IMPROVING STABILITY OF WATER BASED NANOCARBON USING OH-CNT MODIFIED WITH POLYVINYL PYRROLIDONE AS A DISPERSING AGENT

MOHD AMEER AIMAN BIN RUHAIZI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

© Universiti Teknikal Malaysia Melaka

IMPROVING STABILITY OF WATER BASED NANOCARBON USING OH-CNT MODIFIED WITH POLYVINYL PYRROLIDONE AS A DISPERSING AGENT

MOHD AMEER AIMAN BIN RUHAIZI

This report is submitted in partial
fulfillment of the requirements for the award of the degree of
Bachelor of Mechanical Engineering (Thermal-Fluids)

Fakulti Kejuruteraan Mekanikal

Universiti Teknikal Malaysia Melaka

JUNE 2013

© Universiti Teknikal Malaysia Melaka

SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of
Bachelor of Mechanical Engineering (Thermal Fluids)

Signature : ……

Supervisor : ……

Date : ……

© Universiti Teknikal Malaysia Melaka

DECLARATION

"I hereby declare that the work in this report in my own except for summaries and quotations which have been duly acknowledge"

Signature : ……

Author : ……

Date : ……

© Universiti Teknikal Malaysia Melaka

This report was completed in dedication to both my beloved parents, Ruhaizi bin Abdul Rashid and Kalthum binti Hashim

© Universiti Teknikal Malaysia Melaka

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank a number of people who gave suggestions, who encouraged me and helped me with their valuable suggestions and assistance. First of all, I would like to thank En Imran Syakir bin Mohamad for giving me the opportunity to be under his supervision upon completing this project. Thank you so much for all the help and encouragement.

I would also like to acknowledge my other three group member which is Wan Mohd Hanis bin Wan Harun, Syed Zulkarnain Syed Saidin and Khairul Mazni who had helped me a lot on doing this project and for giving me the valuable suggestions and guidance throughout the project.

I would like to express my thanks to UTeM chemistry lab assistant En Ismail bin Ibrahim for giving me some technical advice for my research. I also like to thank all my friends who made my life here colorful and pleasant, especially Razee, Hafiz and Azarul, I am so lucky to have your accompany in the past 4 years. Finally, I am very much grateful to my parents, my sisters and brother for all their supports and encourage though out my studies.

© Universiti Teknikal Malaysia Melaka

ABSTRACT

Nanotechnology is a new kind of field that mostly dealing with a nanosized materials, device or any other structure with dimensions ranging from 1 nm to 100 nm. With a variety of possible application, nanotechnology can be said as a key to the future technology. Many technological advance country like Japan, European country and United States had invest billions of dollar in nanotechnology research. Another branch of application of nanotechnology is nanofluids. Nanofluids is a suspensions that contains nanoparticle inside a based fluids. Nanofluids has become the need in industry or any thermal management application because of its potential and its wonder properties of high thermal conductivity and high heat transfer rate that cannot be obtain from other materials. For this particular project, the nanoparticle that being used is carbon nanotube (CNT). Because of its cylindrical shape, it will have the greatest surface area per volume compare to other. So with this geometry, it also help it to has the highest value for thermal conductivity and heat transfer capacity compare to other nanoparticle. For the based fluids, water has been chosen. The main intentions of this water based carbon nanotube is to be used for the application in automotive or in a central chilled air conditioning system. The real challenge in producing the water based carbon nanotube is to disperse the carbon nanotube in water because of the hydrophobic characteristic of the carbon nanotube itself. To overcome this problem, a dispersing agent is needed which is polyvinylpyrrolidone (PVP) to reduce the surface tension of the water to ensure that CNT can interact well with water molecules. A different weight percentage of CNT and PVP was used to find a suitable ratio between the two parameter. Final result shows some enhancement of thermal conductivity less than 10% compare to water.

