Specialty carbon blacks for tinting applications

Technical Information 1459

ORION ENGINEERED CARBONS

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Contents

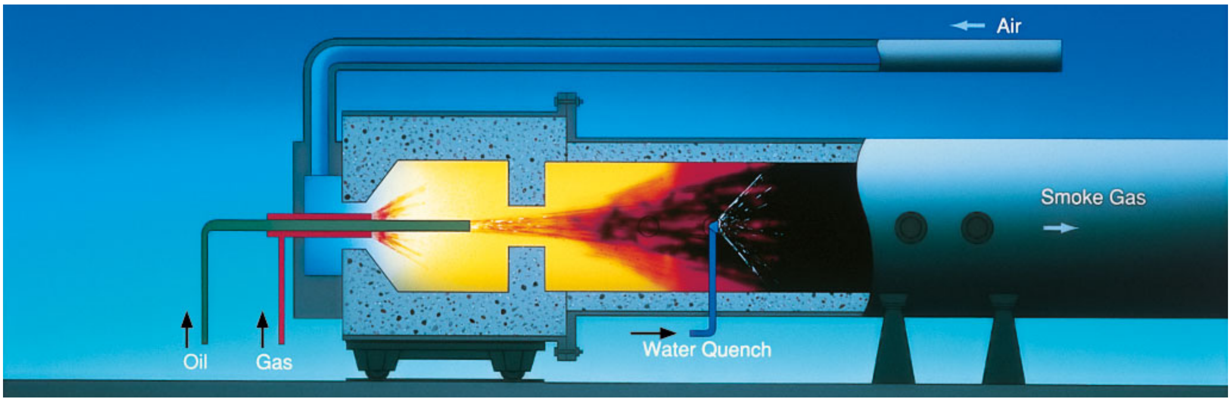
1. Introduction

In the paint and coatings industry the favourite black pigment in use is carbon black due to its outstanding performance. The coloristic properties in mass tone and tinting applications strongly depend on the mean primary particle size. Therefore, specialty carbon blacks (SCB) are categorized according to their jetness (blackness value M_Y) into high, medium, regular and low color pigments. In decorative paints for architectural purposes specialty carbon blacks are used as a tinting agent together with white or other colored pigments. The use of regular and low color specialty carbon blacks is mainly dedicated to tinting applications, which is the subject of this technical information.

2. Manufacturing processes

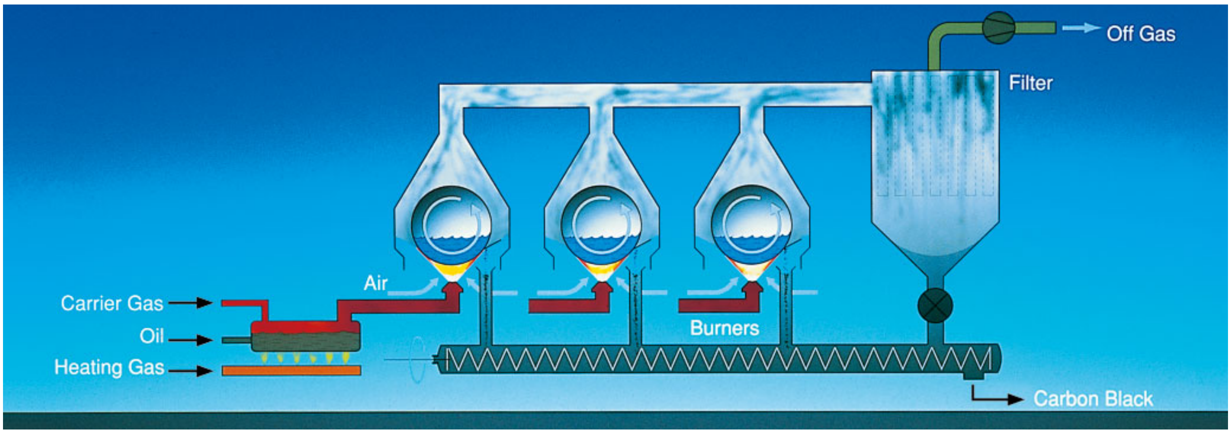
The furnace black process (figure 1) is the most common production method (95 % worldwide). In this case carbon black is produced in a closed reactor (furnace) under a defined atmosphere. The temperature necessary for pyrolysis is achieved by combustion of appropriate gases; the raw material is injected into the combustion chamber through a lance. After the formation of carbon black, the process mixture is quenched by injection of water; this also prevents any secondary reactions. The furnace process allows the particle sizes and structural properties of the product to be varied within wide limits.

