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A Comprehensive Short Review on Polyurethane Foam

Shoaib Suleman[1-2], Shahzad Maqsood Khan[1], Nafisa Gull[1], Waqas Aleem[2], Muhammad Shafiq[1], and Tahir Jamil[1]

[1]Department of Polymer Engineering & Technology,
University of the Punjab, Quaid-e-Azam Campus,
Lahore, Pakistan

[2]Department of Chemical Engineering,
Universiti Teknologi PETRONAS,
Perak, Malaysia

ABSTRACT: Polyurethanes are versatile materials used widely in many applications. Annual production of polyurethanes is increasing day by day. The most important application of polyurethane covering its major market is polyurethane foam. Different type of foaming systems and foaming processes are used for synthesis of foam. There are two major types of polyurethane foam which are flexible foam and rigid foam. This review has been structured to present an overview of different types of foam, foaming systems, and processes used for production of foam. Also major applications of polyurethanes are presented.

KEYWORDS: Polyurethane foam, Flexible foam, Rigid foam, Cup foaming, Machine foaming.

1 INTRODUCTION TO POLYURETHANE

Polyurethanes are broad class of materials used widely in many applications. Polyurethanes are also written as PUR and also called as urethanes. They are characterized by urethane linkage -NH- C (=O) - O - . Polyurethanes are discovered by Otto Von Bayer & co-workers in 1937. The characteristic structure of urethanes is given as:

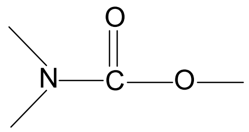

Fig.1. Structure of Polyurethane [1]

Polyurethanes are considered as esters or amide esters of carbonic acid. They are synthesized by the reaction of polyfunctional hydroxyl compounds with polyfunctional isocyanates. Structure of polyurethane formed from di hydroxyl compound and di isocyanate is given as [1- 3].

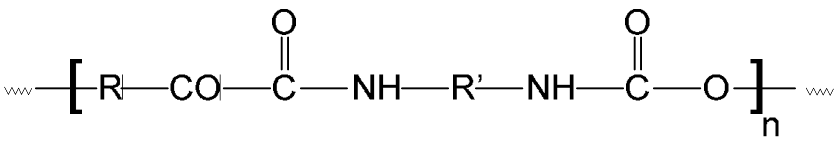

Fig.2. Polyurethane formed from di hydroxyl compound [1]

Globally, annual production of urethanes is about 8 million tons per year and is increasing yearly [4]. Polyurethane is a versatile polymer having unique chemistry with excellent mechanical and optical properties and has good solvent resistance [5]. Polyurethane foam covers almost 29% of the total market of polyurethane [6-7].

2 POLYURETHANE FOAMING SYSTEMS

Foaming systems are classified into three types based on the type of chemicals used in the synthesis process. These types are

- One step One shot system
- Quasi Pre polymer system
- Full Pre Polymer system

One step system and Quasi system are mostly used in foaming industries. One step process is used majorly while pre polymer system was used only in the early times of urethane industry. In one step system Component "A" and Component "B" are taken separately. Component "A" contains only polyisocyanate component while component "B" contains polyol, surfactant, blowing agent and catalyst. Both components are mixed which led to the formation of foam.

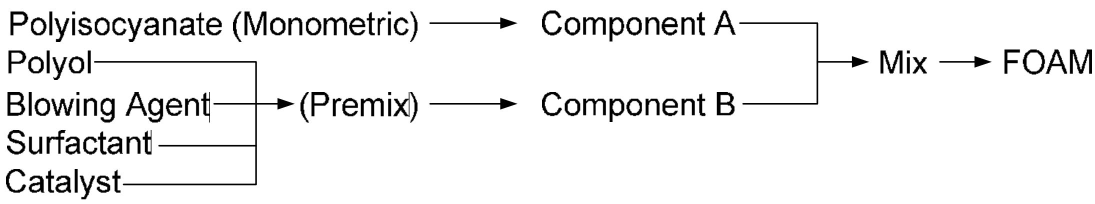

Fig.3. One step one shot system [1]

In Quasi Pre polymer system, in component "A" polyisocyanate component is taken with polyol and in component "B" rest of the ingredients are added with polyol which includes catalyst, blowing agent etc. Mixing forms a foaming product.

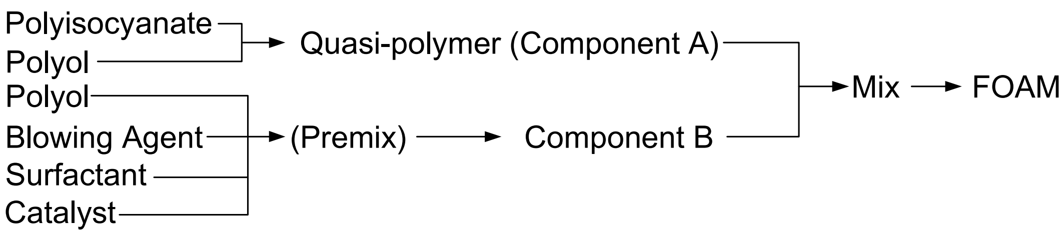

Fig.4. Quasi Pre polymer system [1]

In full prepolymer system in component "A" poly isocyantae component is taken and polyol is also added in it while in component "B" polyol is not added while the rest of chemicals like blowing agents, surfactants and catalyst are taken. Components A & B are mixed.

