Effect of carbon black content to heat conduction in rubber compounds

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This study focuses on the evaluation of the commercially utilized type of carbon black filler (N339) effect on the thermal conductivity of prepared rubber compounds. Thermal conductivity during the vulcanization process represents an important parameter not only in terms of vulcanization time, but also with respect to the formation of an optimal sulfur crosslinking structure. The filler content in rubber compounds significantly affects the rate of heat transfer throughout the material volume, thereby influencing both the quality of the final products and the economic efficiency of the manufacturing process. Based on the obtained results, it is possible to characterize in detail the time required for heating the entire volume of rubber compounds during vulcanization, as well as to analyze the effect of filler concentration on this process. Thermal conductivity was monitored using a sensor platform based on Internet of Things (IoT) principles, designed for monitoring the heat transfer behavior in rubber compounds. Prepared rubber compounds contain carbon black in the interval from 20 to 80 phr with step of 20 phr.

Tab. 1 Composition and designation of prepared compounds

INGREDIENTS	Compound designation			
	CB-20	CB-40	CB-60	CB-80
SMR 10	100	100	100	100
ZnO	3	3	3	3
SA	2	2	2	2
N339	20	40	60	80
TBBS	1.5	1.5	1.5	1.5
S	2	2	2	2

Tab. 2 Rheological properties and vulcanization characteristics of prepared compounds

	Minimum Torque (ML)	Maximum torque (MH)	Scorch time (t_{s02})	Optimum cure time (t_{c90})
CB-20	2.37	22.31	2.48	4.98
CB-40	3.54	30.41	1.7	4.35
CB-60	6.24	36.39	1.02	3.88
CB-80	11.73	44.81	0.65	9.57

