

Synthesis of Ethylene Vinyl Acetate polymer blended foams for various applications: A mini Review

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Abstract—Ethylene vinyl acetate (EVA) is one of the highest demanding materials used in the composition of polymer foam. However, EVA foam may show inferior properties such as poor compression set, poor tear strength and abrasion resistance. Blending of EVA with other polymers may help to overcome this inferiority. This review discusses the synthesis of EVA blended foam and various applications such as footwear innersole or midsole, workout mats, biomedical equipment among others. It had been found during study, blending can enhance the foam properties yet there is scope for further development to regulate the limitation like expansion control, split line mark, and mould design.

Keywords: EVA blend foam, Synthesis, Foaming process, Cellular structure, Application

I. INTRODUCTION

The search for new polymeric material that provide high performance, better properties, and eco-friendly products are critical for manufacturers. In present scenario polymeric foam market is very competitive and manufacturers interested to develop high performance foam. There is wide area of application for polymer foam such as textile, bedding, flooring, insulation appliances, biomedical, automotive applications, sports, toys, exercise mats, car sitting, furniture, wipers etc. The global consumption jumps up speedily with populace growth and their requirements. The global market for polymeric foam was US \$ 118.37 billion in 2016, US \$113.89 billion in 2019 and was expected to grow by 3.8% to US \$ 122.41 billion upto 2021. The prime consumption taken place by construction industry which accounts for 58% consumption of overall polymer foams. Followed by packing is the second largest consumption area. The remaining consumption of polymer foam are in numerous applications such as automotive, furniture, bedding, and other commercial and domestic uses[1]-[2].

Based on density the polymeric foams are sorted into three classes. Foam having 0.5g/cm^3 to 1g/cm^3 is considered to be highly dense. Foams having less than 0.1g/cm^3 density are called low density whereas medium dense foams lies between the range 0.1g/cm^3 to 0.5g/cm^3 . Cell structure is another way of classification of polymer foams. Depending on cell structure, two utmost types of foams are close cell structure and open cell structure. Open cell foams are considered to have inter-connected cell structure, whereas, in close cell structured foams, cells are not associated to each other. Open cell foams are known to be more flexible and softer than close cell foams[3]-[4].

Various materials are available in the market for the production of foam. Few examples of these materials are; Polyurethane, Polyvinyl acetate, Polystyrene, Low density polyethylene, Expanded poly styrene, Ethylene vinyl acetate copolymer, Polypropylene, Nitrile rubber, Polyimide, etc. one of the demanding material used in the synthesis of foam is Ethylene vinyl acetate (EVA), which supposed to lead numerous benefits such as comfort, cost cut, environment friendly, softness, absorb impact from fall, can be easily clean and disinfect. It is a copolymer and synthesized from monomers of ethylene and vinyl acetate, where the Vinyl Acetate ranges in 10-45%. EVA can be expanded according to the formulation and geometry of the design. Due to easy melt processability, EVA is selected for blending with other polymers. [5]. Due to UV stability and comfort, EVA foam is extremely utilized in the manufacturing of shoe mid sole, exercise mats and sports protection paddings. It can be synthesized by injection moulding or compression moulding and has ability to expand up to 90% with suitable selection of blowing agent. However, it expands irregularly and deformed when released from mould[6]. The decomposition of the foaming agent depends on the type of polymer used and their composition[7].

The mechanical, rheological and thermal properties of EVA foam are greatly influenced by the plasticizers and crosslinking agents. As crosslinking leads to formation of closed cells and hence improved the polymeric foam

properties, while adding plasticizers helps to get the soft polymeric foam due to the formation of open cell structure [8]. Low density, improved tear strength, good rebound thermal plastic natural rubber foam could be obtained by blending EVA and natural rubber. The selection of blowing agent and crosslinking temperature play a significant role for the foam production [9]-[10]. Highly porous and lightweight EVA foam could be obtained by using chemical blowing agent specifically azodicarboamide [11].

