluded that the proposed scheme outperforms the other considered schemes at all operating points studied. It provides the SCG system with the highest possible degree of damping while keeping the synchronizing torque at a high level.

8. Conclusion

This study has described the utilization of one of FACTS devices for stability enhancement of superconducting generators. An approach was proposed for the design of a static VAR compensator-based stabilizer in coordination with a governor controller to provide more damping to the mechanical oscillations of the SCG studied. A performance index was defined and the PSO technique was used to select the optimal parameters of both GC and SVC-based stabilizer. Simulation results show the effectiveness of the proposed control scheme in damping the rotor oscillations, and enhancing the SCG stability over a range of operating conditions and various disturbances. Analysis of damping and synchronizing torques was used to provide another quantitative assessment of the SCG performance with the designed GC and SVC-based stabilizer. Results of this analysis verify the effectiveness of the proposed approach.

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Appendix A

The parameters of the SCG system used in this study (inductance and resistance values in p.u; time constants in seconds) are [8, 9]:

Superconducting generator parameters:
L_f=0.541, L_d=L_q=0.5435, L_{D1}=L_{Q1}=0.2567, L_{D2}=L_{Q2}=0.4225
L_{fd}=L_{fD1}=L_{dD1}=L_{dD2}=L_{D1D2}=0.237
L_{fD2}=0.3898, L_{qQ1}=L_{qQ2}=L_{Q1Q2}=0.237
τ_f=750, R_d=R_q=0.003
R_{D1}=R_{Q1}=0.01008, R_{D2}=R_{Q2}=0.00134
H=3 kW.s/kVA
Transformer and transmission line parameters:
X_T=0.15, R_T=0.003, X_L=0.05, R_L=0.005
Turbine and governor parameters:
τ_{GM}=τ_{GI}=0.1, τ_{HP}=0.1, τ_{RH}=10
τ_{IP}=τ_{LP}=0.3, P_o = 1.2 p.u.
F_{HP} = 0.26, F_{IP} = 0.42, F_{LP} = 0.32
Valve position and movement constraints are defined by:
$0 \le (G_M, G_I) \le 1$ and $-6.7 \le (pG_M, pG_I) \le 6.7$

تحسين استقرار المولد فائق التوصيل باستخدام أحد نظم نقل التيار المتردد المرنة

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ملخص البحث. يعتبر استقرار المولد فائق التوصيل أمرا ضروريا في تطوير هذه الآلة. يقدم هذا البحث طريقة لتحسين استقرار مولد فائق التوصيل متصل بنظام قوى لانهائي باستخدام أحد نظم نقل التيار المتردد المرنة. في هذه الدراسة يتم تصميم موازن مؤسس على معوض ساكن للقدرة غير الفعالة بالتنسيق مع ضابط الحاكم. وذلك لإخماد الذبذبات الميكانيكية التي تنشأ في النظام عندما يتعرض لظرف عارض بفعالية. تم تعريف دالة هدف مبنية على الأداء الزمني. ومن ثم تم صياغة مشكلة تصميم الموازن المقترح مع ضابط الحاكم في صورة مشكلة أمثلة. ولقد تم استخدام طريقة أمثلة حديثة (تحاكى أسلوب أسراب الطيور في الوصول إلى أهدافها) لتحديد أفضل مجموعة لقيم ثوابت الموازن والضابط . توضح نتائج المحاكاة وتحليل عزم التخميد أن الموازن المقترح و المصمم بالتنسيق مع ضابط الحاكم يؤدى إلى تحسن ملحوظ في أداء واستقرار النظام المدروس على مدى واسع من أحوال التشغيل.

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Effect of Ventilation Factor and Ventilation Rate on Temperature Distribution through Vertical Heights

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Abstract. This work aims to study the effective parameters on forced ventilation by which the fire can be put under control. There are many parameters which specify the forced ventilation such as ventilation factor, this parameter was investigated experimentally using a modified test rig in order to supply different ventilation rates into the compartment with different ventilation factors while different types of fuel with different masses were used (benzene" gasoline " of 4.4, 8.8 and 13.2 gm and wood particles of 5, 10 and 15 gm..

To perform this study a modified test room was designed. Results of the study show that the effect of ventilation factor and ventilation rate on fire depression (minimum fire duration) in a compartment is mainly represented in the high values of ventilation factors (F_v / 0.0215 $m^{5/2}$) and low values of ventilation rates ($\dot{V}$ [0.067 m^3/s) for benzene (gasoline fuel) at different fuel masses. Also, results indicate that a decreasing in ventilation factor and increasing in ventilation rates result in undesirable effects as the fire duration increased.

***Keywords*:** Benzene, Fire, Temperature, Ventilation, Wood.

1. Introduction

Fire is indeed a major risk for residential, traffic and industrial installations. In the case of residential installation accidental fires result in billions of dollars of property damage, and many murdered people, per year. In the case of traffic installation or tunnels fire cause damage to the wall of tunnel which subjected to convective and radiative heat fluxes from both the flame and the plume gases.

Types of ventilation are, natural which is created by natural forces that result from difference in the distribution of air pressure around a building, since air always flows from area of high pressure to area of low pressure. Some times natural ventilation can not circulate enough air through a building, so forced ventilation creates air flow in rooms or building that would otherwise be stagnant. Forced ventilation can be used to supplement both horizontal and vertical ventilation. Types of fire can be divided into three types, the first type is the fully fire in this type of fire complete burn-out of fire area is assumed. The second type is the limited growth fire this type of fire is a fire which produces a thermal column sufficient to create a heated layer of gases in the upper elevation of the room involved in the fire, and the third type is the limited growth, smoky fire a limited growth, smoky fire is a fire such as smoldering rags or an electrically indicated cable fire. [1]. A pool fire is a type of turbulent diffusion flame, which burns above a pool of vaporizing fuel where the fuel vapor has negligible initial momentum.

Fire accidents form an important part of all accidents which occurred in the industry and in transport of hazardous materials; fire is involved in 41.4% of all these events [2]. Studying the effect of ventilation rate and ventilation factor on enclosure fire is therefore important. The ventilation rate depends on the use of the buildings and their floor area. Usually the smaller the floor area, the larger the ventilation rate consumed. Large open-area offices might have a ventilation rate of about 10 air change per hour, smaller compartments, would have a higher ventilation rate up to 50 air change per hour [3].

W. K. Chow [3] carried out his experiment in a fire chamber of length 4.0 m, width 3.0 m and height 2.8 m and the forced ventilation fires were studied by locating the fire source in a chamber at different positions under different ventilation rates. The mass loss rate of the fuel, temperature distribution in the chamber and the air flow rates at intake and outlet openings were measured. Also he showed that under conditions of low heat release rate and high ventilation rates, the smoke temperature can be calculated.

E. Planas-couchi et al. [2] conducted a large- scale tests in pool- fires in which a horizontal cylindrical tank was engulfed in the fire. They should that for a certain fire sizes; flame temperature is not constant over all the fire. In case of hexane pool-fires temperature decreases with height. However, for larger fires (kerosene) the experimental values of flame temperature did not change with height according to any definite pattern.

K. T. Yang et al. [4] performed a full-scale forced ventilation fire in a test room which has a height of 5 m and contains two double doors, the ventilation exhaust located above the entry room. And they made a numerical simulation; the numerical simulation based on a fire field model showed that during the first four minutes of the fire the hot gas has already penetrated into the floor region. Other than the fire plume region and regions that are immediately affected by the ventilation inlet and outlet, the temperature fields are essentially stably stratified into layer structures.

W. K. Chow [3] carried out his experiment in a fire chamber of length 4.0 m, width 3.0 m and height 2.8 m and the forced ventilation fires were studied by locating the fire source in a chamber at different positions under different ventilation rates. The mass loss rate of the fuel, temperature distribution in the chamber and the air flow rates at intake and outlet openings were measured. And he showed that under conditions of low heat release rate and high ventilation rates, the smoke temperature can be calculated from Eq. (1).

C. Qian et al. [5] developed a pool fire apparatus with a temperature and fuel level control, radial and axial temperature distribution for five different small diameter pool fires were measured by the IR IMAGE temperature measurement technique, and velocity of fuel, oxidizer and the air entrainment near the base of the pool were measured by a particle-track LASER sheet technique and. decided that the structure of a flame base is always laminar regardless of pool diameter, at least for pool fires with diameter between 5 cm and 50 m. This observation suggested that mechanisms of air entrainment and flame structure near the base for a large-scale pool fire can be studied from a small-scale laboratory pool fire. Also they decided that air entrainment and fuel air mixing which occur near the base of pool fires influence soot production rate, flame height and temperature structure.

W. K. Chow [6] carried out a full-scale burning test on wood, PMMA (polymethyl-methacrylate) and methanol fires with forced ventilation in a fire chamber of length 4.0 m, width 3.0 m and height 2.8 m. The gas temperatures at seven positions were measured together with the transient mass loss rate of the fuel. As well as, he concluded that the heat loss coefficient (h_k) included both convective and radiative effects of the walls, ceiling, and floors can be calculated by the expression below when time (t) is smaller than the thermal penetration time t_p:

$$h_k = C_1 \mathrm{Max}\left[\sqrt{k_w \rho_w C_w} \quad K_w / \delta_w\right] \tag{1}$$

$$t_p = \rho_w \; C_w \; / \; K_w \times (\delta_w / 2)^2 \tag{2}$$

Where: t_p is in fact the time taken for the thermal wave generated inside the room to reach the exterior surface of the wall and is given by, the above expression, t is the time, K_w, ρ_w, C_w and δ_w are the thermal conductivity, density, specific heat capacity, and thickness of the wall, respectively. The parameter C_1 is taken to be (0.165).

R. O. Carvel et al. [7] achieved their studies in a tunnel of 9.5 m wide and 6.4

m height, they used three different pool sizes, square pool (25 m^2), small rectangular pool (10 m^2) and large rectangular pool (100 m^2). They noticed that if there is a pool fire in a tunnel, any forced longitudinal ventilation applied will tend to reduce the severity of the fire unless the fire is very large, in which case the ventilation will cause the fire to increase in severity.

H. B. Awbi [8] illustrated that the removal of smoke takes excessive heat away from the fire zones of the buildings as well as lowering the indoor air temperature and radiant temperature. Then a smoke extraction system or ventilation system is most needed in public buildings such as shopping malls, leisure centers and airport terminals.

S. H-K. Lee et al. [9] showed that at low pressure, the mass flow rate of air into the enclosure was independent of temperature difference between the ambient and the enclosure or the vent length. However, at high pressure the flow rate increases with decreasing vent length and temperature difference.

W, K. Chow et al. [10] carried out full-scale tests with wood cribs and methanol in fire chamber of length 4.0 m, width 3.0 m and height 2.8 m to study the pre-flash over stage of a compartmental fire and the effect of ventilation. The mass loss rate of fuel, temperature distribution in the compartment, air flow rates, oxygen, carbon monoxide and carbon dioxide concentrations at the outlet openings were measured. And they decided that for forced ventilation fire, the ventilation rate has a significant effect on the burning process, the peak rate of heat release would be decreased as the ventilation rate increased. Also they mentioned that the ventilation factor has a significant effect in fire control when the ventilation factor was < 0.02 m.

M. Walters et al. [11] after examining a number of disastrous fires concluded that the fire become a disaster and governments adopt fire safety legislation and consider whether performance codes would provide a more a appropriate regulatory environment. The purpose of the present work is to study the influence of some main parameters have a significant effect on the fire depression in compartmental fire under forced ventilation, among these parameters are: ventilation rate (V'), ventilation factor (F_V) and the effect of ventilation factor on the temperature distribution through vertical heights.

The objective of this experimental work is to study the effect of changing the ventilation factor (by change the angle of louvers 'supply air grill' opening by 30^o, 45^o, 60^o, 75^o and 90^o) and the ventilation rates (by change the speed of extracting fans by 2868, 2846, 2810 and 2765 r.p.m.. The speed of fans was changed by using a voltage regulator after that it was measured by electrical tachometer

To study this parameter, a test rig has been modified with dimensions of (100 cm height, 100 cm width and 75 cm length). The room was provided by inlet air opening of (26.5 cm width and 26 cm height) with seven movable louvers and two outlet ducts of 18 cm diameter in which two axial fans were fixed. A variable amount of ventilation rates (0.162, 0.131, 0.078 and 0.067 m^3/s) and different ventilation factors (0.0006, 0.0041, 0.011, 0.0215 and 0.0219 $m^{5/2}$) was put under study.

The test room is provided by one inlet opening with flexible louvers (supply air grill) in order to control the ventilation factor by changing the angle of opening for the louvers "angle of inclination", Also it is provided with two circular outlet openings in the top of the room. The test room has a thermal sight glass to observe the experiment procedures.

2. Experimental Apparatus and Procedure

The test rig consists of the following parts: test room, louvers (supply air grill), thermal glass, ducts, extraction or suction fans, combustion pans, electrical ignition coil, and necessary measuring instruments. Experiments were carried out in the climate chamber. The room dimensions are: 100 cm height, and cross section of (100 cm × 75 cm), Figures (1, 2) show a schematic layout of the test rig and its main components.

An experimental room was designed to study the effect of forced ventilation on a compartmental fire under variable amounts of ventilation rates and different ventilation factors. Air was supplied into the room at a constant temperature (the average ambient air temperature) through the louvers openings. The inlet temperature and velocities of air were measured by using manufactured and calibrated hot wire anemometer.

Chamber walls are made from wood sheets (outer walls of 1 cm thickness) and steel sheets of 0.08 cm thickness (inner walls) and between them filled with 5 cm of insulation material of wood particles. However the air indoor temperature has been measured through seven vertical planes distributed upstream through thermocouple rake with seven thermocouples labeled T_1 to T_7 and spaced at 125 mm intervals. There is another measuring point from the same type in the center of the room labeled T_8 to measure the smoke temperature. Temperature measurement points are shown in figure (3).

Thermal glass has thickness of 5 mm. and area of (40 cm × 20 cm) fixed in the front of the chamber to enable the observation of the experimental procedures and the flame inside the chamber.

There are two ducts to extract the exhaust gases from the chamber . Each duct is supported on the ceiling of the chamber by flanges and insulated by a suitable insulation material. The dimensions of each duct are 50 cm height and 18 cm diameter and enlarged in the center of part two (21 cm dia.) to fix the fan. Ducts were made from steel sheet of thickness 0.8 mm and constructed in this way for the following reasons:

i. To put the fan far from the flame source to protect it from unexpected high temperature.
ii. To fix the fan axially as it designed.

