DESIGN AND ANALYSIS OF POLYMERIC FOAM SPRAYING MACHINE

AZIZIE BIN NASIR

A report in partial fulfillment of the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

MAY 2009

SUPERVISOR'S DECLARATION

"We hereby declare that we have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering"

Signature : ……..
Name of Supervisor : ……..
Position : ……..
Date : ……..

Signature : ……..
Name of panel : ……..
Position : ……..
Date : ……..

STUDENT'S DECLARATION

I hereby declare that this thesis entitled *"Design and Analysis of Polymeric Foam Spraying Machine"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....
Name : Azizie bin Nasir
ID Number : MA05039
Date : ……...

Dedicated to my beloved Family and Friends

ACKNOWLEDGEMENTS

First I would like to express my grateful to Allah S.W.T. as for the blessing given that I can finish my project. In preparing this paper, I have engaged with many people in helping me completing this project. First, I wish to express my sincere appreciation to my main thesis supervisor Mr Mohd Ruzaimi bin Mat Rejab for encouragement, guidance, advices and motivation. Without his continued support and interest, this thesis would not have been the same as presented here. I also wish to express my deep appreciation to all my friends that have been stand by me and laugh or cry with me through thick and thin. I will never forget what we have been through. Last but not least I acknowledge without endless love and relentless support from my family, I would not have been here. Father, mother, sister and, you all have given me the inspirations and encouragement until these days. Thank you all.

ABSTRACT

This project is to design the portable spraying polyurethane machine and analyze the design structure and fluid flow inside the spray gun. The current portable spray gun use pressurize tank but in this design, peristaltic pump is used to create the pressure different to transfer polyol and isocyanate to the spray gun. The suitable devices are select and the design is draw in Solidworks. Using Fluent the outlet mass flow rate of polyurethane are determined for different inner tube diameter and using Algor, the casing strength is determined. The maximum mass flow rate for 6mm tube diameter is 0.393 kg/s, 8mm is 0.699 kg/s, 10mm is 1.092 kg/s and 12mm is 1.573 kg/s. The mass flow rate also increases when the motor speed is increase. With the used of AISI 1020 steel as the material, the maximum von Mises stress value for the FEA analysis is 3.912 MPa and the maximum displacement occurred at the structure is 0.0074mm. The spray machine gives more outlet flow rate using larger inner tube diameter with higher motor speed. The casing structure is observed as capable to support the load on the structure without failure.

ABSTRAK

Projek ini adalah untuk mereka cipta mesin semburan poliuretana yang mudah dibawa dan menganalisis struktur model rekaan dan aliran cecair di dalam pistol semburan. Mesin semburan polyurethane yang ada di pasaran sekarang menggunakan tekanan daripada tangki tekanan, tetapi model rekaan ini, menggunakan pam peristaltik untuk mewujudkan perbezaan tekanan bagi memindahkan polyol dan isosianat ke dalam pistol semburan. Alatan yang sesuai dipilih dan model rekaan dilukis menggunakan perisian Solidworks. Perisisan Fluent pula digunakan untuk menentukan kadar pengaliran jisim polyurethane yang keluar dari pistol semburan untuk diameter dalam tiub yang berbeza manakala ketahanan bekas yang menempatkan motor dan pam ditentukan dengan menggunakan perisian Algor. Kadar aliran jisim yang tetinggi bagi tiub 6mm ialah 0.393 kg/s, 0.699 kg/s bagi 8mm, 1.092 kg/s bagi 10mm dan 1.573 kg/s bagi tiub 12mm. Kadar aliran jisim ini juga akan meningkat dengan pertambahan rpm motor. Dengan menggunakan keluli AISI 1020 sebagai bahan binaan, nilai tertinggi tekanan von Mises yang didapati dari analisis FEA ialah 3.912 MPa dan nilai pembengkokan tertinggi yang berlaku pada struktur bekas ialah 0.0074mm. Ciptaan mesin semburan ini akan menghasilkan kadar aliran jisim yang lebih tinggi dengan penggunaan tiub yang mempunyai diameter yang lebih besar berserta motor yang menghasilkan kelajuan yang lebih tinggi. Struktur bekas yang digunakan juga mampu menampung bebanan daripada radas yang ditempatkan di dalam bekas tanpa sebarang kerosakkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

3D	-	three dimensions
AISI	-	American Iron and Steel Institute
CAD	-	Computer Aided Design
CFD	-	Computational Fluid Dynamics
FEA	-	Finite Element Analysis
kg	-	kilogram
mm	-	millimeter
PUR	-	polyurethane
rpm	-	revolution per minute
s		seconds
U.S.	-	United States
A	-	area
m	-	mass flow rate
ø	-	diameter
ρ	-	density
r	-	radius
v	-	linear velocity
ω	-	angular velocity

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discussed about the project background, problem statement of the project, objectives of the project and the scope of the project.

