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Faculty of Manufacturing Engineering

STATIC COLDCURE VULCANIZATION ON EMBOSSED RUBBER COTSHEETS USING CHAMBERS

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STATIC COLDCURE VULCANIZATION ON EMBOSSED RUBBER COTSHEETS USING CHAMBERS

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DECLARATION

I declare that this thesis entitled "Static Coldcure Vulcanization on Embossed Rubber Cotsheets Using Chambers" 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 : Tony Fam Chee Hoe.

Date : 29/8/19

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature : ....

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DEDICATION

To my beloved mother, wife, son and daughter. Thank you for your support, understanding and encouragement for me to complete this thesis and master programme.

Thank you !

ABSTRACT

Vulcanization is a technological process in rubber production in which raw rubber is converted into cure rubber. In the static coldcure process, vapor or fumed sulphur monochloride (S_2Cl_2) is used to cure the embossed rubber cotsheet in a chamber. Since the embossed cotsheet is not agitated during the vulcanization process, therefore the end products have no folded marks on its surface after being cured. However, the top and bottom surface may be not uniformly cured if the vapor sulphur monochloride is not well controlled. Too high of temperature also can cause the bubbles over expand and become deformed after cooling down. These two factors result in collapsed bubbles on the cotsheet products. Condensation of the sulphur monochloride inside the chamber also leads to formation of sulphur stains which can contaminate the cotsheet. These two main defects result in high product rejection and heavy customers' complaints. Therefore various process parameters such as vulcanization time, inner temperature of chamber, pot surface temperature and amount of sulphur monochloride that cause these two issues need to be studied. Design of Experiment (DOE) was carried out using Response Surface Methodology (RSM). Data collected were analyzed in the Design-Expert 6.0.8 Portable software. The results show that internal heating piping temperature which contributes to the inner temperature of chamber has significant p value (<0.05) to the response of collapsed bubbles and sulfur stains. The amount of (S_2Cl_2) is significant to the collapsed bubbles only. Whereas, the other variables, pot surface temperature and vulcanization time are insignificant to the both responses. Optimization analysis shows that the optimum parameters to minimize both responses are internal heating pipe temperature 0.6kg/cm^2, pot surface temperature 4.0 kg/cm^2, vulcanization time 15 minutes and S_2Cl_2 amount 450ml.

ABSTRAK

Pemvulcanan ialah satu proses berteknologi untuk memasakkan getah mentah menjadi keras. Dalam proses pemasakan sejuk secara statik, asap atau wap sulfur monoklorida (S_2Cl_2) digunakan untuk memasakkan getah dalam bilik ruangan yang terkurung. Oleh sebab produk yang digelar tikar getah bertimbul, tidak bergerak dalam proses ini, maka tikar yang terhasil tidak akan mempunyai kesan-kesan lipatan di atas permukaannya nanti. Walau bagaimanapun, permukaan atas dan bawah tikar ini tidak dapat dimasak dengan rata jika wap sulphur monoklorida tidak dikawal dengan sempurna. Suhu yang terlalu tinggi juga akan menyebabkan timbulan getah berkembang keterlaluan. Ini sebaliknya akan menyebabkan timbulan-timbulan tikar getah ini kempis. Kondensasi sulphur monoklorida dalam ruangan bilik terkurung juga boleh menghasilkan kotoran berwarna kuning yang boleh mencemarkan permukaan tikar getah ini. Kedua-dua kecacatan ini menyebabkan pembuangan tinggi dan aduan pelanggan yang serius. Oleh yang demikian, pelbagai parameter pemprosesan seperti masa pemvulkanan, suhu dalaman bilik terkurung, suhu pot dan kuantiti sulphur monoklorida perlu dikaji. Design of Experiment (DOE) dijalankan dengan menggunakan Response Surface Methodology (RSM). Data yang dikumpul dianalisiskan dalam perisian Design-Expert 6.0.8 Portable. Akhirnya, takat optimum dan interaksi antara empat parameter ini boleh didapati. Oleh yang demikian, proses pemvulcanan dapat dikawal dengan sempurna. Ini meningkatkan kualiti produk pada akhirnya. Keputusan menunjukkan suhu panasan paip dalaman yang menyumbang kepada kepanasan dalam bilik ruangan mempunyai nilai kebarangkalian yang berkesan (<0.05) terhadap kedua-dua tindak balas masalah timbulan kempis dan kotoran sulphur. Kuantiti S_2Cl_2 pula hanya berkesan terhadap masalah timbulan kempis tikar getah. Manakala pembolehubah yang lain iaitu suhu pada permukaan pot dan masa masakan tidak mempuayai kebarangkalian yang berkesan terhadap kedua-dua tindak balas tersebut. Analisis pengoptimuman menunjukkan parameter optimum yang dapat mengurangkan kedua-dua tindak balas ialah suhu panasan paip 0.6kg/cm^2, suhu permukaan pot 4.0 kg/cm^2, masa masakan 15 minit dan kuantiti S_2Cl_2 450ml

