Fillers for Plastics

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A FILLER is any substance, either organic or inorganic, which is mixed with a resin to produce a non-homogeneous mixture that can be subsequently moulded. The filler facilitates the moulding process which is usually very difficult with pure resin and also affects the physical properties of the moulded article. In general, organic fillers impart greater mechanical strength and also low specific gravity, while the inorganic types offer greater dimensional stability and greater resistance to heat and electrical stresses.[1]

General requirements[2,3] for a satisfactory filler are :—

(a) Low cost and abundant supply.
(b) Compatibility and ease of mixing with resins and dyes.
(c) Low moisture absorption.
(d) High mechanical strength.
(e) Ease of moulding.
(f) Ease of preforming of moulding powder.
(g) High heat resistance.
(h) Favourable electrical characteristics.
(i) Absence of abrasive and chemical effect on the mould.

Fillers are usually classified primarily according to the general chemical nature —organic or inorganic—and further divided into groups based on their properties and chemical structure.

Organic fillers: These are derived mainly from either cellulose containing materials, such as wood and vegetable fibres, or are obtained as by-products from textile and wood processing industries.

Wood-flour: Wood-flour is obtained by grinding wood in any suitable equipment, wherein the grinding action is carried out in such a manner that the wood is defibred along the grains. It gives excellent moulding performance and general properties at lowest cost. Soft woods, such as white pine, are superior for the production of wood flour, because of their light colour, low natural resin content and good resin absorption characteristics.

Good shock resistance, high tensile strength, good electrical properties, adaptability to machining and low heat conductivity are typical properties of mouldings containing wood flour. The drawbacks are shrinkage in service, moisture absorption and relatively low temperature resistance.

The suitability of various timber wastes such as saw-dust and waste-veeners from match factories and jute sticks remaining over after the removal of fibre, for making "wood flour" have been investigated. Wood flour prepared from jute sticks compares well with imported material and is suitable for use as a filler for thermosetting resins.[4]

Walnut shell flour: Walnut shell flour, a cellulosic type of filler, is used in place of wood flour where some special properties are desired. As compared to wood flour, walnut shell flour gives a more lustrous finish to the moulded article and slightly better water resistance. Physical properties of the moulded articles containing the filler are similar to the general purpose product containing wood flour except that the impact strength is about ten per cent lower.

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Cotton and other textile by-products: Cotton flock or finely ground cotton as a filler is particularly recommended where high strength is desired, as it imparts high tensile, impact and flexural strength to the moulded piece. Bulk shrinkage is less than when wood flour is used but bulk factor is higher and pourability poorer, making preforming more difficult. Water absorption and electrical properties are about the same order as wood flour filled material.

Chopped fabric: This filler raises impact strength to a value twelve times above that of wood flour but it has a bulk factor four times greater and cannot be readily preformed. Water absorption is higher and electrical properties are poorer.

Paper pulp: Paper fibres, chopped paper and felted pulp are being increasingly used, combining greater impact strength with low price, especially since a method has been developed to make adequate preforms by vacuum techniques.

Lignin, lignin-enriched cellulose, proteins including horn and hoof-wastes are also used as fillers in the preparation of moulding powders.

Inorganic fillers: Inorganic fillers[5] are used to obtain special thermal properties. Maximum temperature for which wood flour or cellulose fabric filler as used is 268°F and 212°F respectively. For working at high temperatures asbestos is used as a filler. Its fibrous structure imparts the typical characteristics of mineral fillers without excessive loss of strength. Asbestos filled material exhibits good dimensional stability minimum mould shrinkage, low moisture absorption and good electrical properties. Their water absorption capacity has led to the use of fine ground slate for electrical purposes, although the impact strength is thereby lowered. Tensile strength of asbestos, however, is very low.

Diatomaceous silica: Diatomaceous silica is controlled within narrow limits of mesh size, colour, density and moisture content. High heat resistance, surface hardness, favourable electrical properties (low power factor) and moisture resistance are characteristics of the products formed.

Mica: Mica imparts excellent insulating properties, low power losses at high frequencies, superior moisture and heat resistance to the moulded article.

