



AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING  
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# **Effect of adding fine solid particles on the hydraulic conveying of coarse solids by inclined pipelines**

A THESIS:  
Submitted for Partial Fulfillment of Master Degree in Mechanical Engineering.

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# *STATEMENT*

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

The work included in this thesis was made by the author during the period from Nov 2005 to July 2009 at 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 or institute.

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# *Acknowledgment*

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## *Abstract*

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The effect of varying fine percentage in the carrier fluid in the slurry was studied regards the flow variables; hydraulic gradient, delivered solids concentration and settling velocity, these variables were investigated in both horizontal and inclined pipes, also two solid mixtures were examined; the first has the same fine and coarse materials (phosphate), while the other, Talc was used as fine material and Sand as coarse material.

Inclination of pipelines results in increasing the hydraulic gradient for all fine percentages examined, where as increasing the fine percentage in the solid mixture was found to decrease the total delivered solids concentrations.

The settling velocity was influenced by varying fine percentage and by varying the inclination angle.

The two-layer model proposed by Gillies et al (1991) was used in predicting the hydraulic gradient and the delivered solids concentration in horizontal and inclined pipes, good agreement was found for the horizontal pipes.

Finally the use of the venturi meter as flow measurement device in slurry pipelines was examined.

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# *Table of contents*

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<b>Examiner Committee</b>	<b>II</b>
<b>Statement</b>	<b>III</b>
<b>Acknowledgment</b>	<b>IV</b>
<b>Abstract</b>	<b>V</b>
<b>Table of Contents</b>	<b>VI</b>
<b>Nomenclature</b>	<b>X</b>
<b>List of figures</b>	<b>XII</b>
<b>1. Chapter One: Introduction</b>	<b>1</b>
<b>2. Chapter two: Literature review</b>	<b>4</b>
<b>2. 1. Introduction</b>	<b>4</b>
<b>2. 2. Flow regime</b>	<b>7</b>
<b>2. 2. 1. Critical velocity</b>	<b>10</b>
<b>2. 2. 1. 1. Critical deposit velocity</b>	<b>10</b>
<b>2. 3. Methods for predicting slurry transport pressure head loss</b>	<b>13</b>
<b>2. 3. 1. Experimental correlations</b>	<b>13</b>
<b>2. 4. Scaling up techniques</b>	<b>20</b>
<b>2. 5. Modeling of slurry flow in pipelines</b>	<b>23</b>
<b>2. 5. 1. Modeling of non-settling slurry flow</b>	<b>23</b>
<b>2. 5. 2. Modeling of settling slurry flow</b>	<b>26</b>
<b>2. 5. 2. 1. Microscopic modeling</b>	<b>26</b>
<b>2. 5. 2. 2. Macroscopic modeling</b>	<b>29</b>
<b>2. 6. Slurry transport using dense phase medium</b>	<b>33</b>
<b>2. 7. Effect of pipe inclination on Slurry transport</b>	<b>45</b>
<b>3. Chapter three: Modeling</b>	<b>52</b>
<b>3. 1. Introduction</b>	<b>52</b>

---

3. 2. Gillies et al (1991) two layer model	53
4. Chapter four: Experimental test rig	60
4. 1. Introduction	60
4. 2. Test rig components	61
4. 2. 1. Mixing tank	61
4. 2. 2. Slurry pump	62
4. 2. 3. Pipeline	63
4. 2. 4. Tilting mechanism	64
4. 3. Instrumentation and measuring devices	65
4. 3. 1. Settling chambers	65
4. 3. 2. Differential pressure transducer	65
4. 3. 3. Manometers	66
4. 3. 4. Perspex pipe	66
4. 3. 5. Delivered concentration measurements	67
4. 3. 6. Measuring tank	68
4. 3. 7. Venturi meter	69
4. 4. Experiment description	70
4. 5. Material used	71
4. 6. Experimental procedure	72
5. Chapter five: Experimental results	73
5. 1. Introduction	73
5. 2. Sand and Talc mixtures	74
5. 2. 1. Results of the pressure head loss	74
5. 2. 1. 1. Comparing the hydraulic gradient of experimental data with model predictions for Talc and Sand mixtures, fine concentration varies from 10 % to 50% , angles varies from 0 to 40, Upward Inclination .	74

