Journal of Engineering and Applied Sciences 12 (21): 5560-5565, 2017
ISSN: 1816-949X

Novel Natural Rubber Latex Memory Foam

R. Roslim, M.R. Fatimah Rubaizah, K. Shamsul, K.L. Mok and M.Y. Amir Hashim
Technology and Engineering Division, Malaysian Rubber Board, Sg. Buloh, Selangor, Malaysia

Abstract: A novel firm and dense yet soft natural rubber latex foam memory foam with delayed-recovery and low-bounce properties has been successfully developed. The developed natural rubber latex memory foam exhibits comparable physical properties as the standard natural rubber latex foam. The foam was observed able to retain an imprint for approximately 5-6 sec when pressed. The degree of bounce from a silica ball after it was dropped onto the foam surface was found to be visibly lower than that from the standard natural rubber latex foam. This shows the developed foam has a low upward pressure as well as able to absorb downward forces. The foam was also able to support a 250 mL filled bottle firmly, indicating its high strength property. The static and dynamic damping test confirms that the foam could absorb and distribute the weight force energy better than standard natural rubber latex foam. A combination of firm, dense yet soft, delayed-recovery, low-bounce and supportive properties is important to provide an all-inclusive bedding system that can contour the body to help relieve pressure from stress points at our body towards a comfortable overnight sleep, aligned posture and improved health.

Key words: Natural rubber latex memory foam, mattress, delayed-recovery, low-bounce, pressure-relief, posture

INTRODUCTION

Sleeping on a mattress that does not properly support the spine and joints at the correct positions during overnight sleep may contribute significantly to poor sleep quality and restlessness (Jacobson *et al*., 2002, 2010; Bader and Engdal, 2000). Thus, developing mattresses which can provide better overnight sleep is an on-going challenge. One such development is the pressure-relief foam mattress known as 'memory foam'. The uniqueness of memory foam mattress relies on its ability to slowly recover (delayed-recovery) from body impression (the sense of 'remembering' body shape). This specific property has been medically tested able to conform to the shape of our body and provide crucial support to the spine's natural curves as well as responding to body weight pressure to provide even weight distribution and extra comfort (Lee and Park, 2006; Buckle and Fernandes, 1998). This reduces the stress and fatigue on our body hence prevents back pain and pressure ulcers (Jacobson *et al*., 2002, 2010; Joyce, 2012; Higer and James, 2016). Another study also shows that memory foam mattress demonstrates strong correlation with improvement in blood pressure and blood flow in our brain (Haesler, 2014).

Ordinary memory foam is made from polyurethanes, containing additional compound which gives the soft and delayed-recovery properties and thus polyurethane memory foam is more expensive than regular polyurethane foam. Addition of this compound also introduces a heat reactive/sensitive property (PFA, 2016; Suleman *et al*., 2014). Thereby, the heat from our body allows the foam to compress and contour according to the shape of our body. However, there is negative impact of this heat reactive property. The poor airflow in the polyurethane memory foam causes the body to become hotter, resulting in sweating and eventually uncomfortable sleep (Mills and Lyn, 2002). Besides this, the mattress also become harder in cooler temperatures and softer in warmer temperatures (Takayuki and Daisuke, 2011).

Another disadvantage of polyurethane memory foam is the 'unsupportive and sinking issues' (Szabolcs, 2015). Polyurethane memory foam is conventionally a very light and soft material hence it gives poor supportive property (Lim *et al*., 2008). When the body generates heat during overnight sleep, the foam becomes softer; as the warmth increases, the body sinks deeper into the mattress. This drawback is crucial for those with heavier body weight. People with heavier weight feel uncomfortable when they sleep on the polyurethane memory foam because their body will sink too far into the mattress. Furthermore, the polyurethane memory foam will take longer time to recover to its original shape, leaving a sensation akin to sinking into a quicksand or 'stuck' in the mattress.

Comfortable mattress which provides reduced pressure at stress points on the body is known to correlate with sleep quality and overall health (Alzoubi *et al*., 2011; Hanel *et al*., 1997; Arand, 2006).