Figure 1
Furnace black process



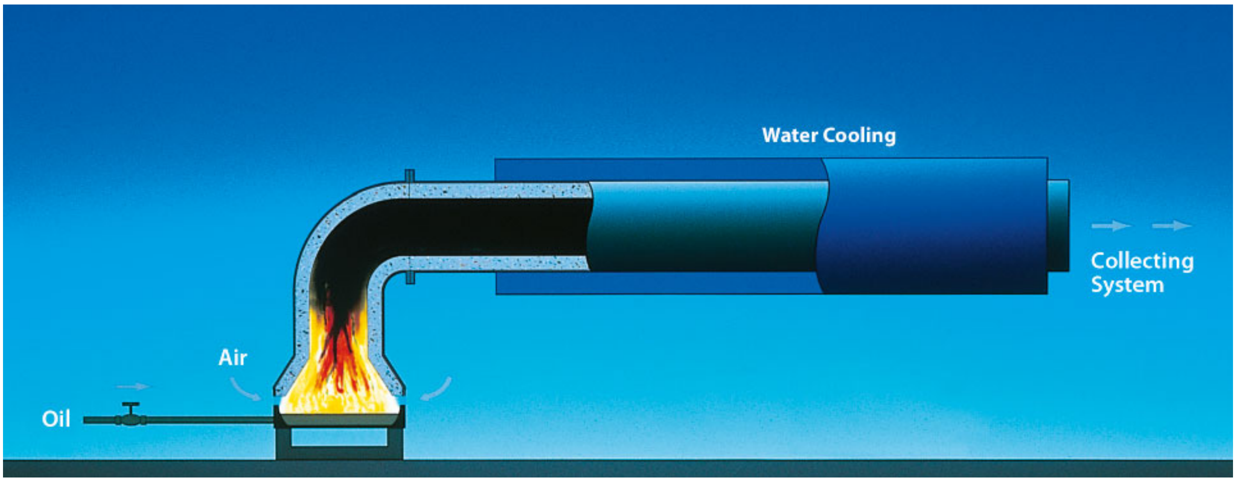
In contrast to the furnace black process, during the Degussa gas black process pyrolysis occurs in the presence of atmospheric oxygen. This means that the gas black Process uses an open reactor (figure 2), which is reflected in the volatile content of the resulting pigment surface. The process derives its name from the fact that the carbon black feedstock is vaporized by heating and is then fed into the combustion chamber by means of a carrier gas. The specialty carbon blacks produced by this method have smaller particles. The particles' sizes can be varied in the production process, but the structure cannot be influenced.

Figure 2
Degussa gas black process



The origin of carbon black production is the lamp black process (figure 3). In this case the raw material is placed in large pans and then vaporized using the heat that is radiated from the covering hood before pyrolysis. The lamp black process is also considered as an open process with access to atmospheric oxygen, to a certain extent through a gap between the combustion pan and the exhaust hood. The particle distribution in a relatively wide range is predominated by large carbon black particles.

Figure 3
Lamp black process



The particle size determines the intensity of blackness, known as jetness or optical density. Carbon blacks are classified according to an internationally recognized system, which signifies the manufacturing process and the jetness.

The first two letters indicate the strength of the pigment: High color (HC), medium color (MC), regular color (RC) and low color (LC). The final letter describes the manufacturing process: The furnace (F) and the gas black (G) processes [1, 2].

3. Product properties

The coloristic properties of each specialty carbon black are dominated by the size of the primary particles involved in the aggregate growth during the carbon black manufacturing process. The degree of aggregation is known as structure.

The primary particles grow together over wide surface areas to aggregates by strong bonding, whereas aggregates are weakly connected over edges and angles to form agglomerates. Figure 5 shows PRINTEX® U in the aggregated and agglomerated forms.

