Effect of Carbon Black On UV Stabilization of PE Rotomoulding

Introduction of UV Stabilization's:

Finished PE products designed for external applications may degrade in use, with time. They are said to "weather" when their structure changes due to light, heat, moisture and oxygen contact. Plastics absorb sunlight radiations and undergo photo-chemical reactions. Oxidation occurs leading to an alteration of their colour, texture or composition resulting in impact loss, embrittlement, chalking or surface cracking. Out of the whole solar emission spectrum, only the smallest part, the 290-400 nm UV region, is responsible for most of the polymer damage. Photo-oxidation of polyethylene proceeds by a free radical chain mechanism in presence of oxygen: the ultraviolet light absorbed by the polyethylene provides sufficient energy to break key molecular bonds and generate free radicals that propagate to give hydroperoxides, compounds containing hydroxyl, carbonyl and vinyl groups, which also absorb UV radiation and undergo further degradative processes. As a result, succession of chain scissions and chain recombination's (crosslinking), including more fragile units, induces drastic physical degradations

In order to limit or postpone the onset of degradation, several types of UV light stabilizers can be added to the polymer. The most important stabilizer types work by screening out the harmful ultraviolet light - for instance UV absorbers such as benzophenones or small dispersed particles such as carbon black or inorganic pigments. Other very effective UV stabilizers are UV quenchers and HALS (Hindered Amine Light Stabilizers).

UV Stability in Water Tanks:

Cylindrical vertical tanks are commonly used for outdoor applications and hence, usually manufactured from

polyethylene resin with addition of carbon black OR Colored with UV stabilizers.

Rotational moulded polyethylene water storage tanks may be produced either with monolayer or multilayer wall construction. For multilayer wall construction, the wall shall consist of minimum two layers to maximum five layers. Tanks produced from multilayer walls, provide improved overall performance and service life owing to each layer providing desired specific functional property. Each layer of the wall shall have uniform thickness.

For monolayer wall construction, compounded resin of polyethylene and carbon black shall be used. Carbon

black provide desired outdoor weathering resistance. A fine, well-dispersed carbon black provides the best. For multilayer wall construction, the typical wall design comprises of inner layer, in contact with water, of white colour and the outer most layer, which is also exposed to the sunlight, shall be of black colour. The thickness of outer layer shall be minimum 50 percent of the total wall thickness. The middle layers, also called as core layers, may be a single layer for 3-layer tank to maximum three core layers for 5-layer tank. Core layers may be made of solid or foamed polyethylene.

Carbon Black as a UV Stabilizer :

Carbon black is one of the most efficient and widespread light absorbers for plastics applications. Several important segments of the plastics industry rely on carbon black for UV stabilization of weather- resistant products like Drip laterals, Plastics Pipes, Agri films & telecommunications and power cable jacketing. Typically, a 40% Carbon Black MB is let down to achieve a Carbon black loading of 2.5% CB in a plastics products to get a desired UV stability.

1. How does carbon black work:

Carbon black is an effective UV absorber. It offers the best UV protection for plastics, by absorbing /screening out damaging wavelengths, and by inhibiting photo-oxidation via its surface

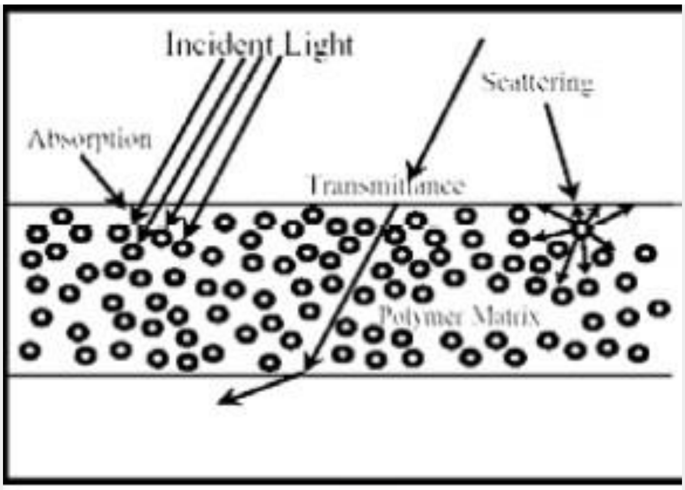

Fig1

2. Factors influencing the performance of Carbon black:

Carbon black (CB) is more than a colorant. In addition to its tinting power, electrical or filler action, it provides plastics with a long-term and low cost UV protection, stabilising polyolefins and other polymers against sunlight.

