# Factors Influencing the Self – ignition and Combustion Process of Carbon Black

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*This paper investigates the influence of main factors determining the trend of self – ignition of carbon black. Experimental determinations were performed on samples of carbon black in different areas of the manufacturing process, working under different conditions, in order to highlight the determinants for the initiation of combustion. Combustion research has been conducted under static conditions using thermogravimetric and termodifferential analysis equipment. The results showed the influence of natural samples, heating rate, the oxygen content of the environment and thermal loading of area on the self - ignition temperature. Findings are particularly relevant to carrying out the parameters of conditioning and avoiding reaching completion conditions of self - ignition. They are crucial to analyse root causes for different fires.*

*Keywords: carbon black, self – ignition, combustion*

There are numerous studies and regulations on the manufacturing process and the impact and fire safety as well as on anti-explosion measures and protection of human health and the environment [1-15]. This paper seeks to address experimentally to the self – ignition trend of carbon black, factors that accelerate or inhibit this trend.

To this end, investigations were carried out with thermogravimetric and termodifferential analysis equipment, considering self-ignition temperature as the onset temperature of exothermic effect with weight loss.

Carbon black is identified by CAS number [Chemical Abstracts Service (USA)] 1333 – 86 - 4 [16].

According to Romanian literature [20-22], carbon black properties are listed in table 2.

Because carbon black particles have a high specific surface (1 g of carbon black has an area of 10 to 250 m$^2$) oxidation per unit volume can be quite intense. In this case, due to poor transmission of heat, self - ignition can be achieved. Carbon black industry specialists explain the phenomenon of self - ignition by the existence of pyrophoric compounds or incomplete decomposition of the raw carbon material that is absorbed on the surface of carbon black particles. Self – ignition of carbon black is the result of mutual action between surface of carbon and oxygen in the air. Carbon atoms with free valence bonds have most activity. For certain abroad categories of carbon black there have been several cases of self - ignition.

Self – ignition of carbon black depends on the temperature at which the technological process take place. If the temperature is 270 – 300$^0$ C, self - ignition occurs after 5 - 10 min [22].

The main purpose of this paper is to highlight the factors that determine self – ignition and combustion of carbon black samples.

## Experimental part

Experimental research aims to determine the beginning of burning, self-ignition temperature. It was used an equipment for thermogravimetric and termodifferential analysis MOM type, in the average air or oxygen enriched air. Quantity of samples was 100 mg and heating rate, typically 10$^0$ C/min, heating rate for the four samples was varied, to know their influence. Carbon black analyses were made according to Romanian and ISO standards in force.

Table 1 presents the technical and elemental analysis of carbon black studied. Table 2 pursues self-ignition temperature variation depending on the collection.

We studied the influence of heating rate on self - ignition temperature of four samples of carbon black. The results are presented in table 3.

**Table 1**
TECHNICAL AND ELEMENTAL ANALYSIS OF CARBON BLACK SAMPLES STUDIED

| Current number | Carbon black type | The technical analysis | | | Granulation | The elemental analysis |
|---|---|---|---|---|---|---|
| | | $W^a$ | $A^{anh}$ | $V^{waf}$ | | $S^{waf}$ |
| | | % | % | % | mm | % |
| 1. | From collectors | 0.5 | 0.6 | 1.5 | < 0.05 | 1.4 |
| 2. | From cyclones | 0.6 | 0.6 | 1.5 | < 0.05 | 1.5 |
| 3. | From condensed | 0.6 | 0.7 | 1.4 | < 0.05 | 1.4 |
| 4. | Granulated | 0.5 | 0.7 | 1.4 | < 0.1 | 1.5 |

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| Current number | Carbon black type | Units | Self – ignition temperature |
|---|---|---|---|
| 1. | From collectors | $^0C$ | 440 |
| 2. | From cyclones | $^0C$ | 437 |
| 3. | From condensed | $^0C$ | 445 |
| 4. | Granulated | $^0C$ | 405 |

**Table 2**
SELF-IGNITION TEMPERATURE OF CARBON BLACK, DEPENDING ON THE COLLECTION

| Current number | Carbon black type | Units | Self – ignition temperature | | |
|---|---|---|---|---|---|
| | | | gradient 5 $^0C$ | gradient 10 $^0C$ | gradient 15 $^0C$ |
| 1. | From collectors | $^0C$ | 430 | 440 | 470 |
| 2. | From cyclones | $^0C$ | 415 | 437 | 475 |
| 3. | From condensed | $^0C$ | 410 | 445 | 465 |
| 4. | Granulated | $^0C$ | 390 | 405 | 415 |

**Table 3**
INFLUENCE OF HEATING RATE ON SELF - IGNITION TEMPERATURE OF CARBON BLACK

| Current number | Carbon black type | Units | Self – ignition temperature | | | | |
|---|---|---|---|---|---|---|---|
| | | | air | 40%$O_2$ | 60%$O_2$ | 80%$O_2$ | 100%$O_2$ |
| 1. | From collectors | $^0C$ | 440 | 398 | 378 | 368 | 363 |
| 2. | From cyclones | $^0C$ | 437 | 395 | 375 | 365 | 360 |
| 3. | From condensed | $^0C$ | 445 | 405 | 387 | 377 | 370 |
| 4. | Granulated | $^0C$ | 405 | 440 | 405 | 390 | 380 |

