POLYURETHANE FOAM WITH HIGH SUPPORT FACTOR AND AIRFLOW

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ABSTRACT

Latex foams are perceived as a “premium” foam product for mattresses toppers and pillows but at the same time, the labor and energy intensive including several production steps process requiring moulds, freezing, vulcanizing, washing to remove additives and then drying besides to be presented generally higher density and cost than PU.

This project defines the main global performance requirements for latex-like or PU-latex foams in terms of density, hardness, durability, support factor, touch etc.

The latex-like system formulation developed by DOW, meets customer requirements and uses polyols and additives commercially available and has presented properties very similar to latex foam.

INTRODUCTION

The market of specialty foams is growing in LAA, especially in Brazil where the demand for products with better quality and improved properties has increased due to the current good Brazilian social classes improvements.

People are looking for products which present better performance and reasonable costs. Thus, DOW Polyurethane R&D in Brazil, took a challenge of developing a PU foam with similar properties to latex foam which is perceived as a “premium” foam product for mattresses toppers and pillows, on the other hand, this kind of foam requires a lot of labor and energy, including 9 step production process requiring moulds, freezing at -30 °C, vulcanizing at 115 °C, washing to remove additives and then drying besides to present higher density and cost than PU.

This study was undertaken to evaluate competitive polyols and isocyanates via performance testing in order to develop a system or formulation that could be presented as an alternative to latex foam and offer a new concept of polyurethane as well. PU foam with improved or similar properties to latex foam can generate a new demand and create a new option for the high-end products in the market.
BRAZILIAN MARKET

The demand for specialty foams in whole LAA is growing but it is more evident in Brazil due to the good economic moment that this country is going through. People are looking for products that can show better performance can provide welfare and better health.

Figure 1 shows the social class growth over the years in Brazil. As you can see, the classes “D” and “E” have been decreased in the last 5-6 years while the class “C” is increasing. Even the classes “A” and “B” have demonstrated a small growth.

![Social Classes evolution (Brazil)](image1)

**Figure 1 Social class evolution in Brazil over the years**

LATEX FOAM – properties and performance

Latex foam requires more energy to produce it and an expensive process. There are 3 types of latex, natural, synthetic and blend.

- Natural latex
- Synthetic latex
- Latex Blends

The two best known processes are Dunlop and Talalay.

**Dunlop**

Dunlop patented the first continuous foaming process. Compounded latex and air were metered into the base of a long vertical chamber and beaten to foam. The foam flowed continuously from the chamber down a chute into a second chamber, also provided with a beater, where the zinc oxide and gelling agent dispersions were metered.
in as the foam passed down to an aperture in the base. It takes only a few seconds to mix and to pass the two stages. The materials to be mixed are proportioned in a continuous stream through the head, and in consequence every region of the mixture is processed to the same extent. In this case the materials being mixed are latex and air, and the result is fine-celled foam of uniform texture.

It is claimed that natural rubber latex foams of specific gravity as low as 0.06 can be produced with this mixing head. The foam density is varied and controlled by means of the ratio of air to the latex which is fed to the machine. The throughput of latex is controlled by means of a latex pump and an air regulator.

Typical specifications for natural rubber latex concentrates are available. The initial ammonia content must be higher for the batch wise processes than when foaming is continuous. This is because a certain amount of ammonia is lost during the stage of prolonged beating and exposure to the atmosphere.

Talalay[3]

The Talalay process requires an intensive six-step manufacturing process:
1. Compounding. Liquid latex, soaps and special curing agents are mixed in a stainless steel temperature-controlled tank.
2. Molding. The compound resulting from the above mixing process is whipped into a froth and injected into an aluminum pin core mold, which creates Latex International Talalay latex’s unique aerated cell structure. After the mold is sealed, a vacuum is exerted to extract air and to fill the mold perfectly with foam. It is then chilled to -20°F which ensures a consistent cell structure by preventing particles from settling. Introduction of carbon dioxide then gels the foam. Next, the foam is cured by heating to 220°F.
3. Washing. After removal from the mold, the latex foam core is transported through a five stage fresh-water washer which removes both residual soaps and curing agents.
4. Drying. The latex then is conveyed through a two-lane dryer who removes residual moisture while completing the curing process.
5. Quality Testing. Every mattress then undergoes Latex International’s stringent nine-point firmness consistency test to ensure conformity to rigid quality standards.
6. Fabrication. The foam is then custom cut to product specifications.

General info about latex foam:

Latex foams are sold based on “firmness” with density varying
- Extra-firm (44ILD), firm (37ILD), medium (31ILD), soft (25ILD)
- Natural latex foams are typically more dense and therefore harder than synthetic foams at identical densities
- Density and hardness are controlled by the amount of latex added to the foam
- Hardness can also be controlled by holes designed into the foam core

LITERATURE REVIEW and RAW MATERIALS.