© Universiti Teknikal Malaysia Melaka

ABSTRAK

Nanoteknologi merupakan bidang baru yang kebanyakannya berurusan dengan bahan berskala nano, peranti atau apa-apa struktur lain dengan dimensi yang terdiri daripada 1 nm hingga 100 nm. Nanoteknologi boleh dikatakan sebagai kunci kepada teknologi masa depan. Banyak Negara maju seperti Jepun, negara Eropah dan Amerika Syarikat telah melabur berbilion dolar dalam penyelidikan nanoteknologi. Satu lagi cabang aplikasi nanoteknologi adalah bendalir nano. Bendalir nano adalah larutan yang mengandungi nanopartikel di dalam cecair asas. Bendalir nano telah menjadi keperluan dalam industri yang melibatkan pengurusan haba kerana potensinya yang mempunyai kekonduksian haba yang tinggi dan kadar pemindahan haba yang tinggi. Untuk projek ini, partikel nano yang digunakan adalah tiub nano karbon. Kerana bentuk silindernya, ia mempunyai luas permukaan yang paling besar per isipadu berbanding dengan yang partikel nano lain. Dengan geometri ini, ia membantu agar tuib nano carbon mempunyai nilai tertinggi untuk kekonduksian haba dan muatan haba pemindahan berbanding nanopartikel lain. Tujuan utama menghasilkan tiub nano karbon berasaskan air adalah untuk digunakan bagi aplikasi didalam industri automotif atau dalam sistem penyaman udara pusat. Cabaran sebenar dalam menghasilkan tiub nano karbon berasaskan air adalah untuk menguraikan tiub nano karbon dalam air kerana ciri hidrofobiknya yang tidak bertindak balas dengan partikel air. Untuk mengatasi masalah ini, penggunaan agen penyerak yang dikenali sebagai polyvinyl pyrrolidone (PVP) adalah perlu. Satu peratusan berat berbeza tiub nano karbon dan PVP telah digunakan untuk mencari nisbah yang sesuai antara kedua-dua parameter. Dalam kajian kekonduksian haba mendapati bendalir nano lebih baik daripada air dengan 10% peningkatan.

© Universiti Teknikal Malaysia Melaka

TABLE OF CONTENT

CHAPTER	CONTENT	PAGE
	SUPERVISOR DECLARATION	**i**
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGEMENT	**iv**
	ABSTRACT	**v**
	TABLE OF CONTENT	**vii**
	LIST OF TABLES	**xi**
	LIST OF FIGURES	**xii**
	LIST OF SYMBOL	**xiv**
	LIST OF APPENDIX	**xv**
CHAPTER 1	**INTRODUCTION**	1
	1.1 INTRODUCTION	1
	1.2 OBJECTIVE	2
	1.3 SCOPE	2

© Universiti Teknikal Malaysia Melaka

	1.4	PROBLEMSTATEMENT	3
	1.5	EXPECTED RESULT	3
CHAPTER 2	**LITERATURE REVIEW**		4
	2.1	HISTORY OF CARBON	4
		2.1.1 Early experiments about carbon	5
	2.2	CARBON	5
	2.3	NANOCARBON	6
		2.3.1 Single wall carbon nanotube	8
		2.3.2 Multi walled carbon nanotube	10
	2.4	PROPERTIES OF CARBON NANOTUBE	11
		2.4.1 Tensile strength	11
		2.4.2 Thermal conductivity	13
	2.5	FLUID	14
		2.5.1 Nanofluids	14
		2.5.2 Stability of nanofluids	15
		2.5.3 Dispersing agent	20
CHAPTER 3	**METHODOLOGY**		21
	3.1	EXPERIMENTAL PROCEDURE	21
	3.2	FLOW CHART	22

© Universiti Teknikal Malaysia Melaka

	3.3	PARAMETER USED IN EXPERIMENT	23
		3.3.1 Deionized water	23
		3.3.2 Type of CNT used	24
		3.3.3 Dispersing Agent Description	24
		3.3.4 Ratio between all parameter (CNT, dispersing agent, water)	25
	3.4	APPARATUS	27
		3.4.1 Homogenizer	28
		3.4.2 Ultrasonicator	29
		3.4.3 pH meter	29
		3.4.4 Stability Test Rig	30
		3.4.5 KD2 Pro	31
	3.5	EXPERIMENTAL PROCEDURE	32
		3.5.1 Nanofluids Formulation	32
		3.5.2 Thermal Conductivity Measurement	34
	3.6	SAFETY PRECAUTION	34
CHAPTER 4	**RESULT AND DISCUSSION**		35
	4.1	STABILITY OF NANOFLUIDS	35
		4.1.1 Stability evaluation methods	36
		4.1.2 Experimental result on stability (Nanoamor)	37
		4.1.2.1 Stability of Nanoamor	39

