ADDING VALUE TO ROTATIONAL MOLDINGS WITH COLOR & SPECIAL EFFECTS

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Abstract

This paper reviews the different ways of adding color in rotational molding and provides technical and economic arguments for each method.

The effects of pigment incorporation on base material properties are discussed and the importance of factors such as pigment type, pigment loading and method of mixing are examined in relation to material processing, physical properties and the aesthetics of the final rotomolded part.

The use of special effects such as stone and antique look colors to give further value enhancement is discussed.

Background

The history of the rotational molding industry is a worldwide success story. Since the early days of its development, the industry has grown at a consistently rapid pace. In recent times particularly, customers for rotomolded parts have become increasingly more demanding in terms of both physical performance and aesthetics.

In the rotomolding industry, *color* is widely used to provide both aesthetic appeal and product differentiation. In terms of its effect on customer perception, color can therefore be seen as a universally beneficial feature. However, from the point of view of the molder, the use of color can present a series of challenges which must be understood and addressed.

Color will add cost, may introduce an extra degree of variability into the process and may result in a deterioration in the physical properties of the molding compared to a completely uncolored part.

The use of color in rotomolding is well established and would, from an initial view, appear to be well understood. However, a close examination of current accepted practice indicates that this level of understanding is not universal and that the real issues are sometimes obscured behind 'rules of thumb' which do not always serve the industry well.

One key purpose of the current paper is to clarify some aspects of the use of color in rotomolding, particularly from the standpoint of the material supply industry.

In recent years, molders and their customers have started to ask for aesthetic effects beyond what a single block color will deliver. For example, the garden and home use market has begun to require effects that obscure the fact that the molded article has been manufactured from plastic. Specialist material suppliers to the rotomolding industry have responded by developing rotomoldable plastics giving the appearance of stone and weathered terracotta. These materials, whilst extremely effective visually, can introduce a *further* level of variability into a process with more uncontrollable features than most molding techniques.

Choice of Pigments for Rotomolding

The correct choice of pigment is absolutely vital to the success of a colored rotomolding material. The rotomolding process puts demands on a pigment which are different from many other plastics molding techniques, particularly in relation to heat stability. Whilst maximum temperatures inside a rotational mold are similar, or even slightly less, than those experienced in the barrel of an injection or blow molding screw, heat will be applied to the plastic for a much longer period of time. This means that pigments for rotomolding must be extremely robust as far as heat resistance is concerned. Temperature stability data is available from pigment manufacturers, but this data is invariably related to extrusion or injection molding and stability data for prolonged exposure to heat is not widely available. Specialist rotomolding color suppliers have found it necessary to generate their own stability data.

The majority of rotomolded parts are destined for outdoor usage and therefore light stability of pigments is another significant issue for rotomolders. Data from pigment suppliers relating to plaques prepared by other molding techniques is relevant in most cases, provided the base material is similar to that used in rotomolding (this is invariably some form of linear medium density polyethylene).

The combined pressures on pigment choice created by the need for excellent heat and light stability means that the available 'palette' of pigments that can be used for rotomolding is restricted. Further restrictions, like the constraints on using cadmium based pigments in some European countries, further reduce choice.

Pigment Incorporation Methods

Color for rotomolding has traditionally been incorporated in the base polymer by one of two methods:

Dry blending - mixing pigment into natural powder
Pre-color - melt extrusion of pigment and natural pellets to form colored pellets, followed by pulverizing to powder.

Dry blending methods have been further subdivided by the suggestion that high intensity mixing, particularly with the generation of frictional heat, significantly improves the physical properties of the finished part.

Dry blending has proved to be a low cost method with the significant advantage of operational flexibility. A single shipment of natural powder can be converted into a variety of different colors within the molder's own facility.

Pre-color is generally viewed as offering superior performance in respect of aesthetics and physical performance, but at an increased cost in terms of material price and longer delivery lead time. Operational flexibility can also be lost since very few molders have in-house compounding facilities.

The choice of pigment incorporation method employed for a particular application will invariably be a compromise between the conflicting requirements of price and performance. Some of the main performance factors to be considered are outlined below.

Aesthetics

Pre-colored materials are widely favored for applications where aesthetic considerations are paramount.

When asked to provide a colormatch, the colorist is frequently asked to match against customer samples such as painted metal. This creates a significant point of discussion regarding the *opacity* of the colormatched plastic in relation to the original sample.

Polyethylene in its natural (uncolored) form is a translucent material and opacity has to be achieved by the addition of pigment. Although different pigment incorporation methods will have some effect on the degree of opacity achieved, this is generally a relatively minor factor. The overriding factor will be the pigment addition rate. How much pigment is required to achieve full opacity will vary significantly depending on the types of pigments used.

Opacity will also be significantly affected by the thickness of the molded part and discussions on opacity are particularly relevant to thin walled parts in the region of 3mm thick.

For many colors, a fully opaque match will only be achieved in a thin walled part by using pigment addition rates in excess of 0.5% (225 g/ 100 lb). Such addition rates simply cannot be achieved with dry blending without an unacceptable loss of physical properties.

