Physical & Chemical Properties

Properties

Carbon black can be broadly defined as very fine particulate aggregates of carbon possessing an amorphous quasi-graphitic molecular structure. The most significant areas of distinction between a thermal black and a furnace black are particle size and structure. Most carbon blacks are classified and assigned a grade number based on surface area and structure measurements.

Sieve Residue

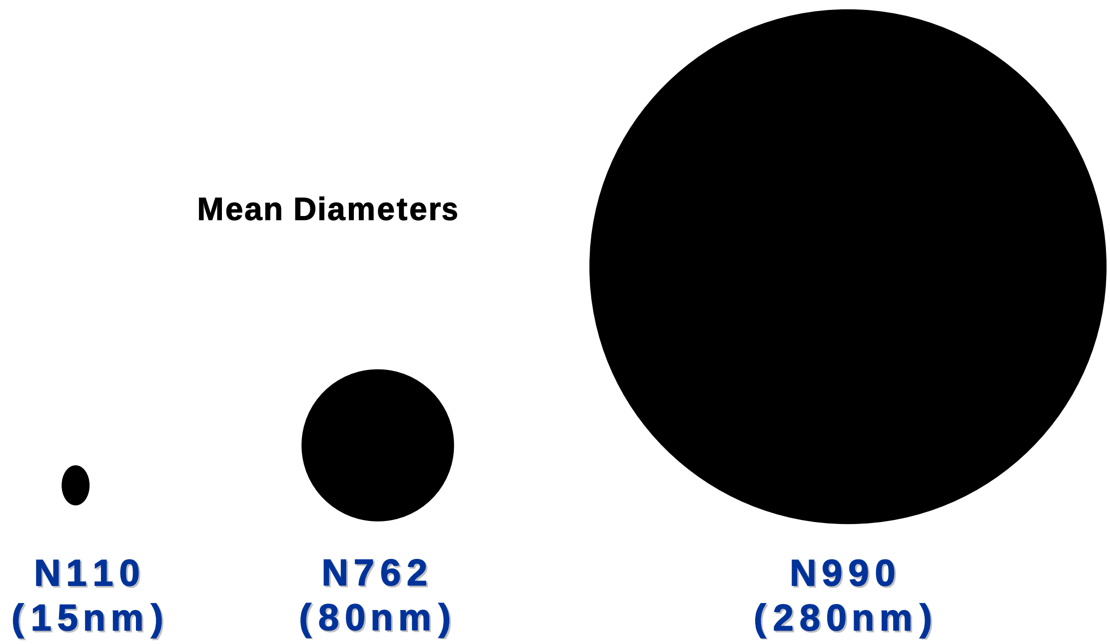
Sieve residue refers to non-dispersable contaminants (such as coke, refractory particles, water soluble salts and metal oxides) and is expressed as a percentage of the carbon black by weight. Sixty and 325 Mesh sieves are used for this test. The resulting grit can cause blemishes and may affect the appearance and performance of some rubber and plastic products. The 325 Mesh grit is also tested for magnetic content.

Surface Area

Surface area measurements give an indirect characterization of carbon black particle size. There are two methods in use for surface area determination. Iodine adsorption (expressed in mg/g of carbon) measures the amount of iodine which can be adsorbed on the surface of a given mass of carbon black. Nitrogen surface area is a measurement of the amount of nitrogen which can be adsorbed on a given mass of carbon black. Both tests have a good correlation for most rubber grades of furnace blacks, but toluene extractables on the surface of thermal blacks interfere with the aqueous iodine-potassium system of the iodine adsorption method, making nitrogen surface area a more suitable test. Accordingly, the American Society for Testing and Materials (ASTM) does not recommend iodine adsorption for surface area measurements of thermal blacks.