5. 2. 1. 2.	Comparing the hydraulic gradients for upward and downward inclinations for Talc and Sand mixtures, fine concentration in the solids varies from 10 % to 50%; angle varies from 0 <sup>0</sup> to 40 <sup>0</sup> .	89
5. 2. 1. 3.	Effect of pipe upward inclination on the hydraulic gradient for Talc and Sand mixtures	100
5. 2. 1. 4.	Effect of pipe downward inclination on the hydraulic gradient for Talc and Sand mixtures	103
5. 2. 1. 5.	Effect of varying fines percentage on the hydraulic gradient for Talc and Sand mixtures, Upward Inclination	106
5. 2. 1. 6.	Effect of varying fine percentage on hydraulic gradient for Talc and Sand mixtures, Downward Inclination	110
5. 2. 2.	<b>Delivered solids Concentration Vs Velocity</b>	113
5. 2. 2. 1.	Comparing the Delivered solids concentration of experimental data with model prediction for Talc and Sand mixtures, fine concentration varies from 10 % to 50% , angles varies from 0 <sup>0</sup> to 40 <sup>0</sup> Upward Inclination	113
5. 2. 2. 2.	Effect of varying fines percentage on the delivered solids concentration for Talc and Sand mixtures, upward inclination	129
5. 2. 3.	<b>Results for deposit velocity</b>	132
5. 2. 4.	<b>Results for Venturi meter</b>	133
5. 3.	<b>Phosphate mixtures</b>	137
5. 3. 1.	<b>Results of the pressure head loss</b>	137
5. 3. 1. 1.	Comparing the hydraulic gradient of experimental data with model predictions for Phosphate mixtures, fine concentration varies from 10 % to 50%, angles varies from 0 to 40, Upward Inclination.	137



5. 3. 1. 2.	Comparing the hydraulic gradients for upward and downward inclinations for Phosphate mixtures, fine concentration in the solids varies from 10 % to 50% , angle varies from 0 <sup>0</sup> to 40 <sup>0</sup> .	152
5. 3. 1. 3.	Effect of pipe upward inclination on the hydraulic gradient for Phosphate mixtures	163
5. 3. 1. 4.	Effect of pipe downward inclination on the hydraulic gradient for Phosphate mixtures	167
5. 3. 1. 5.	Effect of varying fine percentage on the hydraulic gradient for Phosphate mixtures, Upward Inclination	169
5. 3. 1. 6.	Effect of varying fine percentage on hydraulic gradient for Phosphate mixtures, Downward Inclination	173
5. 3. 2.	<b>Delivered solids Concentration Versus Velocity</b>	175
5. 3. 2. 1.	Comparing the Delivered solids concentration of experimental data with model prediction for phosphate mixtures, fine concentration varies from 10 % to 50% , Angles varies from 0 <sup>0</sup> to 40 <sup>0</sup> Upward Inclination	175
5. 3. 2. 2.	Effect of varying fines percentage on the delivered solids concentration for Phosphate mixtures, Upward Inclination	190
5. 3. 3.	<b>Results for deposit velocity</b>	193
5. 3. 4.	<b>Results for Venturi meter</b>	194
6.	<b>Conclusions and Recommendations</b>	198
6. 1.	<b>Conclusions</b>	
6. 2.	<b>Recommendations for future work</b>	
	<b>References</b>	202
	<b>Appendix 1: (<i>Gillies two-layer model</i>)</b>	207
	<b>Appendix 2 :</b>	212