3. Measuring Technique

The inlet temperature and velocities of air have been measured by using manufactured and calibrated hot wire anemometer. Temperatures inside the room have been measured through vertical positions (y/H = 0.25, 0.375, 0.5, 0.625, 0.75, 0.875 and 1.0) by using a manufactured thermocouple from type 'J' connected to a "Fluke Helios I data logger" to record temperature readings instantaneously for all measuring points at the same time for every scan.

In the outlet openings there are two suction fans which are fixed in order to enable the change of air speed extraction rate and then change the ventilation rate. Exhaust velocities are measured by using hot wire anemometer.

From the calibration curve for thermocouple probe the main observation is that the deviation of the data logger thermocouple readings curve from the reference curve is small so that the readings which have been taken by the data logger thermocouple can be used directly without calibration.

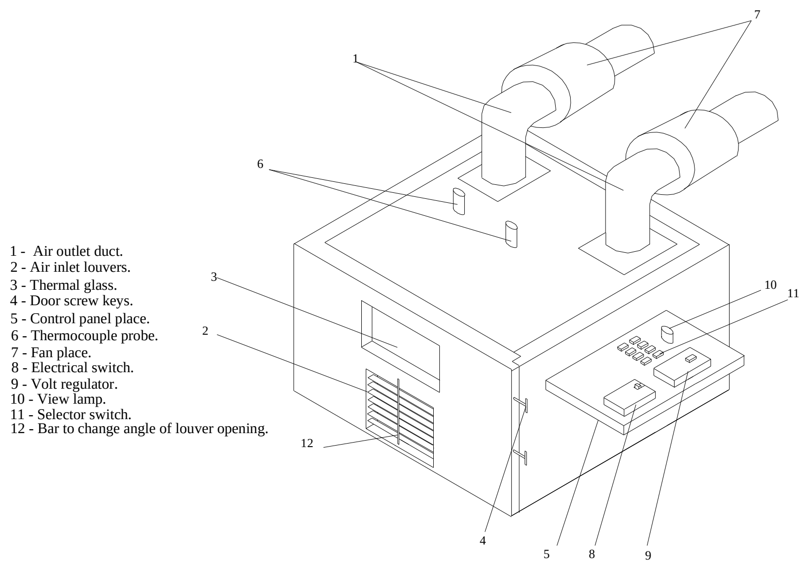


Fig. (1). Layout of the test rig.

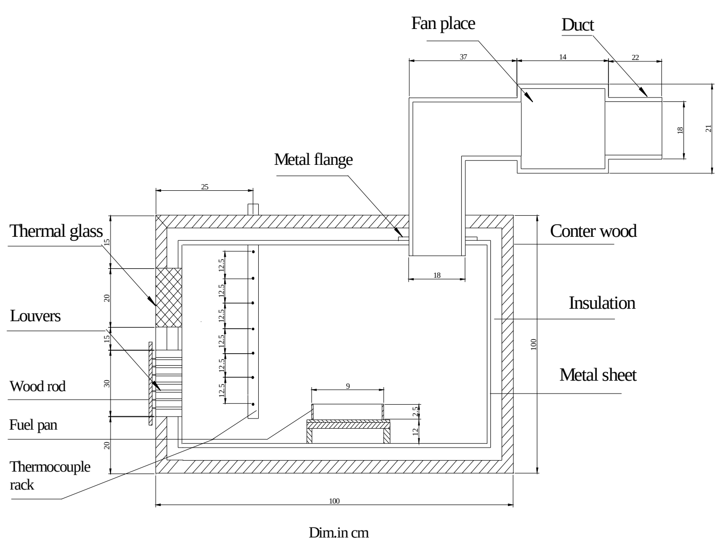


Fig. (2). A-A section in the test room.

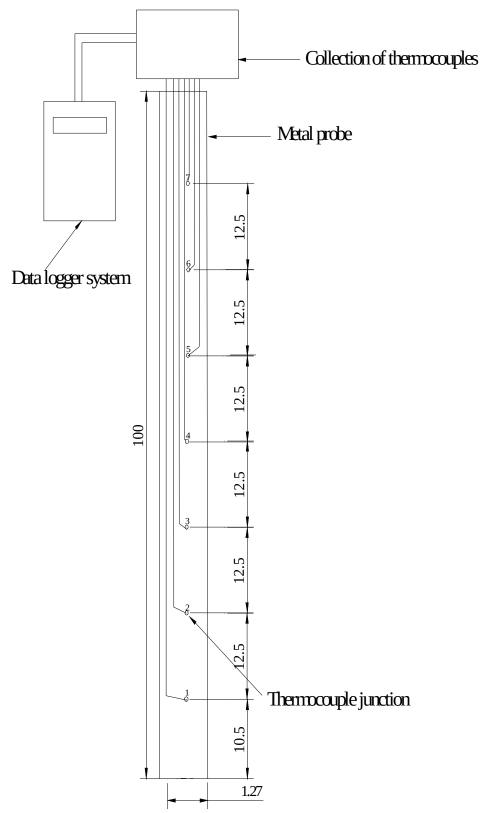


Fig. (3). Temperature measurement points and thermocouple probe, Dim in cm.

4. Results and Discussions

4.1 Effect of Ventilation Factor on the Temperature Distribution through Heights for Benzene.

4.1.1 Results for Forced Ventilation

Figures from (4) to (7) illustrate the relationship between the temperature profiles against fire duration of combustion for benzene at different ventilation factors such as: 0.0006, 0.0041, 0.011, 0.0215and 0.0219$m^{5/2}$. The test conditions were: ventilation rate 0.162, 0.131, 0.078 and 0.067 m^3/s , as well, different measurements temperature at vertical positions (y/H).

By comparing the figures for different ventilation factors the following observations may be obtained from Figs. (4) and (5).

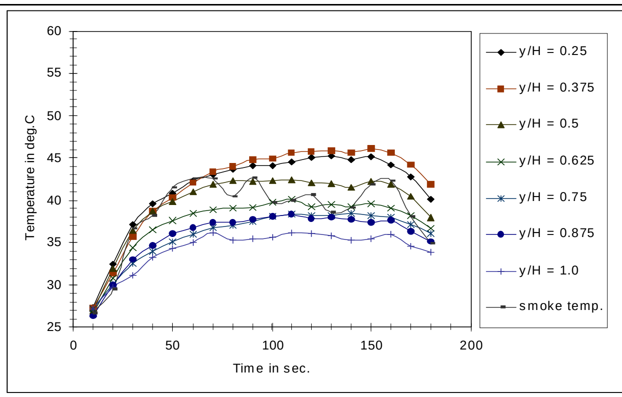
1. For all values of F_V the maximum temperature values were recorded at vertical position of (y/H) = 0.375, this observation may be obtained because this measuring point is the nearest point to the flame.

2. The minimum values of temperature were obtained at vertical location (y/H) = 1.0 or at the top inner surface of the compartment, this observation may be recognized as a result of the effect of forced ventilation which lead to inter fresh air with sufficient speed to overcome the accumulated heat rate of the compartment.

3. For all vertical positions (y/H) the temperature profile indicated that the air layer in the compartment organized in accurate thermal stratified layers.

4. Smoke temperature appeared to be in different thermal stratified layer because the effect of buoyancy and circulation that occurred by the influence of forced ventilation.

5. The maximum temperature was obtained at F_V = 0.0215 $m^{5/2}$ and (y/H) = 0.375.

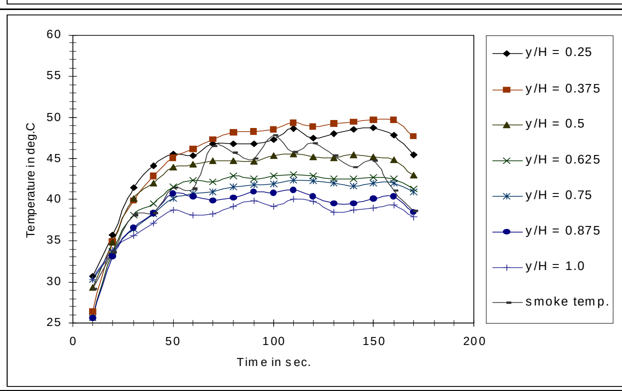


(a)

F_V = 0.0006 $m^{5/2}$,

V = 0.162 m^3/s,

Benzene fuel.

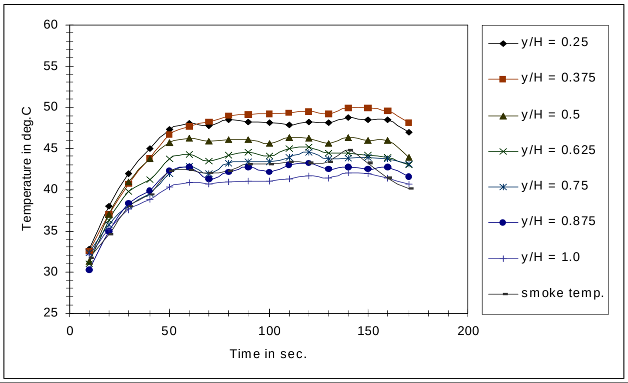


(b)

F_V = 0.0041$m^{5/2}$,

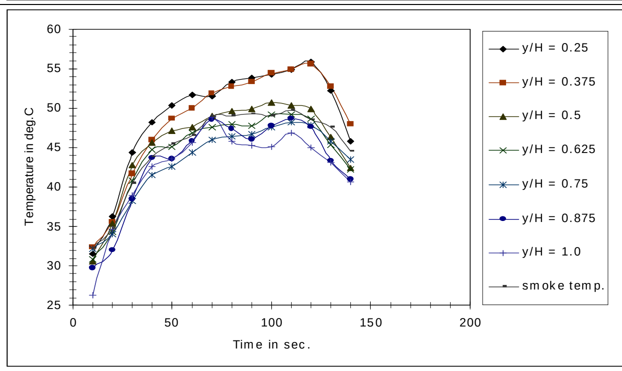
V = 0.162 m^3/s,

Benzene fuel.



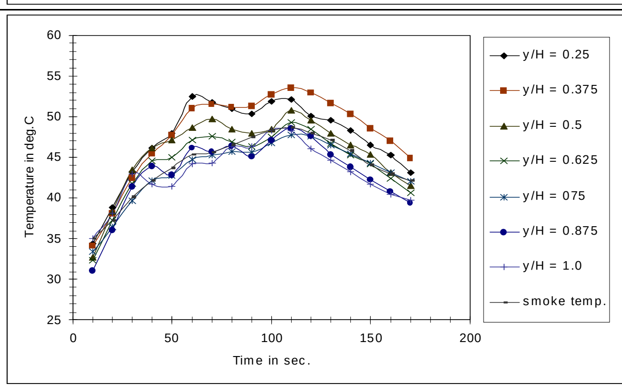
(c)

$F_V = 0.011 m^{5/2}$,
$V = 0.162\ m^3/s$,
Benzene fuel.



(d)

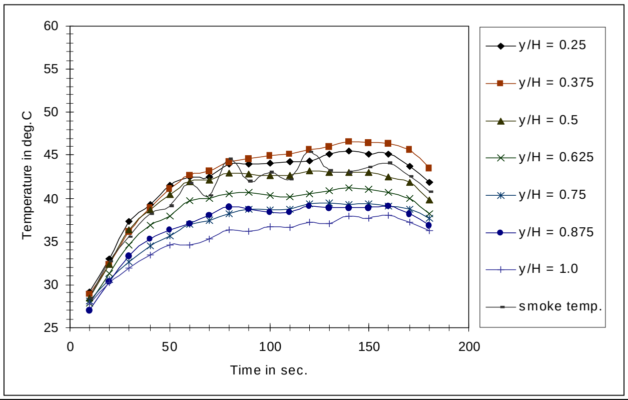
$F_V = 0.0215\ m^{5/2}$,
$V = 0.162\ m^3/s$,
Benzene fuel.



(e)

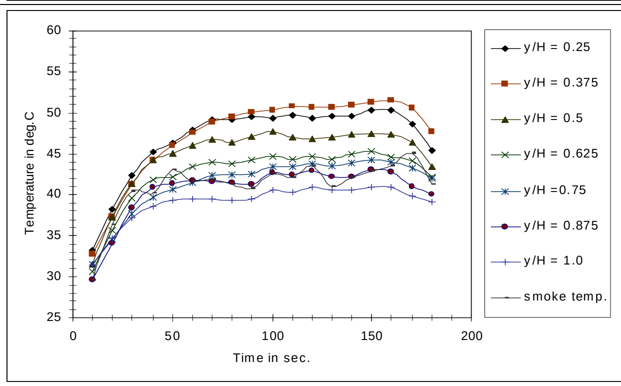
$F_V = 0.0219\ m^{5/2}$,
$V = 0.162\ m^3/s$,
Benzene fuel.

Fig. (4). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.162\ m^3/s$) and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using benzene fuel.



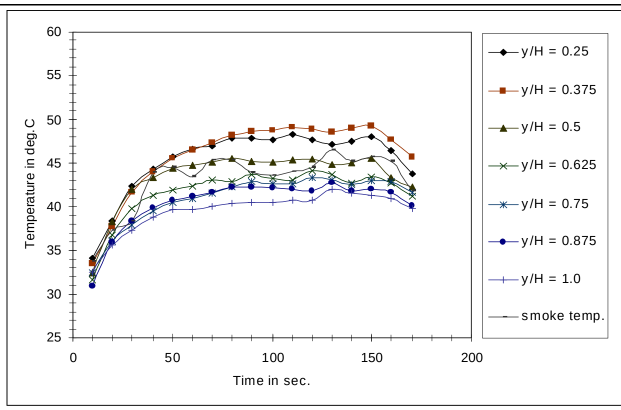
(a)

$F_V = 0.0006\ m^{5/2}$,
$V = 0.131 m^3/s$,
Benzene fuel.



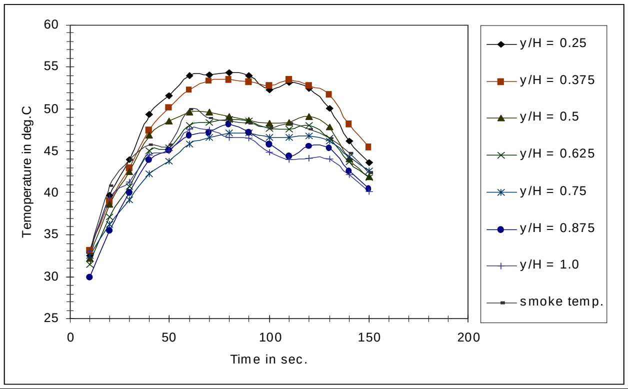
(b)

$F_V = 0.0041 m^{5/2}$,
$V = 0.131 m^3/s$,
Benzene fuel.