Based on surface area, thermal black is classified as an N900 series black while furnace blacks fall within the N100 to N700 series. (N) denotes normal curing material. Thermal black has the largest particle size (mean diameters of 240 - 320 nm) of any carbon black and hence has the lowest surface area at 7 - 11 m2/g. In contrast, furnace black particle sizes are approximately three to twenty times smaller (mean diameters of 15 - 80 nm) providing surface areas from 27 - 145 m2/g. The particle size of thermal black is shown in comparison with the smallest and largest particle size furnace blacks in Figure 1.

Figure 1: Carbon Black Particle Size Comparison

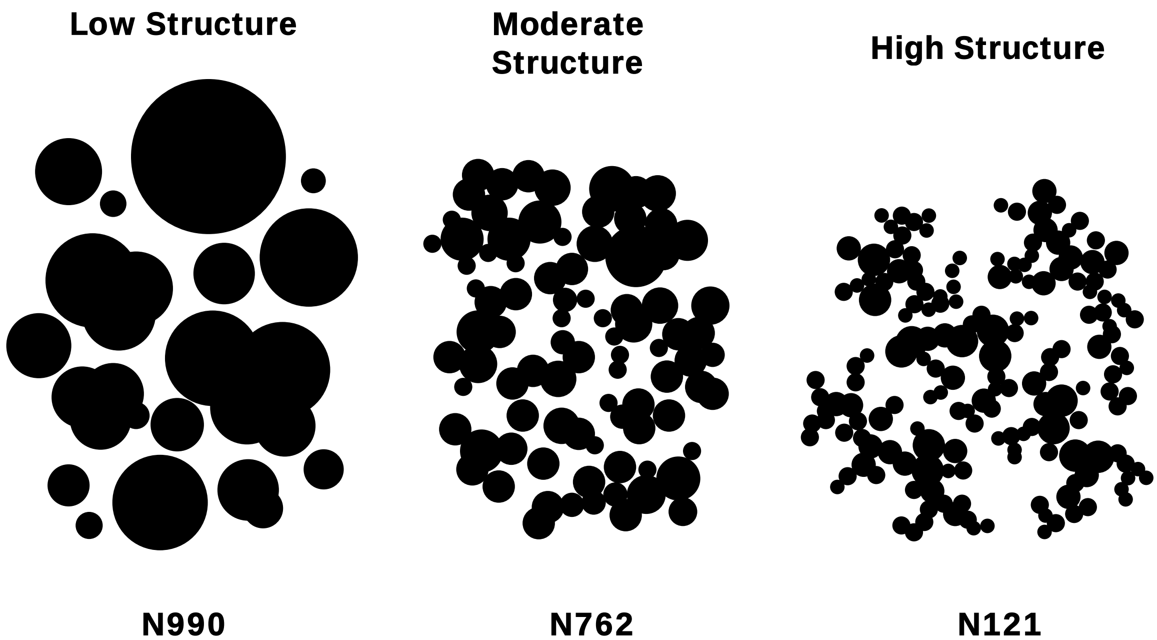


Structure

Measuring the structure or morphology of carbon black is a more difficult task. The current industry test index is the dibutyl phthalate absorption number (DBPA). Dibutyl phthalate (DBP) absorption measures the relative structure of carbon black by determining the amount of DBP a given mass of carbon black can absorb before reaching a specified viscous paste. Thermal blacks have the lowest DBPA numbers (32-47 ml/100g) of any carbon black, indicating very little particle aggregation or structure.

Electron micrographs of thermal blacks show a large number of individual spherical carbon particles. At the same time, aggregates are very limited and consist of no more than a few fused particles. Furnace blacks on the other hand do not consist of individual spheres of carbon but exhibit a rather wide range of particle aggregations in which carbon particles are fused into grape-like clusters and/or reticulate chains or branches. Even the lowest structure furnace blacks can be considered as having moderate structure (DBPA: 65 ml/100 g). High structure furnace black has the greatest amount of reticulation. Figure 2 provides a graphical representation of relative carbon black structure.