© Universiti Teknikal Malaysia Melaka

4.1.3 Experimental result on stability (MER) 40

4.1.3.1 Stability of MER 41

4.1.4 Experimental result on stability (pyrograph HHT 42

4.1.4.1 Stability of Pyrograph HHT 42

4.2 THERMAL CONDUCTIVITY OF NANOFLUIDS 43

4.2.1 Thermal conductivity test result 43

4.3 DISCUSSION OF STABILITY AND THERMAL CONDUCTIVITY 45

4.3.1 Type of CNT 45

4.3.2 Thermal Conductivity Enhancement 45

4.3.3 Comparison between PVP and SDS 48

CHAPTER 5 CONCLUSION 49

5.1 CONCLUSION 49

5.2 RECOMMENDATION 50

REFERENCES 51

APPENDICES 57

© Universiti Teknikal Malaysia Melaka

LIST OF TABLES

TABLE 2.1	List of thermal conductivity	13
TABLE 3.1	Properties of deionized water	23
TABLE 3.2	Effect of pH on viscosity of 5% aqueous PVP K-30 ta 25^0C	24
TABLE 3.3	Effect of PVP K-30 concentration on density in water	25
TABLE 3.4	Ratio between CNT, dispersing agent and water	26
TABLE 3.5	Ratio of Nanoamor and SDS	27
TABLE 4.1	Stability of nanoamor type CNT using PVP as dispersing agent	37
TABLE 4.2	Stability of nanoamor type CNT using SDS as dispersing agent	38
TABLE 4.3	Stability of MER type CNT using PVP as dispersing agent	40
TABLE 4.4	Stability of MER type CNT using PVP as dispersing agent	41
TABLE 4.5	Stability of Pyrograph HHT type CNT using SDS	42
TABLE 4.6	Thermal conductivity of Nanoamor with PVP	44
TABLE 4.7	Thermal conductivity of Nanoamor with SDS	44

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURE

Figure 2.1	A roll up vector of carbon nanotube from graphene sheet	7
Figure 2.2	Type of carbon nanotube	7
Figure 2.3	A single wall carbon nanotube	8
Figure 2.4	Multi walled carbon nanotube	10
Figure 2.5	A series of deformation of MWCNT	12
Figure 2.6	Thermal conductivity enhancement of water based WCNTs and fullerene	16
Figure 2.7	Particle size distributions in nanofluids as a function of the dispersion methods	17
Figure 2.8	Schematic of CNT-water interaction	19
Figure 2.9	Simulation of carbon nanotube in water	20
Figure 3.1	Flow chart	22
Figure 3.2	Mechanical homogenizer	28
Figure 3.3	Ultrasonicator	29
Figure 3.4	pH meter	30
Figure 3.5	Stability test rig	31
Figure 3.6	KD2 PRO device	32

© Universiti Teknikal Malaysia Melaka

Figure 4.1 Graph of thermal conductivity enhancement of nanoamor and PVP 46

Figure 4.2 Graph of thermal conductivity enhancement of Nanoamor and SDS 47

© Universiti Teknikal Malaysia Melaka

LIST OF SYMBOL

$æ, \Psi, \alpha$	Orientations of the water molecule in terms of angle	19

© Universiti Teknikal Malaysia Melaka

LIST OF APPENDIX

APPENDIX A

A comparison of a stable nanofluids on the left side of the picture and unstable nanofluids on the right side. 57

Stability test rig show that all 3 LED lighted indicate that nanofluids is stable 58

Stability test rig shows that only one LED lighted indicate that the nanofluids is not stable. 59

APPENDIX B

Gantt Chart 60

© Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays, nanotechnology has become a major topic for scientist and engineer to further their research. Nanotechnology is a field of science that dealing with a nano sized particle for example nano fluid. In general, Nano fluid is a fluid containing a nano size particle called nanoparticle. These nanofluids are engineered mostly to alter the properties of well-known traditional fluid based suspension for example water or oil that has some limitation that make it cannot be use or apply on certain application. So with the help of some alien particle like in this case is a carbon nanotube being mixed with these base fluid expecting it can change or eliminate the limitation of the base fluid. Nano fluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water (Zhu *et al.* 2011).