Pre-colored materials also offer enhanced aesthetics in relation to surface finish inside and outside the molding. The extent of the enhancement varies depending on color. Whites and pastel shades demonstrate particular improvements in surface appearance.

Physical Properties

Incorporation of pigment will have some effect on many of the physical properties of the base material, but for rotomolders the key criterion is the effect on *impact properties* of the final molded part. Most applications for rotomolding require parts to be tough and resistant to repeated impacts.

Achievement of optimum impact strength is dependent in a major way on correct processing during the rotomolding cycle. This subject has been extensively discussed elsewhere[1] and a method has been described by which rotomolding materials can be characterised.

Typical material characterisation curves for a natural linear medium density polyethylene are shown below. Fig 1 shows the development of low temperature (ARM method) impact strength in a sample material as cook time is increased. Once fusion has been achieved (in this case after 8 min) the impact strength increases until severe overcooking (beyond 17 min) causes catastrophic loss of properties.

The impact strength curve only shows a very limited aspect of the situation. Henwood and Keates reported a much more sensitive and relevant means of characterisation was to study the failure mode of impact samples. They defined a simple and easily measurable criterion, the *percentage of brittle failures* which occurred in a test.

A typical plot of the brittle failures criterion for the same material characterisation is shown in Fig 2. Here it can be seen that samples in the undercook state (below 11 min in this case) exhibit a high degree of brittle failure, even though they have good impact strength. Once optimum cure conditions are reached, samples fail in a purely ductile fashion (ie zero brittle failures). Overcooking (above 16 min in this case) results in sample brittleness, even though impact strength is still high. The *molding window* for the material can be defined as the range of cook times where samples fail in a fully ductile fashion.

Different materials can be compared by using this simple characterisation method.

Table 1 shows a comparison of Low Temperature Impact Strength in J (ARM method) for three different color formulations: blue, red and white.

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[1] NG Henwood and R Keates, "Achieving Optimum Cure In Rotational Moulding", *21st Fall Meeting ARM* (1996)

Each color formulation was prepared using three different pigment incorporation methods: full melt compounding, low shear dry mixing and high intensity dry mixing. In order to make the tests more realistic, the pigment addition rate used for the pre-color material was halved when applied to the dry mix samples.

Table 2 shows a comparison of %age Brittle Failures at optimum cook conditions for the same three colors and pigment incorporation methods.

The results demonstrate a number of important factors which need to be considered when making a choice of pigment incorporation method:

Consistency: Colors prepared by melt compounding showed approximately equal impact strengths. There was significantly more color-to-color variation for the dry mix methods.

Opacity: The melt compounded versions were double strength compared to the dry mix versions, but always had better impact strength. This reinforces the previous comments related to opacity.

Low shear vs. high shear mixing: The results are varied. In the case of the blue formulation, low shear gave marginally better results. In the case of the red, the low shear results were inferior. In the case of the white, the low shear results were significantly worse.

Brittleness: A very clear and important phenomenon is apparent. It is only possible to achieve low temperature ductility by incorporating pigments with melt compounding. Dry mixing creates moldings which are universally brittle in the low temperature condition. There is *no difference* in this respect between low shear and high shear mixing.

Moldability

From the data described above, it might be assumed that pre-colored materials behaved essentially the same as natural materials. Whilst it is true that most measured physical properties, including impact strength, are retained if pigment is added via melt compounding, addition of color can significantly affect processability. The effects on the *molding window* are especially significant.

Fig 3 illustrates the phenomenon. The %age Brittle Failures for natural and pre-color blue materials are shown across the whole cooking window. It is immediately apparent that the molding window (as defined by the criterion of zero brittle failures) has been significantly altered by the addition of pigment.

Firstly, the molding window of the blue material has shifted to the left. Ductility starts at 8 min cook for the blue material compared to 11 min cook for the natural. In this case the blue pigment formulation is causing the base resin to achieve ductile cure more quickly.

Secondly, the molding window has narrowed. The molding window for the blue material is 3 min compared to 5 min for the natural material. The blue pigment formulation appears to be promoting overcooking.

Table 3 gives an assessment of the effect on the molding window of three different color formulations compared to natural.

The width of the molding window is shown, as well as the cook time at which the molding window begins (ie the cook time at which ductile behaviour is first apparent).

Comparison of the three colors show significantly different behaviours.

As previously discussed, the blue pigment formulation appeared to *promote* fusion of the powder particles and therefore ductility was achieved sooner.

In contrast, the red and white pigment formulations both appeared to *delay* fusion of the powder particles and therefore ductility was achieved significantly later.

All the pigment formulations narrowed the molding window to some extent - this was particularly serious in the case of the red formulation.

These effects are of great practical importance to the rotomolder; products often have to be produced in a range of different colors. Molding cycles will need to be optimised *for each color*, even if pre-color is used.

Special Effects

A large part of the success of the rotomolding industry has been its willingness to innovate and develop in line with customer requirements. Visual enhancement of products has become an area of increasing importance as customers demand that rotomolded products have all the benefits of plastics but display a more ‘natural’ look. A leading example of this trend is the home and garden market, but there are many other leisure markets now moving in the same direction.

