Simulation and Modeling of Tower Diesel Power Station in Samawah Using Finite Element Method with MATLAB and COMSOL Programs

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Abstract
In this paper we present work that explores governing equations for heat transfer and fluid dynamics, and we describe and discuss different forms for such equations, that can be applied to formulations of the discontinuous finite element. In general, heat transfer and fluid dynamics problems are categorized as boundary value problems. Thus, the desired initial and final boundary conditions for solving these equations are given in a simulation of a modeling tower for a diesel power plant in Samawah, Iraq, via the finite element method using MATLAB and COMSOL programs. As vertical expansion is limited by the frictional repression of the benthos, an effective vertical force is generated in the tower. If the effective vertical force overtakes the buckle initiation force, the tower will undergo Euler buckling to qualify the resulting high vertical forces in the tower wall. We present numerical results for a mesh in Multiphysics of the lower and upper parts for the tower; an analytical model was built of the upper portion of the tower.

Keywords: Dynamic modeling, finite element, heat transfer, power plant, tower.

1. Introduction
The air that we breathe and the environment are substantially affected by the conversion of energy from one form to another. Figure 1 shows why it is essential to develop an understanding on how the energy impacts the environment. Coal, oil, natural gas and other fossil fuels have been powering industrial development since the 1700s and are at the heart of modern life. Yet it is important to bear in mind that industrial development has had a tremendous impact on the environment, particularly in terms of pollution, which results in climate change. Air pollution also results in heart and lung diseases in humans, and costs many lives each year worldwide. Benzene and formaldehyde are just two of hundreds of elements
that are emitted from power stations where natural gas, oil, coal and wood are burned and converted into electricity. In addition, fossil fuel-operated engines in vehicles, and even fireplaces and furnaces, are known to emit dangerous elements [1,2].

![Figure 1. Environmental pollution from a power station.](image)

2. Aims and Objectives
The objective of this study was to resolve the design problems that affect power plant performance. The first part considers failure analysis for the tower, and shows analysis techniques that are used to resolve and investigate relevant problems. It supplies the basic methodology for failure analysis regarding the power plant.

The second part specifies tower design, installation and working parameters of properties (velocity, temperature, stream line heat, flux) for power plant equipment found in the tower.

This work considers linked problems occurring with the equipment, and using graphical tools it develops the effectiveness of the problem-solving to a great degree, by modeling and accurate evaluation. It solves the problem in two ways, namely the finite element and the finite difference in the tower hole in a tower surface power plant. The factors that affect tower reliability are humidity, temperature variables and other environment-related variables, as shown in Figure 2.
3. Finite Difference Equations for Flow of Gas in Diesel Tower

The approximate algebraic expression replaces the partial derivatives, which appear in the differential equations, in order to supply an algebraic equation called the finite difference equation. The equation is analyzed within a domain that has been divided into equally-spaced grids. In this section, the finite difference equations that are commonly used in the solution of parabolic, elliptic and hyperbolic equations are reviewed.

Second-order differential equation with two independent variables can be written in a general form as [4]:

\[
A \frac{\partial^2 \phi}{\partial x^2} + B \frac{\partial^2 \phi}{\partial x \partial y} + C \frac{\partial^2 \phi}{\partial y^2} + D \frac{\partial \phi}{\partial x} + E \frac{\partial \phi}{\partial y} + F \phi + G = 0
\]

\[
\text{..................(1)}
\]

In this section, a simple equation for diffusion is reviewed for multiple difference equations that are finite and is given by:

\[
\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}
\]

\[
\text{..................(2)}
\]
In order to get a liner equation, $\alpha$ is assumed to be constant. In order to simplify the review process, multiple approaches have been used for each differential formulation (amplification factor, stability requirement, order of accuracy and the corresponding modified equation) and summarized. The nod number is defined as $d$ in the formulations and is defined in Figure 3.

\[ d = \alpha \frac{\Delta t}{(\Delta x)^2} \]  
\[ u_{i}^{n+1} = u_{i}^{n} + d(u_{i+1}^{n} - 2u_{i}^{n} + u_{i-1}^{n}) \]

