Polyurethane synthesis for ceramic foam filter

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Advisor	Asst. Prof. Dr. Wanwilai Evans, Asst. Prof. Dr. Surat Areerat

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Abstract

Currently, metals industrial has an important character that metal usage is annually growing up. The ceramic foam filter is needed to filtrate molten metal for purifying products. The ceramic filter is synthesized from a polyurethane which is 30 ppi of pores size. Most of the polyurethane used in this process is imported and expensive. The aim of this research is to synthesize polyurethane for ceramic foam filter by using elementary experiments. The experimental methods for synthesis this type of PE was investigated by study the effect of the mixing, agitation technique and the amount of distilled water on the polymer structure, texture, and pore size. It was found that the automatic stirring gives a larger pore size than manual stirring, and the amount of distilled water is also affecting pore size of polyurethane. The result was shown that synthesizing flexible polyurethane with 0.5% distilled water, using automatic agitation at room temperature and atmospheric pressure, gave the best result which resembles a prototype.

Keywords: Polyurethane (PU), Ceramic foam filter, Polyols, Isocyanate, Blowing agent.

เรื่อง การสังเคราะห์โพลียูรีเทนสำหรับการทำตัวกรองเซรามิค

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บทคัดย่อ

ในปัจจุบัน อุตสาหกรรมโลหะมีบทบาทสำคัญ ทำให้การใช้โลหะสูงขึ้นในแต่ละปี โดยการผลิตโลหะจำเป็นต้องมีตัวกรองสำหรับกรอง น้ำหล่อโลหะไม่ให้มีสิ่งเจือปน โดยใช้ตัวกรองเซรามิคที่สังเคราะห์มาจากโพลียูรีเทน แต่เนื่องจากโฟมโพลียูรีเทนชนิดนี้มีราคาแพง ส่วนใหญ่ต้องนำเข้าจากต่างประเทศ ดังนั้นเป้าหมายในการศึกษานี้คือการสังเคราะห์โพลียูรีเทนสำหรับทำตัวกรองเซรามิคโดยใช้วิธีการสังเคราะห์แบบง่าย โดยทำการทดลองเพื่อสังเคราะห์โพลียูรีเทนที่มีขนาดรูพรุนและ โครงสร้างที่เหมาะสม โดยศึกษาวิธีการปั่นกวน รวมไปถึงการใส่น้ำเพื่อดูการขยายตัวของรูพรุน จากการทดลองพบว่า โพลียูรีเทนแบบนิ่มเป็นเนื้อสัมผัสมีโครงสร้างเหมือนกับต้นแบบมากที่สุด การปั่นกวนแบบอัตโนมัติให้ผลลัพธ์ขนาดรูพรุนมากกว่าแบบการปั่นกวนด้วยมือ และพบว่าจำนวนน้ำมีผลต่อรูพรุนของโพลียูรีเทน โดยโพลียูรีเทนแบบนิ่มที่มีการใส่น้ำจำนวน 0.5 เปอร์เซ็นต์ของสารละลายทั้งหมด และใช้การกวนแบบอัตโนมัติโดยทำปฏิกิริยาที่อุณหภูมิห้องและความดันบรรยากาศ ได้ผลลัพธ์ที่มีความใกล้เคียงกับเป้าหมายที่ต้องการมากที่สุด

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CHAPTER I
INTRODUCTION

1.1 Background

In Thailand, there are many metal industries and they have been growing up such as aluminum industry, iron industry, etc. Most of metal industry produced shatters, spare parts as a material which has a molten metal process. The problem of molten metal process is the contamination of small particles such as dust, sawdust, etc. The remnant of metal must be filtered out by using ceramic foam filter.

The ceramic foam filter is used to filtrate a contaminate molten metal. Most of the ceramic filter was synthesized from polyurethane foam[1] which was used as a material to coating with ceramic. Currently, the ceramic foam filter is imported from China that causes expensive cost to the metal industrial[2].

Polyurethane foam is widely used and easy to synthesis. Polyurethane foam can be classified into various types such as classified by following the structure of cell and the process production. The cell-structure of polyurethane foam has 2 types, which are open-cell PU and close-cell PU [3]. Open-cell PU is a foam with connections between the pore of cell that helps the circulation of air or gas in the cell. Close cell is a foam that the pores of cell are not connected. In the same way, the polyurethane can be classified by the specific application including the flexible polyurethane, rigid polyurethane, coatings, adhesives, sealants, and elastomers[4]. In ceramic foam production, the open-cell type of flexible polyurethane was used as a material to be coated by ceramic. The preferable pore size is around 8 to 80 ppi (pore per inch)[5].

In this work, we aim to synthesis flexible polyurethane foam for the ceramic foam filter. The open cell of flexible polyurethane has been synthesized by using polyols, water, and isocyanate. The polyols and isocyanate from All-Art center company are used. The blowing agent is distilled water. Moreover, the mechanical properties and texture are investigated.