© Universiti Teknikal Malaysia Melaka

Nanofluids have better properties that make them potentially very useful in many kind of modern application involving heat transfer including microelectronics, pharmaceutical processes, fuel cell technology, and a refrigerant technology that is more efficient that is can be potentially be used in high tech application like space technology, advance defense system, and nuclear reactor cooling system

1.2 OBJECTIVE

The objective of the study is:

- To produce a stable water based carbon nanotube using polyvinyl pyrrolidone as a dispersing agent.
- To investigate the relationship between the amount of carbon nanotube used and the value of thermal conductivity.

1.3 SCOPE

- To find the suitable ratio between the amount of carbon nanotube, amount of the dispersing agent and deionized water.
- To investigate the stability of the water based carbon nanotube using polyvinyl pyrrolidone as a dispersing agent.
- To determine the thermal conductivity value for each of the sample.

© Universiti Teknikal Malaysia Melaka

1.4 PROBLEM STATEMENT

Water are widely used as a coolant in automotive or in central air conditioning system because it is very cheap and the properties of high thermal conductivity and high heat transfer capacity make it very suitable substance to be used as a coolant. By using water based carbon nanotube, the properties of pure water can be alter to make it more efficient as a coolant compare to the standard tap water. Hence a further study about the water based carbon nanotube need to be done to observe whether it is better for coolant than tap water because in the theory, carbon nanotube has more surface area in a molecular level compare to the water molecule. Theoretically when the surface area are high so it maybe has a higher specific heat capacity compare to water.

1.5 EXPECTED RESULT

In this particular research, a stable nanofluid based nanocarbonwill be produced by using polyvinyl pyrrolidone as a dispersing agent. A comparison can be made between others type of dispersing agent in terms of stability.

© Universiti Teknikal Malaysia Melaka

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF CARBON

Carbon is a building block or our life. All of the living things on earth made mainly from carbon even we are call a “carbon based living things”. Carbon has been used or exploit since ancient times in the form of soot, charcoal, graphite and diamonds. Ancient cultures did not acknowledge that all of the materials they used are made from a same materials but in a different form.

© Universiti Teknikal Malaysia Melaka

2.1.1 Early Experiments About Carbon

I. Early1772, a young French scientist name Antoine Lavoisier had done one simple experiment which he place a diamond in a closed glass jar. He focused the sun's rays on the diamond with a giant magnifying glass and let the diamond burn and disappear. Than Lavoisier noted that the overall weight of the jar was unchanged and he conclude that the diamond had combine with oxygen to form carbon dioxide. He noticed that the charcoal also made from the same element that make the diamond. (Krebs 2006)

II. In 1779, Swedish scientist Carl Scheele showed that graphiteburned to form carbon dioxide and so must be another form of carbon. (Mazaheri2011)

III. In 1796, English chemist name Smithson Tennant was established that diamond was pure carbon and not a compound of carbon; it burned to form only carbon dioxide. He proved that when exact equal weights of charcoal and diamonds were burned, they will produced exactly the same amount of carbon dioxide. (Mazaheri2011)

2.2 CARBON

Carbon material are the most promising adsorbents of traces gases or vapor (Liu, X, 2010). Recently, new carbon forms like for example carbon nanofibres (CNFs) or nanofilaments and carbon nanotubes (CNTs) have generated a growing interest in scientific community in these pass several years. the interaction of these structures with environment, an in particular with gases make a huge attractions due to the possibility of using this materials for an efficient gas storage that can maximized space in the same volume (Serp*et al.* 2003). This materials are attractive because of they can join relatively high specific surface and uniform mesoporous diameter is the reasons that make these

© Universiti Teknikal Malaysia Melaka

materials being much more accessible to absorbs compare to the micropores found at common activated carbons (Hong 2005).