(c)

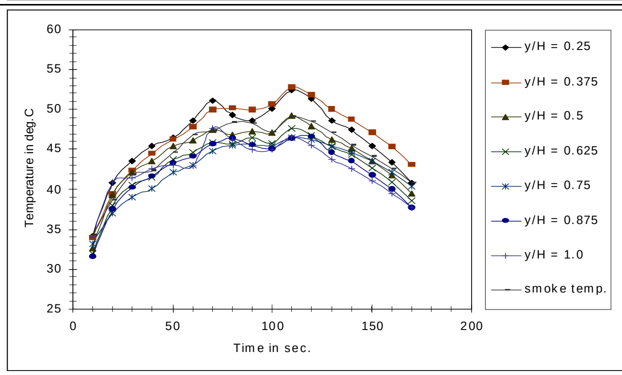
$F_V = 0.011 m^{5/2}$,
$V = 0.131 m^3/s$,
Benzene fuel



(d)

F_V = 0.0215 $m^{5/2}$,

$V = 0.131 m^3/s$,
Benzene fuel.



(e)

F_V = 0.0219 $m^{5/2}$,

$V = 0.131 m^3/s$,
Benzene fuel.

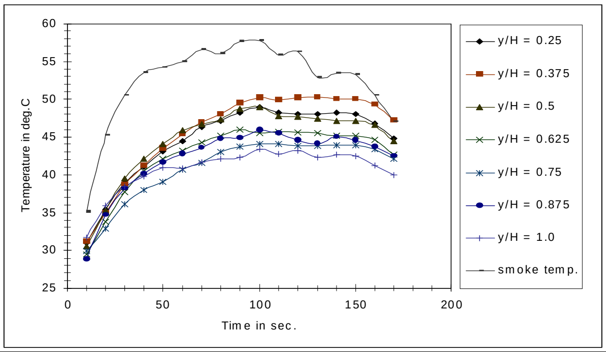
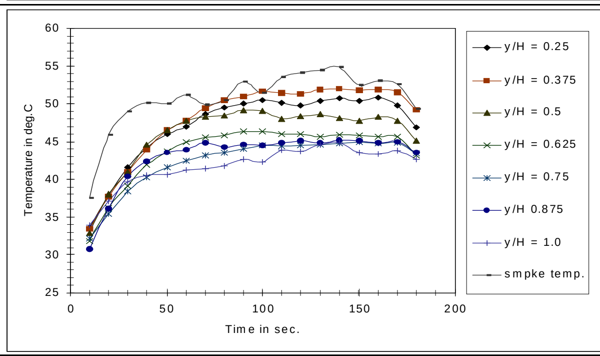
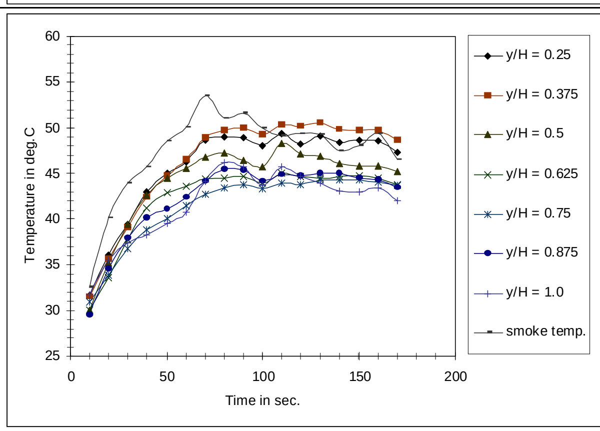
Fig. (5). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.131 m^3/s$) and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using benzene fuel.

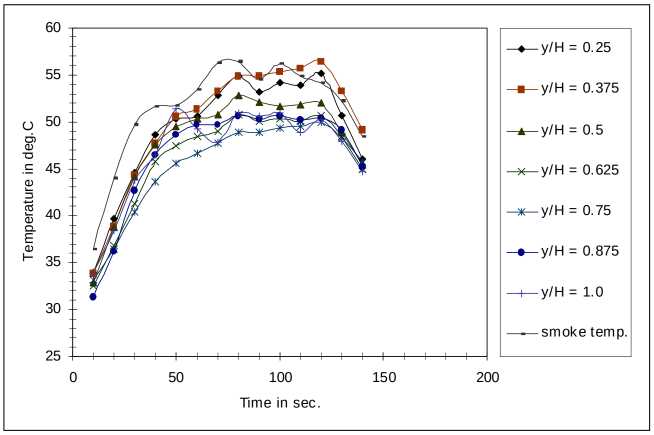
By investigating the results of the different cases of ventilation factors the following observations may report from Figs. (6) and (7):

i) For minimum ventilation factor; F_V = 0.0006 $m^{5/2}$, the maximum temperature were recorded for smoke temperature.

ii) By increasing ventilation factor; F_V, the maximum temperature were obtained for smoke temperature only at the beginning of combustion till reach the maximum value of temperature then its value reduced at the final combustion stages.

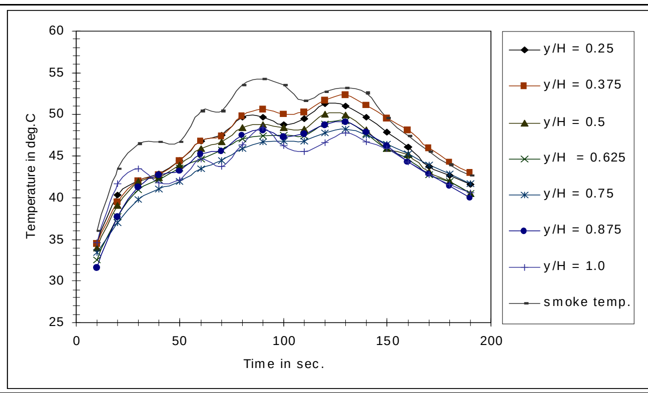
iii) For all vertical positions (y/H) the temperature profile indicated that the air layer in the compartment organized in accurate thermal stratified layers but for vertical position (y/H) = 1.0 its thermal stratified layer follow the same thermal stratified layer of smoke temperature..

	(a) F_V =0.0006 $m^{5/2}$, V = 0.078 m^3/s , Benzene fuel.
	(b) F_V = 0.0041$m^{5/2}$, V = 0.078 m^3/s , Benzene fuel.
	(c) F_V = 0.011$m^{5/2}$, V = 0.078 m^3/s , Benzene fuel



(d)

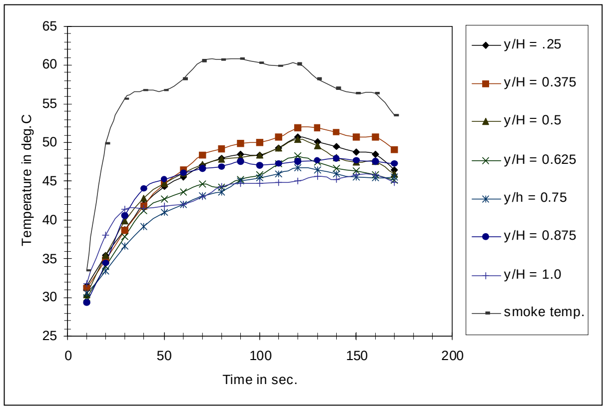
$F_V = 0.0215\ m^{5/2}$,
$V = 0.078\ m^3/s$
,
Benzene fuel.



(e)

$F_V = 0.0219\ m^{5/2}$,
$V = 0.078\ m^3/s$
,
Benzene fuel.

Fig. (6). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.078\ m^3/s$) and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using benzene fuel.

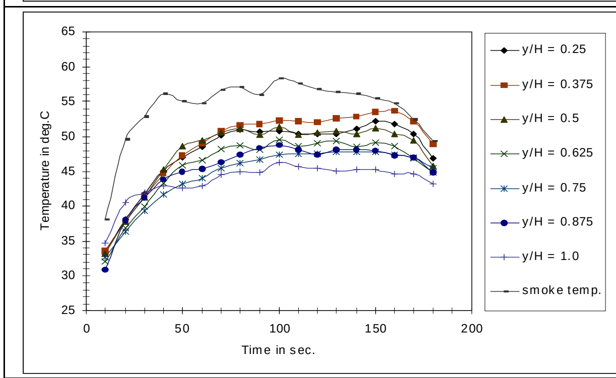


(a)

F_V = 0.0006 $m^{5/2}$,

V = 0.067 m^3/s,

Benzene fuel.

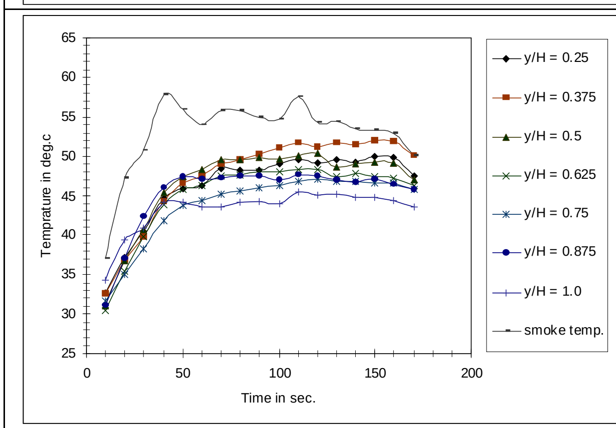


(b)

F_V = 0.0041$m^{5/2}$,

V = 0.067 m^3/s,

Benzene fuel.

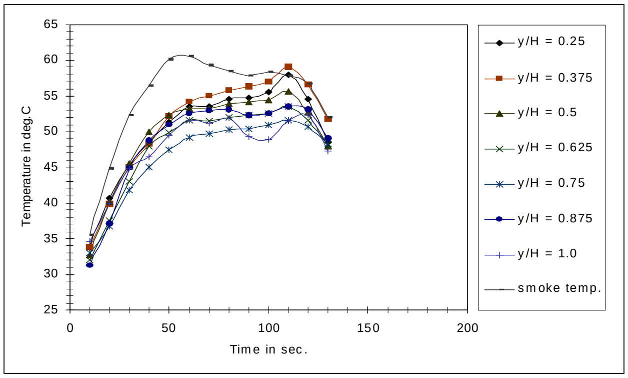


(c)

F_V = 0.011$m^{5/2}$,

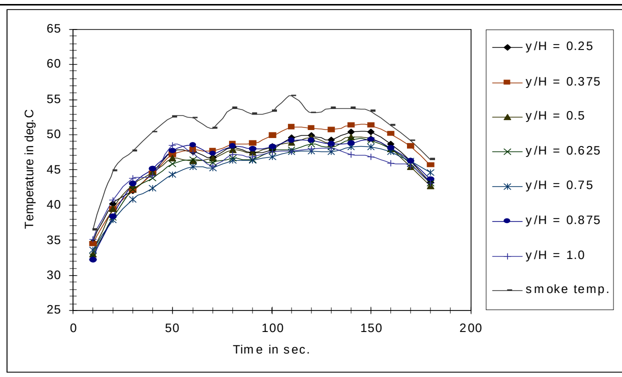
V = 0.067 m^3/s,

Benzene fuel



(e)

F_V = 0.0215 $m^{5/2}$,
$V = 0.067\ m^3/s$,
Benzene fuel.



(e)

F_V = 0.0219 $m^{5/2}$,
$V = 0.067\ m^3/s$,
Benzene fuel.

Fig. (7). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.067\ m^3/s$) and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using benzene fuel.

4.2 Effect of Ventilation Factor on the Temperature Distribution through Vertical Heights for Wood

4.2.1 Results for Forced Ventilation

Figures from (8) to (11) illustrate the relationship between the temperature profiles against fire duration of combustion for wood at different ventilation factors such as: 0.0006, 0.0041, 0.011, 0.0215 and 0.0219 $m^{5/2}$. The test conditions were: ventilation rate 0.162, 0.131, 0.078 and $0.067\ m^3/s$, as well, different measurements temperature at vertical positions (y/H).

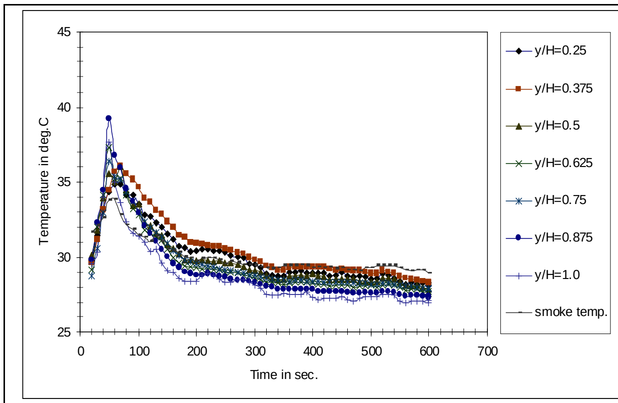
The following observations may be obtained from Fig 5a:

i) For all values of F_V, the maximum temperature values were obtained at smoke temperature except for F_V = 0.0006 $m^{5/2}$ and $\dot{V}$ = 0.162 m^3/s the maximum temperature was recorded at vertical position (y/H) = 0.875 this observation may be obtained because the effect of the ventilation rate as ventilation rate reducing the temperature of the compartment at the inlet openings of louvers but the vertical position (y/H) = 0.875 was not at the inlet opening position.

ii) For all vertical positions (y/H) the temperature profile indicated that the air layer in the compartment organized in accurate thermal stratified layers.

iii) Smoke temperature appeared to be in different thermal stratified layer because the effect of buoyancy and circulation that occurred by the influence of forced ventilation.

iv) The maximum temperature and minimum fire duration were obtained at F_V = 0.0219 $m^{5/2}$.

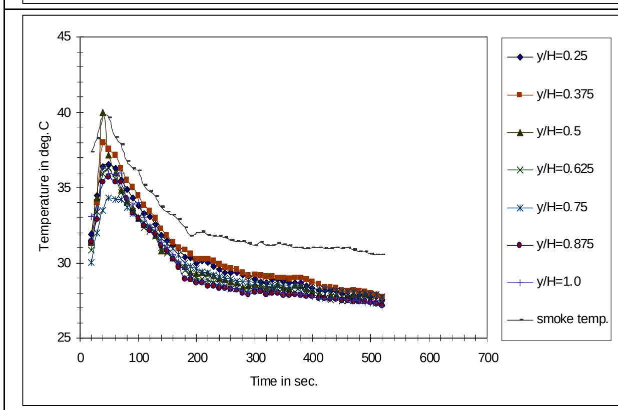


(a)

F_V = 0.0006 $m^{5/2}$,

V = 0.162 m^3/s,

Wood fuel.

