# EFFECTS OF PIGMENTATION ON THE IMPACT STRENGTH OF ROTATIONALLY MOULDED POLYETHYLENE

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## ABSTRACT

Rotational moulding does not benefit from the high shear which is present in other processing methods such as injection moulding or extrusion. Hence, rotational moulders have a dilemma because there are distinct advantages in doing in-house colouring (eg economics, large quantity purchases of natural resin, etc) but it is difficult to get good dispersion of the colour. Compounding of the pigment into the polyethylene before grinding to a powder for rotational moulding gives a much more consistent colour and better mechanical properties, but it is expensive and restricts flexibility in regard to material purchases.

This paper describes the results of an experimental programme to quantify the impact strength of rotationally moulded polyethylene as a function of three different pigmentation methods - dry mixing, turbo-blending and compounding. Different additive levels of a wide range of pigments were used and the results show that the processing window is much broader than was previously believed. This is important practical information for the moulder because these effects have never been quantified before. Another important outcome of the work is that it is shown that it is not possible to generalise in regard to the effects of pigments. Whilst impact strength can be retained across a broad range of parameters for some colours, this is not true for other colours.

## INTRODUCTION

Rotational moulding is a manufacturing method whereby hollow plastic articles are constructed by causing plastic powder to melt and form a coating on the inside surface of a heated, rotating mould (1, 2). This moulding process is different from most other such methods because no stress is used to cause the molten plastic to take up the shape of the mould. In some circumstances this can be an advantage because residual stresses are minimised in the end-product. However, it can also be a disadvantage if one is trying to encourage mixing of an additive, such as a dry pigment, during the moulding operation (3, 4). For the moulder there are significant advantages in purchasing natural material in bulk and introducing the colour during the moulding operation. However, experience has shown that such mouldings tend to be less strong than mouldings produced from plastic material which has the colour introduced at the compounding stage (3). However, this tends to be an expensive route for the moulder and so new techniques such as turbo-blending are becoming popular (4). In this case the moulder can cause the powdered pigment to bond to the surface of the plastic powder by rotating both together at high speed in an elevated temperature environment.

There are many views from the industry about the relative merits of each method but no one has quantified the effects. This paper sets out to investigate the impact strength of rotational mouldings obtained using material produced by each of the three different pigmentation methods.

## MATERIALS AND EXPERIMENTAL PROCEDURE

The plastic material used for this study was BP Rigidex HD 3560 - 1 UA (density = 935 $kg/m^3$, MFI = 6). The pigments used were

- Blue - Ultramarine Blue
- White - Titanium dioxide
- Black - Carbon black
- Green - Phthalocyanines Green
- Red - Cromophthal Scarlet

The turbo-blending was carried out on a CACCIA AVO 150C Turbomixer. The compounding was done on a Killion single screw extruder and the granules were ground to powder on a WEDCO SE-12

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grinder. The mouldings were produced on a Ferry Rotospeed 1600 carousel-type machine. A ROTOLOG device was used to measure to monitor the temperature inside the mould throughout the moulding cycle. The thickness of the mouldings was 5 mm in all cases and the oven cycle was set so that the air temperature inside the moulding always reached 200°C. The impact strength of the moulding was recorded using a ROSAND IFWIT 7U instrumented impact tester.

## RESULTS AND DISCUSSION

A variety of mixing speeds and mixing temperatures were used in the turbomixer to see if these parameters affected the quality and properties of the powder and/or the impact strength of the moulded product. In all cases the Bulk Density and the Dry Flow of the powders decreased as the mixing temperature increased in the region 40°C - 80°C. (see Table 1). However, it was found that there was no measurable effect on energy to break in either the virgin material (turbomixed on its own to set the baseline) or the pigmented materials. At the highest mixing temperature of 80°C there was some evidence of a decrease in impact strength possibly due to the onset of some degradative effects. Figure 1 summarises the results for this part of the work and illustrates that turbomixing causes a reduction in the impact strength similar to that of dry mixing in the mould. There is even a suggestion that for the blue pigment, the dry mixing may produce slightly better results than the turbomixing. However, with dry tumble mixing in the mould there is a residue of colour left on the surface of the mould. All of the pigmented samples failed in a brittle manner whereas the unpigmented mouldings failed in a ductile manner.