Figure 4
Definition of primary particles and aggregate shaped constituents

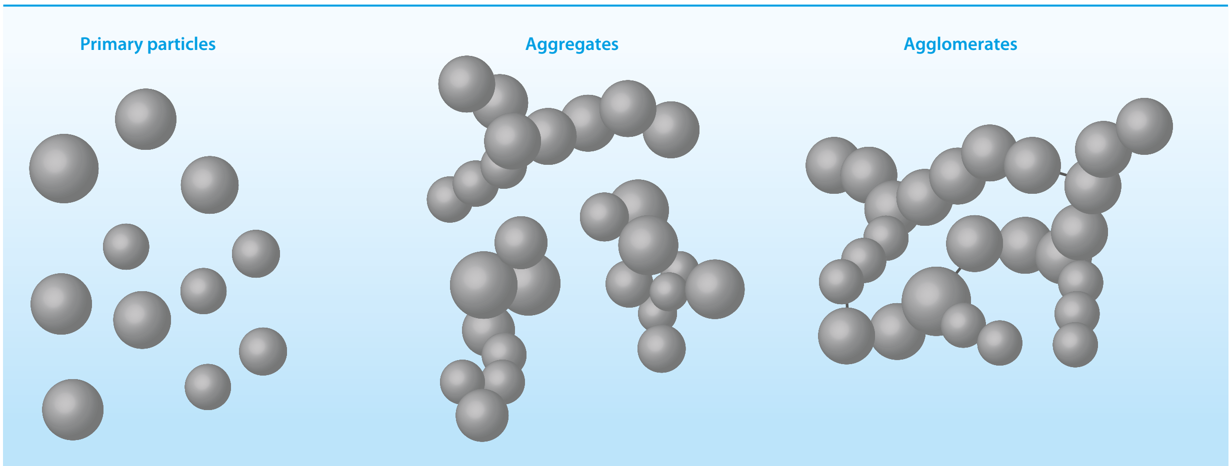
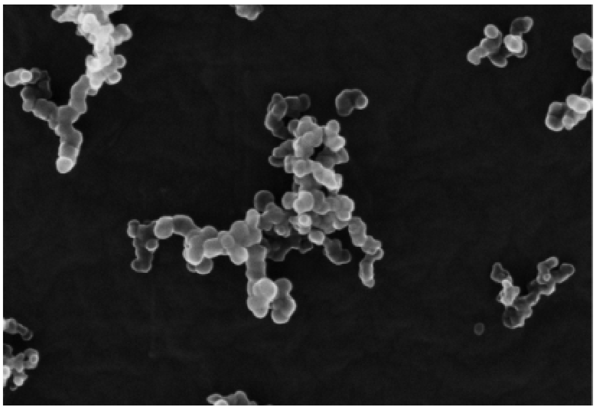


Figure 5

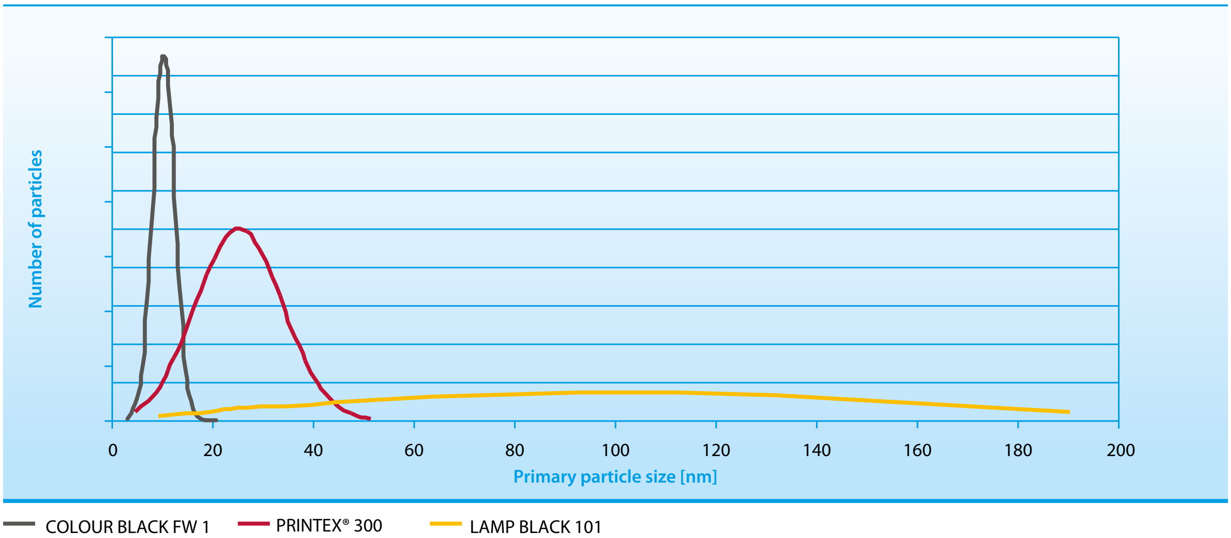
SEM image of PRINTEX® U aggregates with magnification 60,000 times



For analytical purposes only the mean primary particle size is measured, with the help of transmission electron microscopy, using the TGZ 3 semiautomatic particle size analyzer from Carl Zeiss. The resulting average primary particle sizes depend on the production process. These typical distribution curves for gas, furnace and lamp blacks are presented in figure 6.