The problem formulation:

![Figure 3. Sketch of tower hole showing the solution of finite difference](image)

The insolvent finite elements are the ones that are usually dealt with. In the following example, a nodal finite element is shown, which is not insolvent. By considering the polynomial space:

\[ N^1(M_v) = \text{span}(1, \phi_1, \phi_2, \phi_1\phi_2, \phi_2\phi_1, 1\phi_1, 1\phi_2, \ldots) \]
In the cylinder domain \((M_v) = (-1, 1)^2\). The set \(\Sigma\) comprises eight linear forms \(F_i\), \(N^1(M_v) \rightarrow \mathbb{R}\) associated with the edge midpoints function values at \([-1, 0], [1, 0], [0, -1], [0, 1]\),

- \(F_1(y) = y (-1, 0)\),
- \(F_2(y) = y (1, 0)\),
- \(F_3(y) = y (0, -1)\),
- \(F_4(y) = y (0, 1)\),
- \(F_5(y) = y (0, 0)\),
- \(F_6(y) = y (1, 1)\),
- \(F_7(y) = y (-1, -1)\),
- \(F_8(y) = y (-1, 1)\),

As shown in figure (4).

Figure 4. Comparison of finite element model and real tower.
Finite non unisolvent node made of cylinder domain $M_v$, polynomial space

$$N^1(M_v) = \text{span}(1, \phi_1, \phi_2, \phi_1\phi_2, \phi_2\phi_1, 1, 1, 1, 1, 1, -1)$$

and the associated linear forms with the edge midpoints values.

The general form of matrix $F = \{F_i(y_j)\}_{i,j=1}^8$ which is corresponding to the functions in the

$$F_1(y) = 1, F_2 = \phi_1, F_3 = \phi_2, F_4 = \phi_1\phi_2, F_5 = \phi_2\phi_1, F_6 = 1, F_7 = 1, F_8 = -1)\ldots\ldots(6)$$

4. Energy Conservation [5,6]

The first law of thermodynamics sets out the principles of conservation of energy. The time rate of changes for the total energy are equals of the sum for the change of the heat content per unit time, and the work done by the external force. The law of conservation energy for incompressible fluid, has the form:

$$\rho c_p \frac{DT}{Dt} = -\nabla \cdot q + Q + \Phi$$

……..$(7)$

From the equation $(7)$, $C_p$ represents the constant pressure specific heat, $q$ the flux, $T$ is the temperature, and $\Phi$ the viscous dissipation.

$$\Phi = \tau : S$$

Where $\tau$ is the stress tensor and $\Phi$ is the viscous part it and the strain rate tensor $(S)$ which is represented physically be the resulting energy from the friction between fluid element. The following relations define the strain rate tensor:

$$S = 0.5(\nabla u + (\nabla u)^T)\ldots\ldots(8)$$

Where the internal energy generation that results from equation (1) is defined as $Q$, which is a combined sum for all source contributions:

$$Q = Q_S + Q_r + Q_R + Q_C \ldots\ldots(9)$$
The source resulting from mechanical work \((Q_c)\), internal radiation \((Q_R)\) and heat source decayed during the chemical reactions \((Q_r)\); which is zero for incompressible fluids. For all the other forces the value \((Q_s)\) is used.

5. Constitutive Relations

Differences in deformation resistance, or generally in response to a loss of equilibrium in shape, have a substantial effect on the behaviors of many materials including fluids, viscoelastic materials and solids. All materials must obey the essential conservation principle according to the physical rules. The mathematical equations that are referred to as a set of relations for a specific material are known as the “material response”. Constitutive relations comprise the

Figure 5. Power plant in the United States of America [7]
dependence statement of the stress tensor and/or the heat flux $q$ on the field $u(x, t), T(x, t)$ and $D(x, t)$. It was shown that the stress is not included in the constitutive relation for fluids and has an independent state [5]. The Cauchy stress $\sigma$ in a viscous fluid is classified into hydrostatic and viscous parts.

$$\sigma = -pI + \tau$$

.................................(10)

Where $pI$, the thermodynamic pressure (or the hydrostatic pressure) and $\tau$ is the unit tensor.