1.2 Objectives

1.2.1 To synthesis flexible polyurethane foam for ceramic foam filter production

1.2.2 The specify pore size of polyurethane foam is 30 pores per inch (ppi).

1.3 Scope of work

1.3.1 Synthesize the flexible polyurethane foam from polyols, water, and isocyanates.

- Polyols (soft polyurethane foams A: 2) from All-art-center
- Isocyanates (soft polyurethane foams B: 1) from All-art-center
- Distilled water

1.3.2 To synthesize the polyurethane foam from each polyols and isocyanates.

1.3.3 To study texture and surface of polyurethane.

1.3.4 To study increasing pore size by using distilled water.

1.3.5 To study agitate behavior relate to characteristic of foam.

1.4 Expected outputs

1.4.1 Flexible polyurethane foam product can use in the metal industrial.

1.4.2 This flexible polyurethane foam filter can substitute the imported polyurethane foam from China.

CHAPTER II
THEORY AND LITERATURE REVIEW

2.1 Ceramic foam filter

Ceramic foam filter widely is used in molten metal filtration to eliminate contaminants or undesirable in the melt liquid. The ceramic foam filter has a lot of properties according to different usage. The mechanical properties of the ceramic foam are high-temperature resistance, high corrosion resistance, inert with metal, large surface area, and high porosity[1]. Major ceramic foam filter made from polyurethane foam and coating with a ceramic such as Al_2O_3, SiC, and ZrO_2 that the ceramic foam filter must be heat resistance approach at 1700 °C[6]. The pore size of the ceramic foam filter is around 8 to 80 pores per inch (ppi).

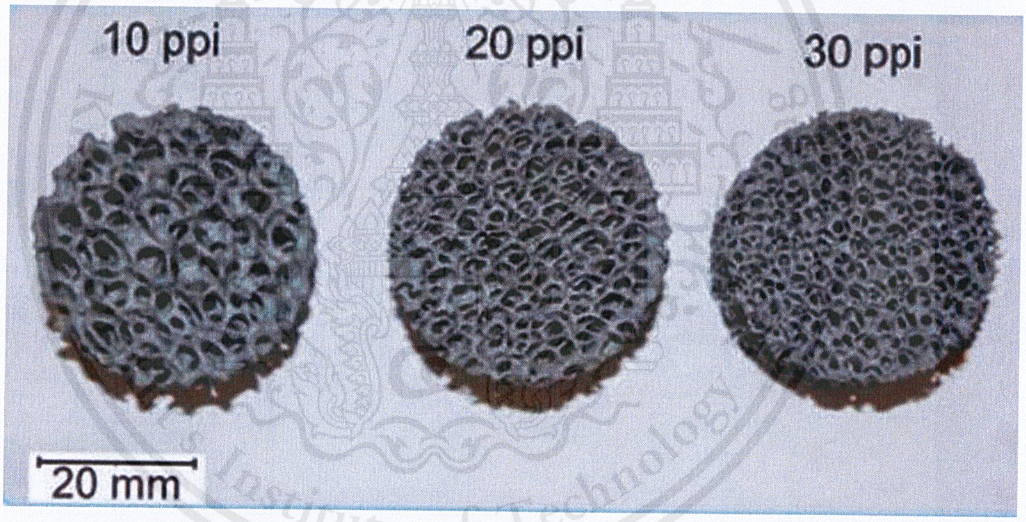


Figure 1. Ceramic foam filter of each pore size[7].

2.2 Polyurethane foam

Polyurethane foam is a production of a polymer that it is widely used in the present such as apparel, appliances, automotive, composite wood, electronics, flooring, furnishings, marine, medical, packaging, building, and construction[4]. In the first generation, the polyurethane foam was discovered by Otto Bayer in 1937 by using TDI generation. From 1960 to 1980, MDI and blends isocyanates was discovered. In 1980, the polyurethane foam widely used in industrial[8]. In the present, the bio-polyurethane foam was spread out to daily life. The reaction of polyurethane is polymerization by an exothermic reaction.

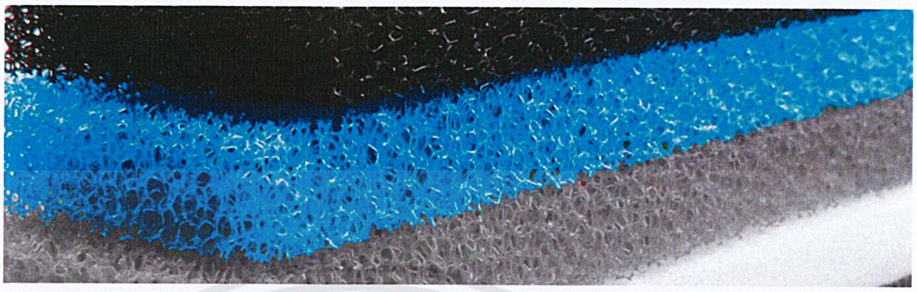


Figure 2. The Polyurethane foam[9].

Most of polyurethanes are thermosetting polymers[10]. The polyurethane can be classified by specific application or stiffness that the flexible polyurethane, rigid polyurethane, coatings, adhesives, sealants, and elastomers. Type of cell structure is also used to classified polyurethane foam (opened cell, closed cell, or mixed cell). The flexible polyurethane is a foam that can be flexible and soften. The rigid polyurethane is a foam that cannot stretch back to the original form and solid.

Isocyanate + Polyols ⟶ Polyurethane

$$R-NCO + R'-OH \longrightarrow R-NH-\overset{O}{\overset{\parallel}{C}}-O-R'$$

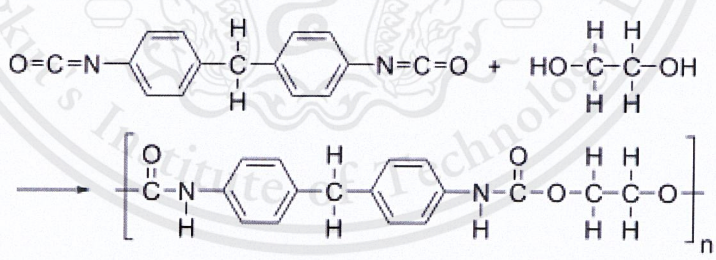


Figure 3. Mechanism of synthesis polyurethane[11].