Figure 6

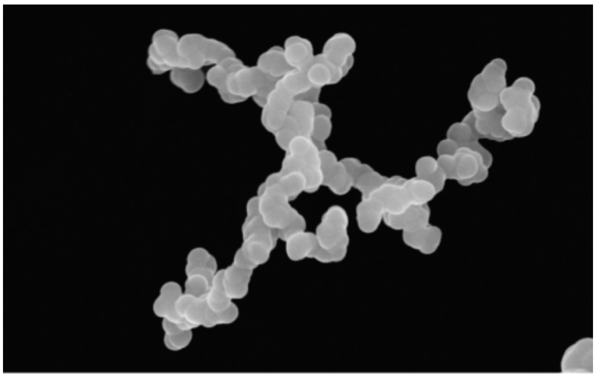
Primary particle size distribution curves of COLOUR BLACK FW 1, PRINTEX® 300 and LAMP BLACK 101



Combining different sizes and numbers of primary particles in the aggregates leads to a specific range of different aggregate sizes, which are characteristic for each product. Figure 7 displays the structural unit of an isolated aggregate of LAMP BLACK 101.

Figure 7

SEM image of LAMP BLACK 101 aggregate with magnification 30,000 times



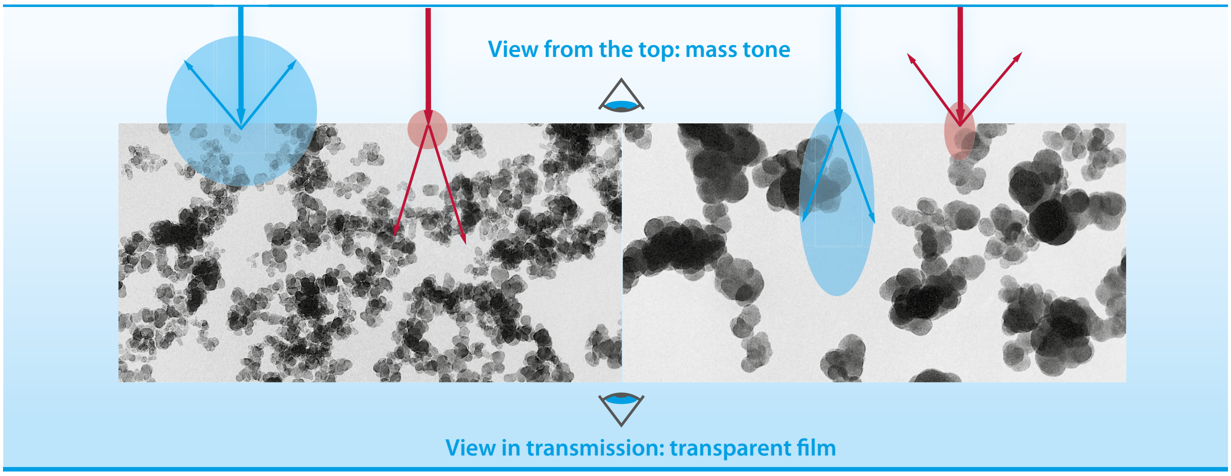
4. Coloristic properties

4.1 Blackness value M_Y

The blackness value M_Y and absolute contribution of hue dM are determined in an alkyd-melamine resin stoving enamel according to the internal method PA 1540. The color depth increases with decreasing primary particle size, as the light scattering intensity reduces. The absolute contribution of hue dM for deep black coatings with fine particles exhibits a blue undertone in mass tone applications. Coarser specialty carbon blacks generate a brown or red undertone.

Figure 8

Microscopic view of the scattering behaviour on fine (left) and coarse (right) specialty carbon black particles



In transparent films or white blends the opposite behaviour is observed, due to different light scattering effects. Coarser specialty carbon blacks display a blue shade, whereas finer particles exhibit a red undertone. In fact, it is the aggregate size and its distribution which is the key parameter for a given jetness.

The degree of blackness, which is equivalent to the jetness $M_{Y,}$ depends on the reflected light in the range between 1 and 0.01 % for mass tone coatings. In grey colored coatings the reflection corresponds to 10 %. White surfaces based on rutile, without any carbon black content, reflect 100 % of the light [3].

Figure 9

Jetness M_Y as a function of the light reflection in black, grey and white coatings