1.2 PROJECT BACKGROUND

Polymeric foam is becoming very important to human community. This foam started in flotation and packaging materials back in 1970s. Then, the further development to this polymeric foam results in a variety of application such as in the construction, automotive, medical devices and so on [3].

One of the important polymeric foam is polyurethane. One of the benefits of polyurethane is the versatility. Insulation, automotive, furnishing and packaging is some examples of polyurethane applications [7].

The polyurethane spraying machine operates by mixing two types of components, polyol and diisocynate in the spraying gun to produce the desirable polyurethane foam. Certain physical characteristic of the polyurethane foam can be achieved by controlling the ratio of the two components. There are also portable spray polyurethane foams available in the market. Generally, it has several common characteristic; simple, portable, fixed polyurethane characteristic and no power supply need to operate the machine [8].

The project involve in designing and analyzing the polyurethane foam-spraying machine. In the current market, to feed the components to the spray gun, conventional pump or pressurize tanks for the components are used but for this project, squeezer or peristaltic pump will be used to replace pump or pressurize tank [8].

1.3 PROBLEM STATEMENT

Polyurethane spraying machine currently use conventional pump for heavy industrial applications so the equipment is fixed and difficult to change its position. The portable polyurethane spraying machine used pressurized tank as its components tank so it need to changed the tank frequently as the components finish.

1.4 PROJECT OBJECTIVES

The objectives of this project are:

i. To design a small and portable polymeric foam spraying machine.
ii. To analyze the design structure and fluid flow of the chemicals in the spraying machine.

1.5 PROJECT SCOPES

The scopes of this project are:

i. To use polyurethane as the polymer for the spraying machine.
ii. To design the spraying machine by using Solidworks.
iii. To analyze the design structure of the machine by using Algor.
iv. To analyze the fluid flow of the chemical mixture by using Fluent.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Review about this topic is necessary because it is the main part of the spraying machine. Polymer can be defined as a natural or artificial substance consisting of large molecules that are made from the combinations of small simple molecules [1]. In other words, polymer can be known as macromolecules, which composed of giant organic molecules. Besides synthetic origin, there are also natural polymers, which are very important to human being such as enzymes, proteins, DNA, starch and cellulose. In daily life, the high strength and toughness combined with low weight and simple processing make it suitable to utilize in the polymer materials. Clothing, building, automotives, electronics, the material contain polymers as their components prove the importance of polymers [2].

2.2 POLYMERIC FOAM

Polymeric foam possesses unique physical, mechanical and thermal properties, govern by the polymer matrix, the cellular structure and the gas composition. Different polymers have different types of properties so it depends on the processing system to accommodate it. The unique properties of several of the foams have made it very important to industry, as it is useful for many possible applications [3].

Table 2.1: Highlights of Polymeric Foam Developments [3]