There are lots of literature[4][5][6][7][8][9] regarding polyurethane for latex-like foams. However, almost all of the articles and studies present work with high molecular weight Polyols, showing that the researches were focused in polyol part. There are few works talking about isocyanate side with limited tests and data.

Our approach was to make researches with the aim of finding technology that could cover properties as high support factor, silky touch, and high air flow. Research tools as Scifinder, micropatent and RIC were used to find this information and to avoid enter in technologies or products already patented.

Our hypotheses was the same at the most literature, in other words, a long chain polyol could be the way to reach a PU foam with typical latex characteristics but for the isocyanate side was not clear what kind of product could be used.

A customer request brought the opportunity to work with MDI since it usually produce molded pillow and prefer to handle products less dangerous than TDI. The literature had few woks about isocyanate but we had a pre-
polymer, in DOW portfolio, which shows very good results in molded foams. The figure 2 below shows us some alternatives in terms of raw material.

![Figure 2- Polyol and Isocyanates caracteristicas](image)

**Formulations and Comparison Tests.**

A series of formulations were tested ranging polyols, additives (silicons and amines) as well as isocyanates. Formulations were combined in different types of polyols and isocyanates in order to achieve the properties of latex foam.

The main features we wanted to achieve were airflow and comfort factor, and the ideal values would be greater than 3.5 CFM for the airflow and around 4 for comfort factor. Another parameter was the foam touch which should have a velvety feel like silk.

Different versions have been developed being one for molded foams, other for slabstok and a high density version with anti-flame additive.

**Comparisons**

We have compared our formulations against latex foam samples and latex-like from Brazilian market. The samples were bought in specialized shops or obtained through customers whom import it from Europe or China.

Although latex foams are rather difficult to handle and cutting to test, we consider the results very reliable.

Below you can find the tables with data and comparison graphs including the main properties proposed and some properties to help us to understand advantages and disadvantages among the samples. The tests were made according to Brazilian norm NBR and can be seen in the table 1.

**Table 1 – physical properties**
The foams are identified as:
• Latex (D60) – latex foam samples with nominal density 60 Kg/m³ from market;
• DOW System (D60) – Polyurethane foam samples with nominal density 60 Kg/m³;
• Latex (pillow) – Latex foam samples with nominal density 36 Kg/m³ from market;
• Market sample (pillow) – Polyurethane foam samples with nominal density 38 Kg/m³ from market;
• DOW System (pillow) - Polyurethane foam samples with nominal density 36 Kg/m³;
• DOW System (D45) - Polyurethane foam samples with nominal density 45 Kg/m³;

All the tests were performed in triplicate to be evaluated with the statistical electronic tool JMP Pro 9.0.1. The methods used to measure the properties showed in this report was the Brazilian ABNT (technical norms Brazilian association).

The third Latex (D60) sample was disregarded due to problems during the tests. We could not find latex samples and latex–like samples with density 45 kg/m³ to perform tests, thus, we have no data to compare with DOW System (D45).

It was not possible measuring the airflow property from Latex (pillow) samples with the same equipment (see attachments) used to the others kinds of foam due to be very difficult to cut small specimen. Other problem to measure airflow for latex samples (pillow) was the high airflow values for this kind foam, especially when these foams are with low density, which is the case for the pillows samples gathered.

**AIRFLOW**

Airflow is a very important property in polyurethane foam, it is expected this property influences directly on the foam properties as hardness, for instance. Generally, the more opened the cell is, softer the foam is. Therefore, the open cells can influence also the support factor, since it is a relation between hardness values.
This property can be correlated to the foam “breathability” giving to the foam a fresh or cold sensation. The figures 3, 4 and 5 show us the comparison among the foams in the table 1 above. The comparisons were among the same kinds of foam in terms of density.

![Figure 3 - Air flow comparison / all samples](image1)

![Figure 4 - Air flow comparison / foams density 60 Kg/m³](image2)
According to the comparison above, DOW system (D60) is higher than Latex foam, Figure 3. It was expected that latex foams had a higher airflow but, probably, due to the high density, the results have not confirmed this expectation. In terms of polyurethane, the airflow is regarded high, especially for foams with density 60kg/m³.

As commented before, we could not measure this property for latex pillow samples however, the values presented by both samples of polyurethane are very good as expected to these densities.

These airflow values presented are very important because they also influence the indentation force deflection, thus, influencing support factor too.

**SUPPORT FACTOR**

The Support Factor is the ratio of 65% IFD to 25% IFD. This number gives an indication of cushioning quality. Higher support factors indicate better cushioning quality. This quantity is also known as the sag factor or as the modulus.