Visual relief from the monotony of a single block color can be provided in very simple ways. The addition by dry blending of a small amount of compounded black powder into a regular colored powder can give visual interest. There is also the additional benefit that scratches and other surface imperfections are less apparent for parts made with this type of 'speckle' effect.

Simple 'home-made' speckles are cheap and easy to produce and sometimes work well, particularly for relatively small moldings. However, even the simple expedient of adding a small amount of black can have significant effects.

If the base resin used in the black is not identical to the base resin used in the color, significant increased brittleness can occur.

As would be expected, the added black darkens the overall color. It also tends to make any shade more 'blue'. For example, an orange/ red shade would be likely to turn to a more red/ purple shade by the addition of black.

Most seriously, *swirling effects* can occur, especially in larger moldings. The dark component of the mix concentrates itself in certain areas of the mold and appears on the molding as an unsightly smear which ruins the aesthetic effect. It is believed that swirling problems are related to static charge created by the polyethylene powder rubbing against the mold surface. However, the effects are highly intermittent and variable in nature and the simple addition of anti-stats does not cure the problem.

Stone effects are extensions of the 'speckle' concept. Different pre-colored powders can be dry mixed together to create effects which look similar to different types of naturally occurring stone.

The variability problems described above are even more prevalent in stone effects. However, they have been overcome as the result of extensive research and at least one specialist material supplier is now offering 'no swirl' stone effect materials.

This success in overcoming the processing and quality problems traditionally associated with stone effects has prompted the development of an increasingly wide range of new effects. Most noticeable is the development of 'antique' or 'weathered' look terracotta effects, which give a very close replication to traditional clay materials. These products have had a major effect on the planter market, which previously relied on a simple pre-color terracotta look which was very obviously plastic in nature.

Discussion and Conclusions

Visual enhancement, whether by the use of a simple color or by using a more sophisticated special effect, has become a major issue in rotomolding today. Increasingly, end-use customers are demanding visual as well as physical performance enhancement. If rotomolders are to continue their success in meeting the needs of their customers, they must continue to be able to respond positively to such demands.

This paper has demonstrated that for most types of visual enhancement, the molder pays a price in terms of increased operational complexity and additional process variability. This is now a fact of life in today's rotomolding market.

Material manufacturers bear an increased responsibility to support their rotomolding customers with detailed information on the products they supply. The days where a simple Material Data Sheet containing a few standard test results (often not even conducted on rotomolded samples!) would suffice are gone. Today's modern rotomolding industry needs supportive material supplier partners who are prepared to commit resources to more accurately defining the behavior and performance of the materials they supply.

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Key Words

Rotational molding, colors, special effects, impact strength

Table 1: Effects on Low Temp Impact Strength (J)

	BLUE	RED	WHITE
Melt compounding	73	78	85
Low shear dry mix	69	53	21
High intensity dry mix	62	67	50

Table 2: Effects on %age Brittle Failures (%)

	BLUE	RED	WHITE
Melt compounding	0	0	0
Low shear dry mix	100	100	100
High intensity dry mix	100	100	100

Table 3: Effects on Molding Window

	WIDTH (min)	START (min)
NATURAL	5	11
BLUE	3	8
RED	1	17
WHITE	2	14

Fig 1: **Impact Strength**

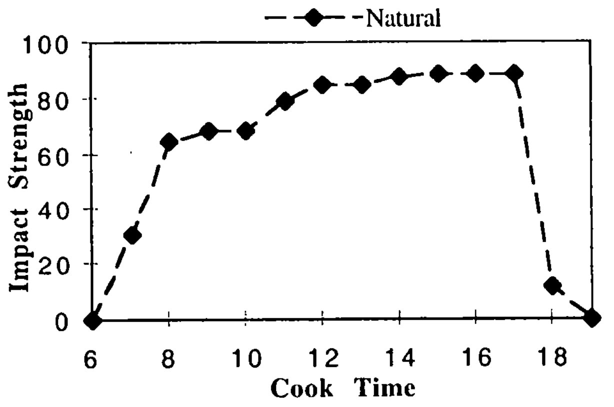

Fig 2: **Brittle Failures**

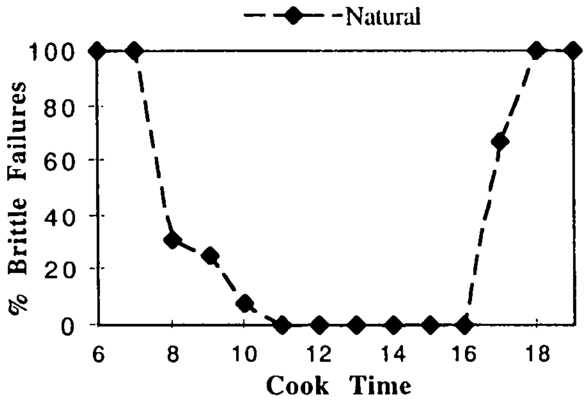

Fig 3: **Natural vs Blue Pre-color**