Corresponding Author: R. Roslim, Technology and Engineering Division, Malaysian Rubber Board, Sg. Buloh, Selangor, Malaysia

Currently, available pressure-relief foam mattresses are made from petrochemical based materials such polyurethanes or blends. With the arising concerns and regulatory controls on health and environmental issues, there is necessity to develop an alternative pressure-relief foam mattress from natural and sustainable materials. This research developed a new generation of pressure-relief foam mattress from natural rubber latex. The natural rubber latex memory foam offers a better and improved quality of pressure-relief foam mattress with additional 'green image'.

MATERIALS AND METHODS

Materials and processes: Natural rubber latex was purchased from Getahindus (M) Sdn. Bhd. All chemicals used in this research are commercially available and purchased from LabChem Sdn. Bhd. Novel compounding formulations and techniques have been developed in this research. The formulations and techniques are currently protected under patent application No. PI2012004904 (Roslim and Hashim, 2012). The manufacturing processes are similar to conventional Dunlop process which involves compounding, frothing, molding, vulcanizing, washing and drying (Blackley, 1997).

Physical properties measurement: Determination of the physical properties of the natural latex memory foam was performed in accordance to the Malaysian Standards (MS) 679:2011 (MS, 2011).

Delayed-recovery property: The delayed-recovery property was observed by pressing the latex foam for 30 sec. Time taken by the latex foam to fully recover to its original shape was recorded.

Supportive property test: A 250 mL bottle filled with natural rubber latex was placed at the corner edge of the latex foam. Ability of the latex foam to support the bottle without tilting was observed. Comparison was made to standard natural rubber latex foam and polyurethane memory foam.

Rebound-resilience measurement: The rebound-resilience property was observed by dropping a silica ball onto the surface of the latex foam. The extent of the silica ball to re-bounce was measured. Comparison was made to standard natural rubber latex foam and polyurethane memory foam.

Static and dynamic damping evaluation: Two aluminium plates were designed and fabricated as a tool to perform the mechanical test at our engineering laboratory. Static and dynamic tests were undertaken on a servo hydraulic MTS Multi Axis testing machine. Multi-Purpose Template (MPT) was used to program all the testing parameters. In the static test, test specimen of latex foam was placed in between two aluminium plates, followed by 5 consecutive cyclic compression in displacement to 50% of strain. The static compression test was carried out at frequency of 0.2 Hz. In the dynamic test, the test parameters used is as mentioned in Table 1.

Table 1: Dynamic testing conditions for the latex foam

	Dynamic test	
Frequency (Hz)	Strain amplitude (%)	No. of cycle
0.2	5	5
0.5	-	10
1.0	-	20
10	-	50

RESULTS AND DISCUSSION

Table 2 shows the physical properties of the natural rubber latex memory foam which fulfill all the standard requirements for mattress stipulated in the Malaysian Standard MS 679:2011. This demonstrates that the natural rubber latex memory foam successfully attains physical properties which are comparable to the standard natural rubber latex foam. In this research, density of the natural rubber latex memory foam was made to 0.2 g/cm^3 in order to give firm and dense properties. This was done by controlling volume expansion of the latex foam during frothing. The idea of having a firm and dense latex foam for natural rubber latex memory foam mattress is derived from the fact that higher density mattress has better quality and provides extra support to the body (Alzoubi *et al*., 2011; Blackley, 1997). On the other hand, there is demand for denser foam mattress due to the tendency of the polyurethane memory foam mattress to be "slippery" during overnight sleep because polyurethane memory foam is a very light material (Takayuki and Daisuke, 2011; Szabolcs, 2015). Firmer natural rubber latex memory foam mattress also gives better supportive quality to heavier weight users.

