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Study & Design of Floating Roofs of Oil Products Storage Tanks

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PREFACE

This thesis is submitted in partial fulfillment for the degree of masters in mechanical power engineering department, Ain Shams university.

The work included in this thesis is carried out by the author at the laboratory of mechanical power engineering department, Faculty of Engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or qualification at any other university.

Signature:

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ABSTRACT

Floating roofs tanks are widely used to store petroleum products with high and moderate volatility to prevent product loss and to insure safe environment around the storage tanks. However, small number of studies are previously accomplished– especially in the Arab region - to study the design of the floating roof and risks that it face during operation. In an effort to investigate the behavior of the floating roof during operation, three studies are going to be summarized.

First study is a comparative study of the stress and deflection analyses of deck plate of the floating roofs under the load of accumulated rainfall. In this comparative study, five different loads on the deck plate are applied by using three different analysis methods to study the deflection and stresses. First method is using the equations of stresses and deformations on thin plates. Second method is a numerical nonlinear finite element analysis by applying the load gradually and study the effect of the large displacement on the material behavior in deformation and stress, Third method is the numerical application of linear finite element analysis by applying full load on the deck without consideration of the large deflection effect on the material. The results show that the nonlinear finite element analysis is the most accurate and applicable to use in the design of the floating roof deck, since it simulate the exact loading cases that happen in reality, however using Roark's Formulas gives higher results but it can be used as reliable and fast method in the analysis of the deck plate.

Second study is the buoyancy analyses of the floating roofs with punctured pontoons. In this study, three cases are used to analyze the buoyancy of the floating roof in each case. First case is to study the buoyancy of the floating roof with the puncture of the deck plate and one pontoon. Second case is study the buoyancy of the floating roof with the puncture of the deck plate and two pontoons and third case is to study the buoyancy of the floating roof with the puncture of the deck plate and three pontoons. The methodologies of these study is by calculating the center of gravity and moment of inertia of the floating roof in each case and determines the submergence height due to weight and tilt and insure that the floating roof will keep float under each case. The results show that the floating roof will remain floating after the puncture of two adjacent pontoons and deck plate according to the design of the physical model but it will sink if the number of punctured pontoons is increased to three.

Third study is CFD analysis of solar radiation on a Gasoline tank in Cairo in 31 July, which supposed to be the hottest time of the weather in the year. The analysis is repeated under corrosion condition to study the effect of the corrosion on the fluid temperature.

The methodologies of our study is by using Computational Fluid Dynamic (CFD) analysis to measure the temperature of the Gasoline along the 1 hour of the study and then calculate the vapor losses by the charts provided by Perry's Chemical Engineering Handbook. The results show that the surface temperature of gasoline increase from 45.6 °C to 54 °C and vaporization increase from 7% to 10% due to decrease of deck plate thickness from 8 mm to 5 mm which caused by corrosion on surface. This study recommended not using external floating single roof to store gasoline in hot regions as Arabian Gulf and Egypt unless the thickness of deck plate is +10 mm and with Anti-corrosion coating. However it is better to use internal floating roof for more safety and to decrease the losses of evaporation.

NOMENCLATURE

SYMBOLS

ρ = Density	$[\frac{kg}{m^3}]$
T= Temperature	[◦c]
Hor= External Rim Height	[mm]
Hir= Internal Rim Height	[mm]
W= Pontoon Length	[mm]
N= Pontoons numbers	[-]
Øor= External Rim Diameter	[mm]
Øir= Internal Rim Diameter	[mm]
Boh= Bulkhead External height	[mm]
Bih= Bulkhead Internal height	[mm]
Wb= Bulkhead length	[mm]
Tor= Bulkhead length	[mm]
Tor= Corroded External Rim Thickness	[mm]
Tir= Internal Rim Thickness	[mm]
Ttp= Upper Pontoon Thickness	[mm]
Tbp= Lower Pontoon Thickness	[mm]
Hsub= Height above deck level	[mm]
Tbp(cor.)= Height above deck level	[mm]
Tb= Height above deck level	[mm]
Td= Deck Thickness	[mm]
Td(cor.)= Corroded Deck Plate Thickness	[mm]
Hfl= Floatation level	[mm]
W roof = Roof Mass	[kg]
t=plate thickness	[mm]
a=outer radius of deck plate	[mm]
r= radius of acting force	[mm]

q =unit lateral pressure	$[(N/m^2)]$
E= Elastic modulus	[GPa]
y=maximum deformation	[mm]
σ= maximum stress combined	[MPa]
ν= Poisson ratio	[-]
A = effective area	[mm]
Y = distance from "bottom" to center of gravity	[mm]
R = Roof Radius	[mm]
d = distance from center of gravity of punctured roof to center of gravity of compartment	[mm]
I = Second moment of inertia	$[mm^4]$
H = submergence due to weight	[mm]
κ =Absorption coefficient	[m−1]
σ_s= Scattering coefficient	[m−1]
I_b(r) =Blackbody emission at r	[Wm−2]
ϕ (ˆs→ ˆs) =Phase function	[-]
∇= Dimensionless derivative	[-]
Pr =Prandtl Number	[-]
H= Enthalpy	[joule]

ABBREVIATIONS

API : American Petroleum Institute

FEA: Finite Element Analysis

CFD: Computational fluid dynamics

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Chapter 1

Introduction

1.1 Storage tanks

Storage tanks are essential part in industry especially in oil & gas fields. They are used mainly to store different fluid products such as oil and gas. To transport fluids from places of production to end users. Storage tanks are needed to store the products since the process of fluid transportation is rarely continuous due to different factors such as:

1- No possibility to match exact production with end user consumption.
2- Rate of production depend on different variable things such as weather and maintenance.

Storage tanks are a key factor of the development of dozens of industries. Petrochemicals industry is a good example for the importance of storage tanks as it couldn't be developed without the ability to store huge amount of crude and refined oils products in an economic and safe storages.

Another example of the usages of storages tanks are the processing plants such as chemicals factory and food processing factory since production pauses are always occur to allow reactions at different stages also after ending the production process safe huge storages are needed as the products cannot transport immediate to the clients and end users.

Steel storage tanks are constructed underground, on ground or over ground. They are constructed in different shapes such as vertical, horizontal, rectangular and spherical forms as shown in Figures (1.1 to 1.4). The products range varies from liquid and gases and mixtures while tanks with solid products are mainly called silos. The Temperature range inside tanks are widely different according to the application and stored fluid from 100° C for Bitumen through -196° C for liquid Nitrogen. [1]

The majority of the storage tanks are working under atmospheric pressure. According to API 620 the maximum allowable pressure for storage tanks is 15 psi and if the pressure is larger than this value it considered a pressure vessel. [2]

Figure (1.1) Vertical Tank

Figure (1.2) Spherical Tank

Figure (1.3) Horizontal Tank

Figure (1.4) Rectangular Tank