Blends of EVA and low density Polyethylene were used to minimize the volatilization of essential oils for packing of agro-food products. This polymeric blend packing showed best performance in retention of microbial activity [12]. For footwear applications, EVA/Polyurethane (PU) blended foams were prepared. These foams have shown improved abrasion resistance, friction coefficient and hardness, however, tensile strength and compression set were found to be inferior to EVA foams [13]. The poor incompatibility of EVA/Thermoplastic urethane (TPU) blend foams can be improved by adding compatibilizer. By the incorporation of ethylene vinyl acetate-grafted-thermoplastic urethane (EVA-g-TPU), the good compatible polymer blend foam was obtained. Moreover, these compatibilized foam have shown good mechanical properties such as tensile strength, tear strength, elongation at break and compression set without affecting the foam density [14].

Ethylene styrene interpolymer (ESI) was incorporated in existing EVA foam to produce sheets and injection moulded foams for footwear application that strengthen the performance of EVA foam [15]. Crosslinking agent and type of ESI plays a major role for obtaining microcellular foam. Good foams of EVA/ESI blends can be obtained by using smaller amount of crosslinking agent at higher content of styrene in ESI [16]. The foaming of open micro-porous EVA foam by supercritical carbon dioxide depends on sorption pressure, temperature and decompression rate. These parameters control the pore size and bulk density of the EVA foam. Increasing these parameters considered to develop small porous structure with greater density and vice versa [17].

In view of above, blends of EVA have significant role and different mechanisms involved. This review focuses to analyse the recent research on polymeric EVA blend foam. It provides the information related to synthesis methods, classification and applications of polymeric foam. This study also discusses the brief summary of mechanism of cellular structure of the foam involved during synthesis and its significance.

II. OVERVIEW

2.1 Synthesis of EVA copolymer -

Bulk Polymerization and Solution polymerization are most widely used methods for copolymerization of EVA. Figure 1 represents the systematic polymerisation of EVA copolymer.

2.1.1 Bulk Polymerization: -The polymerization of EVA takes place at high pressure. The reaction can be initiated by dissolving radical initiator to vinyl acetate monomer while introducing heat or radiation. The reaction is exothermic and evolves explosive gases. The volume of the reactor is kept constant. The ethylene is then added up until desired pressure reached. Viscosity of the mixtures increases as the reaction proceeds. After the desired reaction, the reactor chills slowly and degassed. The polymer is then retrieved by evaporation [18]-[19].

2.1.2 Solution Polymerization: - In this, ethylene and vinyl acetate polymerized in solvent in the presence of initiator. The amount of initiator is dependent on kind of initiator reaction temperature. The solvent absorbs the heat that released during reaction. In addition viscosity of the mixture reduces that causes rise in the rate of reaction. Once the desired polymerization completed, excess solvent is removed so as to achieve pure polymer [19]-[20].

2.2 Fundamental Principle of polymer foam -

The first step for synthesis of EVA foams is to prepare compound composition which includes raw polymers, foaming agents, processing aids, activator, crosslinking agents and some additives. Foams are generally produced either by physical foaming or inducing chemical foaming agent. The cellular structure of polymeric foam is obtained with the choice of foaming agents that induced the chemical reaction. During foaming, gas phase is dispersed in Polymer phase resulted volumetric expansion, the foams so generated comprise of gaseous phase and influenced the foam density and foam cellular structure [21]-[23].

In polymer foams, the foaming process can be done by nucleation mechanism; the formation of gas bubble, growth of gas bubble and bubble stabilization in polymer matrix, shown in Figure 2. The incorporation of

foaming agent in polymer matrix under precise condition leads to the liberation of large amount of gas involving due to chemical reaction. In first stage, as the load of gas moderately increased, there is a formation of small bubble which may lower the density of polymer matrix. In second stage, the pressure inside the bubble increases, due to inhomogeneity of pressure, the size of the bubble gets bigger and allowed to form cellular structure. When bubbles are interconnected, gas transfers from smaller bubble to bigger bubble that resulted distortion of smaller bubble and formation of deformed cellular structure. As a consequence, there is instability in gas/polymer interface. To make it stable, cooling of the foams is a necessary step [3]. Homogeneous and heterogeneous nucleation mechanism can be considered.

