

## TABLE OF CONTENTS

<b>TITLE</b>	i
<b>AUTHENTICATION</b>	ii
<b>PRONOUNCEMENT</b>	iii
<b>FINAL TASK MANUSCRIPT</b>	iv
<b>DEDICATION</b>	v
<b>ACKNOWLEDGEMENT</b>	vi
<b>TABLE OF CONTENTS</b>	viii
<b>LIST OF FIGURES</b>	xii
<b>LIST OF TABLES</b>	xvi
<b>LIST OF ATTACHMENTS</b>	xvii
<b>NOMENCLATURES</b>	xviii
<b>ABSTRACT</b>	xxi
<b>CHAPTER 1 – INTRODUCTION</b>	
1.1 Research background	1
1.2. Problem formulation	3
1.3. Research objectives	4
1.4. Limitation	4
<b>CHAPTER II – LITERATURE STUDY</b>	
<b>2.1. Literature Review</b>	6
2.1.1. Flow pattern maps	6
2.1.2. Analysis of plug and slug flow characteristics	9
2.1.3. Visualization studies and the implementation of image processing technique for slug flow problems	11
2.1.4. Other applications of image processing techniques	15

<b>2.2. Theoretical Background</b>	16
2.2.1. General explanation of gas-liquid two phase flow	16
2.2.2. General parameter in gas-liquid two-phase flow	17
2.2.2.1. Basic equations	17
2.2.2.2. Superficial and actual velocity	18
2.2.2.3. Liquid hold up and void fraction	19
2.2.3. Flow pattern of co-current gas-liquid two-phase flow in horizontal pipe	20
2.2.4. Flow pattern maps of co-current gas-liquid two-phase flow in horizontal pipe	23
2.2.5. Plug flow and slug flow	25
2.2.5.1. Flow parameters in slug flow	25
2.2.5.2. Initiation mechanism of slug flow	27
2.2.5.3. Topology of the elongated bubble in horizontal slug flow	31
2.2.5.3.1. Bubble shape	31
2.2.5.3.2. Motion of long bubbles in still liquid: drift motion in horizontal pipe (the theory of Benjamin)	34
2.2.5.3.3. Motion of long bubbles with the liquid moving ahead it- Shape transition and bubble turning transition	36
2.2.6. Image Processing Techniques	38
2.2.6.1. General definition of image processing	38
2.2.6.2. Images as matrices	39
2.2.6.3. Type of digital images	39
2.2.6.4. General steps in image processing	42
2.2.6.5. Morphological operation	44
2.2.6.6. Image Filtering	45
2.2.6.6.1. Image Noise	45
2.2.6.6.2. Thresholding	47
2.2.7. MATLAB and the image processing toolbox	48
2.2.7.1. Background on MATLAB	48
2.2.7.2. Image Processing Toolbox	48

### **CHAPTER III – RESEARCH METHODOLOGY**

3.1. Location	50
3.2. Research Material	50
3.3. Experiment Apparatus	50
3.4. Research Equipment	51
3.4.1. Liquid Flow (Water –flow)	51
3.4.2. Gas Flow (Air-flow)	52
3.4.3. Image Acquisition Devices	52
3.4.3.1. Visualization Test Section Zone	52
3.4.3.2. Image Capturing Devices	54
3.4.3.3. Procedures of image processing technique	55
3.4.4. Test data	57
3.4.5. Flowchart	59

### **CHAPTER IV – RESULTS AND DISCUSSION**

4.1. Visualization study	62
4.1.1. Image processing result	62
4.1.2. Flow pattern	64
4.1.3. Flow pattern map	69
4.1.4. Bubble nose and tail contours	71
4.2. Liquid film thickness	74
4.3. Liquid hold-up	77
4.3.1. Liquid hold-up characteristics	77
4.3.2. Liquid hold-up distribution	82
4.4. Wave frequency	83
4.5. Wave velocity	85
4.6. Plug wavelength	89
4.7. The single bubble translational velocity	90
4.8. Relationship between wave velocity and plug wavelength	92

<b>CHAPTER V – CONCLUSSION AND FUTURE WORK</b>	
5.1. Conclusion	94
5.2. Future Work	95
<b>BIBLIOGRAPHY</b>	96
<b>ATTACHMENTS</b>	101