For some of the colours the amount of pigmentation caused large differences in the impact strength of the mouldings. The results for turbo-blended material are shown in Figure 2 - the effects for dry mixed pigments are similar. It may be seen that with the red pigment, the toughness of the material drops off quite steadily as the percentage pigment is increased. The green maintains a good impact strength at 0.05% but then drops off very rapidly. The white pigment showed good performance across a range of additive levels, possibly because it was very fine and did not have a tendency to form agglomerates - as occurred with the blue pigment, for example. However, the black pigment also showed excellent results although it has relatively large particles. In all these tests the turbomixing was done at 1400 rev/min and 50°C.

The interesting thing about the compounded results is that impact strength was largely unaffected by the amount of pigment used. This is illustrated in Figure 3 for the blue pigment. At low pigment concentrations the turbomixing appears to be better than the compounded material but it should be remembered that the compounding was carried out using a single screw extruder. Hence the mixing and homogenisation may not have been as complete as would occur in a commercial compounding line. Figure 4 compares the effects of turbomixing and compounding for the 0.3% pigment loading level. In these trials the mixing speed was 1400 rev/min and the mixing temperature was 50°C.

These results are part of an on-going study but already show some very interesting trends. For example, pigmentation levels should generally be lower than those currently used because good colour quality can be maintained at the lower levels and toughness is significantly better. There is an indication that organic pigments (green and red) show poorer impact properties than inorganic pigments but this has to be confirmed with additional testing. It is very clear that compounding gives much more consistency in the degree of mixing but the improvement in toughness may not be as great as was anticipated. At very low levels of pigmentation, turbomixing (or indeed dry blending) appear to be as good as compounding.

### CONCLUSIONS

From this investigation of different pigmentation methods during rotational moulding the following conclusions have been drawn:

(1) The speed and temperature of turbo-blending can affect the physical nature of the plastic powder but do not have any significant effect on the impact strength of the moulded product (0.3% pigment loading).

(2) Dry tumble blending in the mould and turbomixing produce mouldings with similar impact strength (for 0.3% pigment loading). However, the former method causes a residue to form on the mould and this can affect the performance of the release agent.

**Table 1** **Bulk Density and Flowability Data**

| Code | Bulk Density (g/l) | Flowability (g/s) |
|---|---|---|
| Virgin Polymer | 368.9 | 4.45 |

Virgin Polymer Not mixed.

| Mixing Temp. (°C) | Bulk Density (g/l) | Flowability (g/s) |
|---|---|---|
| 40 | 379.5 | 4.92 |
| 50 | 378.7 | 4.92 |
| 60 | 381.7 | 5.20 |
| 70 | 381.2 | 4.92 |
| 80 | 380.4 | 4.92 |

Virgin Polymer with No Pigment Mixed at 1200 rpm

| Mixing Temp. (°C) | Bulk Density (g/1) | Flowability (g/s) |
|---|---|---|
| 40 | 381.1 | 5.50 |
| 50 | 383.3 | 5.50 |
| 60 | 375.8 | 4.92 |
| 70 | 376.7 | 4.92 |
| 80 | 368.8 | 4.45 |

Virgin Polymer with Blue Pigment Turbo Blended at 800 rpm

| Mixing Temp. (°C) | Bulk Density (g/l) | Flowability (g/s) |
|---|---|---|
| 40 | 384.1 | 5.50 |
| 50 | 375.8 | 4,92 |
| 60 | 377.7 | 5.20 |
| 70 | 373.4 | 4.68 |
| 80 | 369.6 | 4.68 |

Virgin Polymer with Blue Pigment Turbo Blended at 1200 rpm

| Mixing Temp. (°C) | Bulk Density (g/1) | Flowability (g/s) |
|---|---|---|
| 40 | 376.5 | 5.20 |
| 50 | 377.5 | 5.20 |
| 60 | 378.9 | 5.20 |
| 70 | 372.5 | 4.68 |
| 80 | 367.1 | 4.45 |

Virgin Polymer with Blue Pigment Turbo Blended at 1600 rpm

(3) During turbo-blending the mixing speed and temperature can have an effect on the colour shade in the moulding. Incomplete mixing produces a deeper shade.

(4) From this work good quality mouldings were obtained in all colours with a pigmentation loading of 0.15%. For black this level could be reduced to 0.1% and mouldings with good colour were produced. This level (ie 0.1% would be preferred in the two organic pigments tested (red and green) but the colour quality was barely acceptable when turbomixing was used.

(5) In general, melt compounding produces a deeper shade of colour.

