Polymer articles provide design engineers with huge room for movement – the entire volume of the articles, i.e. their three-dimensional space. This is due to the possibility of changing the colour of articles through the thickness of the polymer wall. Essentially, two designers work on the development of plastic articles: one is the colour designer, who draws up a pattern and makes colour decisions, and the second is the design engineer, who, in collaboration with the colour designer, develops the design and technology for the manufacture of the article in such a way that the colour impact and surface finish of the article are realised to the maximum degree. In the present work, the authors have attempted to systematise the methods for the decoration of plastics.

The colour range of plastics is formed on the basis of user requirements. The colours of materials for the manufacture of decorated articles are determined by the designers. The colour can be characterised quantitatively using analysis of the colour coordinates $x, y, z$ ($L, a, b$). There also exist the colour schemes RGB, CMYK, etc. These methods are widespread but require expensive apparatus. Reproduction of the colour of polymeric material with such accuracy that all three colour coordinates match is most often impossible (largely because of the technical qualities of the colorants), and often, from the viewpoint of the service and realisation of articles, this is unnecessary, since the user largely does not have such high requirements.

As a rule, the colour of polymeric materials is assessed visually. Under the best conditions of observation, the naked eye can distinguish over 200 different hues. Modern designers are working with international colour scales PANTONE, RAL, etc. The colour shades are denoted by digital codes, which makes their work much easier. In PANTONE, in contrast to RAL, there is also information on the components of a particular hue. Without being in direct contact, and at a distance of hundreds of kilometres from each other, the designer can inform the production engineer about the colour the ordered material should be.

Each shade of the coloured material can be expressed in four variants:
- transparent;
- semitransparent (transluscent);
- non-transparent (opaque);
- pearly (metallic).

In principle there are two possible ways of producing coloured plastic articles: either by using precoloured polymeric materials (or their colouring during processing) – colouring of the entire volume of the polymer, or by subsequent colouring of the surface of the finished (moulded) article.

To colour the entire volume of the polymer, use is made of inorganic pigments, organic pigments, dyes, and lacquers. A transparent colour shade is achieved by adding only melt-soluble dyes to the polymer composite.

Non-transparent polymers are materials coloured with pigments or dyes in a mixture with white pigments. However, pigments, in particular inorganic pigments, and without the addition of white pigments, give the material a certain non-transparency owing to light diffusion by the finely dispersed particles. The pigment is transparent when the refractive index of light largely matches the refractive index of the plastic (transparent materials are normally bodies that pass light entirely, while non-transparent materials are bodies that do not pass light but diffusively reflect light or absorb it).
In order to produce semitransparent material, dyes and turbidifying agents (white pigment) that are soluble in the polymer melt are introduced in a quantity of 0.01–0.1%, or dyes that are insoluble in the melt (pigments) in a quantity of 0.01–0.1%.

To produce a non-transparent intense colour, use is made of pigments in a quantity of 0.1–2% – for purposes of achieving greater covering power – often in combination with white pigment.

Many dyes and pigments in a mixture with white pigment change hue and degree of saturation. Warm red hues become purple pink, blue hues become grey, and black hues become bluish. As artists say – white pigment eats colour.

Fluorescent pigments and dyes give bright, vivid, radiant colours. Such products begin to fluoresce under the action of ultraviolet radiation. The greater the amount of pigment added, the stronger is the luminescence effect (up to a certain limit). Such articles will look particularly beautiful if special lighting fixtures are present for illumination.

A pearly effect is achieved by introducing lustrous pigments into the composite that create, in transparent media, owing to repeated refraction of light, an effect similar to the lustre of mother-of-pearl. The base of these pigments is mica. The remarkable lustre and brightness of pearly pigments are due to the scaly structure of the particles. Repeated reflection of an incident light beam from the surface of particles of the pigment creates the effect of optical interference. Here, the colour effect changes as a function of the angle of observation. The play of light, its intensity, and the colour range are governed by the type of metal oxide and the thickness of its layer on the surface of the mica. Furthermore, the pearly effect also depends on the particle size range:

- 40 µm fraction ensures transparency and a radiant effect;
- 25–40 µm fraction gives brightness and lustre but has a low covering power;
- 15–25 µm fraction is a lightly structured dense hue with an average covering power;
- 5–15 µm fine fraction has smoothness and silkiness, with an average covering power;
- 5 µm microfraction has a satin effect and a high covering power.

Pearly pigments – interference pigments – can recreate unique rainbow colours: yellow, all shades of red, violet, blue, and green. Each colour shade is caused by a certain density of the titanium dioxide layer. The concentration of pearly pigment introduced into the thermoplastic is 0.2–2%. However, higher concentrations are necessary in films and thin layers.

The effect of a metallic surface can be obtained both using pearly pigments and using metal powders (for example, bronze and aluminium powder).