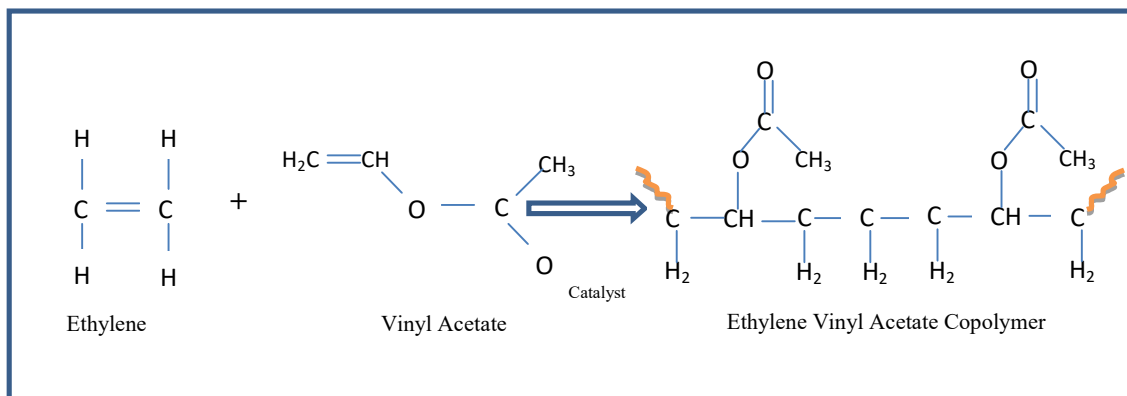


Figure 1. Systematic polymerization of Ethylene Vinyl Acetate (EVA)

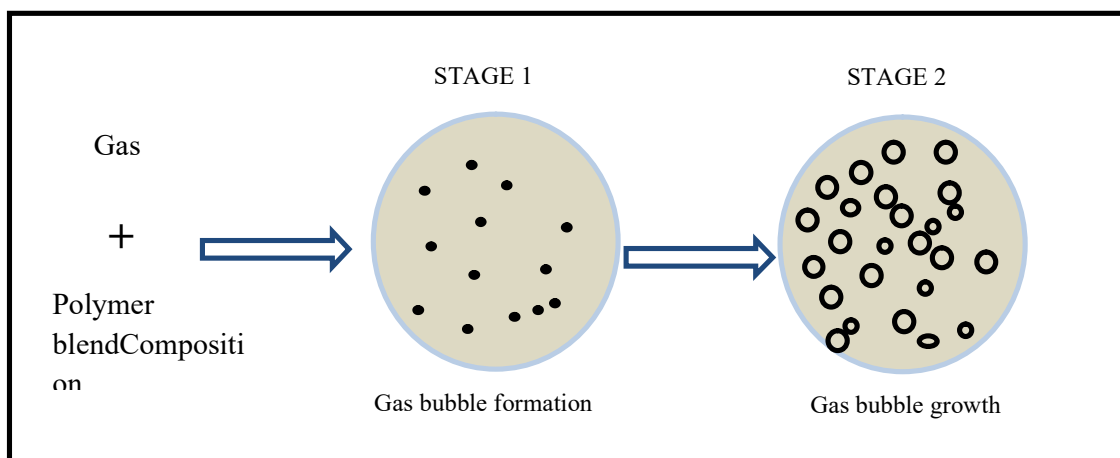


Figure 2. Schematic view of formation of cellular structure of blended foam

Physical foaming includes the foam production by inducing carbon dioxide or nitrogen gas into the polymer matrix at high pressure or inducing solvent with low boiling point such as pentane, hexane [24]. Various chemical foaming agents are used to obtain EVA blended foam such as ammonium bicarbonate, sodium bicarbonate, sodium borohydrate, celogen OT, azides, hydrazides, azodicarboamide [6], [25]. Azodicarboamide (ADC) is one of the most frequently used foaming agents for the EVA blended foams. The decomposition reaction of ADC is shown in Figure 3.

2.3 Classification of polymer foam -

Cellular structure of various EVA foam shown in Figure 4 can be categorized morphologically. Depending on the movement of gas in the polymer matrix leaves two types of cellular structure.