6. The meaning of Discontinuous Finites Element

In order to explain the rationale for discontinuous finite elements, we take a simple, first order D.E. and one dimension for $u$ specified at one boundary [5]: where, without loss of generality, the coefficient $N^i(M_j)$ is taken as functions for field variable $\nu$. By defining the above differential equation (DE) as shown in Figure 6, may be further written as:

$$u_{i+1}^{n+1} = u_i^n + d(u_{i+1}^n - 2u_i^n + u_{i-1}^n)$$

.................................(11)

Figure 6. The illustration for the jump through $u_{i-1}^n$ and $u_{i+1}^n$ a mark the boundaries for elements.
7. Numerical Descriptions

We consider the case illustrated in Figure 4, where the transition element is required to patch a domain of approximately four-node to twenty-node elements. The transition element has five nodes, with three nodes on the sides that are shared with the nine-node elements. To construct the shape function of the five-node elements, first a five-node shaped function that has a quadratic \( u \) is considered as a linear type with spherical and cylindrical co-ordinates. Curvilinear spherical and cylindrical co-ordinates are required to solve problems that require elasticity [5]. Therefore, it is necessary to express the field equations in terms of such co-ordinate systems. The development for the relation of strain-displacement in the spherical–cylindrical co-ordinates is shown in Figures 7 and 8.

![Figure 7. Velocity in top tower power station in MATLAB program.](image-url)
Figure 8. Temperature in the top tower power plant in MATLAB program.
Figure 9. The numerical result obtained for Mesh-constructed diesel power plant.
The numerical results steps obtained by mesh in Multiphysics (COMSOL) program for tower power plant were as shown in Figures 11, 12, 13, 14, 15, 16, 17, 18 and 19:

Figure 11. Free mesh for tower power plant.
Figure 12. Transfer model in free mesh of tower power plant.

Figure 13. Temperature contour of tower power plant.
Figure 14. Arrow total heat flux of tower power plant.

Figure 15. Streamline total heat flux of the tower power plant.
Figure 16. Tower power plant surface temperature.

Figure 17. Tower power plant boundary temperature.
Figure 18. Tower power plant Surface temperature

Figure 19. Tower power plant, surface velocity.
8. Conclusions

The gas and diesel industries have experienced great improvement through innovations, such as rising subsea towers which are required for high grade temperature work and pressure and where the facilities are spaced some distance apart. For that purpose, two different modeling and design towers were constructed:

1. Greater distances between areas of the power plant can lead to multiphase “slug”. This is an internal flow producing dynamic forces from gas and diesel expansion and has the result of generating pressure required for the work of generation. In addition to the pressure, there is increasing temperature of the walls in relation to the seabed’s atmospheric temperature.

2. High temperatures and pressures require normal tower enlargement: they can produce uncontrolled side buckling if improperly mitigated.

3. It is preferable when the force attached to the moving alloy is in direct contact with the nodes, using the method of analysis of the limited elements for the purpose of the solution.
### Nomenclature

| Symbol | Definition |
|--------|------------|
| $\alpha$ | Amplification factor |
| $Q_r$ | Heat source (w) |
| $D/Dt$ | The material derivative |
| $\nabla$ | Vector differential |
| $C_p$ | Specific heat (J/kg.k) |
| $P$ | Pressure (pa) |
| $Y$ | Variable independent (m) |
| $X$ | Variable independent (m) |
| $F$ | Force (KN) |
| $G$ | Constant independent |
| $D$ | Constant independent |
| $C$ | Constant independent |
| $B$ | Constant independent |
| $A$ | Constant independent |
| $M_v$ | Cylinder domain |
| $N^1(M_v)$ | Polynomial space |
| $I$ | Unit tensor |
| $Q_s$ | Applied heat (w) |
| $\phi$ | Flow angle (degree) |
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