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CHAPTER 1

INTRODUCTION

1.1 Background

Unlike the traditional heat vulcanization technique using sulphur powder, the coldcure vulcanization process using vapor or fume sulphur monochloride (S_2Cl_2) is very less popular due to its safety issues and corrosive effects on its surroundings. In addition, the sulphur monochloride solution has high toxicity and the vulcanizates have poor aging properties because the product is vulcanized on the external surface only. Therefore, finding the information to support the research is rather limited. So, down-to-earth approach and hands-on experience are important when handling this coldcure process. Nevertheless, if the process is well controlled after knowing the important factors, rejection of the products will be reduced and hence improve the company's revenue and customers' satisfaction.

The main advantage of coldcure using S_2Cl_2 is that the wastes and scraps produced at the preceding processes of the vulcanization such as calendaring and embossing can be recycled. This is because rubber sheeting has not been cross-linked (vulcanized) yet up to these two stages. Therefore, processing cost can be minimized.

This type of external vulcanization is suitable to vulcanize the final shaped product. For cold coldcure products, most common forming process before vulcanization is the formation of air bubble or known as embossing process to form various shape of bubbles that can be designed for various purposes. Embossed rubber cotsheet is one of them.

1.2 Problem Statement

Vulcanization is a technological process in rubber production in which raw rubber is converted into cure rubber. In the coldcure process, vapor sulphur monochloride is used to cure the rubber. The term "coldcure" is used as the process takes place at about ambient temperature up to 65°C, relatively lower than that of the common heat vulcanization using sulphur powder which can reach as high as 200°C.

In the static coldcure vulcanization process, the rubber product namely embossed or air- filled cotsheet, is placed on a net tray. The tray is then loaded into a trolley which can accommodate 24 units of trays as shown in Figure 1.1. The trolley is placed into a chamber in which vapor sulphur monochloride is pumped into. The engineering structure of a chamber is illustrated in the Figure 1.2. The chamber picture, front and rear view is shown in the Figure 1.3 and Figure 1.4 respectively. Figure 1.5 depicts the view of the chamber when a trolley is loaded in.