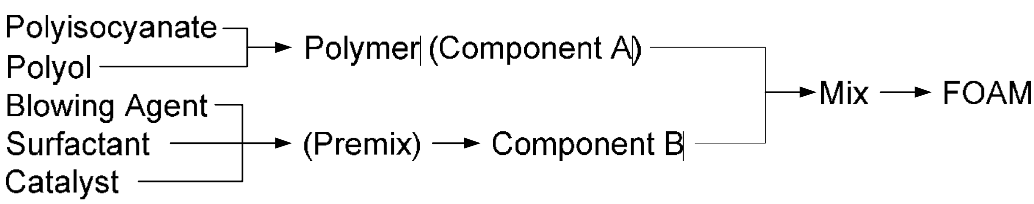

Fig.5. Full pre-polymer system [1]

These foaming systems show only two component system however in industrial processes there are modifications. For example in slabstock process three or four streams are employed carrying different reactants [1, 9].

3 FOAMING PROCESSES

Mainly three types of foaming processes are used, which are cup foaming, box foaming and machine foaming. Machine foaming is further classified into various foaming processes, which are large Box Foaming, Slabstock Foaming, Pour-in-Place Foaming, Sandwich Foaming and Molding, Spraying and frothing [1, 10, and 12].

4 TYPES OF POLYURETHANE FOAMS

Polyurethane foam is prepared by addition, condensation or cyclo-trimerization reactions. Different type of foams and their reactions are shown in table 1.

Table 1: Table showing different types of foam based on their synthesis reaction [1]

Foam	Reaction	Foam Property
Polyurethane	Poly addition	Flexible and rigid
Polyisocyanurate	Poly cyclotrimerization	Rigid
Polyamide	Poly condensation	Flexible and rigid
Polyimide	Poly condensation	Semi rigid and rigid
Polyurea	Poly addition	Flexible and rigid
Poly Carbodiimide	Poly condensation	Semi rigid

Polyurethane foam is classified into two types; flexible foam & rigid foam. These foams are further classified into various sub types in view of their applications [1]. All types of polyurethane foams are synthesized with the proper choice of polyol and isocyanate component. Table 2 shows the classification of polyurethane foam with respect to polyol component and functionality [1, 8].

Table 2: Classification of polyurethane foam w.r.t polyol and functionality [1]

Polyol	Rigid foam	Semi rigid foam	Flexible foam
OH No.	350-560	100-200	5.6-7.0
OH Equivalent No.	160-100	560-280	10,000-80
Functionality	3.0-8.0	3.0-3.5	2.0-3.1

4.1 FLEXIBLE POLYURETHANE FOAM

Flexible polyurethane foams are synthesized by slabstock process or by molding process. They are classified by the technique used for their synthesis and on the basis of polyol. Polyurethane foam synthesized by slab stock process is also called slab stock foam and it is classified into different types which are polyether foam, high-resilience foam, visco-elastic foam, super-soft foam, energy-absorbing foam, and flexible polyester foam; while molded foams are classified into two types' hot molded foam and cold molded foam [1, 13-17, 19-21].

4.2 RIGID POLYURETHANE FOAM

Rigid Polyurethane foam comprises a closed cell structure. At ambient temperature no heating is required to synthesize rigid foam. This type of foam has varying density values. Unique methods are used to synthesize this type of foam like spray foaming, and one component foaming. Rigid foams are further classified in to laminates, sandwich Panels, high density rigid foams and slab-stock rigid foam [1-2, 22, 23]. Flexible and rigid foam can also be synthesized on lab scale using cup foaming [24].

5 Applications

Application of polyurethane material is determined by two important parameters which are density and rigidity of polyurethane material [24]. Major uses of polyurethane material are in making of plastics, cushions, foams, rubber goods, synthetic leathers and fibres. They are also used in furniture industry, construction, and shoe industry, medicinal and agricultural applications. Rigid polyurethane foams have large application area like in thermal insulation products such as refrigerators, freezers, refrigerated trucks, chemical and petrochemical plants, water heaters, portable ice boxes, and thermos bottles. Polyurethane foam is used in many environmental applications in pollution control and pollution prevention [1, 4, 6, 7, 22, and 23].

6 Conclusion

It can be concluded after reviewing the literature that polyurethanes are widely used in many industrial and domestic applications. Due to this reason annual production of polyurethanes is increasing day by day in the world. A major application of polyurethane is polyurethane foam covering its major market.

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