Figure 2: Carbon Black Structure Comparison



(Particle sizes not to scale)

More recently, non-integer dimensional analysis (fractal geometry) has been used to classify carbon blacks according to four simple aggregate shape categories: spherical, ellipsoidal, linear and branched.

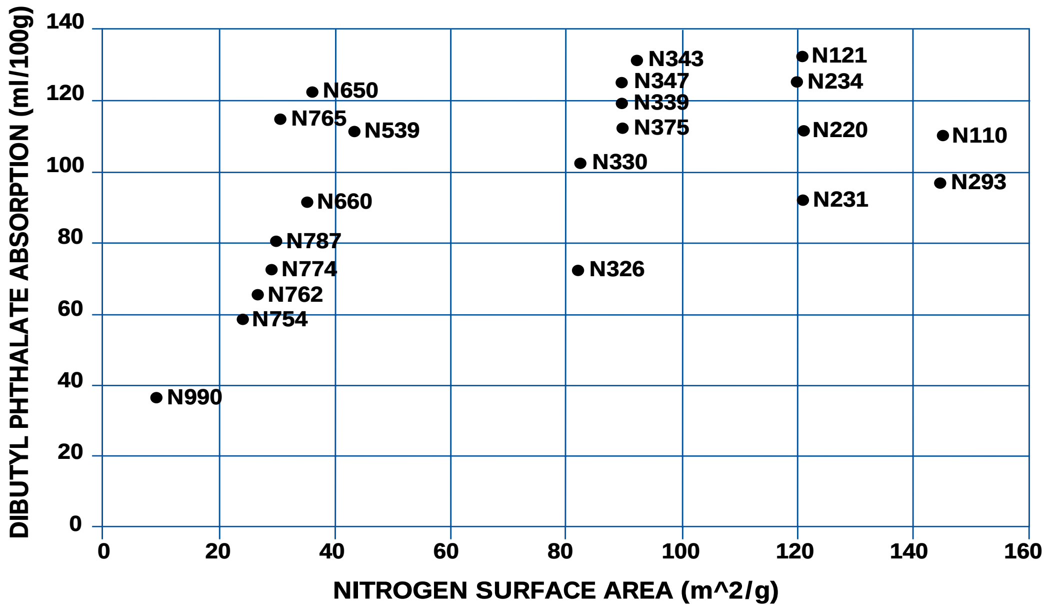
The analyses of thermal black (Figure 3) indicates it contains the highest level of simple spherical and ellipsoidal shapes, which act as essentially independent discrete particles like those seen in electron micrographs.

Figure 3: Weight Percentage of Aggregates in four Shape Categories for Various Carbon Black Grades (Dry State)

Carbon Black	DBPA $cm^3/100g$	Spheroidal	Ellipsoidal	Linear	Branched
N358	155	0.1	7.9	34.9	57.1
N121	134	0.4	8.8	28.7	62.1
N650	129	0.2	9.2	47.0	43.6
N234	124	0.3	9.0	32.5	58.3
N299	124	0.4	10.0	33.2	56.4
N351	120	0.1	9.2	46.9	43.8
N550	120	0.6	13.8	45.3	40.3
N339	118	0.2	9.5	36.6	53.7
N110	115	0.3	8.7	31.1	59.9
N220	115	0.6	11.9	34.0	53.5
N330	100	0.2	10.2	44.1	45.5
N660	91	0.4	15.4	52.5	31.7
N630	78	0.4	21.4	49.0	29.2
N774	77	1.3	20.8	46.3	31.6
N326	72	1.6	23.4	35.2	39.8
N762	67	2.5	22.4	47.7	27.4
N990	35	44.9	34.8	14.4	5.9

By plotting surface area against structure the distinction between the different grades of carbon black becomes readily apparent. Thermal black is at the extreme end of such a plot while the numerous grades of furnace black cover a wide range of values (Figure 4).