An interesting effect is obtained by adding glitter pigments. These are particles, consisting of 0.1–3 µm 0.1–3 µm films of different shape, that are insoluble in the polymer melt (they have a melting temperature that is higher than that of the polymer of the article being manufactured or are thermosetting). The carrier glitter film is made, for example, of polyethylene terephthalate (10–30 µm) with aluminium spraying (1 µm) and pigment coatings based on epoxy polyurethane resins (2 µm), or from aluminium (10–15 µm) with a pigment coating based on epoxypolyurethane (2 µm). Iridescent glitter is cut up from plastic foil, and iridescent colour effects similar to mother-of-pearl are achieved owing to light interference caused by passage through 100 of the finest adjacent layers of the foil. A holographic effect is achieved by laser embossing technology. “Geometric” (or “holographic”) pigments added to the polymer give an effect resembling the bright twinkling of stars in the night sky or the play of a diamond under party lights. Transparent articles containing geometric pigments shot with gold, silver, or copper look most effective against a dark (black or blue) background. Likewise, using non-transparent dull glitters, it is possible to obtain, for example, a granite effect.

Pigments and dyes are not universal. For example, for the colouring of polyolefins, it is not recommended to use polymer-soluble dyes on account of their proneness to fade and low migration resistance.

The selection of the pigment for colouring is determined primarily by the conditions of processing of the material and service of the finished article. The most important of these requirements, along with the prescribed hue, is the heat resistance of the pigment, i.e. its ability to withstand the processing temperature of the polymer, resistance to reagents of the polymer composite and to process additives, light and weather resistance, migration resistance, high dispersability, and physiological harmlessness. Here, the physicomechanical properties should not change when the pigment is introduced.

The colour of plastic articles can also be influenced by process factors. Change in colour can occur both during the manufacture of an article (during the processing of plastics) and during service. The appearance of the article (after its manufacture) often deteriorates considerably. And this is not random, since defects in the plastics processing technology appear most often during the service of articles. Therefore, in the production of plastic articles, it is necessary also to take these factors into account.

The combination of differently coloured internal and external surfaces of articles produced on special multibarrel injection moulding machines and extrusion units using coextrusion heads is extremely effective. Most indicative is the volume pattern (structure) in articles cut out of sheet. Multilayer sheets are often used by designers.
to convey mood. Many variously coloured layers are laid on top of one another and, together, give a quite different colour. The article gives an impression, for example, of a brown colour, but, if the angle of view is changed ever so slightly, it suddenly begins to radiate a lilac colour, or a green colour, or even a red colour. Milled articles are made from multicoloured sheet produced by the “green block”, compression moulding, or extrusion methods. The “green block” technology has been inherited from the days of sheets of plasticised cellulose nitrate (celluloid).

The use of diluents, the many stages, the long cycle, and technological problems have not reduced the keen interest of producers in such plastics. This expensive process, which has already existed for half a century, makes it possible to produce amazing decorative effects. Multicoloured sheets of plasticised cellulose acetate and PVC are now being produced by this technology.

The structure of the compression moulded sheet consists of elements making up a certain pattern. The blanks necessary for making up the pattern are produced by extrusion using special attachments for forming a flow of discharged melt and for its subsequent grinding. A batch of material in a certain sequence is laid out in the compression mould with account taken of the pattern required. Since the plastic being used is a thermoplastic material, the compression mould is initially heated to 180 ± 10°C, held at a pressure of 100 kN/m², and then cooled, without removing the pressure, to a temperature of 50 ± 10°C.

During extrusion, the pattern of the sheet is determined by the design of the coextrusion head and the number of extruders. Thus, it is possible to produce a multilayer sheet or a sheet resembling a tortoise shell, and also certain other pattern variations.

In practice, use is often made of combinations; for example, a multicoloured film produced by the “green block” method is bonded to an extruded sheet.

Surface decoration is possible by the following methods:

- machining of the surface (tumbling, abrasive jet treatment);
- the application of a decorative coating [surface colouring with paint and varnish materials, printing (relief printing – letterpress, flexographic; plane printing – offset, intaglio, stencilling; indirect relief printing – typo-offset, indirect intaglio, indirect stencilling), embossing, appliqué (overlaying, shaping), transfer (wet, dry, thermal), metallisation (chemical metallisation (coating by chemical conversion), electroplating, and metallisation by vacuum atomisation, by pressure spraying, and in a fluidised medium of dispersed metal)];
- the creation of a surface using moulding tools (the application of special compression moulds, extrusion heads, etc.).