Time	Contents	Authors or Companies	References
1931	Foamed Polystyrene	Munters and Tandberg	U.S. Pat. 2,023,204 [18]
1937	Foamed Polyurethane (PU)	Dr. Otto Bayer	K.C. Frisch [19]
1941	Foamed Polyethylene	Johnson, F. L.	U.S. Pat. 2,256,483 [20]
1944	Extruded Polystyrene Foam	Dow Chemical	[21]
1945	Rigid PU Foam	Germany	PU at Farben, Report 1122 [22]
1952	Flexible PU Foam	Germany	K. C. Frisch [19]
1954	Expandable Bead	Stastney and Goeth	U.S. Pat. 2,681,321 [23]
1959	Rigid PU Foam Produce	ICI	G. Woods [16]
1962	PS Foam Injection Molding	Beyer et al.	U.S. Pat. 3,058,161 [24]
1962	Extruded Ethylene Foam	Rubens et al.	U.S. pat. 3,067,147 [25]
1967	Twin Screw for Foam Brt. Pat. 1,152,306	Spa, L. M. P.	It. Pat. 795,393 [26]
1967	ABS foam; Injection Mold	Woollard, D.	SPI 12th Ann. Conf. [27]
1968	Rigid Isocyanurate Foam	ICI	G. Woods [16]
1972	Extruded Propylene Foam	Parrish, R. G. (DuPont)	U.S. Pat. 3,637,458 [28]
1982	Accumulator Extrusion	Collins, F. (Valcour)	U.S. Pat. 4,323,529 [29]
1984	PP Molded Foam Article	Japan Styrene Paper	Jap. Pat. 59-23731 [30]
1990	PET Foam Extrusion	Shell/Petlite®	Xanthos, D. 2000 [31]

The advance improvements in last several decades prove the importance of the polymeric foam to the world [3].

There are many types of polymer such as Epoxy, Fluoroplastics, Polyacetal, Silicone, Polyurethane and many more [4] but for this project, Polyurethane will be the polymer that will be analyze.

2.3 POLYURETHANE

Professor Dr. Otto Bayer from Leverkusen, Germany first invents this special foam back in 1937 [5]. The formation of polyurethane is basically formed by reaction of two main components, which is by reacting a polyol with a diisocyanate in the presence of suitable catalysts and additives [6]. In commercial practice, toluene diisocyanate and polypropylene glycol (PPG) is use to produce one of the most common Polyurethane [7]. Figure 2.1 below shows the chemical reaction to produce the polyurethane.

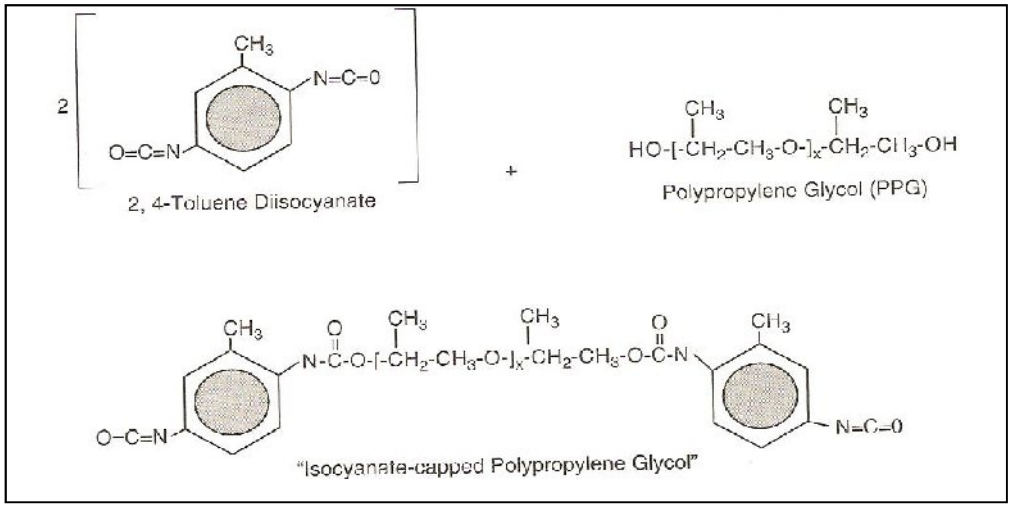

Figure 2.1: Polyurethane Reaction for Producing Prepolymer [7]

Polyurethanes exist in several forms such as flexible foams, rigid foams, chemical-resistant coatings, specialty adhesives and sealants, and elastomers [6]. The applications for polyurethane foam are describe briefly in the Table 2.2 below.

Table 2.2: General Applications for Polyurethane Foam [3]

Items	Markets	Applications
Flexible PU	Transportation	Seating, pads, liners, dampening, carpet backing, filters, flooring, armrests, trim
	Furniture	Bedding, padding, flooring
	Recreation	Sport mats, toys, helmet liner, chest protection
	Packaging	Electronic, computer, china, equipments
Rigid PU	Construction	Insulation, flooring, siding
	Appliance	Refrigerator frame, Door, Dishwasher door
Semi-Rigid	Automotive	Dash panel, liner, viser
	Footwear	Soles

The rigidity of the Polyurethane Foam is independent of the density as it can foam into a wide density range [3]. It is visualize as the Figure 2.2 below for easy view.