Graphite: Inorganic fillers lead to mouldings with higher density, greater mould wear and brittleness. Graphite is an exception. Graphite makes material conductive; it can also be used wherever a low coefficient of friction, as in bearings, is desired.

Miscellaneous fillers: The principal class of miscellaneous types are inorganic materials such as calcium carbonate, barium sulphate, zinc oxide and calcium sulphate. Although such types are more generally applied in rubber compounding, they are often used as fillers with plastics when special characteristics are desired. Acid resistance, low moisture absorption, high temperature resistance, hardness and low cost often favour them.

Fillers for laminates: Laminates are produced by the application of heat and pressure upon superimposed layers of paper, fabric, glass fabric, or other base materials which have been impregnated with heat reactive resin solutions, known as laminating varnishes.

The fundamental difference between the fillers for a moulding powder and a filler for the laminating process is that the latter is of continuous nature.

The selection of a proper filler for a moulding powder has an importance which is secondary to the selection of

the resin. The resin is important because it must give the proper flow and proper bond and must also permit curing to well-finished pieces in a reasonable length of time. The exact nature of resin is important in securing the most desirable properties.[6]

Paper: Rag paper is characterized by its toughness. Kraft paper is most generally used because of its low cost and satisfactory mechanical properties. Paper made from α-cellulose is chosen for applications requiring colourability, uniformity of appearance and good electrical properties.

Fabric: Such types of fabric as canvass, army duck, twill, æroplane cloth and organdie are commonly used. The chief controlling factors are those of weave and weight. The improved mechanical properties obtained with proper fabric base permit the extension of laminates to a variety of applications in the industrial field for which the older moulding resins are unsuitable.

Asbestos: Asbestos is used in the form of a sheet or fabric. The latter ensures greater strength and both types exhibit good heat resistance and good chemical resistance to corrosive agents. Greater moisture resistance and electrical resistance are also provided for by the asbestos cloth.

Glass: Glass cloth, made of staple fibre yarn produces a laminate of excellent resistance to impact, heat and moisture. It is also used for insulation combined with heat resistance.

Fillers for different plastics:—

Phenol-formaldehyde resin: Nine different types of fillers are used with phenol-formaldehyde resins :

(1) Cellulose derivatives, (2) Wood flour, (3) Walnut Shell flour, (4) Cotton seed hulls, (5) Cellulose fibres, (6) Textile by-products, (7) Proteinaceous fillers, (8) Carbon fillers and (9) Mineral fillers.

In the above classification, cotton flock, purified wood cellulose, sisal fiber, commuted paper, diced resin board, creped resin treated paper, resin pulp preforms etc. are grouped together as cellulosic fillers. Similarly asbestos, mica, glass fiber, lead oxide, barium sulphate and stone powder are grouped together as mineral fillers.

Amino-resins[6]: Soluble methylol derivatives, obtained by the reaction of urea or melamine and formalin under favourable conditions of temperature and pH value, are commonly mixed with cellulosic fillers (bleached sulphite pulp or wood flour). Incorporated with fillers and pigments they are used as moulding materials.

Filler-free urea-formaldehyde mouldings develop surface crazing on ageing. In contrast, when cellulosic fillers are present this crazing is practically eliminated. It is believed that there is some form of chemical combination between ureaformaldehyde resins and cellulose.

Recently, however, unfilled transparent moulding powder has been available and mouldings made from it do not show any surface crazing effect on ageing.

Melamine formaldehyde resins: Melamine formaldehyde moulding powders are available as a general purpose cellulose filled material and a mineral filled electrical grade material. A chopped-fabric-filled material is also known.

The general purpose material is supplied as a granular powder with a bulk factor of 2. The colour range is unlimited on both translucent and opaque shades.

The mineral filled material is supplied as a granular powder of bulk factor 2.

The colour range is limited to an opaque grey or brown.

Phenol-furfural resins: An impregnating material for paper and other fibrous materials is formed by the reaction of furfural solution of tung oil with previously prepared phenol-furfural product. Freedom from tackiness at the ordinary temperature is claimed for impregnated products which are suitable for moulding.

Phenol-carbohydrate resins: The properties of phenol-carbohydrate resins are modified by certain fillers usually employed in the moulding composition. The more difficult water soluble metallic bases in particular are said to improve electrical properties of the moulded articles. It is considered that these bases react with other constituents of the resin, probably with decomposition of the water soluble substances.