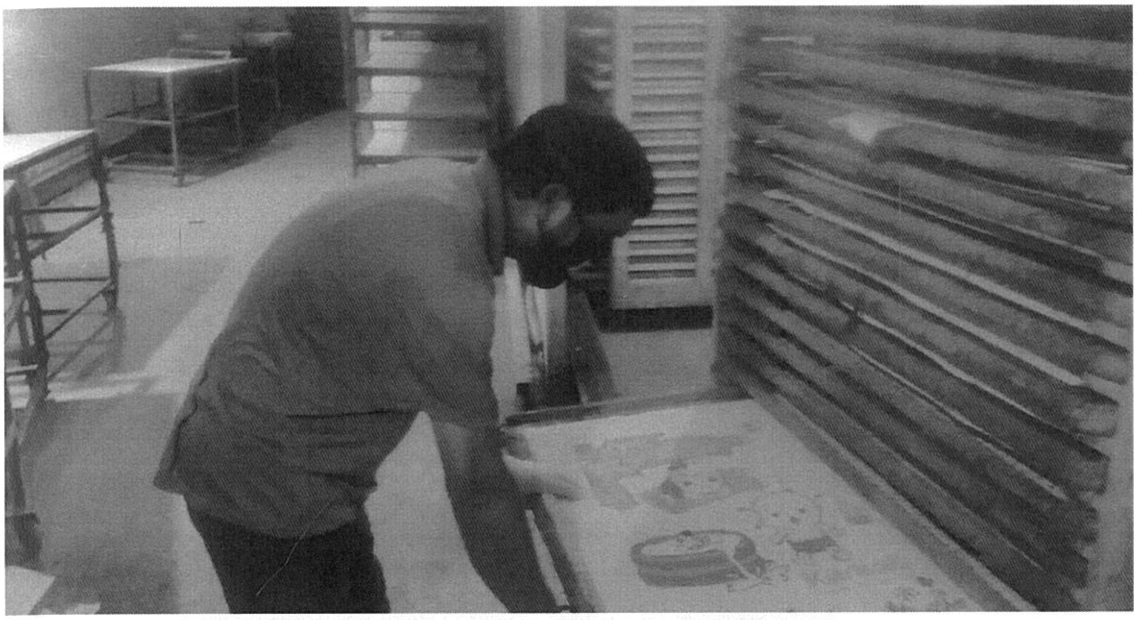

Figure 1.1 : Placing Cotsheet on a Tray and Loading into a Trolley

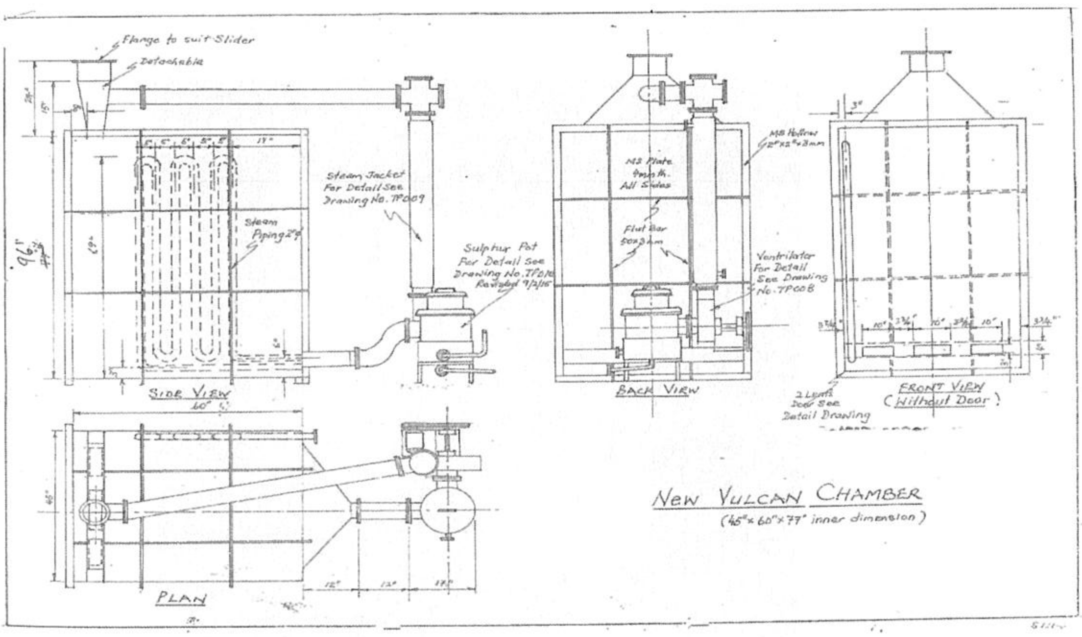

Figure 1.2 : An Engineering Drawing of a Chamber

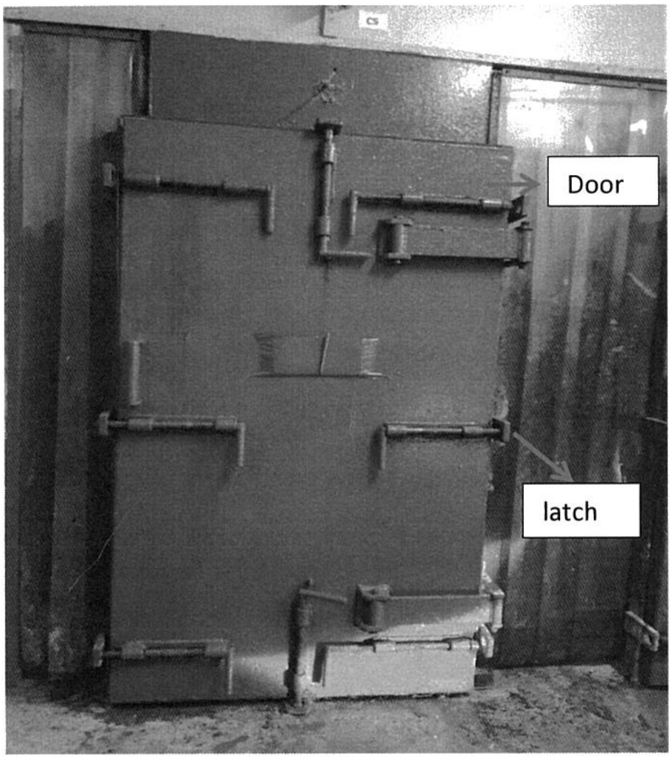

Figure 1.3 : A Front View of a Chamber

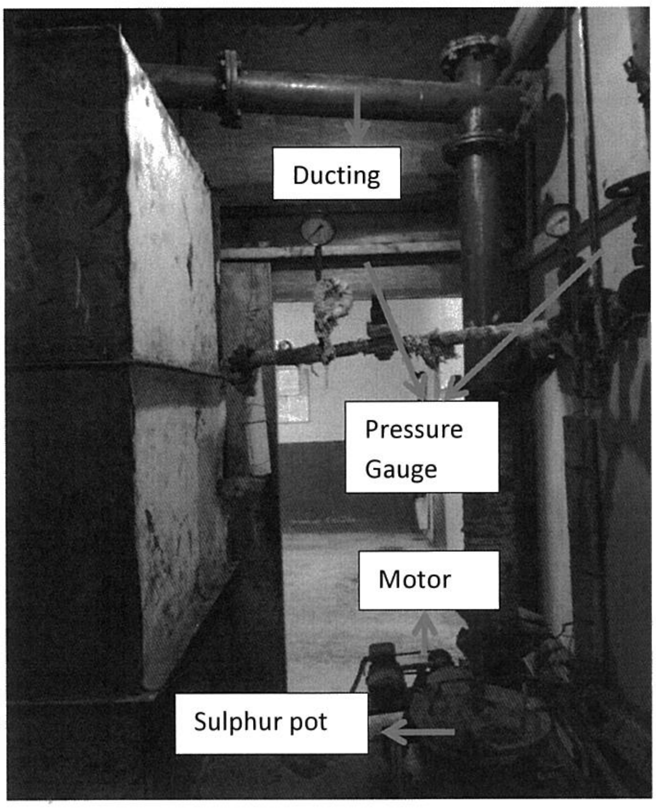

Figure 1.4 : A Rear View of a Chamber

Figure 1.5 : The Loaded Trolley Is Placed into a Chamber and Then Vulcanized

Since the embossed cotsheet "sits statically" on the tray and is not agitated during the vulcanization process, therefore it is not crumpled, so the end product has no folded marks on its surface after being cured. As a result, the cured cotsheet has better bubble appearance compared to the agitated method using rotating drums.

However, since the cotsheet is not agitated, its top and bottom surface may be not uniformly cured if the vapor sulphur monochloride is not well controlled. The cotsheet surface which is less cured will have collapsed bubble appearance. In addition, if the internal temperature of a chamber is too high during vulcanization, the bubbles will over expand and subsequently become deformed and hence collapsed after cooling down. The poor bubble appearance on the cotsheets causes product rejection and customer complaints. Please refer Figure 1.6 and Figure 1.7. Replacement on the rejected quantity incurs additional costs to the production and causes delays in the shipments whereas the customer complaints tarnish the image of the company.

Poor control of this coldcure process will also cause the tendency of the vapor sulphur monochloride inside the chamber to condensate on its surrounding, causing contamination in the form of sulphur stains on the cotsheet surface. Minor stains may be removed using water, but not the major stains which remain permanently on the product surface. The later causes the rubber products to be rejected too. Please refer Figure 1.8

