Closing the loop

Re-use of worn-out car tires for new tires

Elastomer Technology & Engineering

Professorship of Polymer Technology

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Introduction

- 800.000.000 worn out car tires are generated annually (Fig.1, 2).
- Re-using possibilities of the rubber as Ground Tire Rubber (GTR) are increasing (e.g. artificial soccer playingfields) but do not catch up with the available amounts
- Re-use for low noise road pavement is increasing (Fig.3).
- Burning in the open is not allowed anymore (in Europe) but incineration in cement kilns is common practise and growing, however, destroying valuable resources.
- Devulcanization and re-using for new car tires (up to 25%) is a solution of the worn our car tire problem. Re-use of reclaim (Fig. 4) in car tires cannot be more then 5%).

Figure 1: Pile of worn car tires, 800.000.000 annually worldwide.

Figure 2: Piling up all worn tires, annually $2/3^{rd}$ of the distance from the earth to the moon is covered.

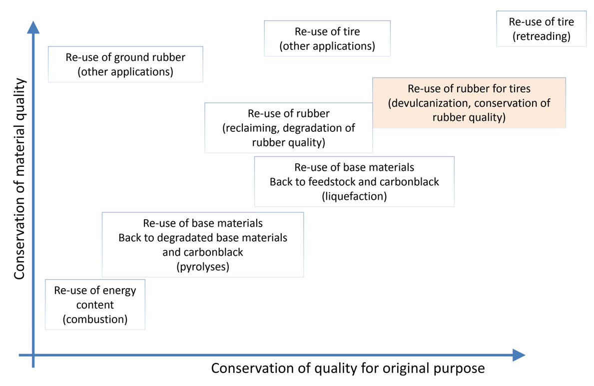


Figure 3: Conservation of material properties
Devulcanization offers the best conservation of material properties and valuable components such as carbon black

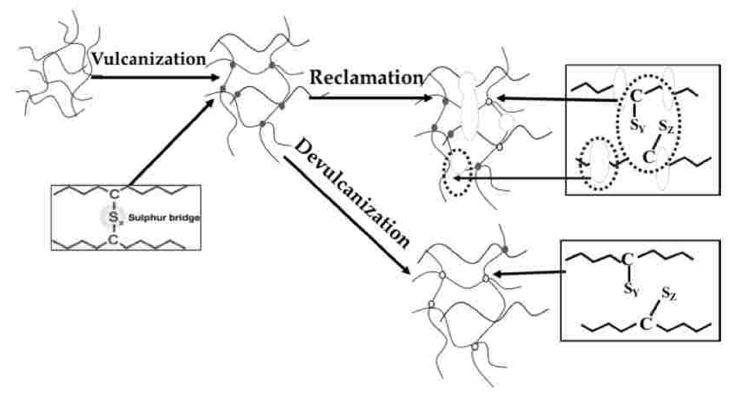


Figure 4: Devulcanization (only breaking crosslinks between the mainchains) vs. reclaim (both crosslinks and mainchains are broken)
Source: Saiwari [1]

Aim of the research

- Upscaling of a small scale batch process for devulcanization of GTR [1] into a continuous extruder process (Fig. 5)
- Finetuning of the continuous process conditions to obtain devulcanized material with optimized material properties
- Investigation of the influence of devulcanized material on the compound properties for various tire components (Fig. 6)
- Determination of the technical and economical feasibility of the overall process (Fig. 3)

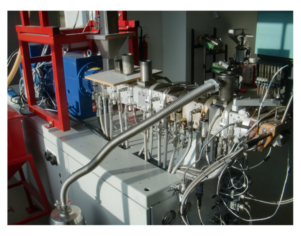


Figure 5: KraussMaffei extruder

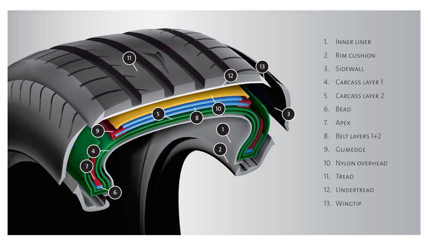
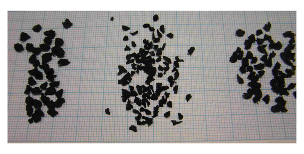


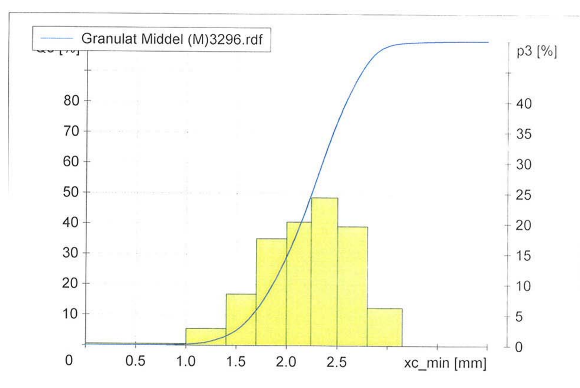
Figure 6: Assembly of a car tire
Source: Apollo Vredestein

Current & expected trends in Tire Developments

- Balancing between maximizing properties for dedicated tire components (e.g. tread) vs. maximizing amount of devulcanization material in compounds (Fig.6).
- Include environmental aspects in the tire design and production
  - Use NR from alternative sources (dandelions instead of rubber tree [2])
  - Use organic source plasticizer instead of mineral ones [3] [4]
  - Minimize the amount of ZnO [5]
  - Increase amount of silica, improve bonding between silica and rubber [6].
- Design with the optimal properties of the blend virgin/devulcanized rubber the cradle to cradle principle which provides a maximal re-usability of the scrap tires.