**Table 4**
INFLUENCE OF ENVIRONMENTAL OXYGEN CONTENT ON SELF - IGNITION TEMPERATURE OF CARBON BLACK ($10^0$ C/MINUTE SPEED)

| Current number | **Oven temperature, $^0C$** | **340** | **440** | **540** |
|---|---|---|---|---|
| | Carbon black type | ***self – ignition time*** | | |
| 1. | From collectors | 6'22" | 2'35" | 1'32" |
| 2. | From cyclones | 6'10" | 2'20" | 1'10" |
| 3. | From condensed | 5'50" | 2'05" | 50" |
| 4. | Granulated | 6'20" | 2'25" | 1'05" |

**Table 5**
TIME TO SELF - IGNITION OF SAMPLES OF CARBON BLACK IN AIR CHAMBER HEATED TO A CERTAIN TEMPERATURE

Oxygen content from the surrounding atmosphere and its influence on the self - ignition temperature was also studied. Results are shown in table 4.

It was also studied the behaviour of the self - ignition of the samples placed in a muffle furnace with a given temperature by determining the time after which the sample is self-ignited. Results are shown in table 5.

Research shows that the generic name of carbon black is not enough to know its behaviour in the self – ignition process. Conditions of production, and processing can influence the process.

The heating speed, meaning speed of propagation of fire is higher when the self-ignition temperature is higher, although the slow propagation is more dangerous.

Oxygen content of environment is a key factor for self-ignition temperature. An increase in oxygen content in air from 21 to 40% decreases with about $40^0C$ self – ignition temperatures. After this period the influence of growth medium oxygen content is lower.

Thermal loading of the enclosure has a particular influence. Self - ignition sampling is also possible at lower temperatures by keeping warm premises.

## Conclusions

Substances of the same type, with a similar chemical composition may behave differently during the ignition because of the specific features.

Low speeds of spread of fires can cause self – ignition at lower temperatures because of the heat accumulation.

Oxygen is a bias, it greatly reduces the temperature at which materials can self-ignite which is why even relatively inert substances necessary for packaging in small quantities in packages with reduced possibility of ingress of oxygen can self -ignite. When starting the combustion process, a first measure is the reduction of oxygen content in the environment, through steaming, carbon dioxide introduction, etc.

It is useful to introduce inert gas (nitrogen, carbon dioxide) in packages of powders to self – ignition disadvantage.

Heating zone favours the self – ignition process and it is necessary to keep dust off hot areas and cool areas where ignition is helpful to settle their problems.

In the case of powders, halting the combustion process by extinguishing water is not sufficient or satisfactory. The self – ignition can appear whenever favourable conditions occur.

Transport of fuel powders can be made only by the packaging, sealed in small quantities, and preferably away from the action of heat in inert atmosphere.

Fire-fighting products for carbon black will use water spray, chemical or mechanical foam and carbon dioxide in the indoor spaces. Do not use compact jets of water as it may cause dust explosions by rummage of carbon black.

The burning carbon black subject, not only provides assistance for problems related to fire fighting and protection, but also environmental pollution problems. Therefore, preventive measures must be directed primarily to these sectors.

Avoiding power loading of all types in a given area, disadvantage self – ignition and facilitates the extinction of fire started.

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Homogeneous charge compression ignition (HCCI) is an alternative combustion technology that is cleaner and more efficient than the other types of combustion.Â  Mohammad Izadi Najafabadi, Nuraini Abdul Aziz, "Homogeneous Charge Compression Ignition Combustion: Challenges and Proposed Solutions", Journal of Combustion, vol. 2013, Article ID 783789, 14 pages, 2013. https://doi.org/10.1155/2013/783789. Show citation. Homogeneous Charge Compression Ignition Combustion: Challenges and Proposed Solutions. Smouldering combustion is the slow, low-temperature, flameless burning of porous fuels, and the most persistent type of combustion phenomena (Rein, 2016). A wide range of materials can undergo smouldering, such as cellulosic insulation, coal, polyurethane (PU) foam, cotton, wood, and peat, making smouldering a serious hazard in both residential and wildland areas.Â  Forward and opposed smouldering propagations represent different heat transfer mechanisms that influence the heating process of the fuel (Ohlemiller, 1985; Rein et al., 2007; Rein, 2009, 2016), thus affecting the occurrence of the StF transition. In opposed smouldering, airflow carries the heat from the smouldering zone away to the ash layer, diminishing the heat supplied for heating the fuel. The term spark-ignition engine refers to internal combustion engines, usually petrol engines, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. This is in contrast to compression-ignition engines, typically diesel engines, where the heat. IJOART. generated from compression is enough to initiate the combustion process, without needing. any external spark.Â  In a reciprocating engine, it is the ratio between the volume of the cylinder and combustion chamber when the piston is at the bottom of its stroke, and the volume of the combustion. Copyright Â© 2014 SciResPub. IJOART.