The UV protection property of CB is dependent upon the following properties:-

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- Morphology,
- Loading
- CB dispersion & Dilution

Morphology :

The morphological characteristics of carbon black are dependent on the following properties :-

- Particle Size,
- Surface Area,
- Structure.
- **See Fig 2**

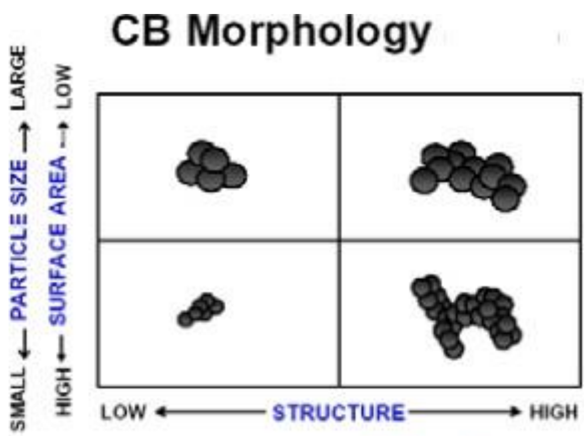
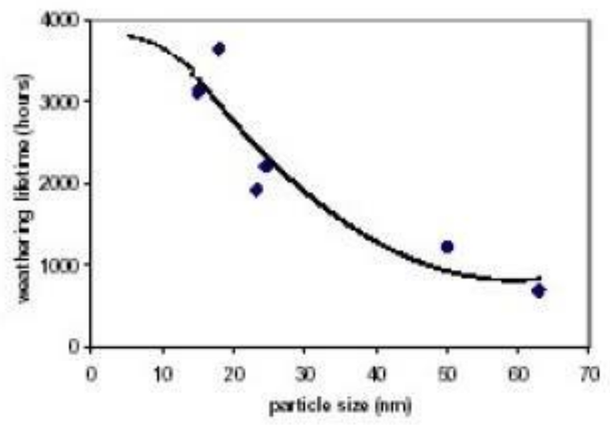


Fig2

Particle size (nm):

It is an arithmetic mean of diameters of primary particles of a carbon black grade. At the same loading a finer particle size grade would offer more surface to incident light and hence a larger UV absorbing efficiency than a coarser particle size grade.

See fig 3&4



Influence of CB particle size - at same loading - on UV stability. (75 µm LLDPE films, 2.5% CB). **[Experiment 1]**

Fig4

- CB Properties -

particle size ASTM D-3849 (nm)	surface area BET / N_2 ads. (m^2/g)	structure DBP abs. ASTM D-2414 (ml/100g)
63	30	72
50	41	125
24	78	72
23	79	102
18	120	114
15	252	68

Fig3

Surface Area(m2/g):

Surface area is determined by nitrogen absorption; smaller particles will offer a larger surface area per unit weight and hence effective UV stabilization..

Structure : Structure or DBP absorption(ml/100g) is the measure of voids volume and describes the degree to which the CB particles are fused to form aggregates.

C Black Loading levels :

The appropriate loading level depends on the part thickness, exposure condition and type of carbon black. Usually loading between 2 to 3% imparts optimum UV protection. The loading level along with the particle size decides the effectiveness of the CB. As can be seen from the corresponding curve(Fig.5 & 6),a finer particle CB at the same loading gives exceptionally effective performance w.r.t UV light absorption.

