

# Comparative Study of Alternative Solvents for Grip Designing Process of Natural Rubber Latex Coated Glove Manufacture

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## Abstract

An investigation and comparative study of alternative less toxic organic solvents for xylene in the grip designing step of the natural rubber latex-coated glove manufacturing process was carried out. In the grip designing step, organic solvents are used to create a crinkled surface on the natural rubber latex coating on the supported glove. The toxic nature of xylene which is the solvent currently in use is the main reason for this exploration. Finding an alternative less toxic solvent instead of xylene is crucial for enhancing the health and safety of workers. Acute toxicity parameters such as lethal concentration ( $LC_{50}$ ), median lethal dose ( $LD_{50}$ ), and other evidence like exposure limit (PEL and OEL), and carcinogenicity of each selected solvent were comparatively studied. n-heptane, n-hexane, and ethyl acetate were selected as less toxic alternative solvents which can be used instead of xylene for this process. The swelling capability of each selected solvent was studied by doing swelling index tests with each maturation level of LC 601 and LC 606 natural rubber latex types. According to the results, aliphatic solvents (n-hexane and n-heptane solvents) indicated more effective responses with xylene than other selected solvents.

## Introduction

The grasping of something is one of the main purposes of a glove product. Therefore having a proper grip is very important in glove products. Especially industrial safety gloves provide good hand protection for the user in their working environment. So the grip designing step is a very important part of the natural rubber latex-coated glove manufacturing process. There are a few major grip designing techniques that are used in the modern hand protection glove manufacturing field such as smooth surface, sanded over-dip, crinkled surface, and textured surface. Making a crinkled surface on the glove coating by solvent dipping method is very

popular among them because of its economical and operational effectiveness. In this step, a volatile organic solvent that mixes with acetic acid is used to make a crinkled surface on the latex coating. Solvent swelling of natural rubber is the scientific phenomenon that has to be used for this procedure<sup>1</sup>. These crinkles make a rough surface and provide a better grip for the consumer. Industries use various kinds of organic solvents for this grip designing technique. Commonly, aromatic organic solvents like toluene and xylene are the most popular chemicals in this process (Xylene is the solvent that they use currently in the industry). But important attention should be paid to the fact that the toxicity level of aromatic organic solvents is very high. Moreover, these chemicals may have a high risk for lung cancers<sup>2</sup>. When these aromatic ring structures enter the human body cells, they are misconceived as the bases of nucleotides. It can induce DNA mutations and these mutations may eventually lead to cancer<sup>3</sup>. In the industrial environment, employees are exposed directly to these solvents during their working hours and it may directly impact their health. Therefore using these aromatic chemicals may directly impact human health. As enhancing the health protection of the employees is the main objective of this research, the exploration of the proper alternative organic solvents with low toxicity levels and comparing the solvent's behaviors with the current solvent creates a good approach to finding the best alternative solvents for this process.



Figure 1: Crinkled surface on the latex coating.

When considering the processing steps of the supported glove manufacturing process shown in figure 2 consist of three main dipping sessions. Pre-coagulant dipping is the 1<sup>st</sup> dipping session and the shell was immersed in a mixture of calcium and methanol. Then the shell was dipped into the natural rubber compound called compound dipping. Finally, the compound-coated glove was dipped into the solvent bath which consisted of a solvent and acetic acid mixture. This is the grip designing part of the supported glove.

When observing the swelling ability of organic solvents with NR latex compound, the maturation level and the maturation period are very important factors in the glove manufacturing process. After adding vulcanizing agents and other ingredients, the compounded NR latex is matured allows for maturing for a certain period (2-3 days). Before using the NR compound, the maturity level was checked. When the maturation level is increased, the swelling ability is decreased due to the increasing of the crosslinking density. Table 2 shows that the maturation levels and the features of NR coagulant. In the industry, the chloroform test that use to predict the maturation level of natural rubber latex after compounding. The levels are checked according to the elastic ability of the rubber coagulant. The maturity level indication includes 9 levels.

Table 2: Maturation levels of NR latex coagulant

| Level      | Feature of the coagulant                                            |
|------------|---------------------------------------------------------------------|
| 1. Level 2 | The coagulant is stuck in the hand and the elasticity is very high. |

|                                |                                                                                                            |
|--------------------------------|------------------------------------------------------------------------------------------------------------|
| 2. Level 3 one new             | The elasticity is not very high, the coagulant can be flatted properly.                                    |
| 3. Level 3 one                 |                                                                                                            |
| 4. Level 3 one old             |                                                                                                            |
| 5. Level 3 two new             | This level is the quality level that can be used to make glove products. The coagulant is cleaved quickly. |
| 6. Level 3 two                 |                                                                                                            |
| 7. Level 3 two old             |                                                                                                            |
| 8. Level 4 one and Level 4 two | The coagulant is not elastic furthermore. After adding chloroform, the coagulant will be crumbled.         |

The swelling capability of selected less toxic solvents was determined under different maturation levels.