Figure 4: Structure vs. Surface Area



Ash Content

Ash level is highly dependent on the amount of inorganic impurities present in the cooling water. It consists primarily of sodium, magnesium and calcium, but also contains minute amounts of other metals.

Toluene Extraction

Minute amounts of polyaromatic hydrocarbons are usually present in thermal black. There is always the possibility that they may leach from the carbon black and stain adjoining compounds.

Cancarb uses two tests to determine the amount of polyaromatic hydrocarbons in its thermal black. Toluene discoloration consists of washing a specified amount of sample with toluene and comparing the spectrophotometric readings of the washings with that of the pure toluene. A more quantitative measurement of polyaromatic hydrocarbon content is Toluene Extraction, in which the hydrocarbons are removed from a crushed carbon black sample by Soxhlet extraction.

Heat Loss

The heating loss of carbon black is important in determining its moisture content. The amount of moisture present is related to: the surface area of the black, relative humidity, ambient temperature and the time for which the material is exposed. Thermal blacks have the lowest surface area per unit mass of all carbon blacks and therefore absorb an insignificant amount of moisture. The heat loss determination is made at 125˚C.

Fines

Fines are the pellets and pellet fragments that pass through a 125 micron sieve (No.120 U.S Standard Sieve series) after being shaken for 5 minutes. The amount of fines in a product can affect its ability to flow, raise dust levels during handling, and decrease dispersion in final rubber and plastics compounds due to the higher surface area associated with smaller pellets.

Pellet Hardness

Pellet hardness is the force required to crush an individual pellet which is between 1000 and 1410 micron sieve (U.S. Standard Sieve No.18 and No.14). The instrument used for this test is controlled by computer, and the test is performed on 20 pellets, after which the computer calculates the mean, maximum, minimum and standard deviation. Pellet crush strength can affect handling, attrition, fines generation and the subsequent level of dispersion in some mixtures.

Surface Activity

Unfortunately there is no direct method for measuring carbon black surface activity. The term refers to the chemical reactivity of the surface. Surface activity is influenced by the graphitic plane orientation as well as the number and type of organic side groups. On a molecular level, carbon black is composed of amorphous graphite layer planes created from the condensation of aromatic rings. The edges of such planes have unsatisfied carbon bonds which can act as chemical reaction sites.

The reaction time for the production of thermal black is long in comparison to the furnace black process. Long reaction times combined with the high temperature required for the thermal decomposition of natural gas feed stock (1300˚C) allows the graphite layer planes of thermal black to become highly ordered so that only layer plane surfaces are at the surface of the particle. As a result, no unsatisfied carbon bonds at the layer plane edges are exposed and therefore no potential reaction sites for elastomer interaction are present in thermal black. Conversely, the shorter reaction times used in making furnace black produce layer planes at the surface which are less ordered, resulting in numerous sites for chemical bonds with elastomers.

Recent scanning tunneling electron microscopy (STM) studies, which characterize the surface of carbon black, clearly support the fact that larger particle size carbon blacks like thermal black tend toward a more organized surface structure with fewer active sites.

The formation of thermal black occurs in the absence of flame or air while furnace black is generally the product of incomplete combustion of petroleum refinery residues. As a result, furnace blacks contain numerous types of organic functional groups such as phenols, hydroxyls, lactones and quinones which also contribute to the level of surface activity. The same organic functional groups are virtually absent from thermal black.

Carbon blacks with a high amount of surface activity often provide high reinforcement. While thermal black does impart some degree of reinforcement to elastomers it is most often referred to as an inactive or non-reinforcing black.

The influence of carbon black on rubber can best be described in terms of processing and vulcanizate properties. In choosing carbon black(s) for an elastomer formulation, the grade of carbon black and the degree of loading must be taken into consideration. The general effects of carbon black on any given rubber property can be summarized according to surface area (particle size), structure and loading level.