Despite achieving the important physical properties requirements, developing natural rubber latex foam with delayed-recovery property is crucial in this research. Figure 1 shows the delayed-recovery property of the natural rubber latex memory foam. The foam was observed to retain the imprint for approximately 5-6 sec when pressed. This suggests ability of the natural rubber latex memory foam to conform to the body contour, thus offers proper spine and joints support, prevents back pains and helps to relieve pressure at stress points of our body

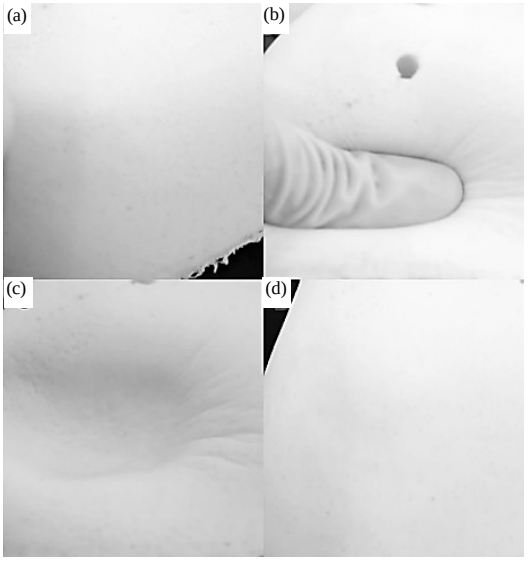

Fig. 1: The delayed-recovery property: a) Before compress; b) Compress; c) Release and d) Recovery

Table 2: Properties of the developed pressure-relief natural rubber latex foam

Properties	MS679	*STD foam	*NRMF foam
Compression set (%)	6 (max)	2.03	2.00
Pounding			
Change in thickness (%)	5 (max)	1.58	2.03
Change in hardness (%)	20 (max)	9.89	11.13
Indention hardness (N)	100<(Soft) 101-170 (middle firm) >170 (firm)	285.74	280.78
Elongation at break (%)	Min 150	225.00	254.00
Accelerated aging (%)	±20	7.62	11.17
Density (g/cm^3)	-	0.20	0.20

*STD foam = Standard natural rubber latex foam; *NRMF foam = Natural Rubber latex memory foam

similar to the polyurethane memory foam (Bader and Engdal, 2000; Buckle and Fernandes, 1998). The rate of "delayed-recovery" was also much faster than the polyurethane memory foam whereby this would not leave sink area on the mattress.

Combination of firm, dense and delayed-recovery properties of the natural rubber latex memory foam is important to allow the latex foam mattress to contour accordingly to the shape of the body as well as firm enough to facilitate proper support to the body during overnight sleep, especially for those with heavier weight. Therefore, the natural rubber latex memory foam not only offers comparable pressure-relief features but also addresses the "unsupportive and sinking" issues associated with polyurethane memory foam.

A mattress that has too strong support and firm will not tolerate to the natural curves of our spine. The body will simply sit on top of the mattress. In contrast, a mattress that has too light support will allow our body to sink too far into the mattress (Takayuki and Daisuke, 2011). Ability of the natural rubber latex memory foam to conform and to distribute evenly the body weight pressure as well as to provide enough support to the body during sleep was further investigated. Figure 2 demonstrates a comparison on the supportive property between standard natural rubber latex foam, polyurethane memory foam and the natural rubber latex memory foam. A 250 mL bottle filled with natural rubber latex was placed at the corner edge of the foam. It is clear that the polyurethane memory foam was too soft and thus not able to uphold the bottle. The bottle tends to fall after few seconds. On the other hand, standard natural rubber latex foam and the natural rubber latex memory foam were strong enough to support the bottle without tilting. The greater supportive property of the natural rubber latex memory foam compared to polyurethane memory foam is due to its intrinsic elastic property of the natural rubber latex. This plays an important role in the supporting and cushioning effects of foam mattresses towards comfortable overnight sleep.