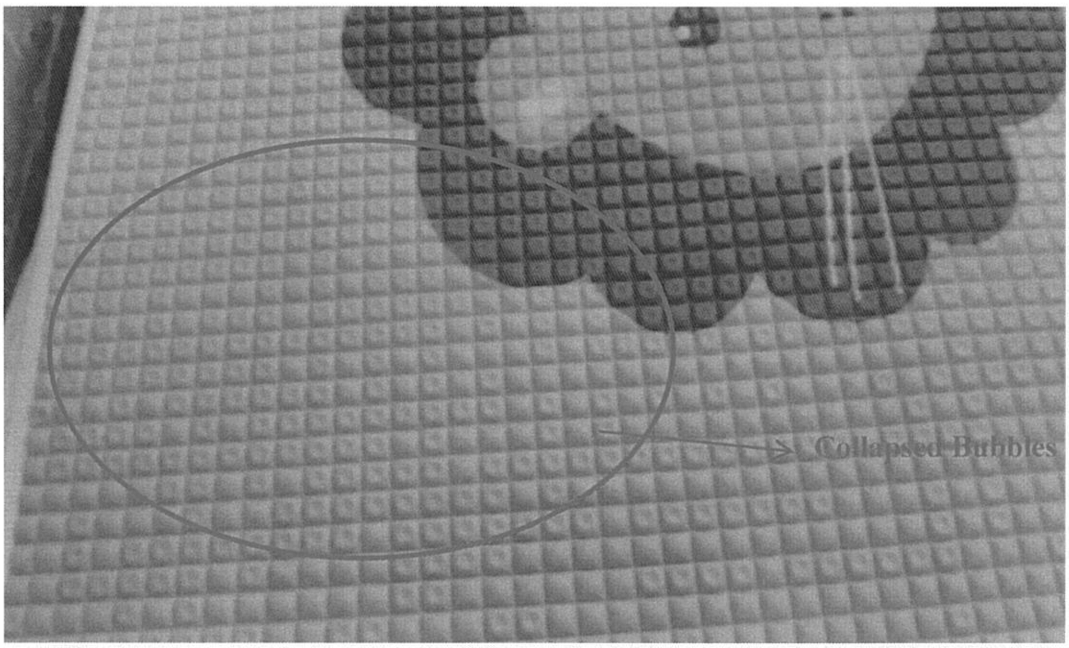

Figure 1.6 : Cotsheet with Collapsed Bubbles

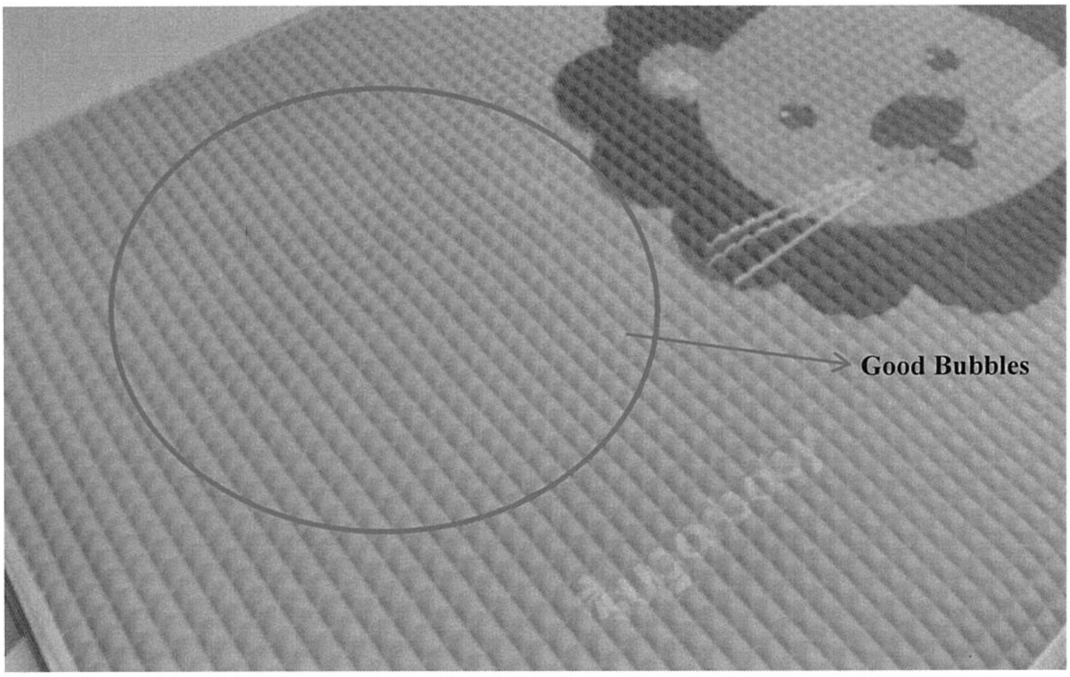

Figure 1.7 : Cotsheet with Good Bubbles

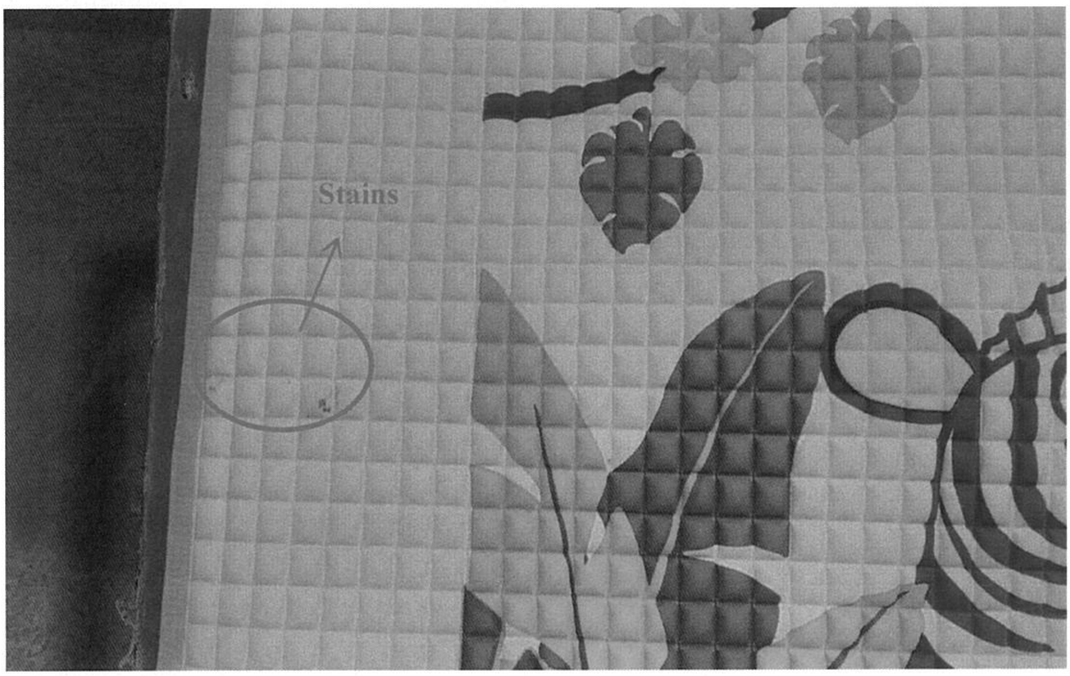

Figure1.8 : Cotsheet with Sulphur Stains

In order to reduce the rejection rate and improve customer satisfactions, these defects need to be eliminated. Various factors that can cause bubble collapse and sulphur stain issues need to be studied such as time of vulcanization, internal chamber temperature, pot temperature and amount of sulphur monochloride. Response surface methodology (RSM) is a useful multivariate statistical tool to serve this purpose. After getting optimum levels of these process parameters, only then the process can be well controlled to reduce and minimize the collapsed bubble and sulphur stain issues.

1.3 Research Objectives

The objectives of this study are:-

i. To investigate the effects of the vulcanization time, internal chamber temperature, pot temperature and amount of sulphur monochloride towards the percentage of collapsed bubbles and sulphur stains of the rubber embossed cotsheets.

ii. To propose the optimum combination of these process parameters that yield good quality of cotsheets with minimum collapsed bubbles and sulphur stains.

CHAPTER 2

LITERATURE REVIEW

2.1 Rubbers

Metador (2007) cited that rubbers are elastomers. They are polymer materials which are characterized by ability of reversible deformation under influence of external deformation forces. This property, marked as elastic, has entropy character. It rests in ability of the rubber macromolecules to occupy more ordered forms under stress, and on removal of stress to return to their ideal statistically random conformation, under ideal conditions without deformation of chemical bond distances or their angles.

The rubbers have usually long and regular macromolecule chains without large substituents, with spatially oriented structural units. Thus their segments are movable and also at low temperatures they can freely rotate around simple chemical bonds.

Presently, a lot of rubber types are on the market that can be divided into more groups in accordance with different criteria, e.g. saturated an unsaturated, natural and synthetic, polar and non-polar, crystallizing and non-crystallizing, etc. In view of their usage and basic properties, they also can be divided into:

i) Rubbers for general use – they have properties complying with requirements of more products, often also with different properties, they are relatively cheap, produced and consumed in big volume.