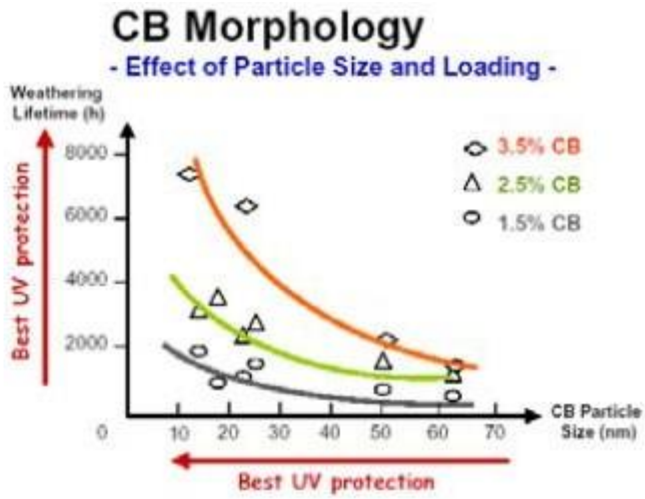


Fig5

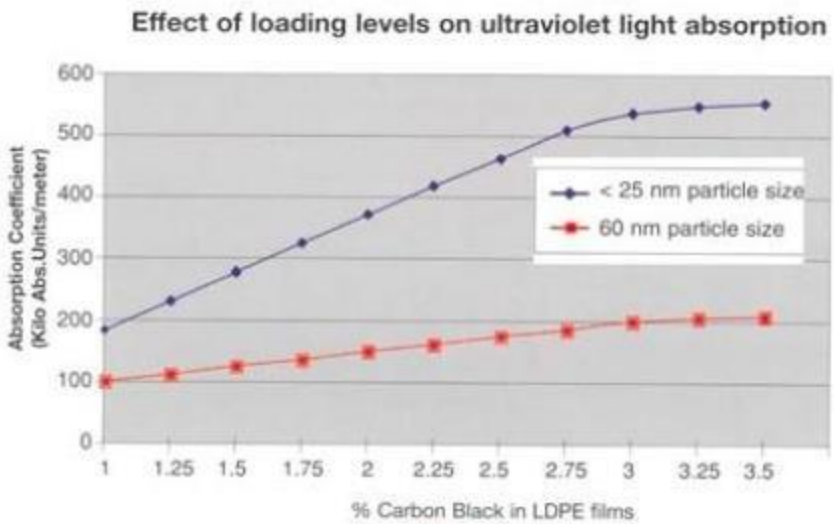


Fig6

Influence of Carbon Black Dispersion:

Choosing a correct grade of C black with small & consistent particle size is a must to get a good weathering performances. However, to get that total benefit, care must be taken to disperse them correctly in the polymer matrix. Dispersion quality impacts the final carbon black agglomerate size in the polymer:- an optimal dispersion is one that evenly distributes carbon black throughout a polymer down to the smallest carbon black units, the aggregates, - a poorer dispersion results in larger agglomerates. In the presence of agglomerates, UV light is more likely to be rather scattered than absorbed, and polymer UV degradation may start as CB screening protective effect is reduced. If the polymer processing equipment's are not good even a good quality C black MB can be poorly dispersed in a polyethylene leading to bad performance in UV protection.

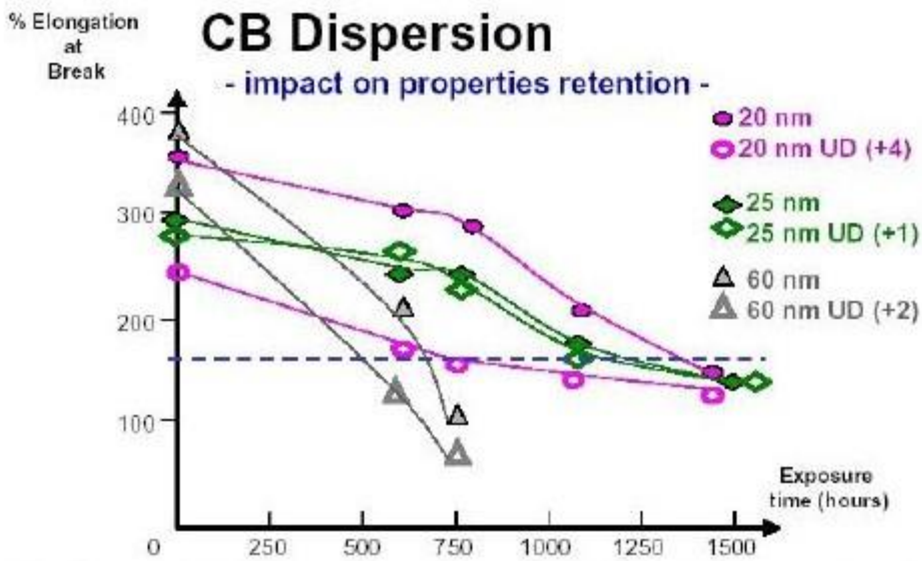


Fig7 :- Effect of undispersed CB on the % elongation at Break for different particle size exhibits poor retention in mechanical properties.