2.3 NANOCARBON

Nanomaterials are fairly new and interesting subject in physics nowadays. This new kind of field in physics had attracted many scientist around the world. The small dimensions, strength and their remarkable physical properties make them very unique materials with a whole range of promising applications like never before for example for the electronic and electromechanical applications of carbon nanotubes (Qiaohuan 2010). Nanomaterials also would be very useful for a mechanical reinforcement in high performance composites, nanotube based field emitters, and any possible new type of high performance materials. Carbon nanotube is one of the type of the nanocarbon family which have two main type that is single wall and multi wall carbon nanotube. Carbon nanotube also can be divided into three other sub family which is chiral type CNT, armchair type CNT and zigzag type CNT. From Figure 2.1 and Figure 2.2 shows how the carbon nanotube roll off geometry from a graphene sheets. This three type of CNT is only the geometry pattern of the carbon atom only.

© Universiti Teknikal Malaysia Melaka

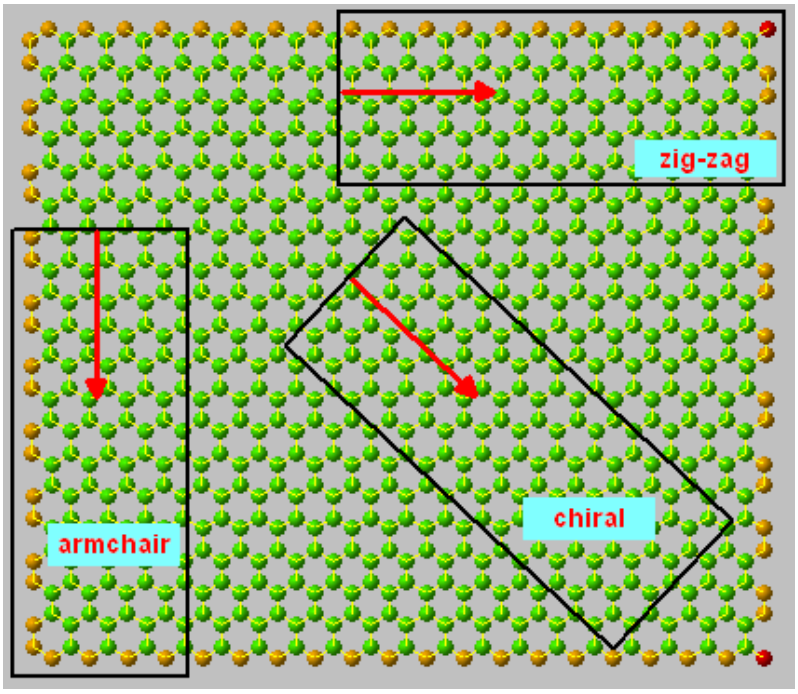

Figure 2.1 : A roll up vector of carbon nanotube from graphene sheet

(Source: Brian, 2002)

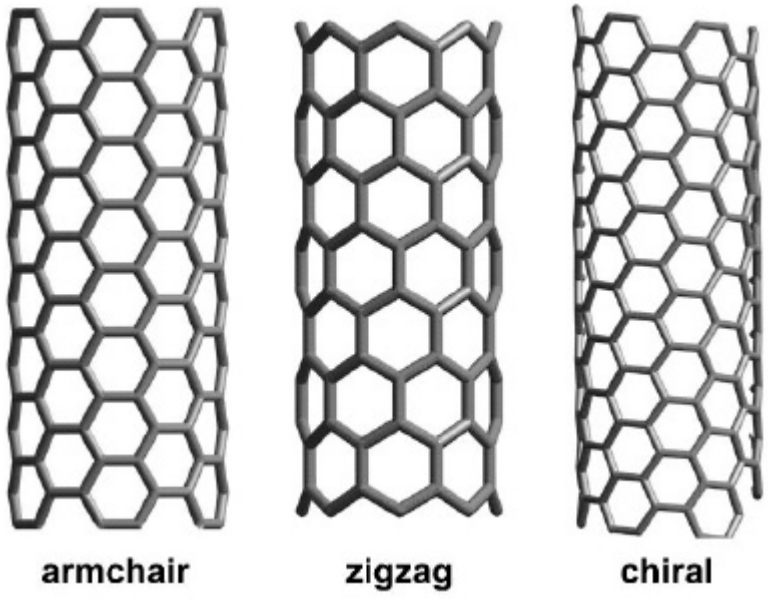

Figure 2.2: Type of carbon nanotube

(Source: Brian, 2002)

© Universiti Teknikal Malaysia Melaka