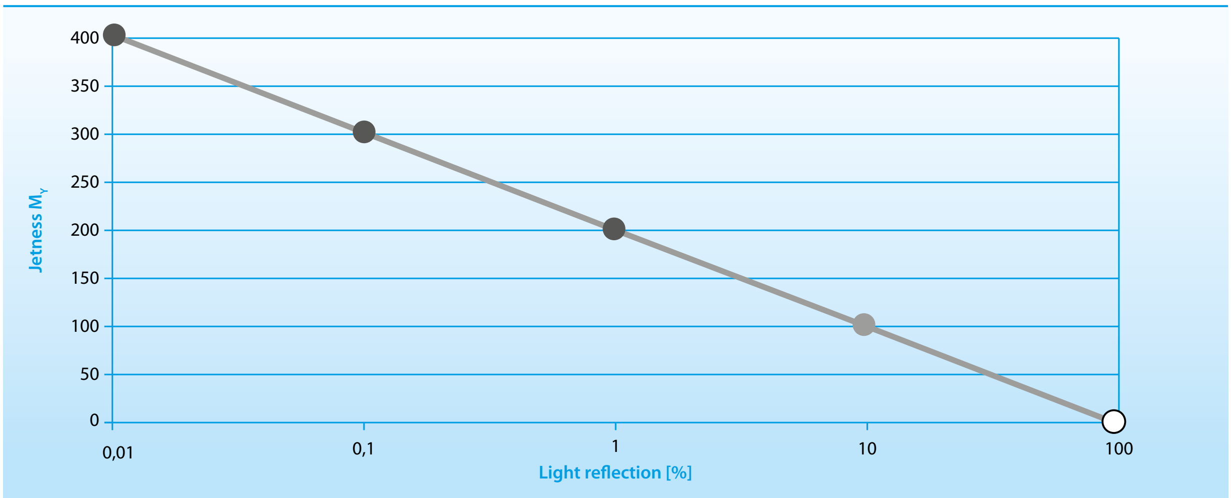


Table 1

Coating formulation for alkyd-based resin systems

Mill base for alkyd-melamine stoving enamel	
Alkydal® F 310 SN, 60 % (from Nuplex Industries)	68.75 g
Shellsol A	23 g
Specialty carbon black	8.25 g
Total	**100 g**

Let down for alkyd-melamine stoving enamel	
Mill base	26.5 g
Alkydal® F 310 SN, 60 %	33 g
MAPRENAL® MF 800/55IB, 55 % * (from Ineos Melamines)	24 g
Diluent	16.5 g
Total	**100 g**
Total quantity of specialty carbon black	**2.2 %**

*** Weight ratio Alkydal (solid): Maprenal (solid) = 70:30**

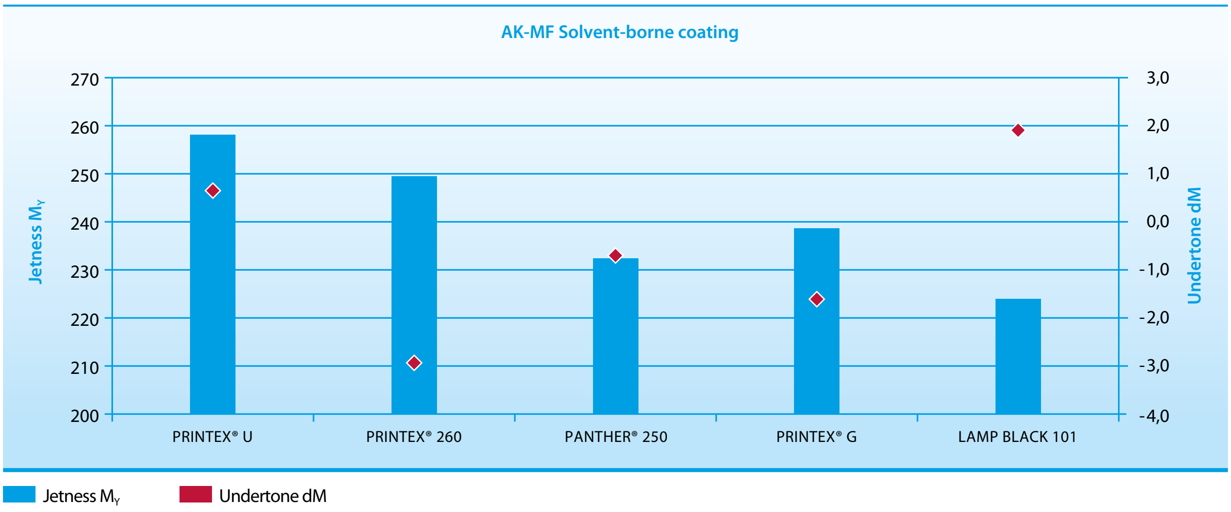
Table 2

Jetness, undertone value and particle size of non after-treated specialty carbon blacks that have a regular and low color

	Type	Jetness M_Y	Undertone dM	Particle size [nm]
PRINTEX® U	RCG	258	0.0	25
PRINTEX® 260	RCF	249	-3.1	25
PANTHER® 205	LCF	232	-1.2	40
PRINTEX® G	LCF	238	-2.0	51
LAMP BLACK 101	LB	224	1.0	95

Figure 10

Colorimetric properties of non after-treated specialty carbon blacks in alkyd-melamine coating systems



Preliminary the jetness is size-dependent, but also related to the particle size distribution shown in figure 6. The PANTHER® type seems to have a higher fraction of coarser particles compared to PRINTEX® G. The blackness value is higher for PRINTEX® G despite its bigger particles. The undertone in all of these non after-treated grades is brownish.