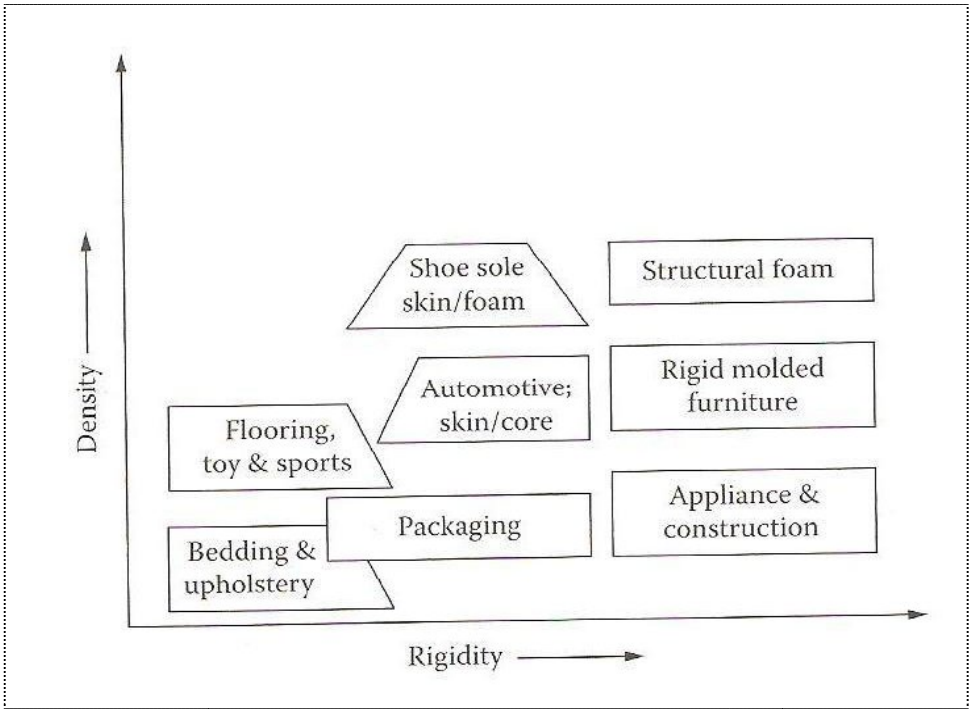

Figure 2.2: Application and Density chart of Polyurethane Foam [3]

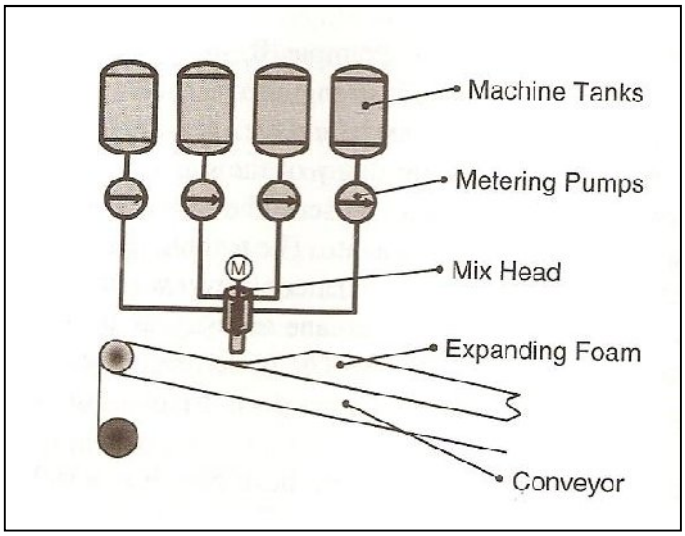

Figure 2.3: One-shot Process for Production of Polyurethane Foam [3]

2.4 SPRAY POLYURETHANE FOAM

Spray Polyurethane Foam is the reacted product of two components that are mix and spray to a substrate. The two components or the chemical are the same as stated before which are the diisocyanate and polyol. The components physical characteristics such as temperature, viscosity and material ratio needed to be known as it is important to make sure the spray polyurethane foam function properly [8].