Influence of Dilution:

Carbon black in masterbatch form is typically added to the polymer while processing. The Dilution is a measure of how well and how easily a masterbatch mixes with a fabricator's polymer. Thus a masterbatch exhibiting good dilution properties will produce processed articles (film, bags,pipe, sheet, etc.) showing excellent distribution of the masterbatch within the fabricator's diluting polymer.

Conversely, a poorly diluted masterbatch will produce processed articles showing surface defects (lumps, voids,poor surface), inconsistent colour and/or opacity, streaking and inferior physical performance(See fig 8).

The masterbatch producer and end user are jointly responsible for ensuring good dilution. They have to design a total "system" to ensure the dilution process is optimized. "System" refers to the various factors which influence the dilution process, i.e.: MFI of the MB, MFI of the diluting resin, types of processing equipment (extruder, injection moulding machine, etc.),processing temperatures, production speeds, back pressure (screen packs, etc.)

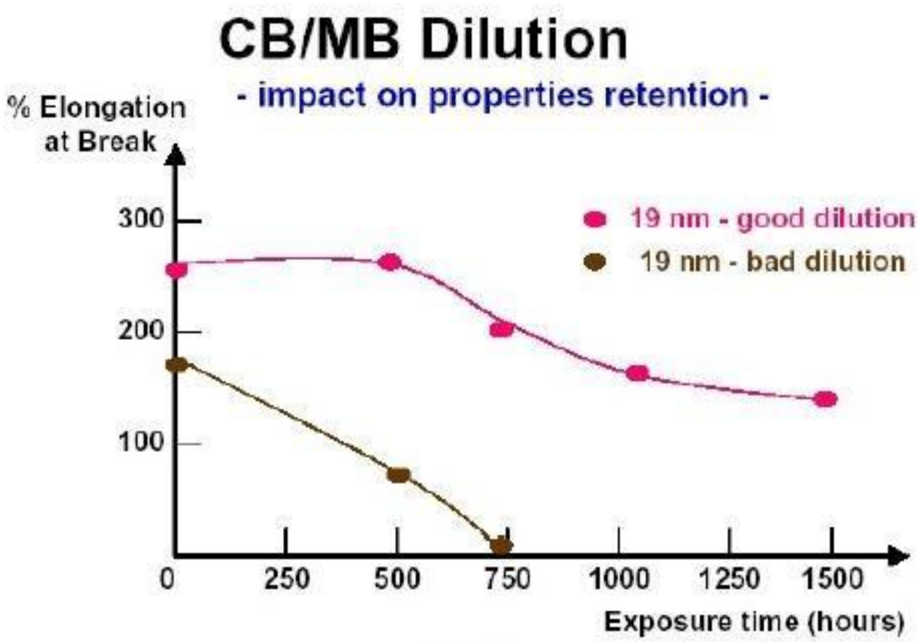


Fig8

Conclusion :-

To achieve optimum UV performance requires the "right mix" of:

- **Carbon Black Particle Size** : The C blacks of type N220 (20nm particle size) will give better UV performance compared to coarser blacks (N660 type with 60nm particle size). Further, mean particle size & particle size distribution of C black should not vary from batch to batch as it has a direct bearing on UV stability
- **Carbon Black Loading** : Optimum loading for N220 type of C blacks is 2.5%. This gives desired UV protection. Coarser blacks even at higher loading will not give desired UV performance.
- **Carbon Black dispersion quality**: C black dispersion in MB as well as end product has to be satisfactory. Even a good quality C black, if poorly dispersed, will give unsatisfactory UV performance. In order to get a satisfactory UV performance in the end- product, all the above factors must be considered prior to selection of Carbon black masterbatch.

Manoj Patria (7738383558) manoj.k.patria28@gmail.com