2.3.1 Open cellular structure:

Open cellular foams are less dense. These foams consist of interconnecting series of gas bubbles. When foams squeezed under external load, these get compress together in unknown direction. On realising the load, the gas inside the bubble allows the matrix to its original stage. Open cell structure does not obstruct the gas or vapour; however, pass through to adjacent bubble in a polymer matrix. These foams have high expansion capability and are usually sound proof. These are of light weight and does not contain any volatile organic compound

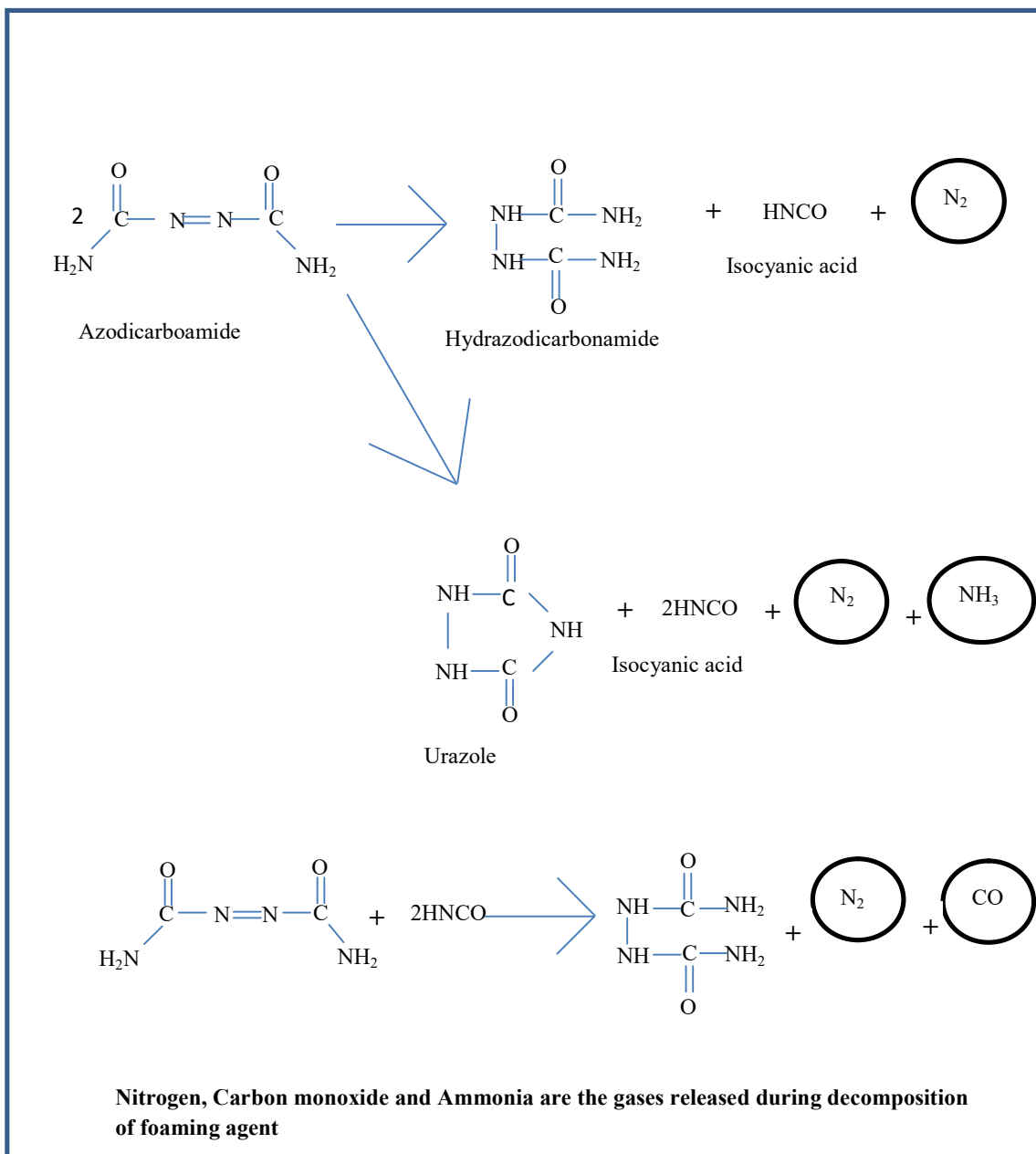


Figure 3. Schematic view of azodicarboamide decomposition

2.3.2. Close cellular structure:

It consists of bundles of small bubbles which are not interconnected together. The gas is entrapped inside each bubble. On applying external pressure, foams get compressed. When pressure released air enters slowly through

the cell walls. These foams are generally resistance to water and moisture. These can use indoor and outdoor applications. These foams are best known to heat and sound insulation.