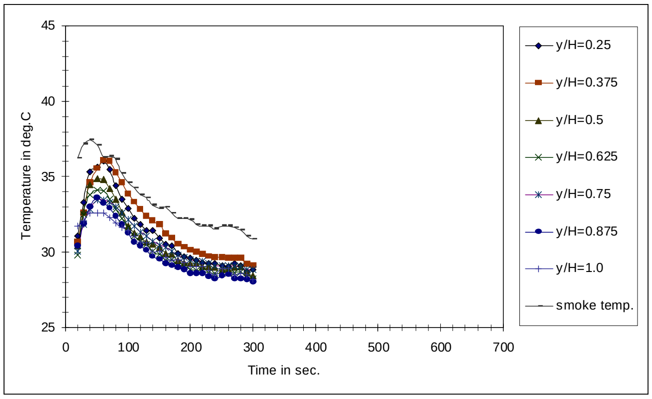


(b)

F_V = 0.0041 $m^{5/2}$,

V = 0.162 m^3/s,

Wood fuel.

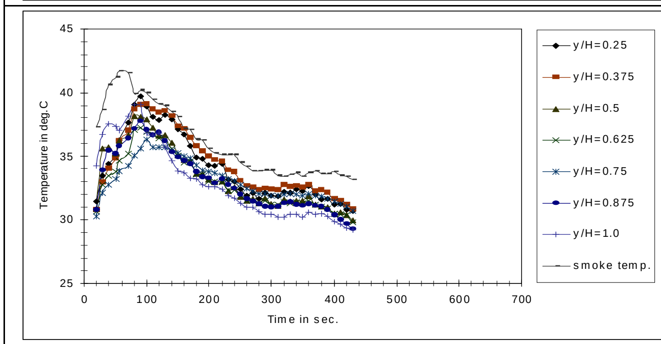


(c)

F_V = 0.011m$^{5/2}$,

$V = 0.162\ m^3/s$,

Wood fuel.

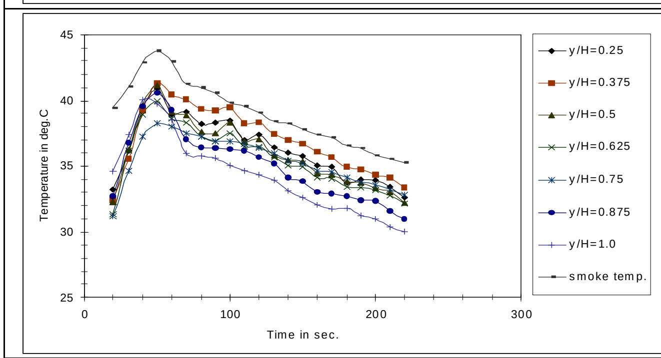


(d)

F_V = 0.0215 m$^{5/2}$,

$V = 0.162\ m^3/s$,

Wood fuel.



(e)

F_V = 0.0219 m$^{5/2}$,

$V = 0.162\ m^3/s$,

Wood fuel.

Fig. (8). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.162\ m^3/s$) and for the (a) ventilation factor = 0.0006 m$^{5/2}$ (b) ventilation factor 0.0041m$^{5/2}$, (c) ventilation factor = 0.011m$^{5/2}$, (d) ventilation factor = 0.0215 m$^{5/2}$ and (e) ventilation factor = 0.0219 m$^{5/2}$ using wood fuel.

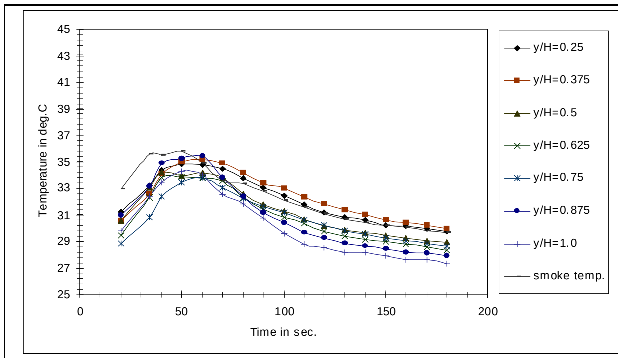
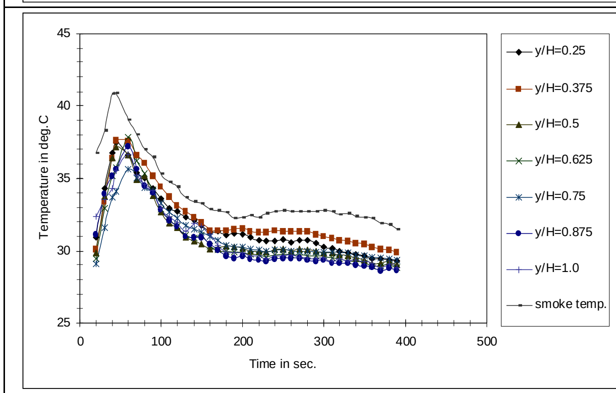
By investigating the results for different ventilation factors the following observations may be obtained from Fig. (9):

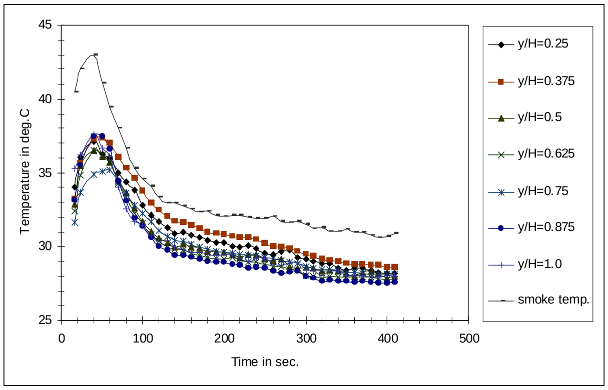
i) For all values of F_V the maximum temperature values were obtained at smoke temperature.

ii) For all vertical positions (y/H) the temperature profile indicated that the air layer in the compartment organized in accurate thermal stratified layers.

iii) Smoke temperature appeared to be in different thermal stratified layer because the effect of buoyancy and circulation that occurred by the influence of forced ventilation.

iv) The maximum temperature and minimum fire duration were obtained at F_V = 0.0041 $m^{5/2}$ and F_V = 0.0006 $m^{5/2}$

	(a) F_V = 0.0006 $m^{5/2}$, V = 0.131 m^3/s , Wood fuel.
	(b) F_V = 0.0041$m^{5/2}$, V = 0.131 m^3/s , Wood fuel.

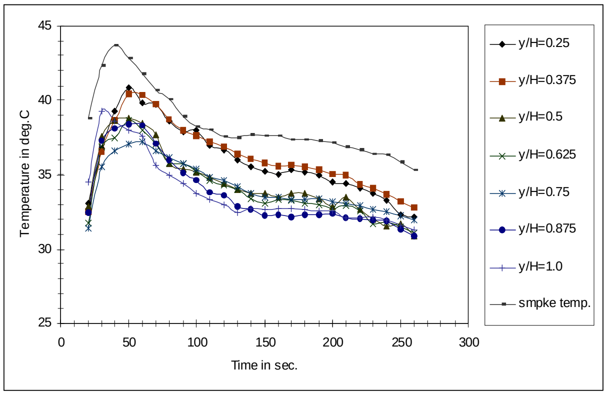


(c)

$F_V = 0.011 m^{5/2}$,

$V = 0.131\ m^3/s$,

Wood fuel.

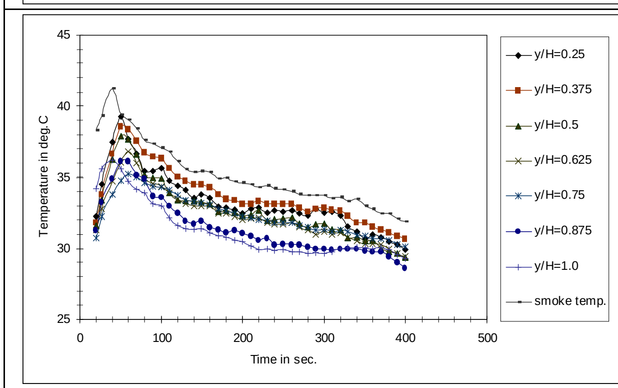


(d)

$F_V = 0.0215\ m^{5/2}$,

$V = 0.131\ m^3/s$,

Wood fuel.



(e)

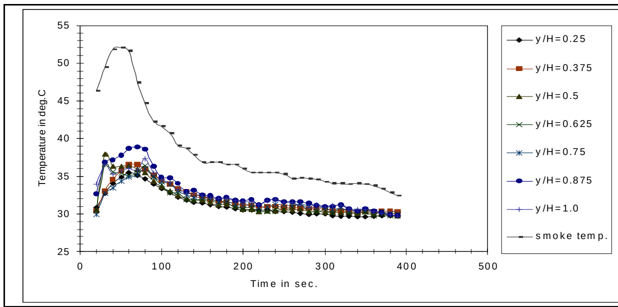
$F_V = 0.0219\ m^{5/2}$,

$V = 0.131\ m^3/s$,

Wood fuel.

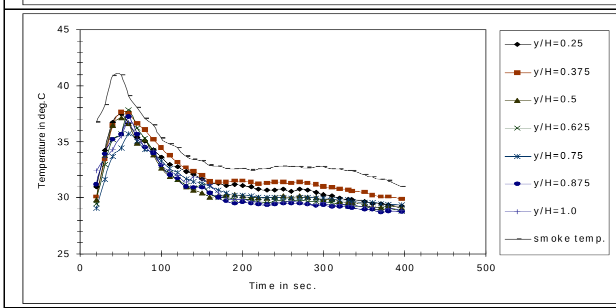
Fig. (9). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.131\ m^3/s$) and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using wood fuel.

Investigating the results of the different cases of Fig. (10) shows that the observations which mentioned in the previous case; (Fig. (9), are the same in this case. In addition to the accurate effect of decreasing ventilation factor on the temperature profile; for smoke, the maximum temperature was at $F_V = 0.0006\ m^{5/2}$ and minimum fire duration was recorded at $F_V = 0.0215\ m^{5/2}$.



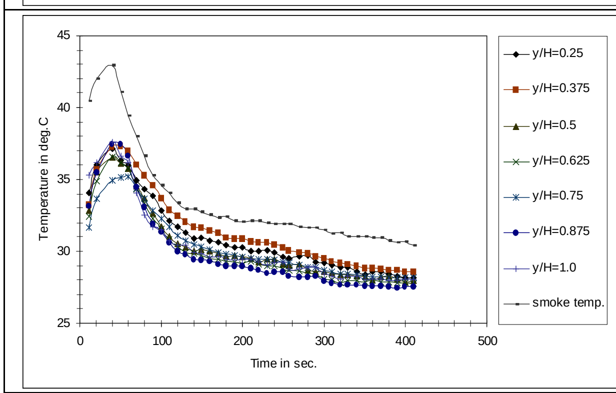
(a)

$F_V = 0.0006\ m^{5/2}$,
$V = 0.078\ m^3/s$,
Wood fuel.



(b)

$F_V = 0.0041 m^{5/2}$,
$V = 0.078\ m^3/s$,
Wood fuel.



(c)

$F_V = 0.011 m^{5/2}$,
$V = 0.078\ m^3/s$,
Wood fuel.

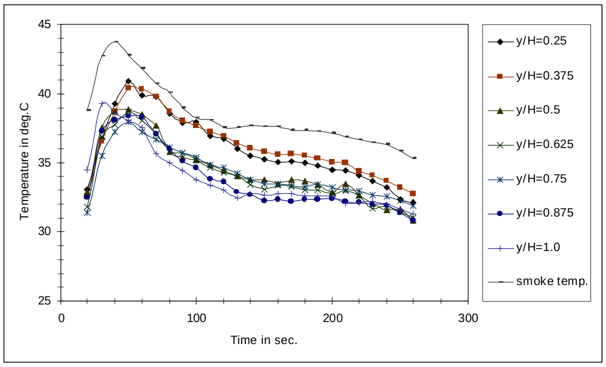
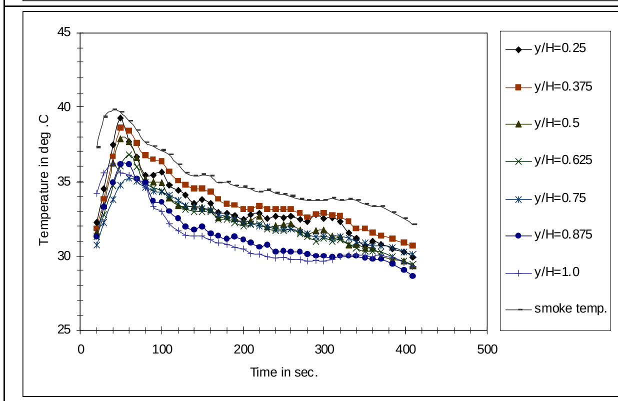
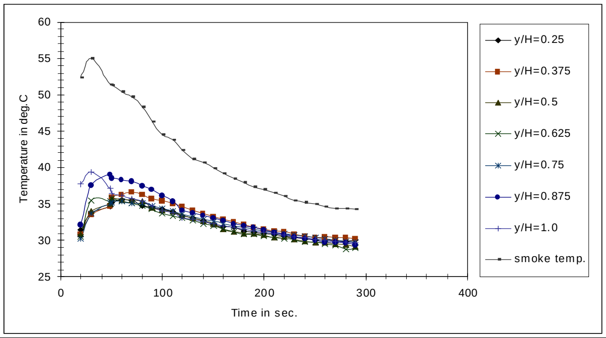
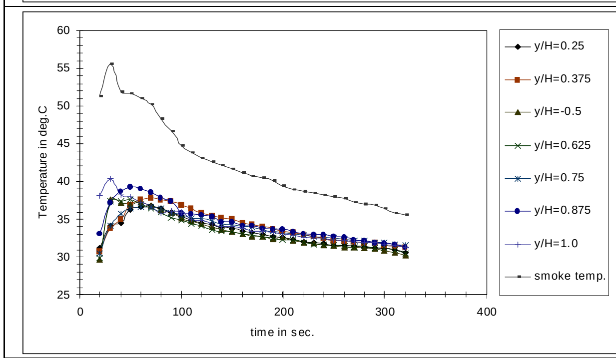
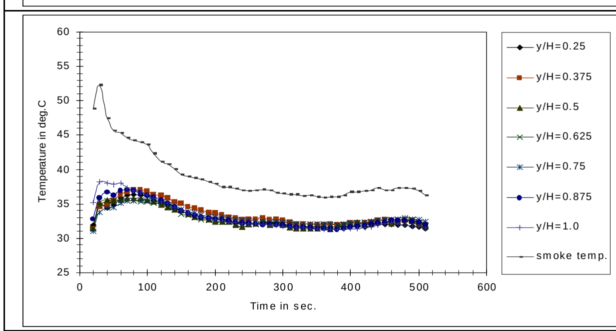
	(d) F_V = 0.0215 $m^{5/2}$, V = 0.078 m^3/s, Wood fuel.
	(e) F_V = 0.0219 $m^{5/2}$, V = 0.078 m^3/s, Wood fuel.