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# *Nomenclature*

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A	cross sectional area	$m^2$
Ar	Archimedes number for a particle settling in the fluid	
C	volume concentration of solids	
$C_c$	contact load fraction	
$C_{cr}$	coarse particle concentration	
$C_d$	particle drag coefficient	
$C_{dis}$	discharge coefficient	
$C_f$	fine particle concentration	
$C_{max}$	maximum packing concentration of solids	
$C_r$	mean in-suite concentration	
$C_v$	delivered solid concentration	
D	mean particle diameter	m
$D_{10}$	particle diameter at 10% passing sieve	m
$D_{50}$	particle diameter at 50% passing sieve	m
$D_{90}$	particle diameter at 90% passing sieve	m
$\Delta_D$	Durand number	
D	pipe diameter	m
F	friction factor	
$F_n$	normal force/unit length	N/m
$F_L$	Durand coefficient in equation (2.3)	
g	gravitational acceleration	$m/s^2$
$\Delta H$	water head loss through the pipe line length L	m of water
I	pressure head gradient (meter of liquid/meter of pipe)	
K	Von Karmen constant	
$K_o$	Von Karman constant for pure water	
$N_w$	force due to weight of solid	N
$N_\phi$	force due to shear on interface	N
Q	volume flow rate	$m^3/s$
P	pressure	Pa
P	power	kW
Re	Reynolds number	
$Re_n$	Reynolds number defined by Metzener and Reed (1959) in equation 2.38	
$Re_{OT}$	Reynolds number defined by Oroskar and Turian (1980) in equation 2.5	
$Re_p$	particle Reynolds number defined in equation 2.29	
S	relative density (solids density/carrier fluid density)	
S	Perimeter	m
V	mean flow velocity	m/s
$V_c$	critical deposit velocity	m/s

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$V_s$	hindered settling velocity	m/s
$V_u$	minimum flow velocity for suspension of solid particles	m/s
$V_\infty$	terminal deposit velocity for particles	m/s
$X$	constant for fraction of eddies with velocities exceeding the hindered particle settling velocity in equation 2.4	
$Y$	vertical distance	m
$y_b$	bed height	m

### Greek letters

$\sigma$	constant in equation 2.18	
$\beta$	constant in equation 2.18	
$\gamma$	constant in equation 2.18	
$\delta$	constant in equation 2.18	
$\varepsilon$	diffusivity coefficient for solid particles in fluid	
$\rho$	Density	kg/m <sup>3</sup>
$\mu$	Viscosity	Pa.s
$\tau_{x,y}$	shear stress	N/m <sup>2</sup>
$\eta$	Efficiency	
$\theta$	bed angle	
$\Phi$	angle of internal friction	
$\dot{\gamma}$	shear rate	1/sec
$\zeta$	specific gravity	
$\epsilon$	Specific weight of water	N/m <sup>3</sup>

### subscripts

1	upper layer (two-layer model)
2	lower layer (two layer model)
12	interface
f	Fines
l	carrier fluid
m	slurry (solid/liquid)
s	solids
w	wall
u	up
d	down
i	input
o	output

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## *List of figures*

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<b>Fig NO</b>	<b>Description</b>	
<b>2.1</b>	flow curve of purely viscous, time independent fluids (a) thixotropic , (b) rheopetic	6
<b>2.2</b>	flow curves of purely viscous time independent fluids, (a) pseudoplastic, (b) dilatant, (c) bingham, (d) Hershel-Buckley, (e) Newtonian	6
<b>2.3</b>	Hydraulic characteristics of slurries	8
<b>2.4</b>	Slurry flow regimes	9
<b>2.5</b>	Values of $F_L$ (Durand et al 1951)	11
<b>2.6</b>	Nomograms for estimating deposition velocity	12
<b>2.7</b>	Determination of constant A in equation 2.37	22
<b>2.8</b>	Determination of constant B and M in equation 2.37	22
<b>2.9</b>	Non-Newtonian flow models (Jacob 1990)	23
<b>2.10</b>	Couette flow viscometer (Shook and Roco 1991)	24
<b>2.11</b>	Tube viscometer (Shook and Roco 1991)	25
<b>2.12</b>	Two layer model (Wilson 1972)	29
<b>2.13</b>	Suspension regimes (Charles and Charles 1971)	34
<b>2.14.a</b>	Effect of adding fine particles (Fangary et al 1997)	35
<b>2.14.b</b>	Effect of adding fine particles (Fangary et al 1997)	35
<b>2.15</b> <b>(a-b- c-d)</b>	comparison of experimental head loss with correlation (2.61 and 2.64)	36
<b>2.16</b>	comparison between Duckworth et al 1986 data and equation 2.73 (Panda et al 1993 )	39
<b>2.17</b>	Correlation plot between the modified pressure drop parameter ..and the modified Froude number ... (Panda et al 1993 )	40
<b>2.18</b>	Relationship of K and relative viscosity for mixture slurries Hisamitsu et al (1978)	41

