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STUDY OF SOLIDS DISTRIBUTION IN MIXING TANKS

A THESIS

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By

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To
Mum, Dad
& My Fiancée

Examiner committee



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STATEMENT

This dissertation is submitted to Ain Shams University in fulfillment of the requirements for master degree in Mechanical Engineering.

This work included in the thesis was made by the author during the period from 2003 to April 2007 at Mechanical Power Engineering Department, Ain Shams University.

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

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Abstract

Mixing tanks are used in many applications such as slurry flow, catalytic reactions, adsorption, crystallization, dissolution and many other industrial applications.

The minimum speed required for complete suspension in mixing tanks (N_{js}) has been extensively studied in the past. The start was by Zwietering(1958) who used visualization method to express a formula for calculating this speed. Micale et al. (2002) determined N_{js} by using a pressure gauge technique in a model vessel. In the present work N_{js} was measured by the same later technique in a more practical vessel and the results were compared to those obtained by Zwietering's correlation. Agreement was found between results from present work and predictions by Zwietering's correlation with average difference of 7% and the maximum difference did not exceed 17%.

The measurement of solids concentration distribution in mixing tanks relied on sampling technique and recently CFD (computational fluid dynamics) predictions were used. Both methods do not offer on-line results as they take a considerably long time in measurements and computations respectively. In the present work a new technique is proposed to measure the solids concentration distribution in mixing tanks using pressure measurements.

Results from the present work showed an inverse proportionality between the normalized pressure difference

(mixture pressure minus clear water pressure normalized by the value of mixture pressure) and the solids concentration in the mixing tank along the tank height. The experimental results obtained were compared with CFD predictions and good qualitative agreement was found. The technique proposed in the present work offers an on-line measurement of solids concentration distribution in mixing tanks.

Table of contents

Examiner Committee	III
Statement	IV
Acknowledgment	V
Abstract	VI
Table of Contents	VIII
Nomenclature	XIII
Abbreviations	XVIII
List of Figures	XIX
List of Tables	XXXVI
Chapter one: Introduction	1
Chapter two: Literature review	4
2.1 Introduction	4
2.2 Mixing in stirred vessels	4
2.2.1 Minimum speed required for complete suspension	4
2.2.2 Solids distribution in mixing tank	36
2.3 Summary	58
Chapter three: CFD in Mixing Process	61
3.1 Introduction	61

3.2 Mixing in stirred vessels using CFD	64
3.3 Summary	78
3.4 Numerical CFD Model of the present work	80
3.4.1 Grid generation	81
3.4.2 Boundary conditions	82
3.4.3 Two phase model	83
Chapter four: Test rig and Experiments	86
4.1 Introduction	86
4.2 Test rig	86
4.3 Materials	91
4.4 Experimental procedure	93
I – Determination of the minimum speed required for complete suspension	93
II – Concentration distribution measurements	94
a. Sampling technique	94
b. Pressure gauge method	96
4.5 Measuring instruments	96
Chapter five: Results and Discussions	100
5.1 Introduction	100
5.2 Determination of minimum speed required for	

complete solids suspension “Njs”	102
5.3 Solids distribution measurements using sampling technique	112
5.4 Measurements of solids distribution by using pressure readings	134
5.4.1 Static pressure distribution for clear water in the mixing tank	135
5.4.2 Static pressure distribution for the solid-liquid mixture in the mixing tank	140
5.4.2.1 Results for coarse phosphate	141
5.4.2.2 Results for sand glass	144
5.4.2.3 Comparison between mixture and water static pressures	146
5.4.2.4 Using measured pressure difference in order to measure the solids distribution in the mixing tank:	156
5.5 CFD predictions for solids distribution in the mixing tank	163
5.5.1 CFD Predictions of velocity profile in the mixing tank	164

5.5.2 CFD Predictions of solids distribution in the mixing tank	171
5.5.3 Checking the validity of the pressure gauge technique	182
5.5.4 Normalized pressure difference	192
5.6 Comparison between experimental results and CFD predictions	195
5.6.1 Comparison between solids distribution obtained experimentally with that predicted using CFD code	196
5.6.2 Comparison between Static pressure differences obtained experimentally with that predicted using CFD code	199
5.7 Power measurements	202
Chapter six: Conclusions and Recommendations	208
6.1 Conclusions	208
6.2 Recommendations for future work	212
References	214
Appendix I: Particle Size Distribution For Used Materials	220

Appendix II: Torque meter calibration curve	221
Appendix III: Published Papers	222
Appendix IV: Relation between impeller rotation	
speed used in the present work and N_{js}	263
Appendix V: Different type of impellers used in	
mixing tanks	264

Nomenclature

A	Factor expressing the physical properties of solid particles in equation 2.33 [-]
A_b	Tank bottom area (m^2)
a	Constant used in equation 2.2 [-]
B_{js}	Ratio between velocity of the liquid at the bottom of the vessel V_B and the settling velocity of particles V_p is constant [-]
C	The impeller clearance measured from the impeller centerline to the vessel bottom (m)
C_b	The impeller clearance measured from the bottom of the impeller to the vessel bottom. (m)
C_D	Coefficient of drag force [-]
C_w	Solids concentration by weight [-]
C_v	Solids concentration by volume [-]
C_0	Initial concentration at $t=0$ used in equation 2.41
C_{av}	Average weight concentration in the vessel
Cv_{av}	Average volume concentration in the vessel [-]

C_{vB}	Volume concentration of solid particles deposited at the bottom, used in equation 2.34 [-]
$C_{av \text{ axial}}$	Average axial concentration at certain radius in the tank [-]
D	Impeller diameter (m)
d_p	Diameter of solid particle (m)
d_{50}	Diameter larger than 50% of solid particles (m)
f	Constant used in equation 2.12 [-]
g	Gravitational acceleration (m/s^2)
H	The height of the liquid in the tank (measured from the straight cylindrical part in the present work) (m)
h	the average distance between the stirrer and the top surface of fillets used in equations 2.27 and 2.29 (m)
h_R	impeller height (m)
K	Blade thickness (m)
K'	Dimensionless parameter used in equation 2.43 [-]
M_s	Mass of suspended solids (kg)
M_{tot}	Total mass of solids (kg)
N	Impeller speed (rpm)

N_{js}	Minimum speed required for complete suspension (rpm)
N_p	Power number $N_p = \frac{\hat{P}}{\rho_L N^3 D^5} \quad [-]$
N_{min}	the value at which suspension starts. (rpm)
N_{span}	Twice its value gives the range of N at which most of suspension takes place as can recognized at $N_{ss} - N_{min} = 2 N_{span}$, the value of $X=0.982$ (rpm)
N_{ss}	Sufficient suspension speed = $N_{min} + 2 N_{span}$ (rpm)
P_{js}	The static pressure at the tank complete solid suspension (Pa.s)
$P_{Hydrostatic}$	Hydrostatic Pressure (pressure results from the weight of liquid column) (Pa)
P_m	Static pressure of mixture (Pa)
P_t	Total Pressure of mixture (Pa)
P_{static}	Static pressure for (Pa)
$P_{dynamic}$	Dynamic pressure (Pa)
P_w	Static pressure of Clear water (Pa)
ΔP	The increase in the static head due to solids suspension (Pa)