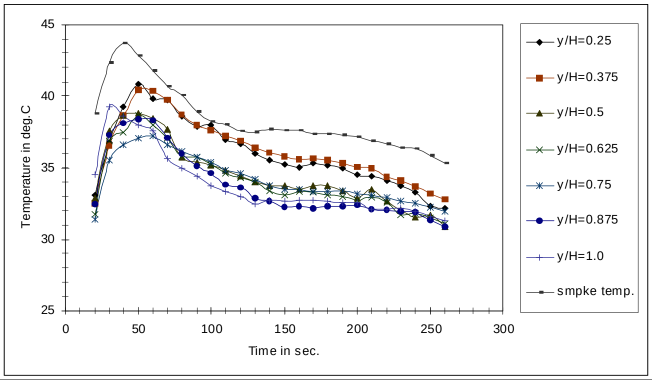
Fig. (10). Effect of vertical height on temperature profile versus time for constant ventilation rate (V = 0.078 m^3/s) **and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using wood fuel.**

The observations results appear from figure (11) as the same mentioned in the previous Fig. (10). In addition to the following observations:

i) First, the high temperature difference between any measuring point and the smoke temperature, this was a resultant of the low ventilation rate.

ii) Second, the minimum fire duration was reached at F_V = 0.0219 $m^{5/2}$.

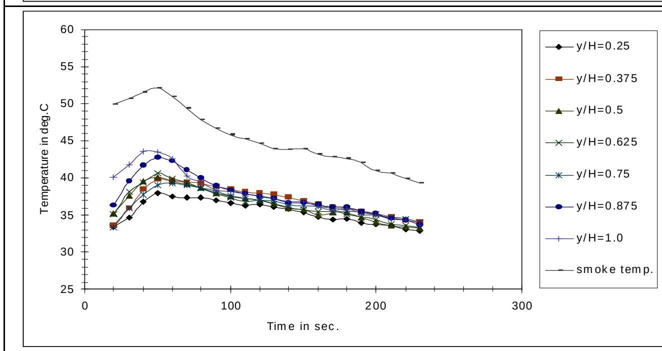
	(a) F_V = 0.0006 $m^{5/2}$, V = 0.067 m^3/s, Wood fuel.
	(b) F_V = 0.0041$m^{5/2}$, V = 0.067 m^3/s, Wood fuel.
	(c) F_V = 0.011$m^{5/2}$, V = 0.067 m^3/s, Wood fuel.



(d)

$F_V = 0.0215\ m^{5/2}$,

$V = 0.067\ m^3/s$,
Wood fuel.



(e)

$F_V = 0.0219\ m^{5/2}$,

$V = 0.067\ m^3/s$,
Wood fuel.

Fig. (11). Effect of vertical height on temperature profile versus time for constant ventilation rate ($V = 0.067\ m^3/s$) and for the (a) ventilation factor = 0.0006 $m^{5/2}$ (b) ventilation factor 0.0041$m^{5/2}$, (c) ventilation factor = 0.011$m^{5/2}$, (d) ventilation factor = 0.0215 $m^{5/2}$ and (e) ventilation factor = 0.0219 $m^{5/2}$ using wood fuel.

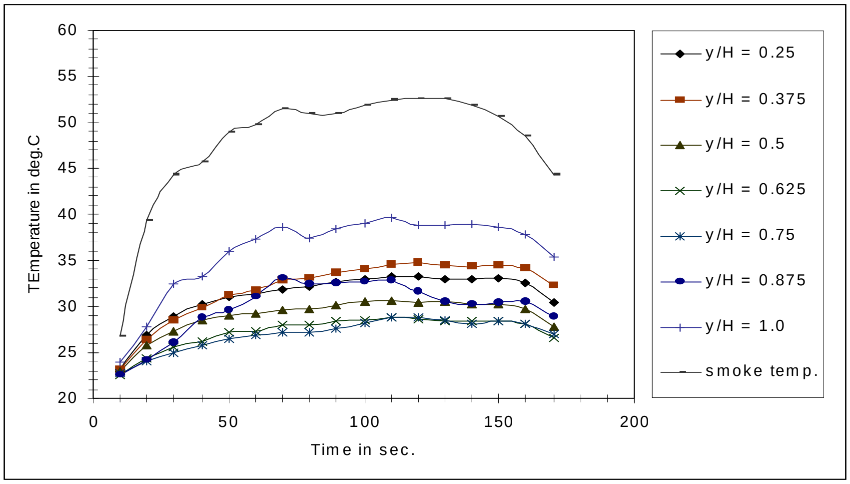
4.3 Results for Natural Ventilation

Figure (12) shows the relationship between the temperature profile and time of combustion at different ventilation factors. The test conditions were: natural ventilation and different vertical positions (y/H). By investigating the results of the two cases for natural ventilation the following observations may be obtained:

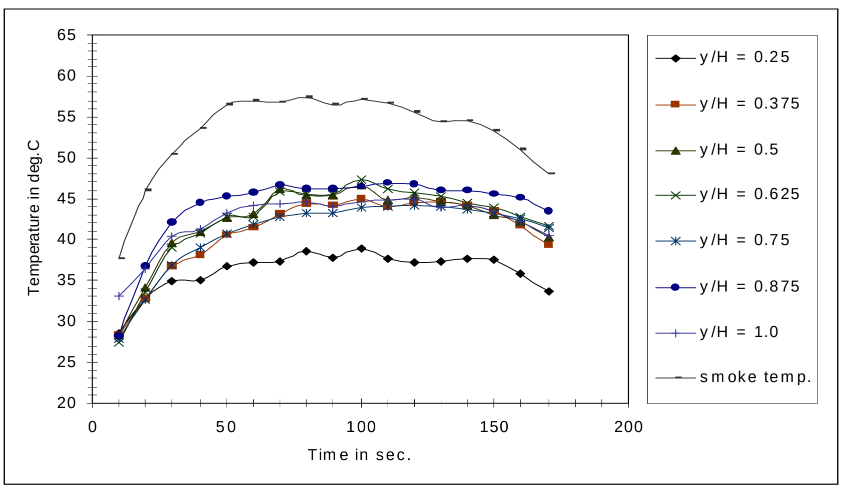
1. at the compartment door was opened the temperature difference between maximum value of smoke temperature and maximum value of temperature at vertical position (y/H) = 1.0 is high about 15 ^{0}C.

2. The maximum temperature was smoke temperature followed by temperature at vertical position (y/H) = 1.0 this observation is the result of natural ventilation as there is no buoyancy of air inside the compartment then at the upper hot layer of the compartment the hot air (smoke) going upstream as shown in Fig. (12I).

3. At door closed the effect of ventilation factor was observed clearly, as temperature at vertical position (y/H) = 1.0 not differed by high value than any vertical position. But smoke temperature remained the maximum temperature in the compartment as shown in Fig. (12).



(a) Door opened



(b) Door closed

Fig.(12). Effect of vertical height on temperature profile versus time for ventilation factor, F_V = 0.0219 $m^{5/2}$ and for wood fuel.

5. Conclusions

The results of experimental tests conducted on the compartmental fire under forced and natural ventilation are concluded in the following points:

• The maximum temperature for benzene "gasoline" combustion according to any measuring point (y/H) were recorded at (F_v = 0.0215 m5/2 and minimum ventilation rate ($V = 0.067\ m^3/s$) and minimum fire duration was obtained at this condition. As well as, the maximum temperature of smoke or exhaust gases were occurred at the same conditions.

• For forced ventilation on benzene "gasoline" combustion process the minimum value of temperature was related to vertical position (y/H) = 1.0, but maximum temperature was obtained at vertical position (y/H) = 0.375 due to F_v = 0.0215 m5/2 also minimum fire duration occurred at this case. By increasing the ventilation factor the maximum temperature was noticed at smoke temperature and smoke layer appeared to be in a different thermal stratified layer by comparing with the thermal stratified layer of air at any measuring point.

• For natural ventilation on benzenes "gasoline" combustion process without the effect of ventilation factor the maximum temperature was related to the exhaust gases followed by the temperature of vertical location of (y/H) = 1.0. In contrary for natural ventilation with the effect of ventilation factor the maximum temperature was also the smoke temperature but not followed by the temperature of vertical location (y/H) = 1.0.

• In the case of using wood particles the forced ventilation effect on the combustion process was, the maximum temperature was related to smoke temperature for all ventilation factors. However the temperature for all vertical positions (y/H) indicated that air in the compartment organized in accurate thermal stratified layers while smoke layer organized in a different thermal stratified layer due to the effect of forced ventilation. The maximum temperature was obtained at maximum ventilation factor F_v = 0.0219 m5/2 although the minimum fire duration was occurred at the same value of F_v.

• For natural ventilation on wood particles combustion process without the effect of ventilation factor, the maximum temperature was related to smoke temperature then followed by the temperature of vertical position (y/H) = 1.0. In spite of this case, for natural ventilation with the effect of ventilation factor the maximum temperature was also the smoke temperature, but temperature of vertical position of (y/H) = 1.0 not differ by high value than any vertical position.

• The maximum heat released rate was obtained at F_v = 0.0215 m5/2 and $V = 0.067\ m^3/s$ for liquid fuel and the maximum heat released rate for solid fuel was obtained at F_v = 0.0219 m5/2 and $V = 0.162\ m^3/s$.

• The recommended ventilation factors on compartmental fire under forced ventilation with liquid or solid fuel it should be > 0.0215 m5/2, otherwise the decreasing of ventilation factor result in undesirable effects i.e. increasing the fire duration.

- The effect of ventilation rates on fire depression depends on the fuel type as observed from the experimental results that the low ventilation rate was suitable for liquid fuel but the high ventilation rate was suitable for solid fuel

6. Acknowledgement

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تأثير معاملِ التهويةِ ونسبةِ التهويةِ على توزيعِ درجةِ الحرارة خلال الارتفاعات الراسية العموديةِ

بهجت خميس مرسى* سيف النصر احمد عبد الغني**

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***الكلية التكنولوجية – بنى سويف – مصر*

(قدم للنشر في١٤/٨/٢٠١٠ ؛ وقبل للنشر في١/١٢/٢٠١٠)

ملخص البحث. يُهدّفُ هذا العمل إلى دِراسَة البارامتراتِ الفعّالةِ التي تؤثر على التهويةِ الإجباريةِ في حالة حدوث الحرائق التي يُمْكِنُ وُضَعهاَ تحت السّيطرة. هناك العديد مِنْ البارامتراتِ التي تُحدّدُ التهويةَ الإجباريةَ مثل عاملِ التهويةِ، هذا البارامترِ تم دراسته بشكل تجريبي خلال غرفة اختبار صممت وجهزت لهذه الدراسة وأجريت الدراسة تحت تغير معدل التهوية وكذلك أنواع مختلفة من الوقود مثل البنزين و وجزيئات خشبِ. كميات البنزينِ التي استخدمت ٤٫٢جرام وجزيئات خشبِ ٥، ١٠ و١٥ جرام.

أوضحت النتائج التجريبية تأثيرَ كل من معامل ومعدل التهويةِ على انتشار اللهب وإخماده عند معامل تهوية عالي بقيمة اكبر أو يساوى 0.0215 ومعدل تهوية منخفض بقيمة اقل أو يساوى 0.067 أيضاً أشارت النَتائِجُ بأنه في حالة نَقْص في عاملِ التهويةِ وتزايد معدل التهويةِ يُؤدّيا إلى التأثيراتِ الغير مرغوبةِ في الوقت المطلوب لإخماد اللهب.

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Water Purification Process by Using One Side Vertical Solar Still

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Abstract. Solar desalination is a rapidly growing field of research. The coming global oil crisis implies that alternatives to the conventional desalination plants based on fossil fuels must be developed. Solar desalination can be either direct, with collectors and condensers integrated with each other, or indirect, with condensers externally connected to the condensers. Direct solar desalination requires large land areas and has a relatively low productivity compared to the indirect technologies. It is however competitive to indirect desalination plants in small-scale production due to its relatively low cost and simplicity. Indirect solar desalination usually means combining conventional desalination techniques, such as MSF, ME or RO, with solar collectors for heat generation. The main advantages of the investigation is providing for water purification process in the desert of K.A.S. The paper presents the performance evaluation of one-side vertical solar still tested under desert climatic conditions of K.A.S. Hourly and daily measurements of still productivity, temperatures of water film, glass cover, inlet of brackish water into solar still, ambient air temperature and solar radiation were recorded. The highest value of hourly still efficiency is 59 % recorded at 15:30.

Keyword: Solar energy – Desalination – Solar collector - Productivity

1. Introduction

Water is available in abundance on the earth; however, there is a shortage of potable water in many countries in the world. In the MSF and RO countries and elsewhere, non-renewable energy from oil and natural gas is used to desalinate water from sea water in multi-effect evaporators. Water shortages occurs most at places of high solar radiation, which usually peaks during the hot summer months of maximum solar radiation. Hence, solar desalination could be one of the most successful applications of solar energy in most of the hot climate countries having limited resources of fresh water.

Solar energy is the most appropriate energy source for desalting water. It is sufficient to remember that it is simply due to solar radiation that the renewal of water on earth is made possible, by the cycle of evaporation and successive water condensation in the form of rain. Solar stills could, however, be considered attractive for domestic purposes, especially in areas having no access to the electric grid and low labor cost.

The coupling of solar energy and desalination systems holds great promise for increasing water supplies in water scarce regions. An effective integration of these technologies will allow countries to address water shortage problems with a domestic energy source that does not produce air pollution or contribute to the global problem of climate change. Meanwhile the costs of desalination and renewable energy systems are steadily decreasing, while fuel prices are rising and fuel supplies are decreasing.

2. Literature Review

Solar stills Interest in seawater desalination goes back to the fourth century BC, when Greek sailors used to obtain drinking water from seawater. However, the first solar still was designed and constructed in Chile by the Swedish engineer, Carlos Wilson, in 1872, as described by Malik et al. [1]. Following that, no work was conducted on solar desalination till the end of the First World War. During World War II, Telkes [2] developed a plastic still inflated with air, which was used by the US Navy and Air Force in emergency life rafts.