---

<b>2.19</b>	Settling velocity of coarse materials in fine slurry (Sakamoto et al 1978)	42
<b>2.20</b>	Pressure head loss for coarse particles in fine slurry Sakamoto et al (1978)	42
<b>2.21</b>	Power for hydraulic transportation of coarse materials using 50mm pipe Sakamoto et al (1978)	43
<b>2.22</b>	Efficiency Vs Cv by theory Hou (1988)	44
<b>2.23</b>	coefficient of pressure loss Vs mean velocity Kawashima and Noda (1970)	46
<b>2.24</b>	coefficient of pressure loss Vs mean velocity Kawashima and Noda (1970)	46
<b>2.25</b>	Effect of pipe inclination on modified Froude number Hashimoto et al (1980)	47
<b>2.26</b>	Effect of pipe inclination on modified Froude number Hashimoto et al (1980)	48
<b>2.27</b>	Relation between transport parameter and shear intensity parameters Hashimoto et al (1980)	49
<b>2.28</b>	variation of deposition limits velocity with inclination angle for partiles of various Sizes Wilson and James. (1984)	49
<b>2.29</b>	Difference of Durand parameters versus inclination Wilson and James. (1984)	50
<b>3.1</b>	(a) pipe cross section, as idealized in the model, (b) concentration variation with elevation according to the model.	52
<b>3.2</b>	cross section of the pipe	57
<b>4.1</b>	Test rig schematic	61
<b>4.2</b>	Mixing tank	62
<b>4.3</b>	Mixing tank impeller	62
<b>4.4</b>	Slurry pump	62
<b>4.5</b>	Test rig pipeline	64
<b>4.6</b>	Settling chamber	65
<b>4.7</b>	Pressure transducer	66
<b>4.8</b>	Perspex pipe	67
<b>4.9</b>	Inverted U-loop	67

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<b>4.10</b>	measuring tank	69
<b>4.11</b>	Venturi meter	69
<b>4.12</b>	Phosphate El-Sebaeia particle size distribution	71
<b>4.13</b>	Sand glass particle size distribution	71
<b>5.1</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 10% fine / 90% coarse, Angle 0 ( Upward ).	75
<b>5.2</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 10% fine / 90% coarse, Angle 10 ( Upward ).	75
<b>5.3</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 10% fine / 90% coarse, Angle 20 ( Upward )	76
<b>5.4</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 10% fine / 90% coarse, Angle 30 ( Upward )	76
<b>5.5</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 10% fine / 90% coarse, Angle 40 ( Upward )	77
<b>5.6</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 20% fine / 80% coarse, Angle 0 ( Upward )	78
<b>5.7</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 20% fine / 80% coarse ,Angle 10 ( Upward )	78
<b>5.8</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 20% fine / 80% coarse, Angle 20 ( Upward )	79
<b>5.9</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 20% fine / 80% coarse, Angle 30 ( Upward )	79
<b>5.10</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 20% fine / 80% coarse, Angle 40 ( Upward )	80
<b>5.11</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 30% fine / 70% coarse, Angle 0 ( Upward )	81

<b>5.12</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 30% fine / 70% coarse, Angle 10 ( Upward )	81
<b>5.13</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 30% fine / 70% coarse, Angle 20 ( Upward )	82
<b>5.14</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 30% fine / 70% coarse, Angle 30 ( Upward )	82
<b>5.15</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 30% fine / 70% coarse, Angle 40 ( Upward )	83
<b>5.16</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 40% fine / 60% coarse, Angle 0 ( Upward )	84
<b>5.17</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 40% fine / 60% coarse, Angle 10 ( Upward )	84
<b>5.18</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 40% fine / 60% coarse, Angle 20 ( Upward )	85
<b>5.19</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, 40% fine / 60% coarse, Angle 30 ( Upward )	85
<b>5.20</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, (40% fine / 60% coarse), Angle 40 ( Upward )	86
<b>5.21</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, (50% fine / 50% coarse), Angle 0 ( Upward )	87
<b>5.22</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, (50% fine / 50% coarse), Angle 10 ( Upward )	87
<b>5.23</b>	Comparing hydraulic gradient of experimental data with model predictions at different flow velocities for Talc and Sand mixture, (50% fine / 50% coarse), Angle 20 ( Upward )	88
<b>5.24</b>	Comparing hydraulic gradient of experimental with model predictions at different flow velocities for Talc and Sand mixture, (50% fine / 50% coarse), Angle 30 ( Upward )	88