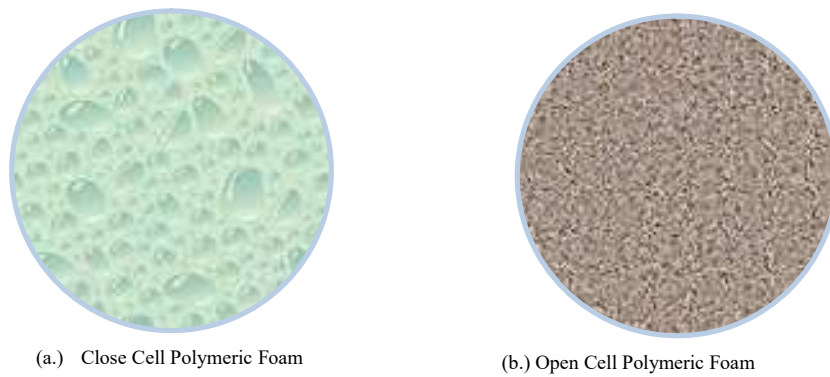


Figure 4. Cellular structure of polymer foam

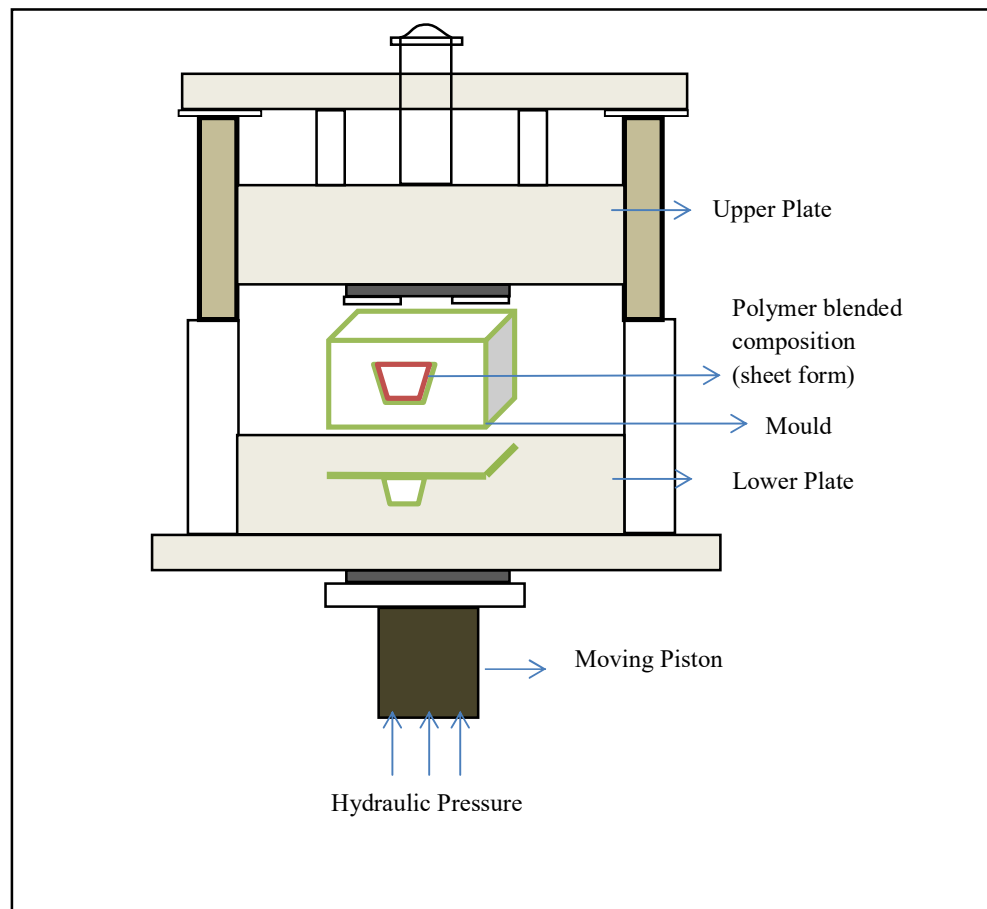


Figure 5. Schematic view of Compression moulding process

III. FOAMING PROCESS FOR EVA BLENDED FOAM

3.1 Compression moulding -

The processing parameters involve temperature, curing time and pressure. This process employs the use of moulds that are made up of two halves of metals typically known as male and female dies. For compression moulding the composition of all material including raw EVA, other polymer, additives, crosslinking and foaming agents has to be prepared firstly. The common compound composition used in this moulding is usually in the sheet form, sometimes granular or pellets may be used. The polymer to be foamed is placed directly into preheated mould. Once the sheet settled in the mould, the male and female parts of the die are closed as shown in Figure 5. The mould gets compressed with hydraulic press. The composition inside the mould gets soften by the heat and takes the shape of the mould. The extra material taking out from the mould may be removed after the compression process. The curing and expansion of the polymer blended foam processed under high pressure and temperature in the compression moulding press. The foam is then released from the mould [10], [26]–[28]. However, compression moulding process have limitations which are mentioned below:

- a.) Extra material often introduced in mould cavity in order to achieve uniform pressure, which in turn increase wastage.
- b.) Manual handling may become an issue resulted higher labour cost.
- c.) It may be contaminated with dust particles.
- d.) Split line mark often visible.
- e.) Moulds can be damaged