The single insulated basin still was found to distill water with low efficiency (usually below 45%), depending on the operating conditions, as reported by Malik et al. [1], Cooper [3], Kudish et al. [4] and Farid and Hamad [5]. The low efficiency of the still is mainly due to the high heat loss from its glass cover. They found that a double glass cover reduces heat losses, but it also reduces the transmitted portion of the radiation. The productivity increases when the solar still is operated under reduced pressure Yeh et al. [6]. However, this was found impractical because of the difficulties associated with the reduced pressure operation. Solar radiation received by a horizontal surface is not at its maximum except near the equator. Many investigators have modified the horizontal single-basin still, usually fixed on a horizontal surface, to an inclined type to receive maximum solar radiation. Later, the tilted tray and the wick-type solar still were developed.

However the construction cost of these complicated stills added significant cost penalties, while the increase in the productivity of the stills was very limited. The loss of energy in the form of latent heat of condensation of water at the glass cover is the major problem of the single-basin still. Tiwari et al. [7] arranged the still in such a way as to have the water flow over the glass cover. Preheating of the feed water by passing it over the glass cover allowed only partial recovery of the latent heat, with an increase in the still production. The flow of water over the glass cover reduced the amount of solar radiation received by the water in the still. Accumulation of salts and vapor leaks also frequently caused defects in these units. Further work in improving the efficiency of solar stills was carried out by El-Bahi and Inan [8]. The effect of adding an outside passive condenser to a single-basin-type solar still with minimum inclination (4º) was investigated experimentally. This solar still yielded a daily output of up to 7 L/m^2. They have reported still efficiency of 75% during the summer months. They also found that when the solar still was operated without a condenser, the yield decreased to 70% of that with a condenser. Solar stills were presented by Fath [9], who highlighted the impact of utilizing latent heat of condensation via multi-effect solar stills. Mink et al. [10] conducted an in-depth study on heat recycling using a laboratory-scale solar still of 1 m^2 area, designed to recycle the condensation heat of the distillate. The exposed wick surface area was 1 m^2, with thermal incident energy of 650 W/m^2 being supplied by a solar simulator at a tilt angle of 20º. The forced circulation of ambient air was achieved using a low-pressure variable speed ventilator. Preliminary results showed an increase in productivity per unit area by a factor of two to three compared with tilted wick or basin-type solar stills, respectively.

One of the most recent designs of such a still is that described by Grater et al. [11] and Rheinlander and Grater [12] of a four-effect still. The evaporation process in a four-effect still for the desalination of sea and brackish water was experimentally investigated in a test facility under different modes and configurations of heat recovery. The experimental unit consisted of a base module of the four-effect distillation unit. Multi-effect still: technology for the desalination of 10 ml/d of water Rheinlander and Grater [12].

The gain output rate (GOR) increases by up to 80% due to heat recovery from the distillate latent heat. The model predicted a distillate output in the first effect that was 50% higher than the measured values when the feed temperature was raised to 90°C. It is to be noted that the unit of Grater et al. [11] and Rheinlander and Grater [12] was operated with hot water at a constant temperature of 90°C. Under such high operating conditions, the evaporation and condensation will be very efficient, but long-term operation is not practical due to scale formation. Furthermore, if a solar collector is used to drive the desalination unit, then its collection efficiency will drop to a very low value at such a high temperature. Thus, multi-effect solar stills may carry out more efficient desalination of seawater compared to a single-basin still, but for only small capacities since the condenser and the evaporator are integral parts of the still. The low heat and mass transfer coefficients in this type of still require operation at a relatively high temperature and the use of large and expensive metallic surfaces for the evaporation and condensation. In the following sections, a new class of solar desalinations system is discussed, whose design is based on a more efficient utilization of the latent heat of condensation. Using solar energy source for water desalination, power generation and many other thermal applications has a great deal to save the total national income, Hammons [13] and Ozgener and Kocer [14].

Many studies have been compared between the different renewable energy as desalination driven power for each of brackish and seawater Tzen et al. [15] and Rodrhguez [16]. They found that solar energy is suitable for different desalination process at reasonable cost wherever a proper source is available. One of the main disadvantages is that energy storage is required.

3. Experimental Set Up and Procedures

For the purpose of this study a One Side Vertical Solar Still was constructed and erected in the College of Engineering, Qassim University. A photo of the test rig is shown in Fig. (1). It consisted essentially of three main parts:

(a) Flat plat collector
(b) Evaporation chamber
(c) Condensation chamber.

Fig. (1). Photo of the test rig.

A complete layout of the test rig and details of the test section are shown in Figs. (2-3). It consists of a solar collector which is made of a 1.2 mm thick black steel enclosure (1), covered by a 4 mm thick ordinary glazing (2), supported by a wooden frame (3) and sealed by mastic silicone (4) and an aluminum frame (5) which is support also the glazing. In the evaporation chamber (b), a copper tube distributor (7) of brackish water is provided by holes of circle cross section. The distributor is equal to width of the sponged cloth (8), and the holes are made along the copper tube distributor. Brackish water flows down through the sponged cloth. It is collected in a bottom gutter (9) and discharged from still as a waste. The wire screen (6), black steel plate (10) sponged cloth (8), and wire screen (6) form the absorber unit. In the condensation chamber (c), distilled water is collected from the lower edge (11) of the condensation surfaces in a certain time which is detected by stop watch. The vapor is transferred from the evaporation chamber to the condensation chamber through an upper vent (12) and a lower vent (13) which is made of an insulation layer (14) between the two chambers. The solar still unit is supported by an adjustable vertical stand (19) and the solar radiation intensity is measured by Pyranometer (21).

The brackish water (BW) inlet temperature T_2 , brackish water (BW) outlet temperature T_3, to the flat plate collector for and ambient temperature T_1 are measured by copper-constantan thermocouples (22) which are attached to a temperature recorder (23).

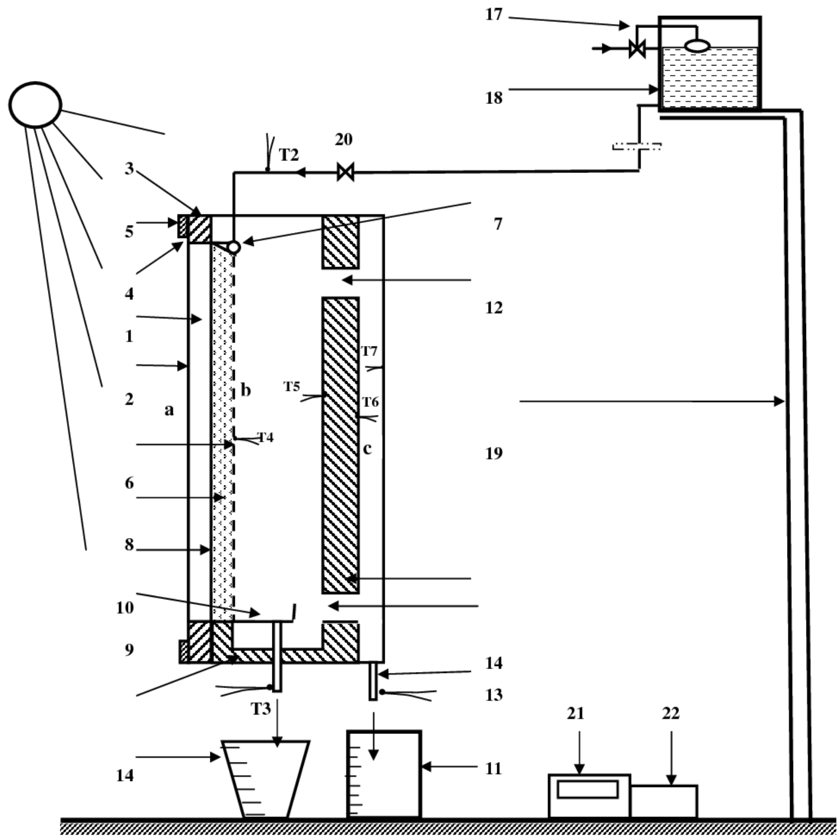

Fig. (2). Test rig of the indirect vertical solar still

1. Collector enclosure	2. Glazing	3. Wooden frame	4. Silicon mastic
5. Aluminum frame	6. Wire screen	7. Water distributer	8. Sponged cloth
9. Bottom gutter	10. Black steel plate	11. Distilled water exit	12. Upper vent
13. Lower vent	14 Insulation layer	15. DW outlet	16. B W outlet
17 Float valve	18. Constant head tank	19. Vertical stand	20. Globe valve
21. Pyranometer	22. Thermocouples	23. Temperature recorder	

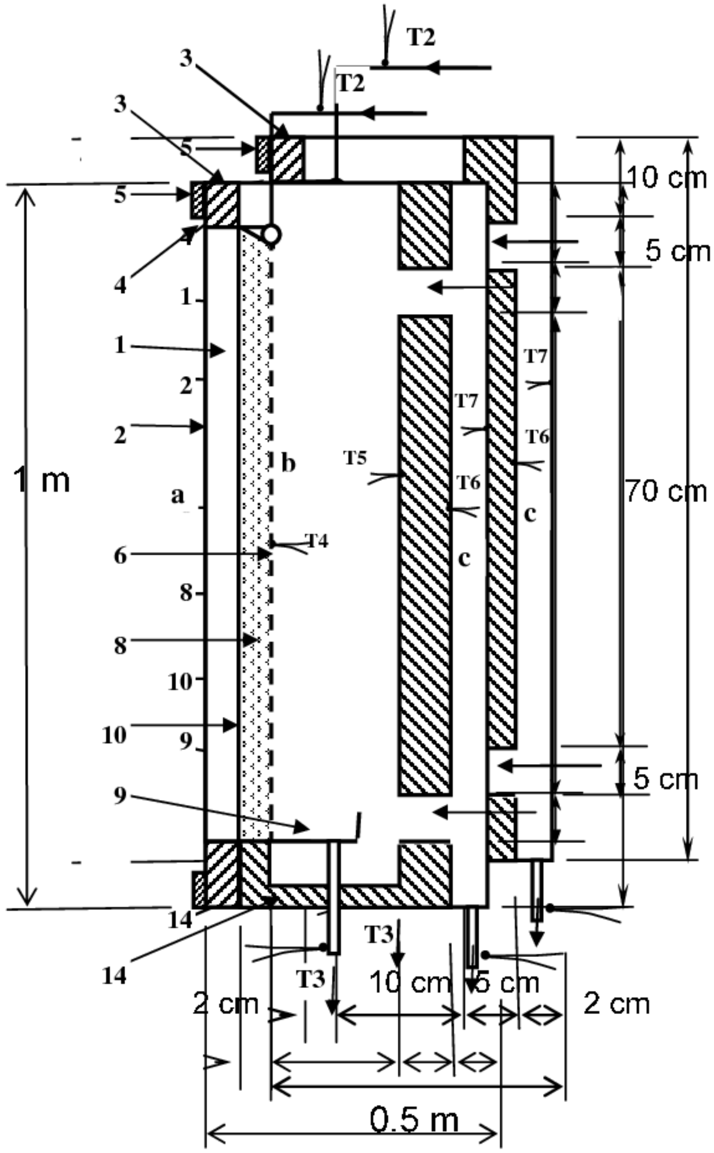

Fig. (3). Test section details.

4. Operating Principle of the Still

Also, figure 2 shows a schematic diagram of the working principle of the solar still. The raw brackish water from constant heat tank (18) enters the still via a copper tube with the help of float valve (17). The flow rate of brackish water is adjusted by means of globe valve (20), and then the brackish water is distributed by a copper tube (7) and water trickle on the back of the absorber plate on the sponged cloth and the wire screen (6). The brackish water exists from the still unit through a bottom gutter (15). Solar radiation, after passing the glazing (2) is absorbed by the absorber unit. The evaporation chamber is connected to the condensation chamber through 5 cm x 10 cm bottom vent (13). The transfer of water vapor from the evaporation chamber could be done through natural circulation. Saturated hot air inside the evaporation chamber tends to move upward, while saturated air inside the condensation chamber tends to move downward. Then, low humidity concentrated condenser on sides of the condensation chamber; distilled water is then collected at the bottom gutter (16).

5. Design Parameters

The design of the prototype is influenced by the desire for flexibility. The intention is to be able to evaluate different design approaches and so the initial apparatus is very easy to dismantle and modifying. During operation, water vapor will diffuse from the highly concentrated evaporator to the low condenser. The collection part of the solar still is made from black steel with the front area 1m x 0.5m. The front area of this enclosure is the absorber plate. The condensation and the evaporation chamber length and width are respectively 1 m, 0.5m, 1m and 0.5m. The air gap depth of the solar collector, evaporation chamber, and isolation layer and condensation chamber are 0.03, 0.02, 0.05 and 0.03 m, respectively. During the experiment, the brackish water flow rate varied from $1x10^{-5}$ to $1.15x10^{-5}$ kg/s.m^2, at an ambient temperature ranging from 22^{o}C to 46^{o}C and the average solar radiation intensity along a vertical surface of 640 W/m^2. Also, the distilled water flow rate varied from $0.9x10^{-5}$ to $3x10^{-5}$ kg/s.m^2. Both the mass flux of brackish water and distilled water is calculated based on the surface area of solar still.

The temperatures of brackish water at inlet T_2 and outlet T_3 of solar collector, temperature T_4 of absorber unit (evaporator), T_5, temperature of galvanized sheet forward the absorber unit, T_6, temperature of the galvanized sheet forward the condensing plate, T_6, temperature of the condensing plate, T_7 and ambient temperature T1 are recorded continuously for 12 hours. The distilled water produced by the solar still and the outlet brackish water flow through the vertical still are measured each hour by graduated test tube. The test is performed on several clear summer days.

6. Data Reduction

At any time, the still produces an amount of distillate water equal to the daily yield is the summation of the productivities over period of 24 hrs and it is expressed as the following:

$$M_d = \sum_{J=1}^{24} m\ dJ$$

Where:

M_d is the daily yield in kg/m^2

The hourly efficiency η is the energy used for evaporation to that received by the vertical solar still, it is expressed as follows:

$$\eta = \frac{M_h\ H_{fg}}{I_h\ A}$$

Where:

M_h is the hourly yield in $kg/h.m^2$

H_{fg} is the latent heat of evaporation in kJ/kg

I_n is the solar radiation intensity received on the vertical surface of the solar collector, W/m^2

A is the surface area of the collector, m2

According to **Holman [17],** H_{fg} can be expressed in term of condensation temperature T_4 as:

$$H_{fg} = 2501 - 2.16\ (T_4 - 273.15)$$

So, the collector efficiency is calculated from:

$$\eta = \frac{M_h\left(2501 - 2.16\ (T4 - 273.15)\right)}{I_h\ A}$$

Where:

Mb is measured each hour by a graduated test tube.