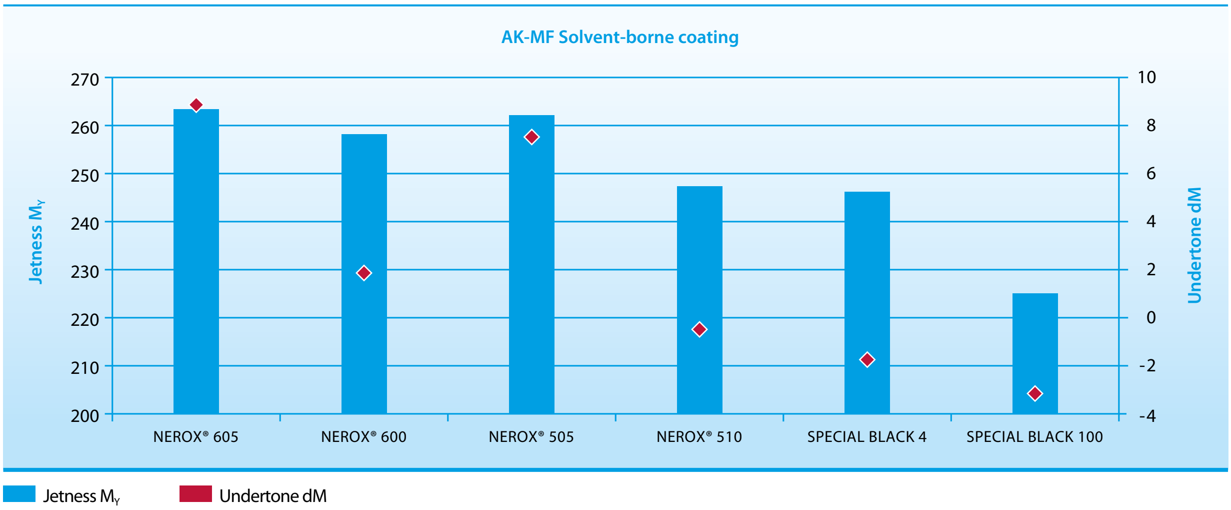
Table 3

Jetness, undertone value and particle size of after-treated specialty carbon blacks that have a regular and low color

	Type	Jetness M_Y	Undertone dM	Particle size [nm]
NEROX® 605	RCF	263	8.8	22
NEROX® 600	RCF	258	1.8	22
NEROX® 505	RCF	262	7.5	24
NEROX® 510	RCF	247	–0.5	24
SPECIAL BLACK 4	RCG	246	–1.8	25
SPECIAL BLACK 100	LCF	225	–3.2	51

Figure 11

Colorimetric properties of selected NEROX® and SPECIAL BLACK specialty carbon blacks in alkyd-melamine coating systems



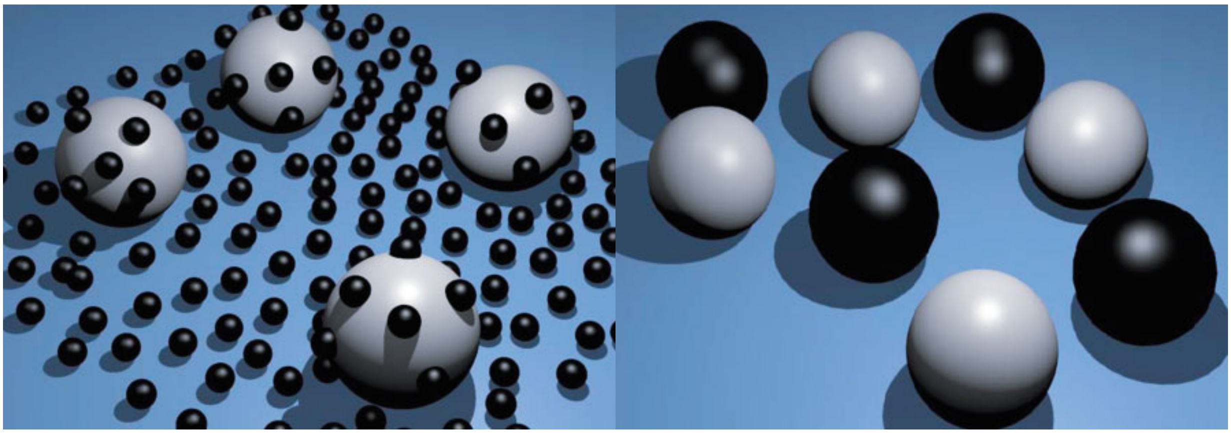
The after-treated NEROX® and SPECIAL BLACK types show a direct correlation between the particle size and the undertone, which tends to bluish with finer particles. In particular, the low-structured pigments NEROX® 605 and 505 exhibit a very strong blue shade.