A gloss is characteristic of a well polished surface. As a result of polishing, light is mirror-reflected from the surface without any selective absorption. In a well polished article, all defects of the material stare one in the face, but the play of colour dreamed up by the designers and realised by the production engineers can be appreciated to the full. The first and simplest means of distinguishing the real thing from a fake is to compare the gloss of articles. In most cases, a gloss is achieved by a high purity class of the shaping surface of the tool and by the composition of the polymeric material. If, in the manufacture of an article, use has been made of machining methods (milling, turning, etc.), then, to achieve a gloss, tumbling is used. The process usually consists of 4–6 stages (depending on the technology developed by each individual company and jealously guarded by them). Apart from the tumbling drum, carriers are needed, and also an abrasive – pumice, glass powder, etc., and special oil. Most often, the abrasive is premixed in some liquid until a pasty consistency is obtained. Let us give an example of the tumbling process:

Stage 1 Rough grinding is carried out using diamond-shaped carriers, special oil, and a comparatively coarse pasty abrasive; duration 15–40 h.

Stage 2 Fine grinding. Finer abrasive particles; duration 15–40 h.

Stage 3 Polishing – is carried out using wedge-shaped carriers and an abrasive resembling cheese curd in consistency. Duration 30–60 h.

Stage 4 Washing. After grinding and polishing, the mounts are washed in a special ultrasonic machine to remove particles of coarse abrasive.

Stage 5 At the stage of glossing, the abrasive resembles cream. Duration 15–30 h. Only after this stage do the articles acquire a gloss and lustre.

According to some designers, it is necessary to give the surface of articles the feeling of a natural surface finish – to produce a superior mat surface – a velvety effect. For this, tumbling is ended at the second stage, or, instead of the glossing stage, a mat finish stage is carried out (a special mat finish paste is added).

Methods of surface colouring include colouring from baths (dipping), brushing, rolling, wiping, and spraying.

When colouring compositions are applied to the surface of a plastic article, the dye, together with the solvents, penetrates into the surface layer of the polymer, which swells partially and in this state promotes their further penetration and subsequent fixing of the coating. The diffusion properties of the materials increase with increasing temperature.
Colouring by dipping is carried out from highly dispersed suspensions of dye in a solvent. To intensify the process, besides the solvent (for example, water), additives and surfactants are introduced into the colouring bath to activate the process of dye adsorption. Components to be coated, hanging from the conveyor, are immersed successively into the bath with the dye. The conveyor moves such that, as the components leave the bath, any excess dye manages to run off back into the bath, and the components, on the same conveyor, start to dry.

To colour with a sprayer, a solution is prepared: polymer + dye + activator + solvent. The article is covered with the solution, often through a stencil. If two or three stencils are used in this case, taking a new solution colour each time, then it is possible to achieve a fairly food decorative effect.

Colouring by brushing differs little from painting.

The application of paint and varnish materials to the surface of articles by an elastic roller to some degree resembles the manual variant of the flexographic method of printing. In the presence of the appropriate relief elements on the surface of the article or roller, it is possible to produce colourful patterns.

Colouring with a wiper is used in those cases where, on the surface of the articles, there are specified points to be coloured (for example, in the digital scales on instrument panels). The wiper is a trowel, by means of which the dye applied in excess is removed from the surface of the article, remaining in this case in the corresponding hollows.

Colour produced by surface colouring is comparatively non-fast, the dye migrates with time and fades, and therefore articles coloured by this method are normally coated with polyurethane, acrylic, or epoxy lacquers.

Coatings containing polymer microspheres are unusual. They transform relatively inexpensive plastics into materials with more valuable and attractive properties. These modified plastics feel and look like natural materials, retaining a number of functional advantages inherent in plastics. Coloured polymer microspheres have a wide range of application. The size of the microspheres lies in the range 10–200 µm, and their colour range is very wide. By combining different types of polymer or mixing particles of different colours and size, it is possible to achieve unusual decorative effects, to obtain a superior mat surface, to create abrasive-resistant coatings, to enhance their light resistance, and to give, e.g. a film of PVC, the velvety feel of natural leather.

Assessment of an article is based not on its purely external decorativeness but on the correct determination of the functional task of its colour, its plastic expressiveness, the appearance of shape design features, and accurate distribution of colour ratios.

Colour and shape are the main characteristics governing the individuality of the appearance of articles. Of course, shape, determined largely, in turn, by the functional designation of the article and the type of material from which it is made, is one of the main qualitative characteristics. Colour is normally allocated a secondary role. However, colour gives charm and individuality to the shape, together with which it is viewed. It is quite probable that each shape will have its own strictly defined colour (combination of colours). In view of the practical insolubility of this problem, the manufacturer of the article often proposes 2–4 variants of colour designs for the same article shape. And this more often than not makes the marketing of the article more difficult, not easier.

Here, in our view, it must always be remembered that, in contrast to the functional designation, the shape and colour of the article are subjects of fashion. What is avant-garde today is old-fashioned tomorrow. What was aesthetically unappealing yesterday may be the height of fashion today.

Thus, we understand the term "colour" to mean nothing more than simply the colour of the article. However, the concept of colour includes the dye characteristic, the method of achieving it, the surface finish, and the colour pattern of the surface and/or volume of the article.

REFERENCES


(No date given)