T4 is the temperature of the evaporator; is recorded continuously for 24 hrs.

I_h is the solar radiation intensity on the vertical still.

7. Results and Discussion

Typical days are presented in this paper 4, 5 and 6 July, the solar still was oriented to south and it was oriented continuously toward the sun.

Figure (4) illustrates the variation of brackish water (BW) inlet temperature T_2, brackish water (BW) outlet temperature T_3, to the flat plate collector for and ambient temperature T_1, for the summer days, 5 July and 6 July, respectively. It is clear that high values of the temperatures of T_1, T_2 and T_3 products correspond to a certain value of local time during the day.

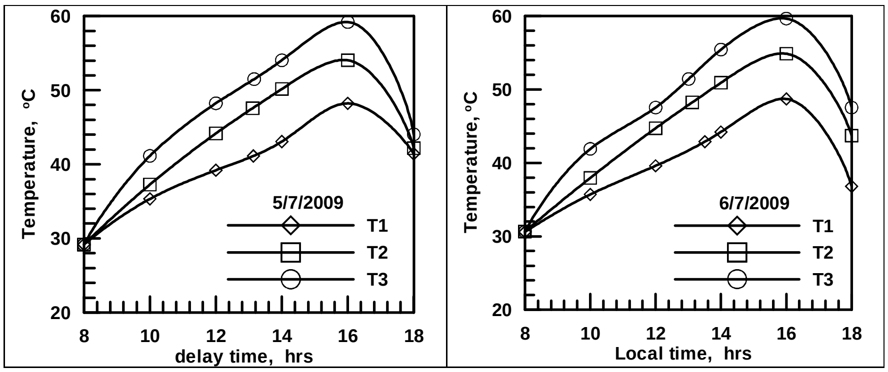

Fig. (4). Brackish water temperature versus time.

Figure (5) illustrates the variation of evaporation temperature T_4, condensation temperature T_7 and ambient temperature T1 for 5 and 6 July. It could be shown that the highest value of evaporation temperature is nearly 80^{o}C was obtained on 5 July. The ambient temperature varied from 26^{o}C to 44^{o}C.

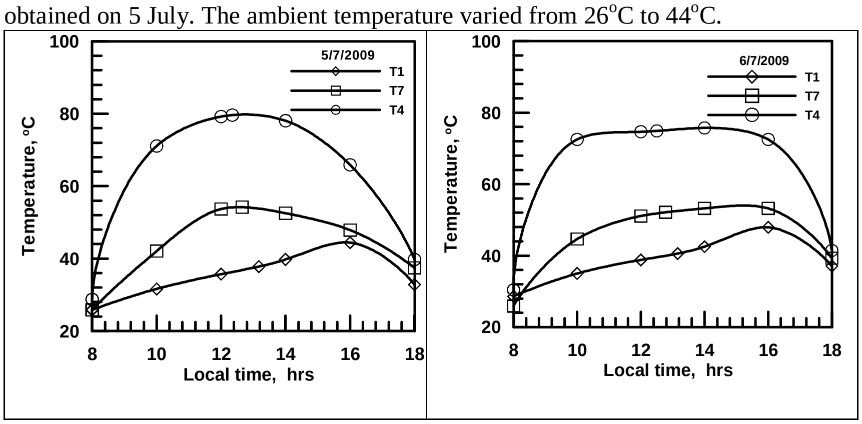

Fig. (5). Condensation and evaporation temperatures versus time.

Figure (6) illustrates the variation of temperatures respectively T1, ambient temperature, T4, evaporation temperature, T7, condensation temperature, T5, galvanized plaque in the evaporation chamber forward absorber unit, and T5, temperature of galvanized plaque in the condensation chamber forward the condensation plaque. From this figure, it is clear that the higher values of T5 were obtained on 5 July and the maximum value obtained was 58^{o}C**.**

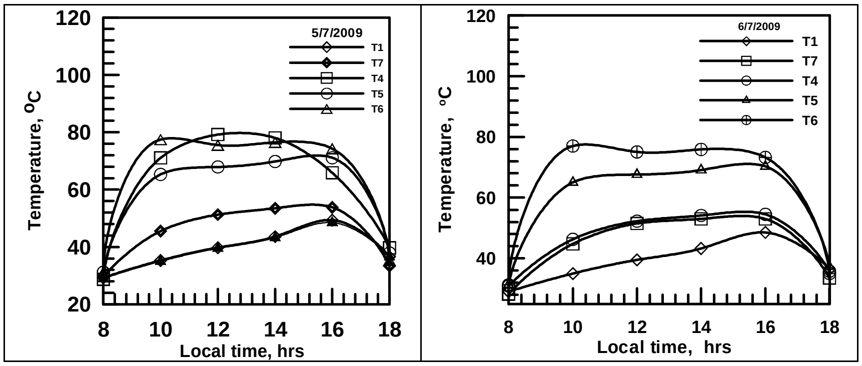

Fig. (6). Temperature variation versus time.

Figures (7 and 8) shows the variations of hourly temperature difference (T3 – T2) and brackish water yield outlet, respectively. We distinguished two intervals: before 15:00, the highest values were registered for 6 July and after 16:00 the highest values were registered for 5 July because the solar still was oriented toward sun: the solar collector was exposed to sun in the afternoon.

The highest values of brackish water was registered for 5 July, expect for the beginning, the brackish water outlet flow was equal to that 4 July and the steady values were those of 6 July, and were almost constant from 11:30 to 16:00, the lowest value of the brackish water outlet flow was on 5 July.

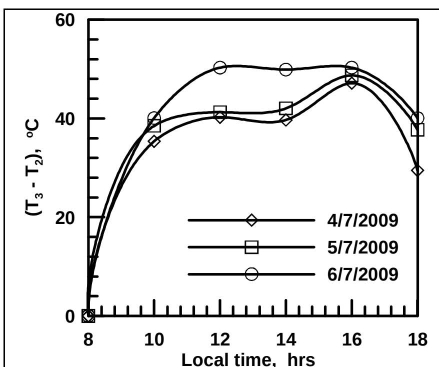

Fig. (7). Driving force temperature difference versus time.

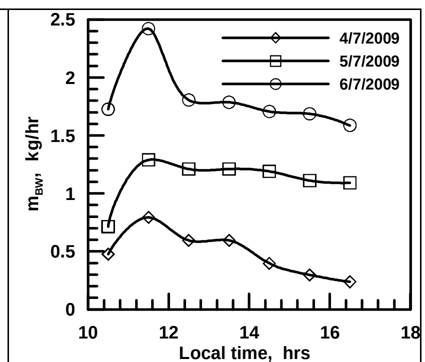

Fig. (8). Brackish water outlet flow rate versus time.

Figures (9 and 10) show the hourly efficiency and yield. The hourly efficiency of the indirect vertical solar still for this three day was almost the sun from 11:30 to 13:30. For the day of 4 July, the highest values of hourly still efficiency 59 % was registered at 15:30. For these three days the hourly efficiency varied from 19 % to 59 %. Also for these three days the hourly yield varied from 0.145 kg/h.m^2 to 0.265 kg/h.m^2

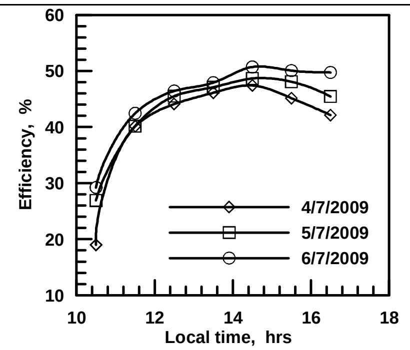

Fig. (9). Desalination efficiency versus time.

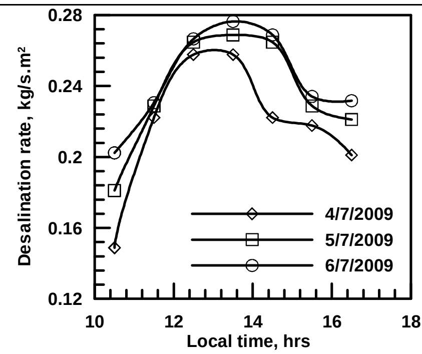

Fig. (10). Desalination rate versus time.

8. Conclusions

The preliminary performance testing of the indirect vertical solar still has been presented and the main conclusions of this research project are:

- The highest value of evaporation temperature of 80 ^oC was obtained on 5 July.
- The best brackish water outlet flow rate was 1kg/h.m^2.
- The maximum value of the evaporation temperature obtained is 77 ^oC for ambient temperature ranging from 22 ^oC to 46 ^oC.
- The highest value of hourly still efficiency is 59 % recorded at 15:30.

9. Recommendations

For future investigations more types of spongy cloth and insulation layer have to be tested to find the best one for evaporation chamber and condensation chamber. Also, a study of the effect of the multiple vertical solar still on the amount of water distillation may be performed.

10. Acknowledgement

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عملية تنقيةِ المياهِ باستعمال وحدة شمسيةِ عموديةِ جانبيةِ من جانب واحدْ

بهجت خميس مرسى ، جمال سلطان

كلية الهندسة – جامعة القصيم – المملكة العربية السعودية

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(قدم للنشر في٣/١١/٢٠١٠م ؛ وقبل للنشر في ١٢/٣/٢٠١١م)

ملخص البحث. استخدام الطاقة الشمسية في تحليه المياه مُتزايد بسرعة في المجال البحثي والتطبيقي لما لها من مميزات كثيره بالإضافة إلى التغلب على نقص إمدادات الطاقة التقليدية مستقبلا ويهدف البحث إلى دراسة عملية النحلية باستخدام الطاقة الشمسية عن طريف تصميم وتشغيل وحدة شمسية جانبية عمودية من جانب واحد في صحراء المملكة العربية السعودية وقد أوضحت النتائج المستنتجة كفاءة الوحدة المستخدمة

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A Proposed Model for Applying the Problem-Based Learning (PBL) Approach in Engineering Schools

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Abstract. In the last decades there have been a great increase in engineering knowledge and a rapid rate of what students should learn. Also, there has been a rising need for gaining different skills. This led education institutions to try some student-centered learning approaches such as problem-based learning (PBL). This approach showed many advantages. Nevertheless, it suffers from some problems and disadvantages. In the present paper, many of the PBL trials have been reviewed thoroughly. A model for applying PBL approach in engineering education has been proposed. The model enables benefiting from the advantages of this approach such as increasing the students' motivation and increasing their skills. Also, the model avoids the disadvantages and cures the problems of the PBL approach.

Keywords: PBL, problem-based learning, engineering education, student-centered learning.

1. Introduction

One glance to the amount of knowledge that engineering students are expected to acquire is enough to show the dilemma that engineering education is facing. Dilemma posed primarily by a dramatic increase in specific knowledge and the rapid obsolescence rate of much amount of what students learn. Also, there has been a rising need in engineering practice for other kinds of knowledge, including skills such as problem-solving, teamwork, resources management, self- and peer evaluation and attitudes such as ethics, motivation, cooperation, self-directed and life-long learning. This led some worldwide engineering institutions to try some student-centered learning approaches such as Problem-Based Learning (PBL), which is considered a very effective approach in medical schools

Boud and Feletti [1] consider the PBL as one of the most influential innovations of the last decades, and define it as a carefully planned curriculum, which is entirely based on practical cases and on solving practical problems. PBL originated at McMaster University Medical School in the late 1960s. Later on, PBL spread to different disciplines, such as law, economy, business administration and engineering [2,3].

1.1 What is a Problem Based Learning Approach?

PBL is an instructional approach that uses problems to initiate, focus and motivate students' acquisition of specific knowledge and development of professional skills and attitudes. PBL offers an environment in which learning is triggered and guided by a problem, which may interdisciplinary drive the curriculum. In PBL students must define the problem, identify and acquire the skills and knowledge needed to solve it, and work through the solution. Students are required to take responsibility for their own learning as well as the groups learning, and hence they are both autonomous and dependent. Learning is self-directed and takes place in the context of a realistic problem. The manner of work is being close to that of engineers in industry [4].

1.2 Scope of the Paper

The literatures in the last decade show that many worldwide engineering institutions tried to introduce the PBL approach in their programs using different methods of application. Some of them applied curriculum-wide PBL. Others applied the PBL on senior students or on certain courses. In this paper most of these trials will be reviewed, and the problems they faced will be investigated. The merits and drawbacks of using the PBL approach will be highlighted. Finally, an application model for using the PBL approach in engineering education will be proposed. This model will avoid the problems inherent in PBL approach and compromises between the merits and drawbacks of applying this approach in engineering education. The different application modes and assessment strategies are beyond the scope of this paper. They are covered extensively in the literature [5-9].

2. Review of Previous Trials in Applying PBL

Many universities and engineering institutions around the world in the last decade tried to apply the PBL approach in different ways, some of them applied PBL as a curriculum-wide. Others applied it as a part of the curriculum in one year, or at least in one course.

The following trials applied the PBL approach for the entire or part of the curriculum:

i) In Denmark Aalborg University had implemented the PBL approach in all engineering programs. The curriculum consists of 50% project work, 25% course work that support the project work, and the remaining 25% coursework in fundamental studies such as mathematics, physics etc. which is taught primarily in a traditional format. Project-based teaching at Aalborg university is strongly problem- oriented, and the projects are often practical industry problems [10, 11].

ii) In 2001, Manchester University in UK introduced the PBL as the primary teaching method for undergraduate engineering programs. The purpose was to organize the curricular content around problem scenarios rather than subjects or disciplines [12,13].

iii) In 1998, Monash University in Australia had implemented problem based learning in several courses within its civil engineering program [11, 14].

iv) In 1998, Central Queensland University introduced a PBL approach in four of engineering programs; civil, electrical, mechanical and computer systems engineering. All of these programs have adopted a problem-based model in 50% of the student's workload in each semester. The projects gradually increase in length and difficulty throughout the program [11, 15].

v) In 2001, the Dokuz Eylul University in Turkey has adopted the problem based active learning system in electrical and electronics, geological and geophysics engineering and mining engineering departments. The system is based on real engineering problems which values teamwork and the integration of information from different disciplines and it places the student at the center of the learning process [16].

vi) in 2003, the Turku Polytechnic University of Applied Sciences introduced the PBL approach in the program of Information Technology [17].

vii) In 2001, the Lahti University of Applied Sciences in Finland used a PBL approach as curriculum strategy in the mechatronics program [18].

viii) At Republic Polytechnic in Singapore a different approach has been developed. This approach is termed "one-day one-problem approach", where students spend one whole day working on a single problem [7].