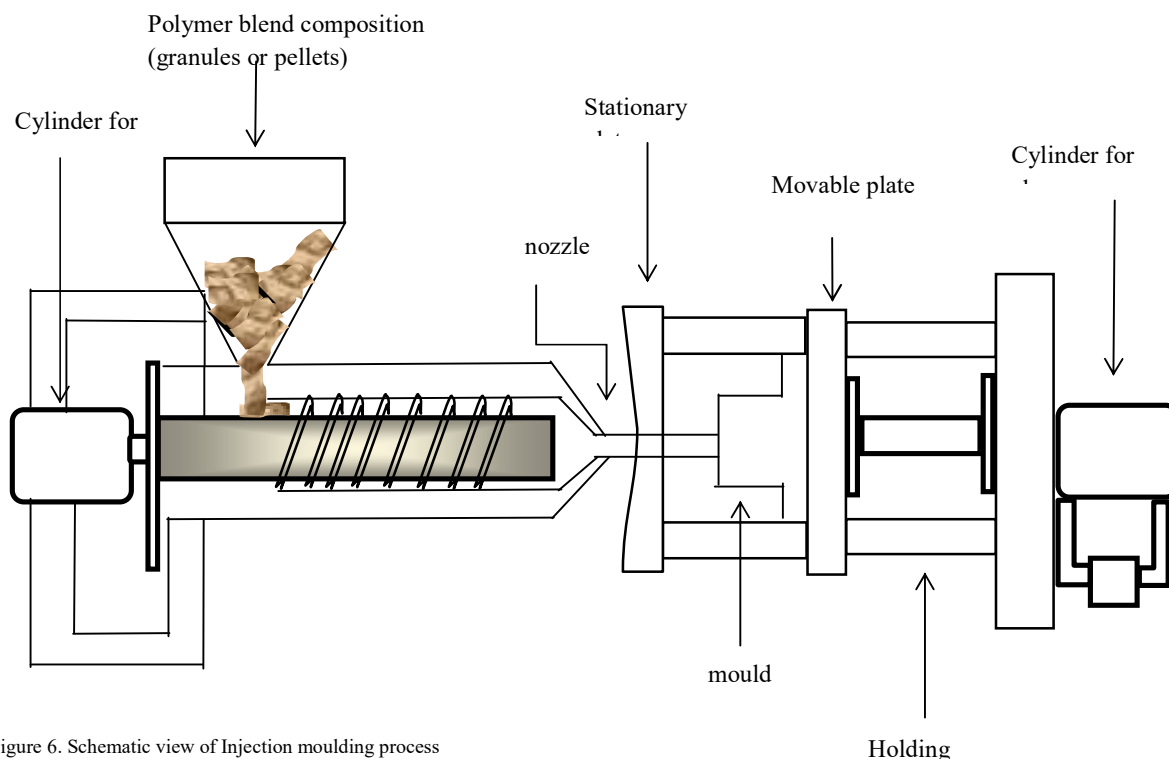


Figure 6. Schematic view of Injection moulding process

3.2 Injection moulding

The processing step involved in injection moulding is shown in Figure 6. includes clamping the mould, injecting the raw composition, cooling and ejecting of foam. Important parameters comprise of mould temperature, injecting pressure, injecting time, holding pressure, holding time and cooling time. The polymeric composition in granular or pellet form put in a hopper into heating barrel. Male and female part of the mould is attached to the injection moulding machine, one half is fixed and other half is sliding. The force is applied hydraulically so that sliding mould exerts sufficient force to keep both halves clamp together while injection polymer

composition. During this process composition gets soften due to heat. Build-up pressure holds the material inside the mould cavity for the duration of cooling time. As composition cools it takes the shape of the mould. Upon reaching the required cooling point, mould open and foam is ejected by the ejecting system. In order to ease the ejection of polymer foam, the foam releasing agent may be used prior to injection of the raw composition. The structural foam injection moulding technique is another method for producing lightweight polymeric foam material. In this process the inert gas such as nitrogen, pentane, butane is introduced at high pressure along with the polymer composition[29]–[33]. The limitations of injection moulding are high initial cost including tools and design, Part design limitation, and prolong duration for designing and manufacturing of tools.

3.3 Characteristics of EVA blended foam

There are numerous benefits of EVA blended foam including light weight, colour subsuming property, shock absorption capability, flexible, economical, can provides comfort due to softer material, resistant to water, moisture, ozone, weathering, UV, Oxygen, vibration and sound. Table 1 shows the brief application of polymer blended foam together with desired properties. However few limitations are also found. For instance usage of chemical blowing agents are carcinogenic in nature.

Table1: Application of EVA blended foam