Polyurethane was synthesized from a mixture of isocyanates, polyols, blowing agents, catalysts, surfactant, and additives etc. by mixing[12]. The properties of polyurethane foam depended on application usages such as automotive interiors use flexible polyurethane foam and insulate windows use rigid polyurethane foam. A pigment or other specific properties is added to respond a consumer.

Table 1: Types of polyurethane and application[4].

Types of polyurethane	Application
Flexible polyurethane	- Bedding - Furniture - Automotive interiors - Carpet underlay - Packaging
Rigid polyurethane	- Insulation materials - Roof and wall insulation - Insulated window and door - Air barrier sealants
Coating, Adhesive, Sealants and Elastomers (CASE)	- Enhance product's appearance - Lengthen its lifespan - Strong bonding advantages - Tighter seals - Instead of metal product (elastomers lighter than metal)
Thermoplastic polyurethane (TPU)	- Footwear - Automotive - construction

2.3 Flexible polyurethane and rigid polyurethane

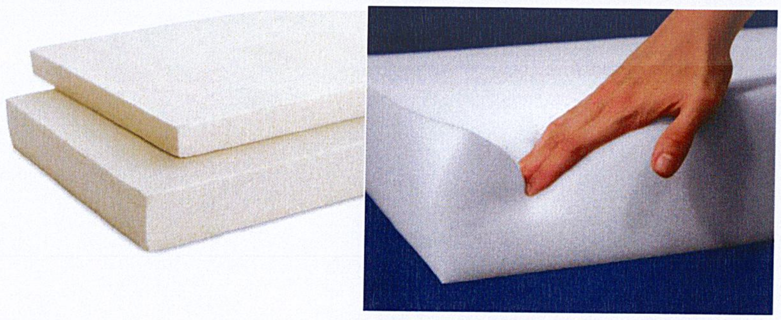


Figure 4. Rigid polyurethane[13] (left) and flexible polyurethane[14] (right).

From **Figure 4**, flexible polyurethane is softer than rigid polyurethane that flexible polyurethane can be compressed and it can return to an original form. Furthermore, rigid polyurethane can be compressed but it will be out of shape.

2.4 Cell structure

The cell structure of polyurethane can distribute into 3 types (open, close, and mixed). Open cell is a foam that the cell cavity interconnect together cause gas or air can circulate inside. The cell cavity that not interconnect is close cell. The mixed cell will depend on foam processing and type of foam.

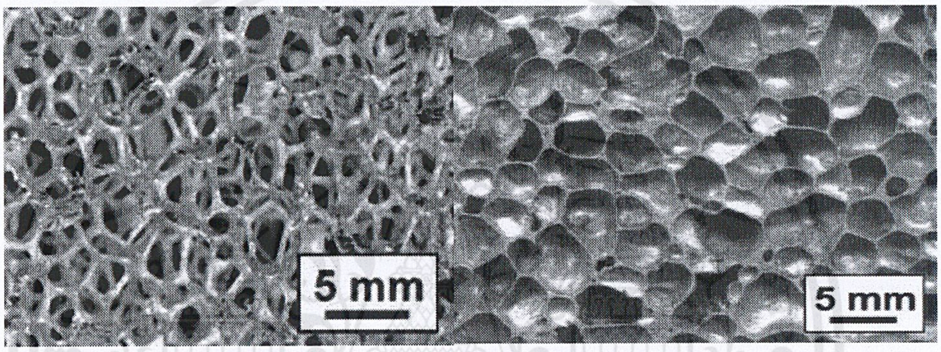


Figure 5. Open-cell (left) and Close-cell (right)[15].

The open cell normally uses as a filter since cell that interconnects and a pollutant will be attached in the cell.

2.5 Polyols

Polyols are compounds of hydroxyl groups that polyols have molecular weights from 200 to 8000. Polyols react with isocyanate to produce polyurethane. Normally, polyols are produced by the reaction of a hydroxyl group. Polyols are distributed into 2 types there are polyether polyols and polyester polyols[16]. Most of polyether polyols used to produces PU foam but mostly of polyester polyols used to produces PU that not a foam. Ethylene oxide, propylene oxide, and tetrahydrofuran are cyclic ethers that commercial use in the industry[8].

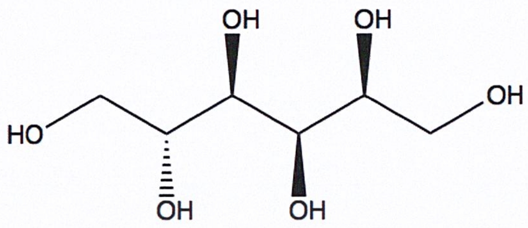


Figure 6. Chemical structure of Sorbitol or sugar alcohol[8].

Nowadays, polyether polyols are widely used in the industrials since it has low cost and easy to be handle.

2.6 Isocyanates

Isocyanates is a main raw material to synthesize polyurethane foam. Common polyols are toluene diisocyanate (TDI) or methylbenzene diisocyanate, methylene diphenyl diisocyanate (MDI) or diphenylmethane diisocyanate[17]. Toluene diisocyanate or TDI is used for flexible foam. On the other hand, methylene diphenyl diisocyanate or MDI mostly is used for rigid foam[11].