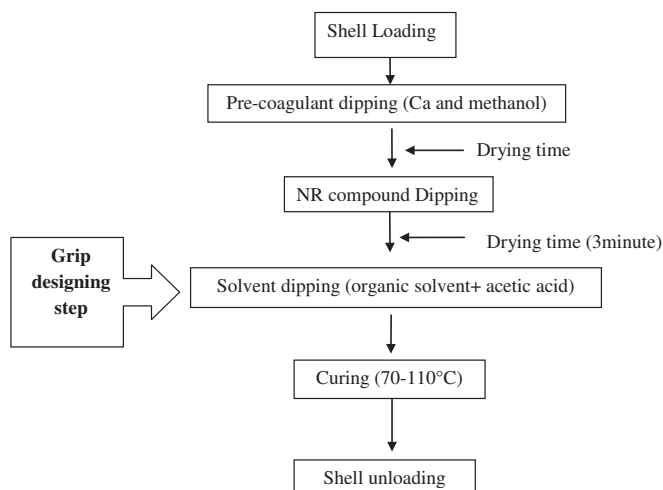


Figure 2: Processing steps of NR supported glove manufacture

## Methodology

The molecularly and thermodynamically compatible solvents with natural rubber were investigated, and secondary sources were used for this. When a solvent is selected for a relevant polymer, the chemical structure, interactional compatibility, and thermodynamical closeness are the major factors should be concerned. Natural rubber is a non-polar polymer, so it will dissolve or swell with non-polar solvents as well. Hence, it is important to study non-polar solvents that are compatible with NR. The solubility parameter models could be used for finding thermodynamically compatible solvents with NR. Finally, common and non-polar solvents which have the closest solubility parameters to NR were investigated. Then The solvents which are selected by

the above step were compared for toxicity. The acute toxicity of the solvents is the main factor in this study. Acute toxicity parameters like  $LC_{50}$  values,  $LD_{50}$  values, and other toxicity parameters such as PEL, OEL values, and carcinogenicity of the solvents were evaluated by comparing them with the current aromatic solvent

(m-xylene). Finally, the swelling capability, swelling time, and crinkle formation ability were identified by using selected less toxic solvents. According to the toxicity evaluation results, hexane, heptanes, and ethyl acetate were identified as the less toxic solvents which are suitable for the grip designing process.

## Results and Discussion

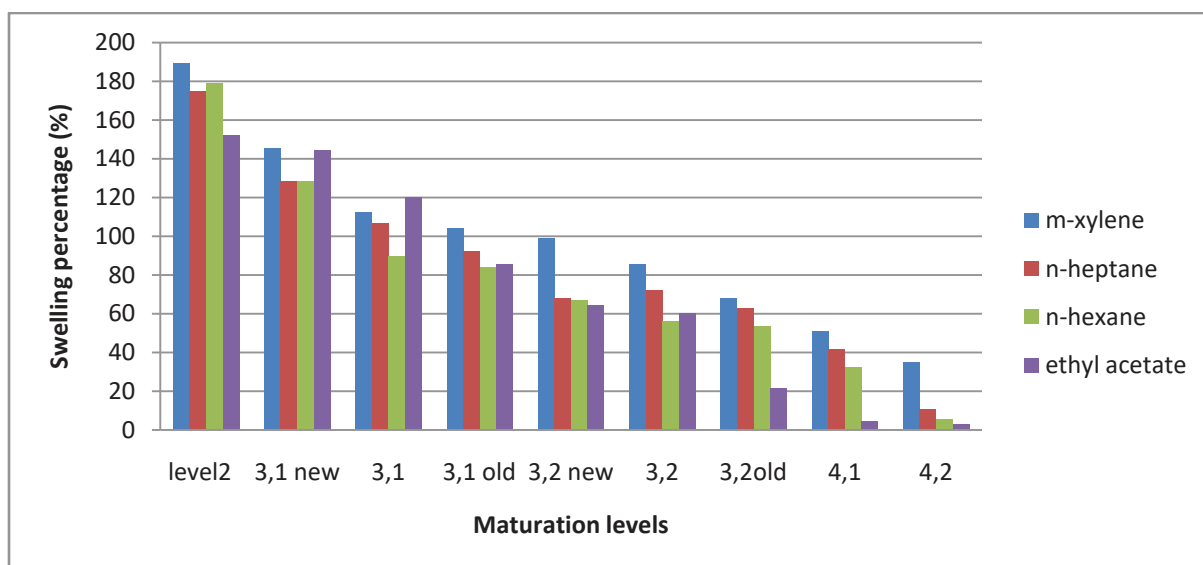
**Table 1: Toxicity evidences of selected solvents** <sup>4,5,6</sup>