4.2 Relative tint strength

The determination of relative tint strength is important for the use of specialty carbon blacks in grey coatings or white blends. The tint strength results in the ability of a carbon black to darken a white pigment, in this case zinc dioxide. The tint value is measured following ASTM D 3265 and compared to IRB3 (industrial rubber black) standard that is assumed to be 100 %.

Figure12

Effect of darkening by carbon black particles of different sizes



The primary particle size gives an indication of the tinting strength of specialty carbon blacks.

4.3 Greyness value G_Y

The greyness value G_Y and the absolute contribution of hue dG are determined by spectral photometry. This is done by mixing the black lacquer, that is manufactured according to PA 1540, with a standard alkyd-melamine resin-based white lacquer containing TiO_2. The greyness value increases with decreasing particle size and therefore serves as an indirect method for determining the mean primary particle size.

The hue dG is fundamentally influenced by the scatter and absorption behavior of small particles. Coarse specialty carbon black particles in the white mixture create a blue undertone, while fine particles produce a red hue. This represents a reversal between full shade application and white reduction [3].

Figure 13

The greyness and floating behavior of various specialty carbon blacks in alkyd-melamine coating systems

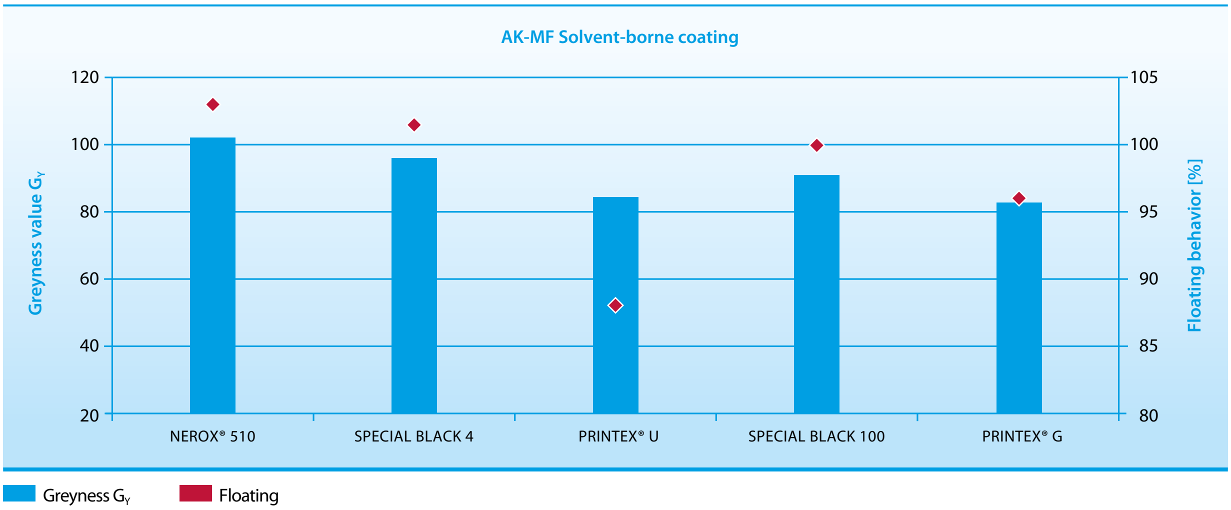


Table 4

The greyness value and floating behavior of various specialty carbon blacks in white reduction with TiO_2

	NEROX® 510	SPECIAL BLACK 4	PRINTEX® U	SPECIAL BLACK 100	PRINTEX® G
Ratio TiO_2: CBP	100:4	100:4	100:4	100:5	100:5
Greyness Value G_Y	102	96,3	84,5	91	83
Floating Behavior	103	101,5	88	100	96

The floating behavior is an indicator of the pigment stabilization within the grey coating. To illustrate the pigment separation a post-dispersion by thumb is made in the rubout area of the wet coating film. For a stable system the floating behavior corresponds to 100 %, as no separation between the Specialty carbon blacks and coarse TiO_2 particles occurs. Less than 100 % means micro-flocculation of the specialty carbon blacks. In this case the non rubout area is brighter than the rubout area. In contrast to this, a level above 100 % results in the floating of specialty carbon blacks, where the non-rubout area is darker than the rubout area. The bigger the particle size difference between the white and black pigments is, the higher the floating tendency will be.