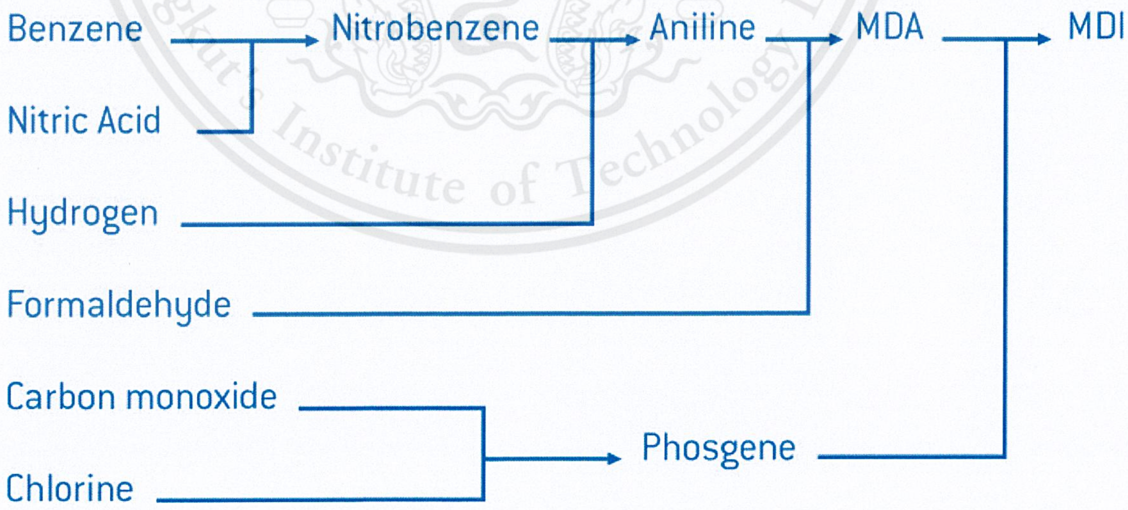


Figure 7. Benzene to MDI[8].

From **Figure 7**, benzene is a raw material to produce the MDI. Nitration change benzene to nitrobenzene after that add hydrogen and catalyst to hydrogenation of nitrobenzene to aniline. Then, add CH_2O and HCl to produce MDA/DADPM and use phosgene to change MDA/ DADPM to MDI mixture plus hydrogen chloride by phosgenation. Then, distillation and separation to give polymeric MDI and MDI mixed Isomers (low 2,4'). MDI mixed Isomers (low 2,4') is purified to get pure 4,4'-MDI and MDI mixed Isomers (high 2,4')[8].

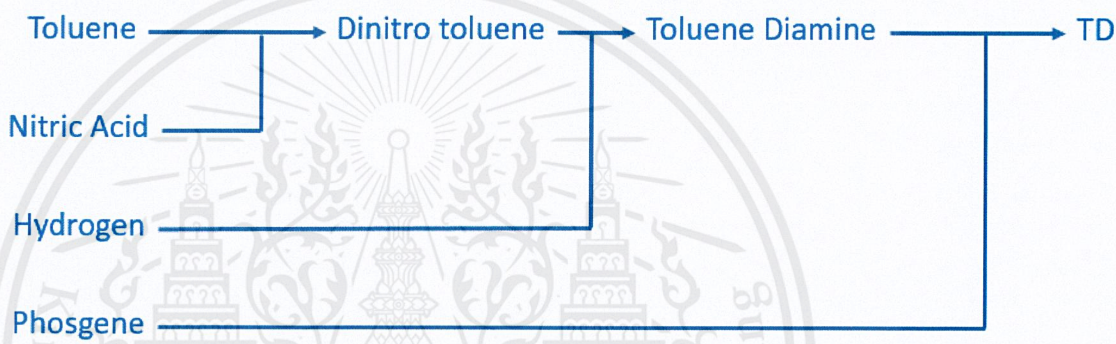


Figure 8. Toluene to TDI[8].

From **Figure 8**, nitric acid and some catalyst are added into toluene to produce dinitrotoluene by nitration and then hydrogenation to produce toluene diamine. Then, purification of toluene diamine gets m-TDA isomers and o-TDA isomers. The m-TDA isomers change to biurets, crude TDI, and hydrogen chloride by phosgenation. Then, purification all the product gets TDI (80/20) and Biurets residue. Finally, differentiation of TDI (80/20) gets pure 2,4-TDI and TDI 65/35[8].

$$R-N=C=O \;+\; H-O-H \longrightarrow R-NH_2 \;+\; O=C=O \;+\; \text{Heat}$$

Figure 9. Reaction of isocyanate and water[11].

From figure 9, isocyanate can react with water to produce carbon dioxide and amine that carbon dioxide is used in the production of polyurethane foam as blowing agent.

2.7 Blowing agents

Blowing agents was used to polymer processing for increasing foam or porous structure. The blowing agent can distribute into 2 types (Physical blowing agent, Chemical blowing agent). Physical blowing agents are mostly damaged to an environment such as carbon dioxide (CO_2), chlorofluorocarbons (CFC), methylene chloride, hydrochlorofluorocarbons (HCFCs), etc.[11].

Table 2: Properties of CFC and other physical blowing agent[11].

	CO_2	CFC-12	CFC-11	Methylene Chloride
Chemical formula	CO_2	CCl_2F_2	CCl_3F	CH_2Cl_2
Molecular weight	44	120.9	137.4	85
Boiling point, °C	-78.3	-29.8	23.8	40
Specific gravity at 25°C	n/a	1.31	1.48	1.33
Heat of vaporization at BP, kJ/mole	6.8	20.0	24.8	28.0
Gas conductivity, mW/(m.K) at 25°C	16.4	9.9	7.9	n/a
Vapour pressure, kPa at 25°C	6400	640	110	60
Flammable limit in air, vol-%	None	None	None	12-19
OEL, ppm	n/a	1000	1000	35-100
ODP (with CFC-11 = 1)	0	1	1	0.007
GWP (100-year., CO_2 = 1)	1	10600	4600	0.02
Atmospheric lifetime, years	120	100	45	0.5

*OEL Occupational Exposure Limit, ODP Ozone Depletion Potential, GWP Global Warming Potential

Chemical blowing agents have used an extension of plastics and polyurethane production. Example of chemical blowing agents is carbon dioxide that generated by a reaction of isocyanate and water[3]. This type is used in polyurethane form that carbon dioxide blows the polyurethane foam.

