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Authors: Rodrigo Diaz, Gaël Colomines, Edith Peuvrel-Disdier, Rémi Deterre



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Thermo-mechanical recycling of rubber: Relationship between material properties and specific mechanical energy

Rodrigo Diaz^{1,2}, Gaël Colomines¹, Edith Peuvrel-Disdier³, Rémi Deterre^{1*}

¹Université de Nantes, IUT de Nantes, CNRS, GEPEA, UMR 6144, 2 Avenue du professeur Jean Rouxel, BP 539, 44475 Carquefou, France

²REP International, 15 rue du Dauphiné 69964 Corbas, France

³MINES ParisTech, PSL Research University, CEMEF - Centre de Mise en Forme des Matériaux, UMR CNRS 7635, CS 10207, 06904 Sophia-Antipolis, France

*Corresponding author/ Phone: +33 228092060, E-mail address: remi.deterre@univ-nantes.fr

Abstract

The studied and optimized devulcanization process is known as “High Shear Mixing” (HSM) recycling process. In the process the rubber is sheared between two metallic cones with special geometries. One cone is static as the other one rotates simultaneously and applies pressure to the material.

Among the different parameters that are controlled and/or measured during the process two are highlighted for their importance: the temperature of the rubber, and the specific mechanical energy consumed during the process. It is shown that the energy consumed by the rotor can be correlated to the degree of devulcanization of the rubber which is measured by means of physicochemical analyses. An optimal state of surface activation on the treated rubber is also described. A physical model of the rubber network evolution along the HSM treatment is proposed.

Keywords: Devulcanization; recycling; rubber; crosslink density; surface activation

1. Introduction

According to the International Rubber Study Group (IRSG), (2016) the world produced about 26,000 tons of rubber in 2015. At some point or another all of this rubber will become waste, either as production waste or as end of life waste. This waste poses an enormous challenge for its disposal or recycling. The waste can be disposed of by sending it to landfills to be buried, by incineration or by pyrolysis. The recycling of rubber is a more complicated matter as it will be shown. De et al., (2005) presented an excellent overview of recycling techniques that do not intend to devulcanize the rubber.

When rubber is vulcanized the polymer chains that compose the rubber are chemically attached by a vulcanization agent (usually sulfur) at different points along the chains, as shown in Figure 1-B. These attachments are known as crosslinks and they form a 3D network of polymer chains when the vulcanization is completed. It is this crosslinking of the chains that gives the rubber its mechanical characteristics.

Ideally the recycling of rubbers should be the devulcanization of the rubber, which consists of the breakage of all crosslinks so the polymer chains can be freed and subsequently vulcanized into another product. However, once they are created crosslinks are very difficult to break. This is an advantage during the useful life of a rubber product but it is also the main challenge for devulcanization.

The subject of this work is the study of a thermomechanical devulcanization process, called High Shear Mixing (HSM).

Nomenclature and symbols used in this work are listed in table 1.

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