Particles in GTR, largest, smallest, medium



Indicated distribution of GTR.
Source: Genan

Powder of car tires is relative expensive, granulate gives some processing challenges
Figure 7: Size distribution of Ground Tire Rubber (GTR)

Items to investigate

The process: Mix the devulcanization aids with the granulated rubber, swell, heat and devulcanize at high temperature, cool down and evaluate the properties of the devulcanizate. Blend with virgin rubber and vulcanization aids, vulcanize and evaluate the rubber properties.

- The impact of granulate instead of fine powder (homogeneous concentration of processing aids, homogeneity of devulcanization) (Fig. 7, 8)
- Determine the devulcanization parameters for the continuous process (time, temperature, shear, extruder screw configuration) (Fig. 9, 10)
- Determine the compatibility of the devulcanizate with the virgin rubbers, necessary adjustments of the compound recipes and the impact on blend qualities
- In depth study of the morphology of devulcanizate - virgin rubber blends and property profile (mechanical- and dynamical properties: $G^{'}$, $G^{''}$, $\tan(\delta)$)

Preliminary results

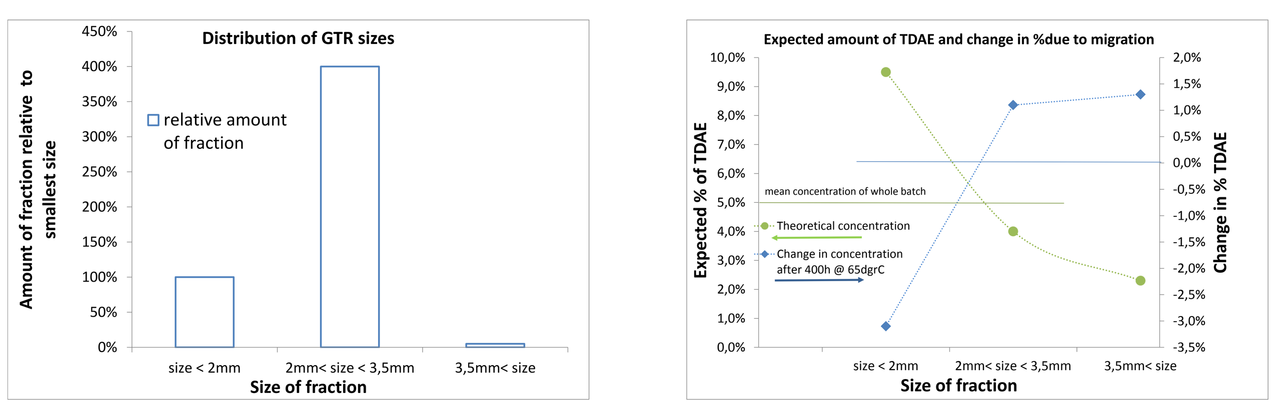


Figure 8: -Actual distribution of GTR:
(size $<$ 2.0mm, 2.0mm $<$ size $<$ 3.5mm, 3.5mm $<$ size)
-Theoretical distribution of TDAE over a complete batch of GTR because of different surface/volume ratio of the particles
-Change in concentration after swell for 200h @ 65 °C due to migration of the TDAE.

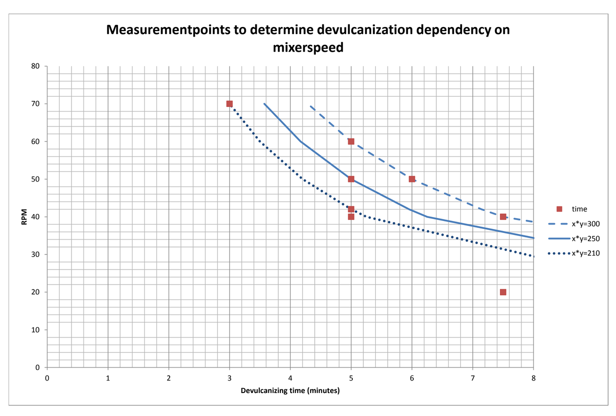


Figure 9: Testmatrix for the investigation of the impact of shear during processing vs. processing time at fixed process temperature. The original process was established at 6 min.@ 50 RPM

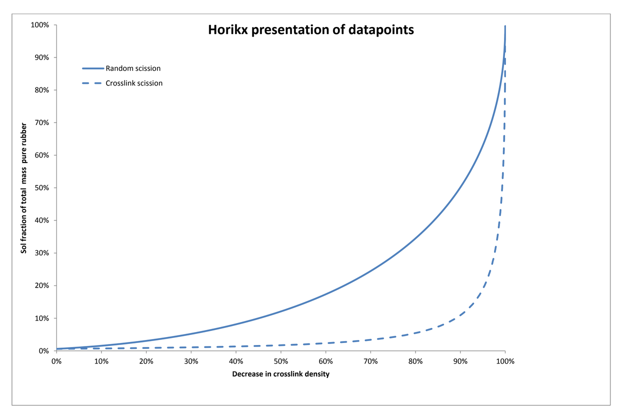


Figure 10: Horikx representation of crosslink scission vs. mainchain scission and amount of remaining crosslinks.
Test results not available yet.

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Fig.1: http://ts1.mm.bing.net/th?&id=HN.608019068649079334&w=300&h=300&c=0&pid=1.9&rs=0&p=0
Fig.2: http://ts1.mm.bing.net/th?&id=HN.608004113571316805&w=300&h=300&c=0&pid=1.9&rs=0&p=0

Acknowledgments

DSM-Zwolle, Usage of process equipment

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