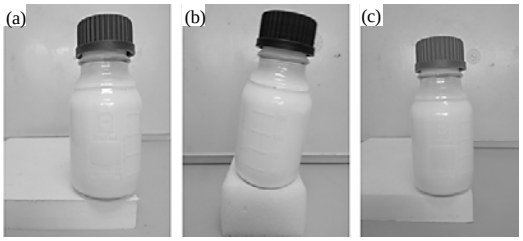

Fig. 2: The supportive property: a) Standard natural rubber latex foam; b) Polyurethane memory foam and c) Natural rubber latex memory foam

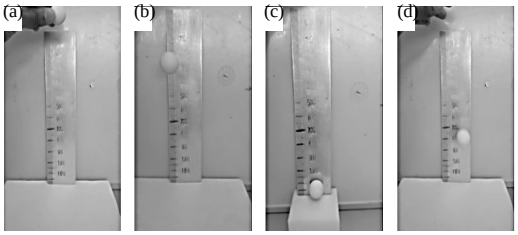

Fig. 3: The silica ball rebound test: a) Initial height; b) Standard natural rubber latex foam; c) Polyurethane memory foam and d) Natural rubber latex memory foam

Figure 3 shows the degree of bounce from a silica ball after it was dropped onto the surface of the natural rubber latex memory foam where the rebound was much lower compared to standard natural rubber

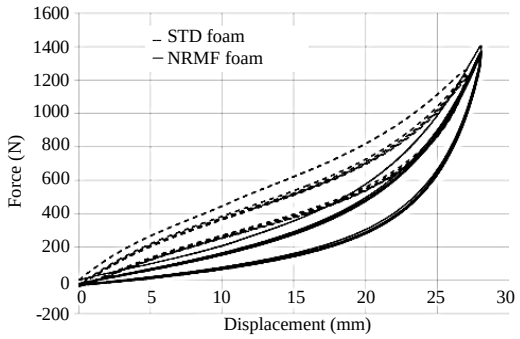

Fig. 4: Hysteresis curves of natural rubber latex foam at 50% strain: Dashed line = Standard natural rubber latex foam; Solid line = Natural rubber latex memory foam

latex foam. In contrast, there was no rebound at all for the polyurethane memory foam. From this experiment, it confirms that the standard natural rubber latex foam is a very elastic material. Thus, it was able to bounce back the silica ball into the air with the same force that the silica weight was applied onto the foam earlier (Zhang and Dupuis, 2011). In comparison, polyurethane memory foam is a soft material thus it can absorb downward forces easily nevertheless, it has very little upward pressure to bounce back the silica ball up into the air. On the other hand, due to its delayed-recovery property, the natural rubber latex memory foam has lower upward pressure and softer surface compared to standard natural rubber latex foam. Therefore, it could absorb downward forces of the falling silica ball, resulting in lower degree of bounce.

The ability of natural rubber latex memory foam to absorb energy and/or relief pressure was further investigated through static and dynamic damping measurements. Under static situation, latex foam exhibits hysteresis behavior (Zhang and Dupuis, 2011; Kim *et al*., 2014). The significant of hysteresis study is that it gives a strong indicator on the capability of latex foam to absorb energy (Zhang and Dupuis, 2011). In Fig. 4, the dashed line represents standard natural rubber latex foam whilst the solid line represents natural rubber latex memory foam. The area under the upper curve is the total mechanical energy imputed. The area under the bottom curve is the return of stored energy and the area between the two curves is the energy loss or dissipated and converted to heat. Figure 4 confirms that both standard natural rubber latex foam and natural rubber latex memory foam demonstrated a viscoelastic behavior. The hysteresis curve shows that the response displacement of natural rubber latex memory foam undergoing compressive loading was much higher than standard natural rubber latex foam. Further at 50 % strain, natural