2.8 Catalysts

Catalysts are substances that are added to the reaction. Make the reaction faster. Or increase the rate of reaction. The catalyst may also be involved in the reaction. At the end of the reaction, these catalysts will have the same amount with before reacting and have the same properties. In polyurethane synthesis, there are three commercial catalysts were used i.e. organometallics (primarily tin compounds), tertiary amines, and carboxylic acid salts[11].

2.9 Surfactants

Surfactants or surface-active material is an important material to provide a stabilization of the forming foam and as emulsification ability. The surfactant is influenced on surface tension between liquid since the liquid will be well dispersion. The surfactant has both of polar and nonpolar. Emulsifiers, foam stabilizers, and cell regulators are types of surfactant which are used in polyurethane production. Emulsifiers are important with the manufacture of polyurethane foam which is influence the surface tension of polyether or polyester as foam stabilizers. Foam stabilizers act as emulsifiers for the entire system and influence on foam formation. The foam stabilizers effect on an open cell which the cell can stands[11].

2.10 Cross-linkers/Chain Extenders

Cross-linkers and chain extenders are used to connect between chain polymers. Variety of different cross-linkers with different reactivity and functionalities are used for different application. Alcohols and amines are used as cross-linkers[11].

2.10.1 Alcohol

Commercial alcohols of cross-linker are ethylene glycol, 1,4-butanediol, and bis-(hydroxyethyl) hydroquinone[11]. For elastomers, 1,4-butanediol is the important chain extender. A PU-rubber also used Bis-ethoxylated hydroquinone in cast elastomers. Glycerol, trimethyl-ol propane, and some sorbitol serve as cross-linkers that in order to introduce a gradation of hardness.

2.10.2 Amines

Commercial of cross-linkers and chain extenders of amines used primary, secondary di- and polyamines. In cold cure molded foam formulations, aliphatic-alicyclic polyamine is used as cross-linkers. Diethyl-toluene is used as a chain extender in polyurethane production by using RIM technology[11].

2.11 Additives

Additives is a material which is different according to different usage. A various additive can be classified by their application. Additives for flame retardance, filler, an antiaging agent, coloring agents, mold release agents, and special additives are commercial additives of polyurethane production[11].

Literature reviews

There are many research works about polyurethane foam or reinforcement of polyurethane foam that focused on properties and reinforce the polyurethane foam. Chan Wen Shan[18] studied about coir fibers and water to reinforced the flexible polyurethane foam. Coir fiber extracted from the shell of coconut that it is biomaterial, cheap, and low density. There are two types of water that they use in this work. Distilled water and water was used. They study untreated and treated coir fiber that which one is better to reinforce polyurethane. The treated coir fiber shown a better composite formation and not have losses or leakage on the product that the better bonding will improve the mechanical properties. On the other hand, water and distilled water was studied by add to a polyol and mix with another raw material. The result was shown that a polyurethane which adds distilled water will clearly see and better to rising foam up.

In 1957, Norman H.Stark[16] presented the polyurethane filter for removing solid particles from fluids. They produced the polyurethane filter to comparison with a metal filter that the polyurethane filter was formed by using isocyanate and polyester resin. The reaction between toluene diisocyanate with adipic acid and diethylene glycol. The foam was soft, resilient, flexible and highly porous. Then, they cut the foam like a sponge and comparison with a metal filter. The result of this work was shown that the polyurethane filter better than a metal filter. The efficiency of polyurethane filter about 99% but the metal filter only 88%.

In 2002, Henry Mattesky[17] presented method of making open-celled polyurethane foam. Water was used as a blowing agent in this work. They used three polyols to compare the properties (ARCOL HS 100 Polyol, ARCOL polyol U-1000, 7057).

L-5770 and L-620 were used as a stabilizer. The catalysts are Niax A-1, amine, T-10 Tin. Polydimethylsiloxane oil was used as cell-opener.

This work study and synthesize the flexible polyurethane foam (30 ppi) for using as a molding metal filter. Polyols and isocyanate are used as a commercial product to synthesize polyurethane foam. In addition, the blowing agent is a water. The main properties of the flexible polyurethane foam: texture and pore size will be analyzed about hardness and stiffness.

CHAPTER III
RESEARCH METHODOLOGY

The purpose of this research is to synthesis 30 ppi polyurethane foam by using polyols, distilled water, and isocyanates. In this research, flexible polyurethane was used. Both of component A (polyols) and B (isocyanate) already have mix some catalysts, surfactant, blowing agent, and additive. In this case, distilled water was added as blowing agent to increasing pore size of polyurethane foam. The polymerization of polyurethane occurs between polyols and isocyanate. This reaction is exothermic. The reaction was carried out at room temperature and atmospheric pressure.

3.1 Chemicals and Materials

1. Polyols (soft polyurethane foams A: 2) from All-art-center as Component A.
2. Isocyanates (soft polyurethane foams B: 1) from All-art-center as Component B.
3. Distilled water.

3.2 Equipment and Apparatus

1. Automatic stirring rod
2. Plastic mold (rectangular shape)
3. Plastic cylinder 100 ml.
4. Beaker
5. Plastic spoon
6. Rubber gloves

3.3 Procedures

3.3.1 Preparation of the flexible polyurethane foam by using the polyols, water, and isocyanate.

1. Measure the polyols (component A) and isocyanates (component B) (2:1 respectively) such as polyols 40 ml. and isocyanate 20 ml by separate into two cylinders.
2. Pour distilled water about 0.5 to 3 per 100 parts of solution into polyols.
3. Pour the solution of polyols into beaker.
4. Pour the isocyanates into polyols solution.