In addition, many of engineering institutions or universities tried to apply the PBL approach in a single course such as: communication systems course in University College in London [19], administration theory course for the electrical engineering students at a public university in Brazil [20], digital electronics course at Chitkara Institute of Engineering and Technology In India [21], mathematics at college of Maryland in Cumberland, USA [22], mathematics in the Republic Polytechnic in Singapore [23], statistics course for engineering students at Slovenian University in Slovenia [24], and control theory course at Linkping University in Sweden [25].

3. Evaluation of The Previous Trials of Applying PBL

A deep study have been applied on all studies illustrated in the previous section to determine the merits and drawbacks of applying the PBL approach in engineering education, and to highlight the problems they faced. During this study, the following questions had to be answered:

How did they deal with these problems?, Are these problems inherent in the PBL approach or as an implementation problems?, What is the response of students and professors about using PBL in engineering education?, Is PBL suitable for application on all types of courses.

In this study, all these questions and more will be addressed. Then, depending on the findings a model will be proposed for applying the PBL in engineering education. This model will determine the conditions of using the PBL in engineering education and will formulate the specifications of courses that are suitable for applying PBL.

3.1 The Merits of Using the PBL Approach in Engineering Education.

Many advantages of using PBL have been reported by the previous studies as follows:

i) Improving the soft skills of students such as: problem solving, time and task managements, reporting, negotiating and communication skills [11, 13, 19, 26].

ii) PBL is more effective in motivating students and improving their study habits. It encourages life-long and self-directed learning [11, 13, 19, 26, 27, 28].

iii) PBL transfers the responsibility of learning to student side [13, 19, 26]

iv) PBL engages the students in a deep and effective learning experience and encourages their participation and commitment [8, 13, 26, 29]

v) PBL improves the skills of team working and team managements [11, 19, 26]

vi) PBL approach is favorable by students and they enjoy it [11, 13, 27, 30, 31].

3.2 The Drawbacks of Using the PBL Approach in Engineering Education.

i) The acquisition of knowledge using PBL approach does not follow a certain order. The student may acquire certain knowledge before acquiring its basic concepts, or may go deep through unneeded knowledge while skip a necessary knowledge. This is due the hierarchical structure of most of engineering courses where many topics must be learned in certain order. If the student missed the earlier topic, it will be very hard to continue in the next topic. This problem of the particular hierarchical structure of engineering courses is the most obstacle which faces applying the PBL approach in engineering education [7, 11, 19, 24]. This is the cause behind the success of applying PBL approach in medical learning as Perrenet et al describe the medical courses as “encyclopedic knowledge structure”, (i.e. any topic will not be affected by missing the earlier topic) [32].

ii) PBL approach doesn’t give the students sufficient theoretical background for the problem under study. This led to lack in basic knowledge and concepts. This issue is stated extensively by students [13], and it is clear from the low quality of the theoretical parts in the student's reports [11, 13, 19]. The students in medical schools which apply the PBL suffer from the lack in the basic theoretical information while these students are excellent in application side [27].

iii) The PBL approach increases the time or the workload of students, because they have to seek knowledge. Also, they have to process this knowledge and apply it to solve problems. Team work is time consuming as well. Tasks such scheduling extra meetings, collecting work done by team members and building consensus do need more time. So, The PBL approach consumes more time than traditional teaching methods. This time may reach up to 300% both in class and out of class work [8, 11, 13, 19, 21, 26]

iv) It is difficult to use PBL approach in teaching the mathematics or analytical courses such as static, dynamics, analysis of electric circuits. The analytical and mathematical skills should be owned by each individual and the PBL approach doesn't give the student the chance to do more practice which is essential skill for learning mathematics or any analytical course [18, 23, 25, 33].

v) The assessment system used in PBL approach, which originally depend on teamwork activates, may give a chance to the ineffective student to pass the course depending on the teamwork only (i.e. lets him pass without learning the contents) [13].

vi) PBL approach, originally, is unguided learning process. Some studies emphases that the unguided or minimal guided PBL is significantly less effective than guided process that is specifically designed to support the cognitive processing necessary for learning [21, 34, 35]. Also, the unguided PBL may have negative results when students acquire misconception or incomplete knowledge [34, 35]

3.3 Recommendations for Resolving the Drawbacks of PBL

i) The problem of particular hierarchical structure of engineering courses, and the problem of lack of theoretical information and basic knowledge and concepts associated with PBL may be resolved by mixing the PBL approach with some lectures in a traditional way. This insures that the student has acquired all necessary information and basic concepts in its correct order.

ii) The long time needed for doing the PBL activities and the extra loading of students are inherent problems of PBL. These problems are obvious in case of curriculum-wide application of PBL, or when the student has many PBL courses in the same semester. In curriculum-wide mode, the engineering program should be five years or more if all or most courses should be taught using PBL, otherwise some courses should be omitted to limit the program by four years as most of engineering programs in the world. So, the curriculum-wide mode is not recommended for this cause. The problem may be resolved if PBL courses was limited by one or two courses in each semester. The rest of courses in the program may be taught in traditional way. This partial application of PBL is enough to satisfy all the merits of using PBL approach and gives a reasonable student loading in each semester without increasing program period.

iii) For reinforcing the individual analytical skills of students, the analytical courses and mathematics and similar courses should be excluded from teaching using PBL. The application courses which are rich in real world problem are the best candidates for applying the PBL approach. For example, in electrical engineering program courses such as electronics, electrical machines, high voltage engineering, industrial power system design and digital design are recommended

iv) The problem of assessment system, which may give a chance to an ineffective student to pass depending on the teamwork only, may be resolved by designing an assessment system where the mark of all team activities is less than the grade required for passing the course. Thus, a part of passing mark should be collected from individual work only.

v) The problem of the low effect of unguided PBL, where the students may acquire misconception or incomplete knowledge may be resolved by adopting the guided PBL approach, where the objectives and steps of problem should be clear to the students. As Paul A. Kirschner [35] showed in his study that the guided students can achieve more than double the knowledge that the unguided students can achieve in half of the time needed

4. The Proposed Model for Applying PBL

From the analysis and recommendations in previous section we can determine the main specifications and conditions of applying the PBL approach in engineering education as follows:

i) The program should be a mixture of PBL courses and traditional courses where the percentage of PBL courses does not exceed 25% of the total courses in the program, and at the same time does not exceed two courses in each semester.

ii) PBL approach is applied in teaching the application courses, while the mathematics and analytical courses are taught using traditional methods.

iii) The PBL courses should be inoculated with some necessary and key theoretical lectures.

iv) The PBL activates should be guided (i.e. the objectives and instructions are given and should be clear).

v) The assessment system should be well designed to prevent the ineffective students from passing depending on team work only.

5. Conclusion

Several engineering institutions in the world have incorporated the PBL approach in their engineering curricula in last decade for resolving some of critical issues of engineering education. In this study, a review of several trials of incorporating the PBL approach in engineering education has been done to recognize the problems of implementation and to extract the merits and drawbacks of applying PBL in engineering education. The reviewed studies showed the effectiveness of PBL approach in enhancing the soft skills of students such as problem solving, communication skills, teamwork, lifelong learning, etc. However, some of key drawbacks were reported, such as the weakness of theoretical knowledge and basic concepts for students, extra time loading, inadequacy of teaching mathematics and analytical course, and the gaps in assessment system. In this study, a group of solutions and precautions have been recommended to achieve the merits and avoid the drawbacks of applying the PBL approach in engineering education. Finally, a model for applying the PBL approach partially in engineering education has been suggested. This model can satisfy all the advantages of PBL, while avoids the drawbacks at the same time.

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نموذج مقترح لتطبيق طريقة التعلم المعتمد على حل المشكلات في كليات الهندسة

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ملخص البحث. خلال العقود الماضية حدث زيادة كبيرة في المعارف الهندسية مما أدى إلى زيادة معدل ما يجب أن يتعلمه الطالب. وكذلك وجود حاجة متزايدة لاكتساب المهارات المختلفة، مما حدا بالمؤسسات التعليمية إلى محاولة استخدام بعض أساليب التعلم المتمركز حول الطالب ومنها طريقة التعلم المعتمد على حل المشكلات، ومع أن هذه الطريقة تمتاز بعدد من الخصائص إلا أنها لا تخلو من بعض السلبيات. في هذه الورقة تم استعراض عدد من محاولات تطبيق هذه الطريقة في التعليم الهندسي في جامعات مختلفة حول العالم مع استخلاص الإيجابيات و السلبيات و الأخطاء في التطبيق ومن ثم تم اقتراح نموذج لتطبيق هذه الطريقة في تعليم المقررات الهندسية، هذا النموذج يمكن من استثمار ايجابيات هذه الطريقة مثل زيادة الدافعية لدى الطلاب و تحسين مهاراتهم مع تجنب السلبيات ومعالجة أخطاء التطبيق.

قواعد النشر

أهداف المجلة

تهدف المجلة إلى نشر إنتاج الباحثين من داخل الجامعة وخارجها في جميع تخصصات العلوم الهندسية وعلوم الحاسب، والمجالات الرئيسية التي تشملها المجلة هي:

- الهندسة الكهربائية
- الهندسة المدنية
- الهندسة الميكانيكية
- الهندسة الكيميائية
- هندسة التعدين والبترول
- هندسة الحاسب
- علوم الحاسب
- تكنولوجيا المعلومات
- نظم المعلومات
- العلوم الهندسية الأساسية

لغة المجلة:

تقبل المجلة البحوث باللغة الإنجليزية.

أ) المواد التي تقبلها المجلة للنشر:

١- البحث: وهو عمل أصيل للمؤلف (أو المؤلفين) يضيف جديداً للمعرفة في مجال تخصص (فرع المجلة).

٢- المقالة المرجعية: وتتناول العرض النقدي والتحليلي للبحوث والكتب ونحوها التي سبق نشرها في ميدان معين والرسائل العلمية المتميزة.

٣- المقالة القصيرة (تعليق تقني): مقالة قصيرة تحوي تطبيقاً تقنياً.

٤- الابتكارات العلمية المتميزة وبراءات الاختراع.

٥- المراسلات: وتتناول عرض فكرة أو رأي علمي أو اقتراح بحثي.

٦- انتقادات الكتب

ب) شروط النشر:

١- أن يكون البحث متسماً بالأصالة والابتكار والمنهجية العلمية وسلامة الاتجاه وصحة اللغة وجودة الأسلوب.

٢- أن لا يكون البحث قد سبق نشره أو قدم للنشر لجهة أخرى.

٣- جميع البحوث المقدمة للنشر في المجلة خاضعة للتحكيم.

ج) تعليمات النشر:

عند تقديم البحث للنشر يشترط الآتي:

١- أن يقدم الباحث طلباً بنشر بحثه، ويوضح فيه العنوان الالكتروني للمراسلات.

٢- لا يجوز إعادة نشر أبحاث المجلة في أي مطبوعة أخرى إلا بإذن كتابي من رئيس التحرير.

٣- يرسل الباحث بحثه باللغة الانجليزية عن طريق البريد الالكتروني على العنوان الالكتروني المذكور في فقرة المراسلات، وكذلك ملخص باللغتين العربية والإنجليزية بحيث لا تزيد كلماته عن ٢٠٠ كلمة.

٤- يكتب البحث باستخدام برنامج (Microsoft word) ويستخدم font 12 Times New Roman في كتابة المتن، مع ترك مسافة ونصف بين الأسطر.

٥- يجب ألا يزيد عدد صفحات البحث شاملا الرسومات والجداول عن ٢٠ صفحة حجم A4.

٦- أن يكتب عنوان البحث واسم الباحث وعنوانه ولقبه العلمي والجهة التي يعمل بها على الصفحة الأولى مستقلة.

٧- توضع هوامش كل صفحة أسفلها.

٨- يشار إلى المراجع داخل المتن بالأرقام حسب تسلسل ذكرها وتثبت في فهرس يلحق بآخر البحث.

أ) الدوريات: يشار إليها في المتن بأرقام داخل أقواس مربعة على مستوى السطر. أما في قائمة المراجع فيبدأ المرجع بذكر رقمه داخل قوسين مربعين فاسم عائلة المؤلف ثم الأسماء الأولى أو اختصاراتها فعنوان البحث (بين علامتي تنصيص) فاسم الدورية (تحته خط) فرقم المجلد، فرقم العدد فسنة النشر (بين قوسين) ثم أرقام الصفحات.

مثال: الحميدي، إبراهيم عبدالله. "الهجرة الداخلية في المملكة العربية السعودية حجمها واتجاهاتها." مجلة كلية الآداب، جامعة الملك سعود، م١٦، ع١ (٢٠٠٤م)، ١٠١-١٥١.

ب) الكتب: يشار إليها في المتن داخل قوسين مربعين مع ذكر الصفحات، مثال ذلك [٨، ص١٦]. أما في قائمة المراجع فيكتب رقم المرجع داخل قوسين مربعين متبوعاً باسم عائلة المؤلف ثم الأسماء الأولى أو اختصاراتها فعنوان الكتاب (تحته خط) فمكان النشر ثم الناشر فسنة النشر.

مثال: اليوسف، صالح سليمان. المشقة تجلب التيسير: دراسة نظرية وتطبيقية، الرياض: المطابع الأهلية للأوفست، ١٩٨٨م.

٩- ترفق جميع الصور والرسوم المتعلقة بالبحث في ملف مستقل.

١٠- ترقم الجداول والرسومات ترقيماً مستقلاً عن ترقيم البحث ويعنون الجدول بعنوان فوق الجدول والرسم بعنوان تحت الرسم.

١١- لا يعاد البحث إلى صاحبه سواء نشر أو لم ينشر.

١٢- يعطى الباحث نسختين من المجلة وعشرين مستلة من بحثه المنشور.

١٣- يلزم الباحث إجراء التعديلات المنصوص عليها في تقارير المحكمين، مع تعليل ما لم يعدل.

١٤- تعبر المواد المنشورة في المجلة عن آراء ونتائج مؤلفيها فقط.

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رجب ١٤٣٢هـ - يوليو ٢٠١١م

النشر العلمي والترجمة

هيئة التحرير

رقم الإيداع : ٢٠٢٣ / ١٤٢٩

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المجلد (٤)، العدد (٢)، ص ص ١٠٧-١٨٦ بالإنجليزية (يوليو ٢٠١١م / رجب ١٤٣٢هـ)

المحتويات

صفحة