PALM OIL-BASED MEMORY FOAM

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Unlike conventional flexible polyurethane (PU) foams, memory foams are characterised by their slow recovery after compression. For example, when the human hand is positioned (*Figure 1*) on the memory foam, the foam progressively conforms to the shape of the hand, and after the hand is removed, the foam slowly resumes to its initial shape. In general, memory foams are used in pillows, upholstered furniture, flooring underlays, cushioning, and as foams for noise and vibration harshness (NVH) control (*Figure 2*).

Figure 1. Memory foams retains the shape of the hand after compressed.

Memory foams are produced mostly via slab-stock process with toluene diisocyanate (TDI) based formulations. Recent trend in development of methylene diphenyl diisocyanate (MDI) based formulations for manufacturing of both slab-stock and molded memory foams are driven by the need for performance and processing improvements as well as environmental (regulatory) demands and safety concerns (Smiecinski and Neff, 2006)

This technology relates to the development of environmental-friendly memory foams made from palm oil-based polyols (Pioneer E-120 and Pioneer ES-145). These memory foams contain MDI as the polyisocyanates component, palm oil-based polyols and petroleum-based polyols in the presence of additives and water as a blowing agent.

PROPERTIES OF PALM OIL-BASED POLYOLS

Palm oil-based memory foams can be formulated using two palm oil-based polyols; Pioneer E-120 and Pioneer ES-145 polyols (*Table 1*). The technologies for the production of these polyols had been patented (Hazimah *et al.*, 2011).

Figure 2. Potential applications of memory foams.

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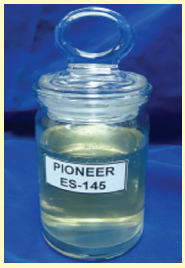
TABLE 1. PROPERTIES OF PALM OIL-BASED POLYOLS

	Pioneer E-120	Pioneer ES-145
		
Description	Polyol of 100% palm olein, alcoholysed with ethylene glycol	Polyol of 90% palm olein and 10% soya bean oil, alcoholysed with ethylene glycol
Appearance	Liquid yellow	Liquid yellow
Hydroxyl number, mg KOH g^{-1} (ASTM D 4274-99)	110-130	146-181
Acid value, mg KOH g^{-1} (ASTM D 4662-03)	0.3 – 0.7	0.8-1.0
Viscosity at 25°C, cPs	5 800 – 7 600	13 498-15 216
Molecular weight (Mn)	2 175	2 065

FORMULATION OF PALM OIL-BASED MEMORY FOAM

Palm oil-based memory foam was formulated by incorporating palm oil-based polyols, petroleum-based polyols, additives and a blowing agent. The mixture was reacted with isocyanates to form the memory foam (MF) (*Figure 3*).

ADVANTAGES OF PALM OIL-BASED MEMORY FOAM

Palm oil-based memory foams performed better in term of mechanical properties than commercial memory foams (*Table 2*). The load-bearing properties of the memory foams (MF) such as compression force deflection (CFD) and hysteresis loss increased significantly with the introduction of palm oil-based polyols. Dissipation energy of the foams normalised to the same density increased significantly with the increasing amount of palm oil-based polyols, indicating the foams had improved energy dampening property.

POTENTIAL TAKER

This technology could be adopted by PU product manufacturers and PU in-house formulators, mainly for mattresses and pillows.

POTENTIAL MARKET

Malaysia is currently going through a real estate boom. Subsequently, there will be an increasing demand for PU-based construction materials such as roof insulators, wall panels, ceiling panels and cornices. Besides flexible polyurethane foams, memory foams are also used in furniture and bedding. Memory foam provide a different degree of coziness. Flexible PU foams manufacturers are expected to be the fastest growing consumers of polyols in Malaysia. In terms of monetary value, polyols consumption for flexible foam PU was USD 31.2 million (RM 102 million) in 2012 and is expected to reach USD 62.1 million (RM 203 million) by 2018, growing at a Compound Annual Growth Rate (CAGR) of 12.2% from 2012 to 2018 (Markets and Markets, 2014).

ECONOMIC ANALYSIS

The price for commercially available memory foams in the market depends very much on the density and the shape of memory foams (*Table 3*).

TABLE 3. PRICE OF COMMERCIAL MEMORY FOAMS

Supplier	Price (RM)	Dimension (cm x cm x cm)
Company A	82.60	56 x 36
Company B	159.00	60 x 36
Company C	199.00	50 x 32 x 8

The expenditure for the production of slabstock memory foams involves raw materials, high pressure machines, boxes, conveyor and a cutter. Expenditure of palm oil-based memory foam were estimated based on the production of palm oil-based polyols, namely Pioneer E-120 and Pioneer