Mode of application	Usages	Desired properties	Reference
Sports Equipment	Exercise Mats, Children foam Stickers, Football Ankle Protector, Helmet, Padding agent for body protection, floatation belts, water toys, swimming kickboards	Light Weight, Environment Friendly, skin friendly, easy to clean, disinfect, water resistant, cushioning, UV resistant, good Rebound, ample colour choice, shock absorption	[6], [34], [35]
Packing	Packing Films, thermal bags, overlap sheeting, agro food packing, insulated box liner, insulated delivery bags	Antimicrobial, light weight, Resilience, Water resistant, thermal insulation	[12]
Footwear	Insole, midsole, ladies high heel, athletic shoes, casual shoes.	Cushion, abrasion resistance, compression set, resiliency, heat shrinkage, split tear, softness, low weight	[6], [15]
Domestic	Furniture, Bedding, carpet underlay, Wipers, Textile	Light weight, ample colour availability, easy to clean and dry, environment friendly, cushioning,	[23]
Biomedical	Orthopaedic shoes, ortho-prosthesis, Plaster, Tissue engineering, Tissue generation, drug delivery, Foam baths	Biocompatible, Non-toxic, chemical resistant, Hygiene, potentially controlled degradation, large surface area	[36], [37]

IV. CONCLUSIONS

In this review, the synthesis, morphology and application of blended EVA foam was discussed briefly. These foams are light weight, excellent barrier to moisture, providing thermal and sound insulation, resistant to weather condition and widely used in various applications. Compared to various foaming process, chemical foaming process is one of the most extensible processes. However, yet there is lot of complication while preparing the foam such as designing appropriate tools, expansion control and initial high cost. Taking into consideration of literature review and increasing demand, there is lot of opportunity for further development in production method and range of properties of blended EVA foam, which can be attained by developing new technologies. Extrusion foam moulding is one of the most recent focused areas for the EVA foam preparation.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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