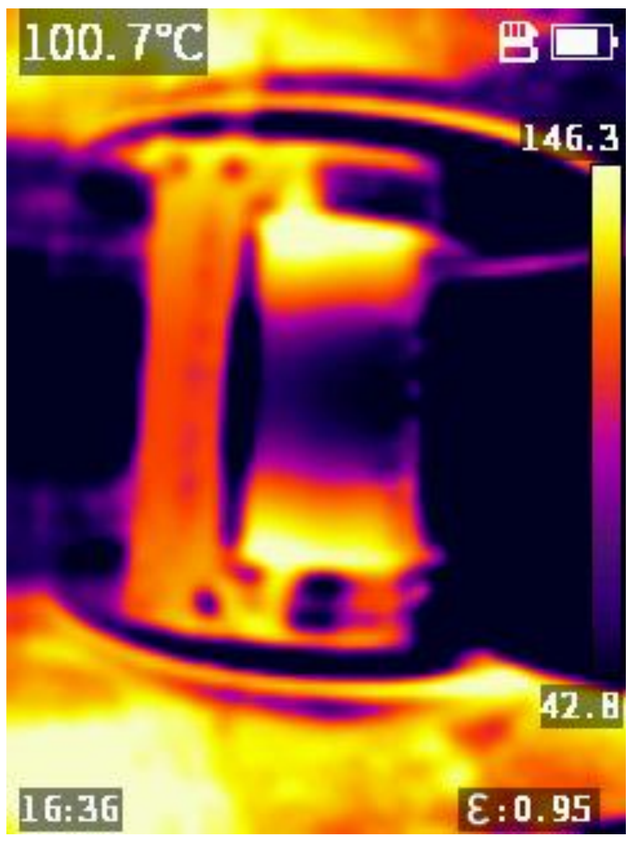

Fig. 1 Thermal scan of form during test

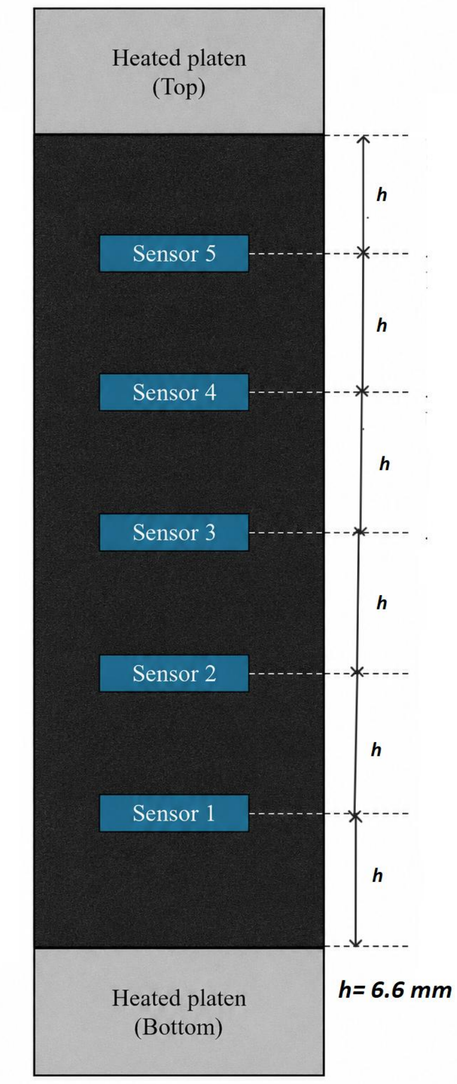

Fig. 2 Placement of sensors in the volume of the elastomer compound

Conclusion

The results of the study showed:

- Increasing carbon black N339 content enhanced heat transfer through the elastomer compound
- Lower t_{s02} and t_{c90} values confirmed faster activation of the vulcanization system with increasing filler loading.
- Value of optimum vulcanization time decreasing with increasing of filler content up to 60 phr.
- At excessive filler loading (80 phr), a slight increase in t_{c90} was observed, likely due to restricted mobility of vulcanization components.
- Increasing filler content resulted in higher minimum and maximum torque values, indicating increased stiffness and stronger filler–rubber interactions.

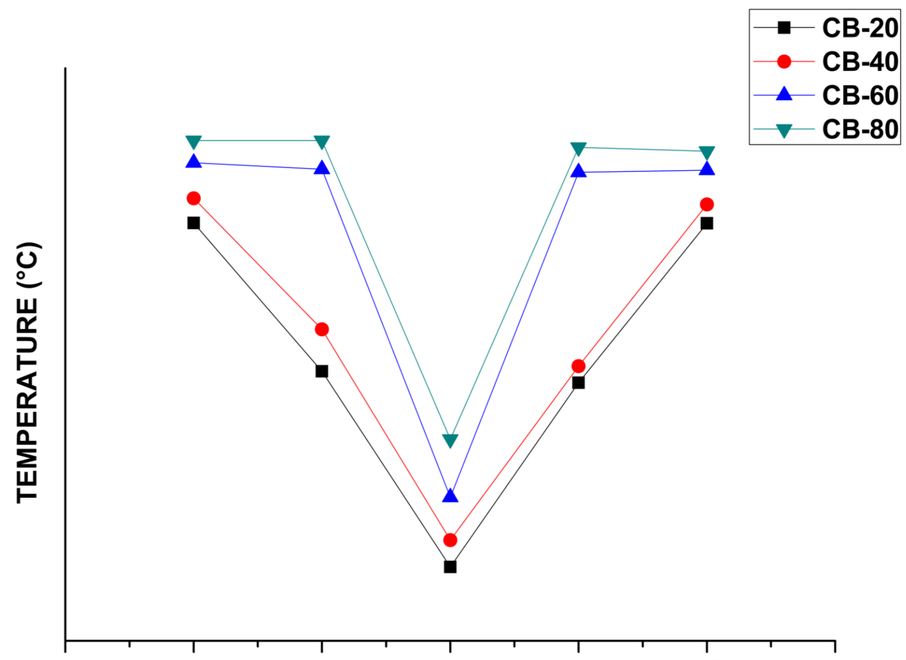

Fig. 3 Maximal temperature achieved for each sensor

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