5. Mixing the solution of polyols, water, and isocyanate by using automatic stirring rod and make sure that the completely reaction.

6. While stirring, the foam is growing up then pour into the rectangular mold.

7. Waiting until the polyurethane foam is completely set which take 15 – 20 minutes.

8. Remove the polyurethane foam from the rectangular mold.

3.3.2 Measurement of the polyurethane foam pore size and check simple mechanical properties

1. Measurement a foam density by using electronic densimeter (MD-2005).

2. Characteristic measurement of each polyurethane foam by using 100X camera.

3. Comparison between foam product and prototype for measure efficacy of water to flow through.

CHAPTER IV
RESULTS AND DISCUSSION

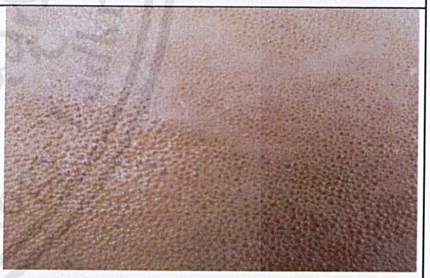
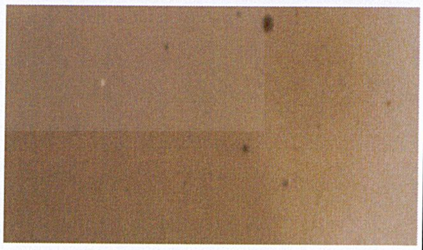
The aim of this research is the polyurethane filter which 30 ppi of pore size. This research was divided into 3 sections by parameters distribution. The first section is a characteristic experiment for finding the texture of polyurethane. Then, the second section studied the effect of a characteristic stir (Manual stir as mechanical move and Automatic stir as shear move). The effect of the blowing agent was studied in the last section. All this research to find the best product which resembles a prototype.

4.1 Texture comparison of each Polyurethane.

In this section, different types of polyurethane were studied for finding an eligible texture. Flexible polyurethane is a choice for synthesis ceramic filter because of flexible polyurethane have open-cell which can filtrate adulteration.

<u>Table 3:</u> Texture comparison of each Polyurethane.

No.	Component A (Polyols)	Component B (Isocyanate)	Texture	Setting time	Product
1	Flexible polyurethane foam 2 parts	Flexible polyurethane foam 1 part	Flexible	15 minutes	
2	Rigid polyurethane foam (expand 25 times) 1 part	Rigid polyurethane foam (expand 25 times) 1 part	Hardness	5 minutes	

3	Rigid polyurethane foam (expand 25 times) 1 part (Flame resistance)	Rigid polyurethane foam (expand 25 times) 1 part (Flame resistance)	Stiffness	5 minutes	
4	Rigid polyurethane foam (expand 10 times) 1 part	Rigid polyurethane foam (expand 10 times) 1 part	Hardness	5 minutes	
5	Rigid polyurethane foam (fake wood) 1 part	Rigid polyurethane foam (fake wood) 1 part	Hardness and texture like wood	5 minutes	
6	Rigid polyurethane foam (casting PU) 5 parts	Rigid polyurethane foam (casting PU) 1 part	Reaction not occur	2 hours	

From **Table 3**, it was showed that only sample No.1 is flexible which resemble prototype because polyols and isocyanate of No.1 are used to produce flexible polyurethane foam which has open-cell. The sample No.2 to No.5 is rigid and stiffness which is close-cell so No.2-No.5 are not typical to produce a ceramic filter. The reaction of sample No.6 is not occurring because this type has high viscosity which manual stir cannot make a reaction. Therefore, the sample No.1 was chosen and studied in the next section.

4.2 Agitation comparison of flexible polyurethane.

From the previous section, the flexible polyurethane was studied to pore size comparison by different types of agitation. The first type of agitation is manual stir by using stirring rod but another type is automatic stir by using milk-frother.

<u>Table 4</u>: Agitation comparison of flexible Polyurethane.

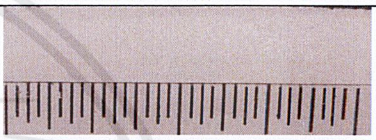
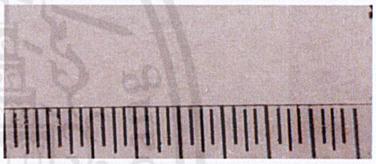
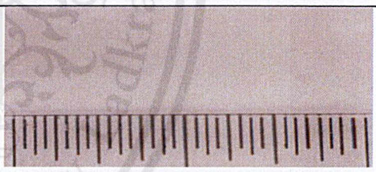
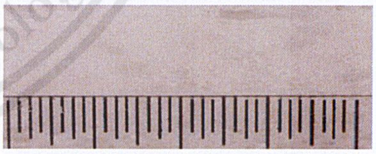
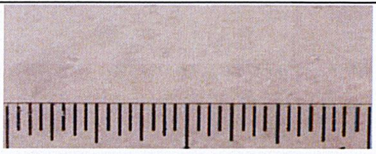
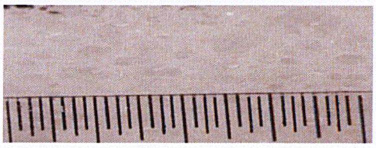
No.	Texture	Agitation	Pore size	Product
1	Flexible	Manual	Small pore size	
7	Flexible	Auto-stir	Pore size larger than No.1	

From **Table 4**, it was found that the automatic stir gives large pore size which larger than the flexible polyurethane by manual stir because a milk-frother will increase air into flexible polyurethane foam which effect to increase pore size. The disadvantage of an automatic stir (milk-frother) is irregular pore size because milk-frother cannot control inlet air, so some pores are bigger than another pore.