The indentation force deflection test (IFD) is a measurement of the load bearing properties of foam. In this test the force required to depress a circular plate into the foam is measured (Figure 6.4).

The figures 6, 7 and 8 show the comparison among the samples according to its densities and kind of foam.
Figure 6 - Support factor comparison / all samples

Figure 7- Support factor comparison / foams density 60 Kg/m³
The figures above show that latex foams are, generally, better than the polyurethane foams as expected. On the other hand, if we compare the DOW system (D45) with the latex (D60) we can say that they are statistically equals (Figure 6).

Unfortunately, we could not get a latex sample with density 45 which, normally, is used to comfort layer that is the application for what the DOW system (D45) was developed but, we know the hardness in latex foams are regulated according to the foam density (the higher is the density/ higher is the hardness) and, although, a latex foam with density 45 would have a very good support factor, it would be very soft also, jeopardizing other properties as tear and elongations that are already problematic for this kind of foams.

**COMPRESSION SET**

In the constant deflection compression set test (commonly called compression set), three carefully measured samples of the foam are placed between metal plates (figure 6.9) and compressed to 50 or 90% of the sample’s original thickness. The samples are held at 70°C for 22 hours, removed from the plates, allowed to recover for 30 minutes, and measured again. Samples for this test are normally oriented so that compression set is measured in the direction of blow.

Compression set values are correlated with the in-service loss of cushion thickness and changes in foam hardness, this way, directly correlated to foam durability.

Figures 9, 10 and 11 show the comparison among the samples.
Figure 9 - Compression set comparison / all samples

Figure 10 - Compression set comparison / foams density 60 Kg/m³
For compression set property, the lower is the result the better it is. Density influences significantly and the results for each sample are a mean of 3 specimens of each foam sample.

The figures above show that the Latex (D60) shows results worst than to DOW system (D60). For pillows, it is clear that DOW system is better than Latex pillow and much better than the market pillow although all the samples are under 10% what is regarded a good result especially for these densities.

Other important property for high-end foams is the touch that the foam provides. We do not use any kind of assessment or test to evaluate this property but it is known that the latex foams are considered as having an excellent touch for human skin and, although, the polyurethane foams are also recognized by having a nice and pleasure touching, we considered that, for this property, the latex foams are the best.

In order to compare all the properties and better understand the advantages and disadvantages among the foams, The properties were ranked from 0 to 10, where zero was the worst result for that property and 10 was the best performance for the property and this ranking was compared it in a radar chart in the figures 12 for molded (pillows) and figure 13 for foams with density D60. Historically, latex foams have a cost greater than polyurethane foams and only as a comparison effect it was included foams costs in the radar chart.
System profile

Before producing the product at industrial scale, the product tested and its profile is determined in terms of pressure and hardness. This test is called “Cake Mold” and it is made with lab samples and replicated several times to reduce errors. Only after these parameters have been established, the product goes to the first production.

The red line in the figure 14 shows the product pressure profile average from an experimental batch produced at DOW facilities in Jundiaí- SP and it indicates that the system is performing well showing that the product is consistent at industrial scale too. The dashed lines are the superior and inferior limits and the other color lines profile are the samples took from the experimental batch and used to calculate the average.
CONCLUSION

Regarding the data presented in this report, we can affirm that the polyurethane foam developed can be used as high-end foam and compared to latex foams. Its “breathability”, demonstrated by the airflow values, is high and, in some cases, better than latex foams what gives to the foam a cold sensation. Support factor results have shown that latex are very good, however, PU foams have presented high levels of this properties, especially the DOW system developed.

With respect to the foam durability, compression set tests is much correlated to the in-service cushioning loss. In this property, PU foams were better than latex foam samples tested and the system developed by DOW has presented very good results when compared to the market PU foams in Brazil.

Although foams latex are recognized as a premium foams, in terms of formulation adjustment, its latitude of working is very narrowed being restrict to the foam density. On the other hand, PU foams have a large range of adjustments that can improve foam properties significantly.

Overall, I believe that the DOW systems presented in this work could be set among the most comfortable foams in the market of bedding and furniture.

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BIOGRAPHIES

Rogério Baixo joined Dow Brazil in Guarujá - SP, in 1990. He has received his B.S. Information technology at Santa Cecilia College (Santos-SP) and his Master’s degree in Inorganic Chemistry at Federal University of São Carlos (UFSCar) in São Carlos-SP. He joined Dow’s at polyol plant production where performed several roles. In 2003 he went to R&D department focusing on process research and support for oil&Gas. In 2009 he was transferred to the Polyurethanes Group and has held various roles in R&D/Ts&D with emphasis on flexible and semi-flexible foams.