| Solvent       | $LD_{50}$<br>(mg/kg) | $LC_{50}$ (ppm) 4h<br>(Rat) | PEL for 8<br>hours work shift<br>(ppm) | OEL for 8<br>hours work shift<br>(ppm) |
|---------------|----------------------|-----------------------------|----------------------------------------|----------------------------------------|
| Xylene        | 3523- 8000           | 6700                        | 100                                    | 50                                     |
| Hexane        | 25000                | 73500                       | 500                                    | 20                                     |
| Cyclohexane   | >5000                | >32.88                      | 300                                    | 200                                    |
| Heptane       | >5000                | 17937                       | 500                                    | 500                                    |
| pantane       | >25.3                | 3000                        | 200                                    | 1000                                   |
| Ethyl Acetate | 5620                 | 22,627                      | 400                                    | 200                                    |

Table 1 shows the values of toxicity parameters of selected non-polar solvents.  $LD_{50}$ ,  $LC_{50}$ , PEL, and OEL (permissible and occupational exposure limit values) were considered in this part. According to the above values hexane, heptanes, and ethyl acetate shows an effective toxicity level than other selected solvent and current industrial solvent. Therefore, these three solvents were used for further experiments in the research.

The swelling capability of each selected solvent was determined under the different maturation levels.

The swelling ability of each solvent was decreased with increasing the maturation levels. The cross-linking density is increased with maturation time, so the polymer chains become very short, and swelling decreases. This phenomenon is represented in Figures 3 and Figures 4. According to the graph, n-hexane and n-heptane solvents showed a similar swelling pattern to m-xylene (current solvent). The variation of the swelling pattern in both of the aliphatic hydrocarbons was similar. However, the swelling capability of xylene is not lower than other selected solvents. The main reasons for that



**Figure 3:**The swelling percentages of each solvent against the maturation levels of LC601

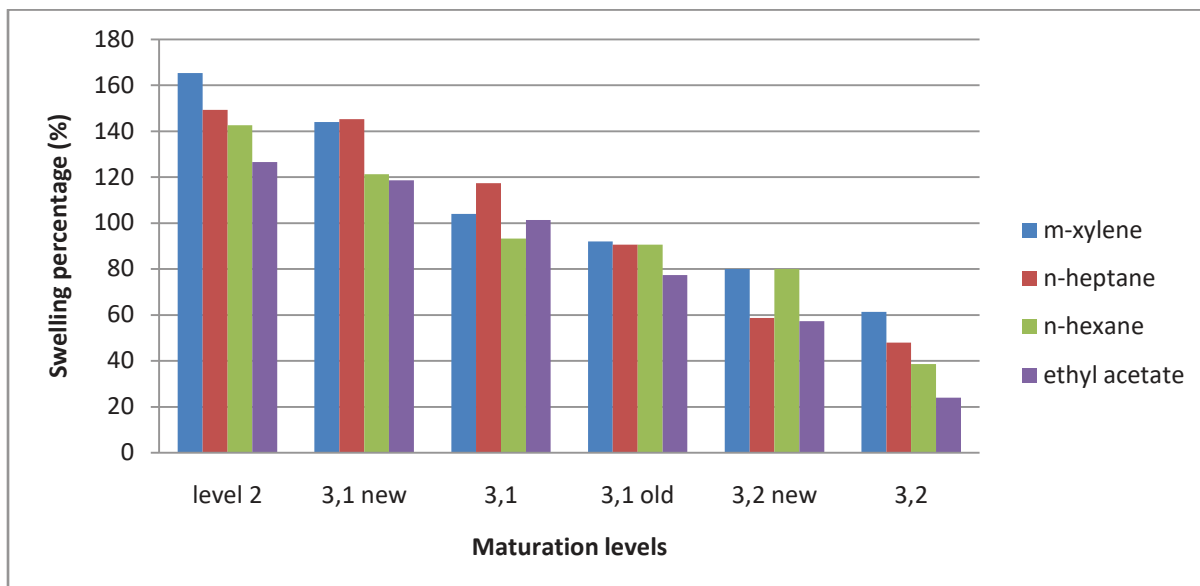


Figure 4: The swelling percentages of each solvent against the maturation levels of LC606

can be identified as the high non-polarity behavior and the compatibility of solubility parameters.

## Conclusion

The main target of this study was to find an alternative organic solvent/solvent for xylene in the grip designing process of NR latex-coated glove manufacturing. The main reason for this investigation was the toxic nature of xylene and other aromatic solvents. After analyzing the toxicity of selected solvents and comparing it with xylene, three main organic solvents were identified for the laboratory experiments.

According to the swelling capability results, aliphatic hydrocarbons like n-hexane and n-heptane solvents showed positive results with the current solvent m-xylene. However, the swelling percentage variation results of aliphatic hydrocarbons have not exceeded the results of m-xylene. Finally, it can be concluded that the application of the aliphatic hydrocarbons (hexane and heptane) as an alternative for the grip designing step is effective to some extent level.

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