4.3 Amount of distilled water comparison of flexible polyurethane.

From **4.2**, the flexible polyurethane by using automatic stir (milk-frother) was studied the effect of blowing agent (distilled water) to pore size. In the part of the literature review, the comparison between water and distilled water which are a cheap blowing agent is showed that distilled water will produce product less unadulterated than water.

<u>Table 5</u>: Amount of distilled water comparison of flexible Polyurethane.

No.	Agitation	Texture	Amount of water	Product
1	Manual	Flexible, not out of shape, soft and firm	None	
7	Auto-stir	Flexible, not out of shape, soft and firm, and larger pore size than No.1	None	
8	Manual	Soft and not firm (reaction not complete)	2 parts of the solution	
9	Auto-stir	Flexible, soft and firm, irregularly, and most of broken pores.	2 parts of the solution	
10	Auto-stir	Flexible, soft and firm but irregularly pores	1 parts of the solution	
11	Auto-stir	Flexible, soft and firm, and resemble pore size of the prototype	0.5 parts of the solution	

From **Table 5**, the best pore size which appropriates to produce ceramic filter is sample No.11. The sample No.11 resemble the prototype. The reaction of sample No.8 was not complete because the amount of distilled water and agitation type does not make a complete reaction to the product No.8 was soft but not firm like an icing. Therefore, a large amount of distilled water will disintegrate a structure of polyurethane foam. In this section, distilled water can be used only 0 to 2% of the solution.

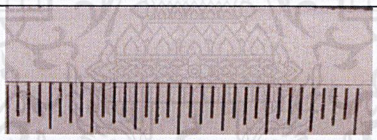
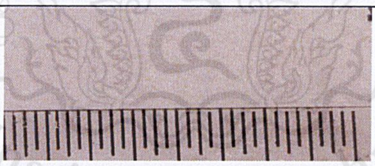
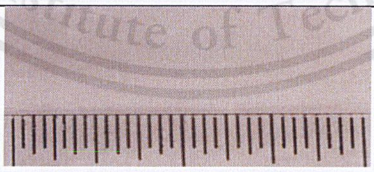
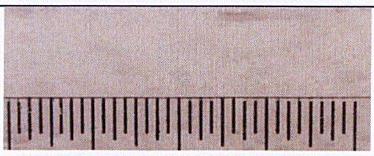
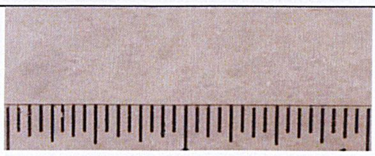
4.4 Mechanical properties or usage testing.

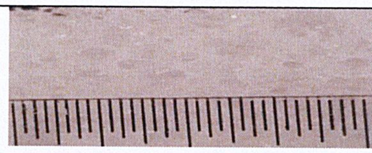
After varying parameter for synthesis polyurethane foam which resembles prototype. Then, analysis of mechanical properties such as foam density and 100X of the microscope. The usage testing is flow-through testing by comparing with the prototype.

4.4.1 Measurement of foam density.

An electronic densimeter (MD-2005) was used for measure foam density.

Table 6: Foam density of each polyurethane.

No.	Sample	Foam density
1		0.3
7		0.432
8		0.239
9		0.24
10		0.133

11		0.215

4.4.2. Characteristic measurement of each polyurethane foam by using 100X camera.

The 100X camera was used for viewing a morphology of the elect polyurethane.

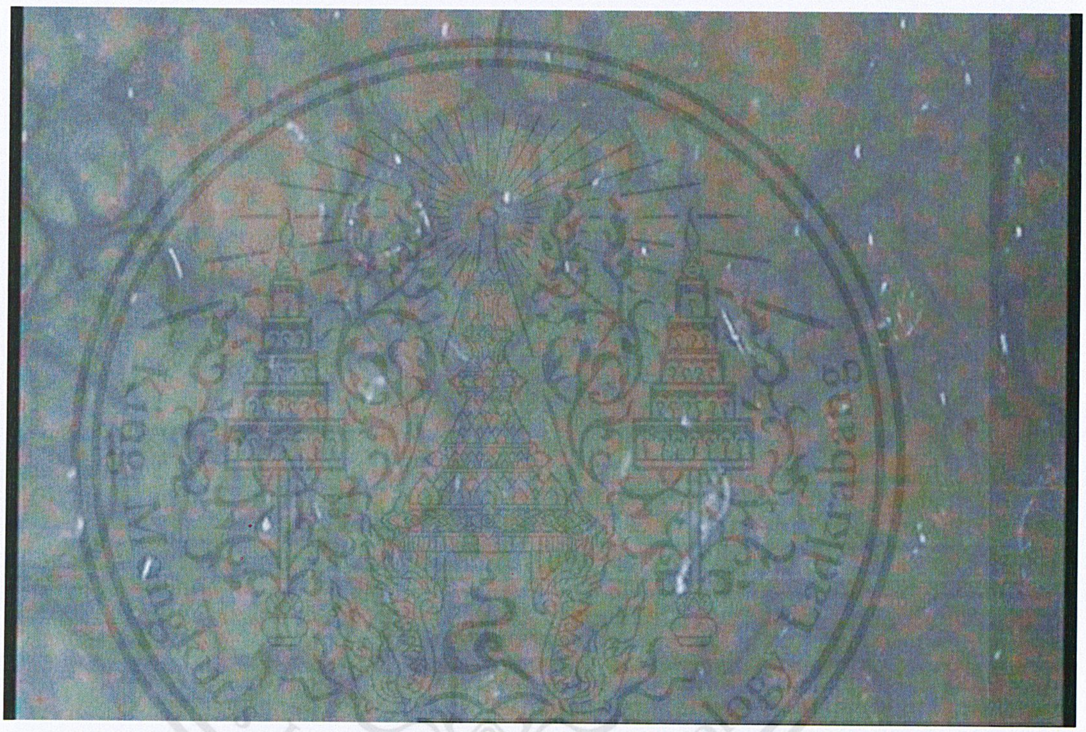


Figure 10. Morphology of the elect polyurethane.