Alkyd resins: The incorporation of alkyds with phenol-formaldehyde resins is capable of giving plastics which, in certain respects have better qualities than either component individually. The properties of the resin blend could be varied widely by incorporating suitable fillers. Greater proportion of filler is used when operating only with phenol-formaldehyde resin. When no fillers are added and when the resin is fusible, the two resins may be melted together. When one or both the resins, however, are infusible, it is more advantageous to swell the resin together with the fillers by the use of hot acetone.

Cold moulded articles may be produced from a mixture of asbestos filler and other mineral fillers with an alkyd resin, the articles are subsequently stored in order to obtain specific performance. Alkyds are also employed as binders for mica flakes, in the manufacture of " sheet mica."

Allyl polymers: These are of special interest, as they can be processed at low pressures. In effect no more pressure is required than is necessary to hold the sheets in contact. During polymerization, there is a contraction of about 14%. Base materials such as wood, fabrics, felts, paper and glass fibres are simply impregnated by brushing the monomer, building up successive layers to form laminates and curing under slight pressure.

Silicones: Some types are suitable for laminating glass, cloth and asbestos. The marked feature are high insulating power, moisture resistance and retention of properties over a wide temperature range.

Polyesters: In contrast to alkyds, where the repeating unit is an ester group, polyesters are vinyl derivatives, being either esters of vinyl alcohol e.g. vinyl acetate, or acrylic acid e.g. methacrylic acid. When the alcoholic or acid component is in turn unsaturated e.g. allyl alcohol, maleic acid etc., polymerization can be done in two stages to get essentially linear derivatives in the first stage and subsequently cross-linked at high temperatures through the allyl or maleic group.

The three different types of 'polyesters' are (A) Saturated polyesters, (B) Unsaturated polyesters and (C) Polyfunctional unsaturated polyesters. Out of these three classes, class B i.e. unsaturated polyesters is the most important. Modifications through the use of various dibasic acids, different glycols and several monomers permit preparation of the end-product with almost any desired properties.

Reinforcement can be provided for by fibrous glass in some form of paper. Articles made are strong, durable, dimensionally stable and solvent resistant.

Mineral filled thermosetting unsaturated polyester moulding compound has a significant advantage of high-speed production. These polyesters are highly filled and require relatively high pressure to mould. The products have relatively low but very adequate physical strength for many uses. They have excellent electrical properties. Moisture and solvent resistance are also good.

Excellent casting of *B* or *C* type materials can be made with or without fillers. Filled compositions are being used extensively in electrical components. Miniature electrical circuits and magnet coils have been successfully encopsulated in either clear or filled composition on a production scale.

Bitumen : Bitumen is obtained either as such, or by the evaporation of specific petroleum crudes. It can be mixed with fibrous materials or other fillers. Bituminous compositions can be modified by rolling a charge of plastic materials (-asphalt-filler mixture) in a moulding powder containing a condensation resin to form a coating on the mass before moulding.

Lac : The major use of lac resin is in the manufacture of gramophone records, wherein the proportion of mineral filler is high since great strength is not required but hardness is essential. The relative proportions are usually specified for products requiring greater strength and therefore should be incorporated with only small quantities of mineral fillers.

India[1] is favourably placed with respect to fillers but practically no work has been done for processing and producing them. The various inorganic fillers, such as asbestos, mica etc. are readily available though work will have to be carried out to get them in the required size for use in plastics. Organic fillers, such as coconut shell flour, coir, jute stalks, walnut shell flour, agricultural residues e.g. corn cobs, flex shred, ground-nut shell, rice husk, proteinous materials, etc. are readily available but systematic work will have to be done to determine their suitability.

Too much importance is sometimes attached to the resins and the fillers are altogether neglected, but fillers play an important rôle in the case of thermosetting resins. Upon the proper selection and use of filler depend the qualities of the moulded product. While it is true that the cost of fillers on a volume basis is generally less than that of the resinous binders which hold them together, filler in no wise should be considered adulterants, for choice based on this view is sure to reduce the value of the products[8].

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