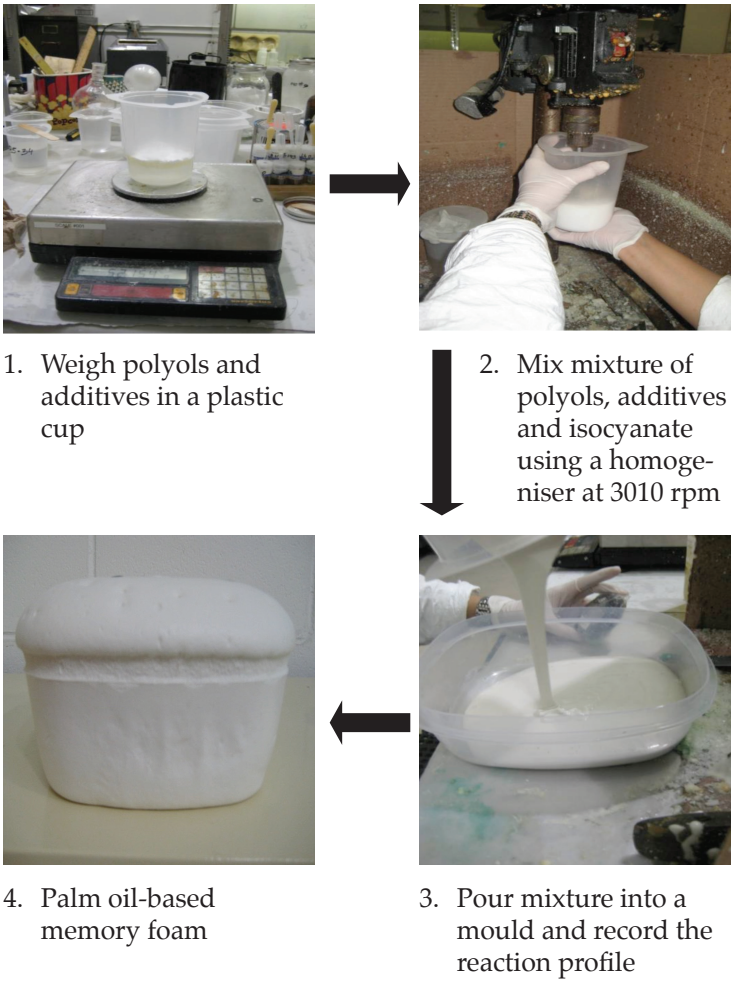


Figure 3. Production of palm oil-based memory foam.

TABLE 2. PALM OIL-BASED MEMORY FOAMS (MF) BASED ON PIONEER E-120 POLYOL AND PIONEER ES-145 AS DROP-IN REPLACEMENT FOR POLY-G 01, POLY-G 02 AND POLY-G 03 POLYOLS AT 80% ISOCYANATE INDEX

Designation	Petroleum-based MF	Pioneer E-120 MF 1	Pioneer E-120 MF 2	Pioneer ES-145 MF 1	Commercial MF**
Pioneer E-120, %	0	25	35	25	-
Pioneer ES-145, %					
Isocyanate index	80	80	80	80	-
Properties*					
Free-rise density, kg m^{-3}	42.08 ± 0.32	54.40 ± 4.16	51.84 ± 5.28	51.04 ± 2.24	76.96
Resilience, %	4.6 ± 0.7	7.1 ± 0.6	9.7 ± 0.7	6.61±0.57	8.1 ± 0.7
Support factor #2, 65% CFD /25% CFD	2.36	2.38	2.16	1.83	2.24
Tensile strength, kPa	62.05 ± 7.58	101.42	68.05 ± 7.52	72.05 ± 2.07	61.29 ± 3.65
Elongation at break, %	244 ± 28	95±10	207 ± 66	140 ± 20	369 ± 24
Tear strength, N cm^{-1}	3.70 ± 0.42	6.41±1.20	4.17 ± 0.37	6.44 ± 0.39	3.04 ± 0.32
Hysteresis loss, %	74 ± 1	72±4	77 ± 3	83 ± 3	35 ± 0
Dissipated energy in hysteresis loop , J	0.054 ± 0.001	0.144	0.186 ± 0.024	0.154	0.029 ± 0.003
Recovery time, s	17 ± 5	34 ± 7	23 ± 3	32.50 ± 3.80	6 ± 1
Compression set - dry heat,%	1.5 ± 0.3	0.7 ± 0.3	3.5 ± 0.2	1.25 ± 1	1.6 ± 0.2
Compression set - wet heat,%	1.1 ± 0.8	1.4 ± 0.4	5.5 ± 0.2	0.90 ± 0.13	0.4 ± 0.3

Note: Poly-G 01, Poly-G 02 and Poly-G 03 are commercial petroleum-based polyols.
*All relevant properties were tested parallel to the foam rise.
**Commercial "5 PCF" memory foam were obtained from Foam N' More & Upholstery, Troy, MI, USA.

ES-145, at RM 7.80 kg^{-1} and at RM 7.85 kg^{-1}, respectively. The estimated cost of PU production system that produces 25 000 pieces per year of palm oil-based memory foams for standard size of pillows is RM 2 286 573 (*Table 4*). The selling price for one piece of standard palm-oil based memory foams pillow is projected at RM 75.

TABLE 4. ESTIMATED PRODUCTION COST OF PALM OIL-BASED MEMORY FOAM FOR A STANDARD SIZE PILLOW

Item	Cost (RM)
Total capital expenditure (building, equipments, vehicle, *etc.*).	1 864 000
Total operating expenses (OPEX)	422 573
TOTAL (CAPEX + OPEX)	2 286 573
Net present value (NPV)	1 215 687
Internal rate of return (IRR)	32%
Payback period	3 years

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