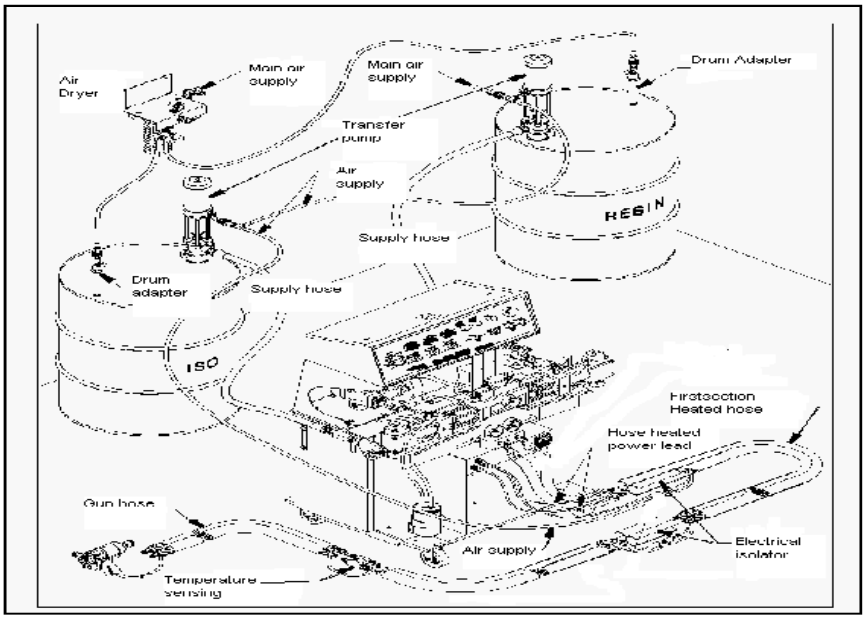

Figure 2.4: General Equipment of the Spray Polyurethane Foam [8]

In order to prevent the spray polyurethane foam from catastrophe, such as plugged and blocked, the diisocynate and the polyol should be kept separately. They should only mix in the spraying gun. Before choosing the type of equipment used in the spray machine, considering the output range of the project should be estimate is necessary [8].

Table 2.3: The Output Range According to the Certain Typical Projects [8]

Market	Typical Projects	Output Range
Residential, light commercial, light industrial	Residential insulation, small tank insulation, small roof spray adhesive, etc.	Up to 7 kg/min (15 lb/min)
Large residential, commercial, industrial	Roofing, residential insulation, medium tank insulation, large roof spray adhesive, etc.	Up to 14 kg/min (30 lb/min)
Heavy commercial, heavy industrial	Large roofing, large tank insulation, etc.	Up to 21 kg/min (45 lb/min)
OEM (Original Equipment Manufacturer)	Boat floatation, spa insulation, specialty molding, manufactured housing, insulated consumer products	Up to 27 kg/min (60 lb/min)

Generally, there are five main elements to consider in the spray polyurethane foam; material storage and handling system, material feed system, proportioner-pumping system, material delivery hose system and the spraying gun [8].

2.4.1 Material Storage Handling System

This system stores and moves the polyol and diisocyanate according to application. The material storage must be able to store the components within the temperature ranges of the components. There are two types of feed, obviously, to feed the polyol and diisocyanate; direct from containers and feed from the tanks [8].

2.4.2 Material Feed System

The purpose of the feed system is to deliver the polyol and the diisocyanate to the proportioner at suitable volume and pressure to overcome cavitations. The system usually consists a pump for each component and a hose. As an alternative, it can feed the proportioner by controlling the pressure itself from the feed tank [8].

2.4.3 Proportioner Pumping system

This is where the Spray Polyurethane Foam is important. The proportioner is design to meet these four objectives:

1. Proportion the polyol and diisocyanate in the appropriate ratio;
2. Pressurize the polyol and diisocyanate so they will mix properly in the spray gun.
3. Move the polyol and diisocyanate at the desired output to the spray gun.
4. Heat the polyol and diisocyanate so that viscosities allow for proper mixing in the spaying gun.

Figures below show some of the proportioner available in the market.

Figure 2.5(a): Guardian A-series Tier 2 – Pneumatic Proportioner by GlasCraft