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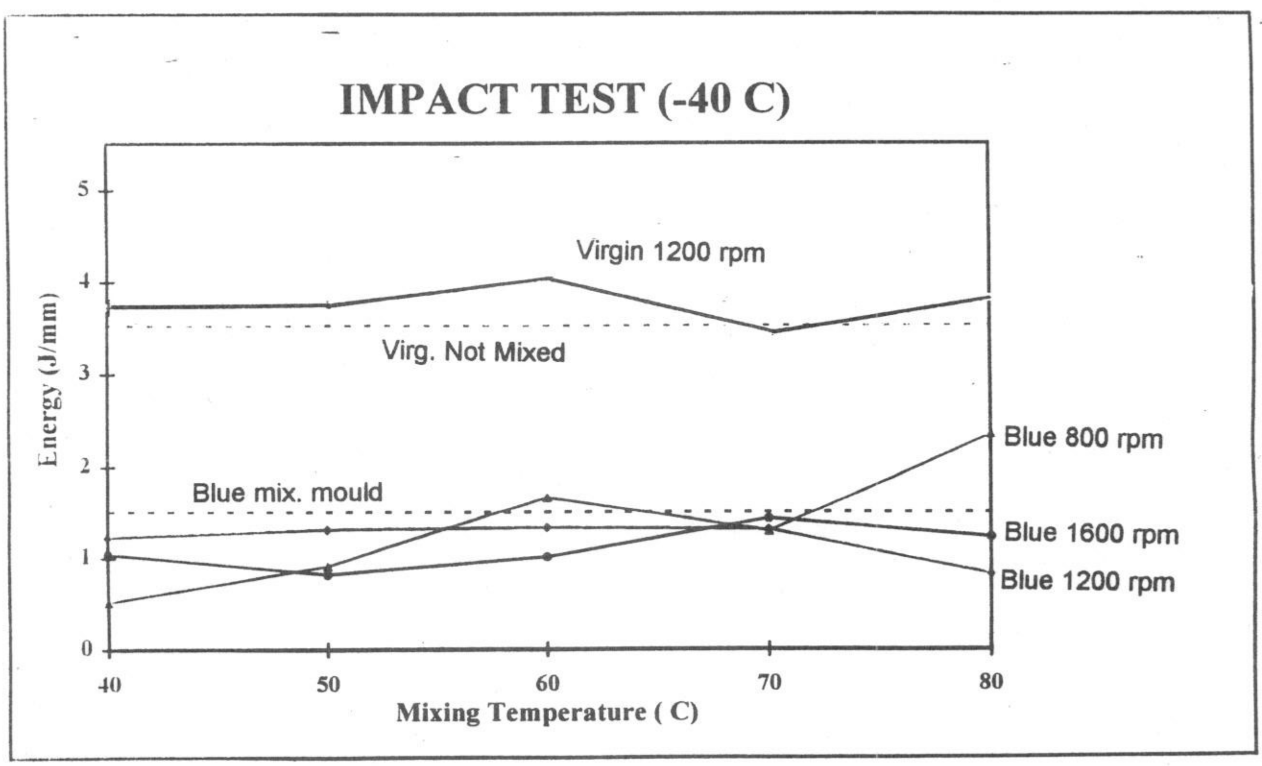

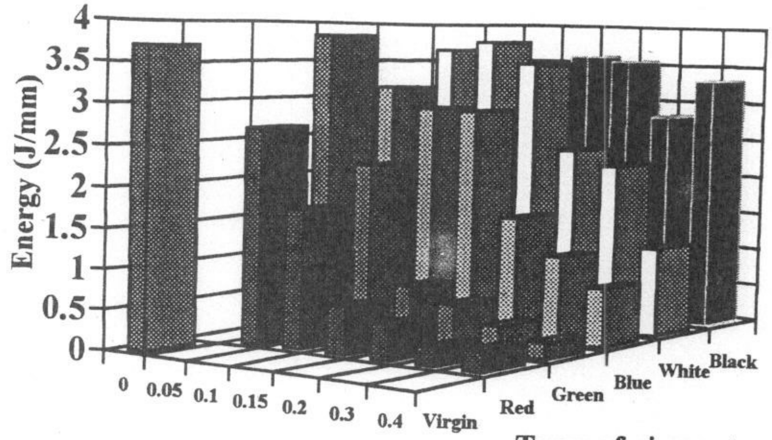


IMPACT TEST (-40 C)