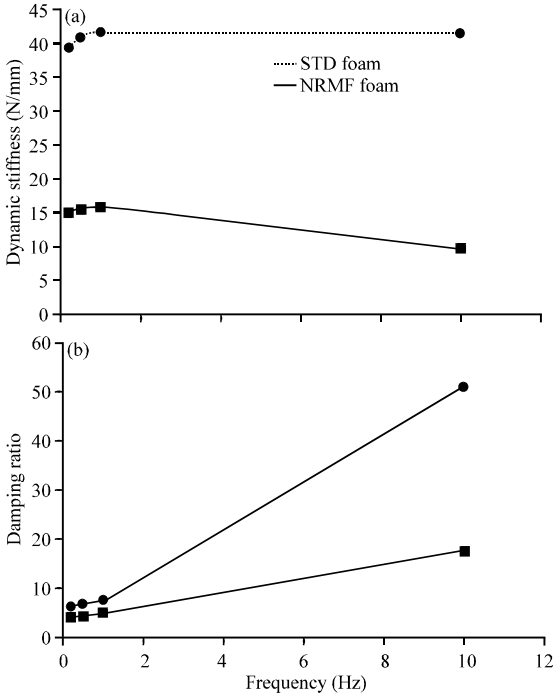

Fig. 5: Dynamic damping at 5% strain: a, b) Dashed line = Standard natural rubber latex foam; Solid line = Natural rubber latex memory foam

rubber latex memory foam demonstrated a softer property, indicating its ability to absorb downward force energy was much better than standard natural rubber latex foam.

In the case of dynamic damping, there was no significant changes on dynamic stiffness of standard natural rubber latex foam with increasing vibration amplitudes. However, for natural rubber latex memory foam when the vibration amplitude was increased, the dynamic stiffness decreased (Fig. 5). These results relate to the comfort of foam mattress during use. Further, the degree of vibration transmitted through the latex foam is associated with the motion isolation of foam mattress. Motion isolation property is important to ensure that sleeping partners will not be disturbed by movement of the other person or when one needs to get up off the bed in middle of the night. The dynamic test results obtained in this study can also be likened to the dynamic movement of vehicle in which the natural rubber latex memory foam produced in this research can potentially reduce vibration from being transmitted from the ground to the driver, hence helping to reduce the vehicle related whole-body vibration adverse effects. Potential application of the natural rubber latex memory foam for automobile seating remains to be investigated in future.

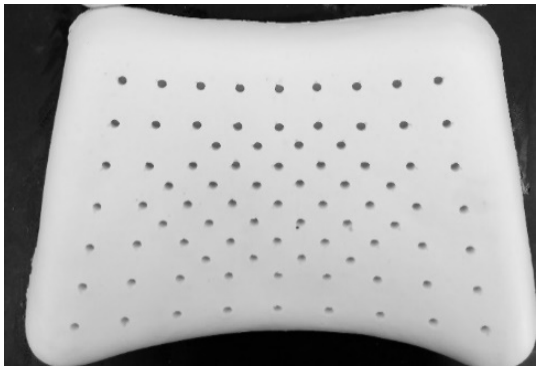

Fig. 6: The natural rubber latex memory foam with pin-hole structure

Another advantage of natural rubber latex memory foam over polyurethane memory foam is on its improved ventilation property. Normally, standard natural rubber latex foams are fabricated with intermittent pin-hole structure which are designed to improve the air flow. For polyurethane memory foam, manufacturers found difficulty to produce foam with pin-hole structure because the material is too soft. The polyurethane memory foam tends to tear or rupture when the foam is peeled out from the mold. Thereby, without the pin-hole structure, polyurethane memory foam exhibits poor ventilation compares to standard natural rubber latex foam. On the contrary, pin-hole structure can be produced in the natural rubber latex memory foam because of the elasticity and strong property of natural rubber latex (Fig. 6). Thus, the natural rubber latex memory foam produced in this research will give better air flow compares to polyurethane memory foam.

CONCLUSION

A novel natural rubber latex memory foam for bedding has been successfully developed. This foam can offer proper spine and joints support, prevents back pains and improves blood flow in our body. Furthermore, it can also provide extra comfort during overnight sleep because of its supportive, motion isolation and good ventilation properties. The natural rubber latex memory foam is made from 100% natural and renewable material, offering a green alternative to the ordinary synthetic memory foams.

ACKNOWLEDGEMENT

The researchers wish to thank to the Malaysian Rubber Board for permission to publish this study.

REFERENCES

Alzoubi, M.F., E.Y. Tanbour and R. Al-Waked, 2011. Compression and hysteresis curves of nonlinear polyurethane foams under different densities, strain rates and different environmental conditions. Proceedings of the International Mechanical Engineering Congress and Exposition, November 11-17, 2011, ASME, Denver, Colorado, USA., ISBN:978-0-7918-5495-2, pp: 101-109.