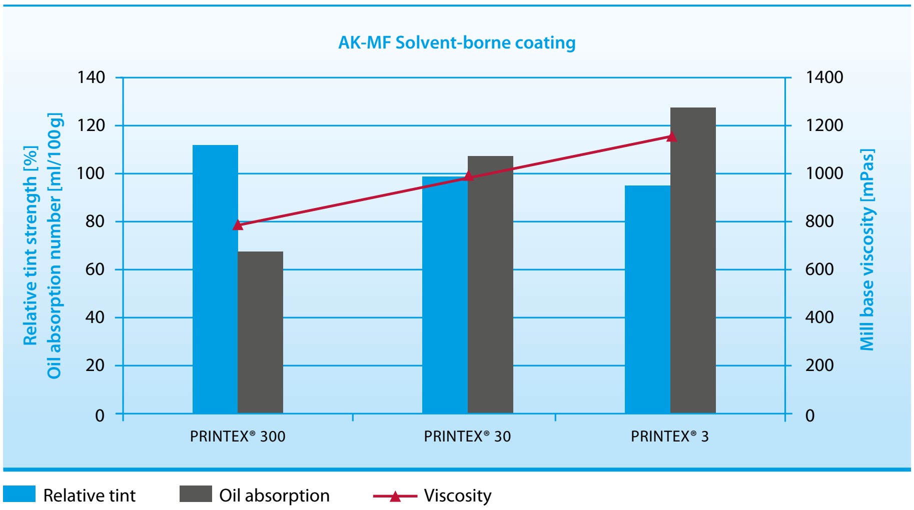
The presence of functional groups containing oxygen on the pigment surface also affects the stability of the coating system. Due to the functionalized surface of after-treated specialty carbon blacks, their floating behavior is higher than for non-treated pigments. This effect can be observed between PRINTEX® U and SPECIAL BLACK 4 or PRINTEX® G and SPECIAL BLACK 100.

4.4 Other technical data

Technical parameters related to the rheological behavior of liquid coatings are of practical relevance for the coating manufacturer. Three different regular color furnace (RCF) grades are compared regarding their structural influence on the relative tint strength and the viscosity at 800 s^{-1}. The corresponding specialty carbon blacks are PRINTEX® 300, PRINTEX® 30 and PRINTEX® 3, all having the same primary particle size (27 nm).

Figure 14

Relative tint and viscosity of selected PRINTEX® grades as a function of the OAN in alkyd-melamine coating systems



	PRINTEX® 300	PRINTEX® 30	PRINTEX® 3
Relative tint [%]	113	100	96
Oil absorption [ml/100 g]	68	108	128
Viscosity [mPas]	850	1020	1190

The dynamic viscosity, as a rheological parameter, that is displayed in figure 13 correlates with the oil absorption number (OAN). This in fact reflects the structure of each pigment and finally indicates its binder or resin demand. However, the relative tint value shows the opposite trend as it decreases towards the higher structured pigment.

Table 5

Relevant technical data for specialty carbon blacks related to the tinting applications published in this brochure

	Type	Jetness M_Y	Relative tint [%]	OAN [ml/100 g]	Particle size [nm]
NEROX® 600	RCF	-	130	100	22
NEROX® 605	RCF	-	143	56	22
NEROX® 510	RCF	-	120	100	24
NEROX® 505	RCF	-	134	58	24
SPECIAL BLACK 4	RCG	244	100	115	25
PRINTEX® U	RCG	246	112	115	25
PRINTEX® 260	RCF	-	130	61	25
PRINTEX® 300	RCF	242	113	68	27
PRINTEX® 30	RCF	240	100	108	27
PRINTEX® 3	RCF	239	96	128	27
PANTHER® 205	LCF	-	56	72	40
SPECIAL BLACK 100	LCF	217	60	100	51
PRINTEX® G	LCF	223	57	104	51
LAMP BLACK 101	LB	209	26	140	95

For the specialty carbon blacks that are used in tinting applications it is important to consider the primary particle size, respectively the jetness, the relative tint strength, the oil absorption number and, the volatile content at 950 °C which corresponds to the amount of functional groups on the pigment surface. Further characteristics of specialty carbon blacks are published in our brochure entitled technical data for Europe [4].

5. Literature

[1] What is carbon black?
General literature, brochure, Orion Engineered Carbons (2015)

[2] Specialty carbon blacks in modern coating systems,
Industry Information Europe 0402, Orion Engineered Carbons (2015)

[3] Coloristic properties of specialty carbon blacks in full tone and tinting applications for coatings,
Technical Information 1464, Orion Engineered Carbons (2015)

[4] Specialty carbon blacks,
Technical Data Europe, Orion Engineered Carbons (2015)

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OEC-TI 1459-03/2023