In this **Figure 10**, It was showed that this foam is open-cell but some point the structure is unconnected because milk-frother cannot control the air which are put in a solution before setting.

4.4.3. Comparison between foam product and prototype for measure efficacy of water to flow through.

The prototype has more efficiency than foam product because some pores of foam product have not completely open-cell. Water can through to foam product.

CHAPTER V
CONCLUSION

5.1 Summary of the result

The flexible polyurethane by using automatic stir (milk-frother) and adding a distilled water about 0.5% of the solution as close to the original. This experiment extrapolated at room temperature and atmospheric pressure. The experiment separated into 3 experiments. The first experiment is a batch reactor with 4 paddles-blade. The second experiment is Kirei pump bottle. The third experiment is a batch reactor with milk-frother that this experiment can produce the expected product. This research can conclude that a ceramic foam filter can be synthesis from the flexible polyurethane foam which is an open-cell. The agitation types effect to pore size. The flexible polyurethane is an open-cell which water can pass through a structure of polyurethane foam. The blowing agent is water which reacts with isocyanate to produce carbon dioxide. The automatic stir or milk-frother will increase air inside a mixture of polyols and isocyanate before setting form. The best choice is adding a 0.5% solution which pores size resemble 30 ppi as same as the prototype. Moreover, the foam density of the elect polyurethane is 0.215. The elect polyurethane can be passed water through their structure but it is still not perfect.

5.2 Suggestion

1. This experiment used milk-frother for automatic stir which a problem is the polyurethane foam attach with the head of milk-frother cause to decrease efficiency. Therefore, should be used polyethylene (PE) or polypropylene (PP) because the polyurethane foam cannot attach to PE or PP.

2. This experiment has a lot of parameters which should be control some parameter such as pressure, temperature, etc.

3. The final product cannot perfectly filtrate because some cell is closed.

4. This work is a laboratory scale. In pilot scale, the experiment must change the rate of agitation or adding some air in the system.

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APPENDIX

APPENDIX A

Electronic Densimeter (MD-2005)

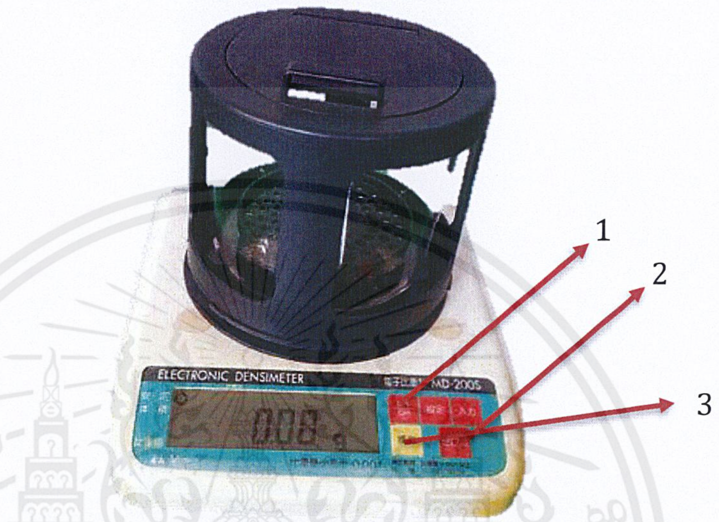

Figure A1. Electronic densimeter (MD-2005)

Instruction:

1. Open this electronic by a red button number 1.
2. Adding water inside black block and then set zero (button number 2) for calibration.
3. Weigh a sample by put it on black cover and press a yellow button number 3 for memory weigh of the sample.
4. Put the sample inside black block and then press on a yellow button again.
5. Densimeter will calculate the foam density.

Example:

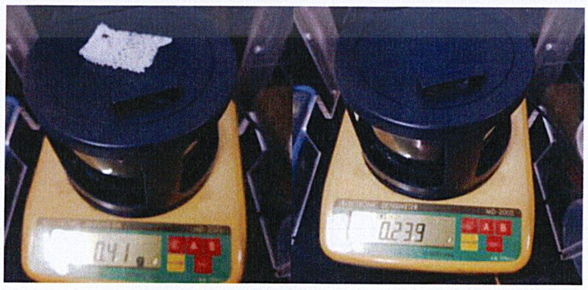

Figure A2. Example of foam density measurement.

APPENDIX B

Experiment

In this research, 3 types of experiment were used. The first experiment is batch reactor by using 4 paddles-blade. The second experiment is Kirei pump bottle. The last experiment is batch reactor by using milk-frother.

1. Batch reactor by using 4 paddles-blade.

Figure B1. Batch reactor by using 4 paddles-blade and stirring motor.

The results of this reactor were not type for used to synthesis ceramic foam filter.

2. Kirei pump bottle.

Figure B2. Pump bottle resembles Kirei.

This type cannot make a large pore size. The mood is not our target.

3. Batch reactor by using milk-frother.

Figure B3. Milk-frother for mix a solution.

This experiment gives a highest of pores size because milk-frother put the air inside the solution when foam rising, pore size will larger.

BIBLIOGRAHPY

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