Arand, D.L., 2006. The MSLT/MWT should be used for the assessment of workplace safety. J. Clin. Sleep Med., 2: 124-127.

Bader, G.G. and S. Engdal, 2000. The influence of bed firmness on sleep quality. Appl. Ergon., 31: 487-497.

Blackley, D.C., 1997. Polymer Lattices: Science and Technology. 2nd Edn., Chapman and Hall, London, ISBN:0412-62880-5, Pages: 577.

Buckle, P. and A. Fernandes, 1998. Mattress evaluation-assessment of contact pressure, comfort and discomfort. Appl. Ergon., 29: 35-39.

Haesler, E., 2014. Prevention and pressure ulcers: Clinical practice guideline. Cambridge Media Portals, Perth, Australia.

Hanel, S.E., T. Dartman and R. Shishoo, 1997. Measuring methods for comfort rating of seats and beds. Intl. J. Ind. Ergon., 20: 163-172.

Higer, S. and T. James, 2016. Interface pressure mapping pilot study to select surfaces that effectively redistribute pediatric occipital pressure. J. Tissue Viability, 25: 41-49.

Jacobson, B.H., A. Boolani, G. Dunklee, A. Shepardson and H. Acharya, 2010. Effect of prescribed sleep surfaces on back pain an sleep quality in patients diagnosed with low back and shoulder pain. Appl. Ergon., 42: 91-97.

Jacobson, B.H., H.A. Gemmell, B.M. Hayes and T.S. Altena, 2002. Effectiveness of a selected bedding system on quality of sleep, low back pain, shoulder pain and spine stiffness. J. Manipulative Physiol. Ther., 25: 88-92.

Joyce, B., 2012. Support surfaces for pressure ulcer prevention. Safe Practices, 6: 2-6.

Kim, D., K. Min, H. Park and J. Park, 2014. Measurement of the distributed dynamic stiffness of seats under compression to analyze dynamic characteristic of seats. Proceedings of the 43rd International Congress on Noise Control Engineering, November 16-19, 2014, Institute of Noise Control Engineering, Melbourne, Victoria, Australia, pp: 3650-3652.

Lee, H. and S. Park, 2006. Quantitative effects of mattress types (comfortable vs. uncomfortable) on sleep quality through polysomnography and skin temperature. Intl. J. Ind. Ergon., 36: 943-949.

Lim, H.S.H.K., S.H. Kim and B.K. Kim, 2008. Effects of silicon surfactant in rigid polyurethane foams. Express Polym. Lett., 2: 194-200.

MS., 2011. Standard latex foam rubber mattresses for domestic and general use-Specification. Malaysian Standards, Malaysia. https://www.scribd.com/document/302106512/MS-679-2011.

Mills, N.J. and G. Lyn, 2002. Modelling of air flow in impacted polyurethane foam. Cell. Polym., 21: 343-368.

PFA., 2016. Viscoelastic memory foam. Polyurethane Foam Association Inc, Tennessee.

Roslim, R. and M.Y.A. Hashim, 2012. Natural rubber latex foam. Patent Application, USA.

Suleman, S., S.M. Khan, N. Gull, W. Aleem and M. Shafiq *et al*., 2014. Synthesis and characterization of Visco-Elastic (VE) polyurethane foam. Intl. J. Innovation Appl. Stud., 9: 1878-1886.

Szabolcs, B., 2015. Visco-hyperelastic characterization of polymeric foams. Ph.D Thesis, Budapest University of Technology and Economics, Budapest, Hungary.

Takayuki, S. and K. Daisuke, 2011. Next generation PU foams for mattresses benign to human body. Ph.D Thesis, Asahi Glass Co. Ltd., Tokyo, Japan.

Zhang, L. and R. Dupuis, 2011. Measurement and identification of dynamic properties of flexible polyurethane foam. J. Vib. Control, 17: 517-526.