Process Mapping and Scenario Development for an Upscaled Devulcanization Process Recycling Car Tire Rubber.

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In 2020 in the Netherlands alone 9.5 million passenger car tires were discarded, of which 65% were downcycled (RecyBEM, 2021, pp. 16, 20-22). One of the research projects of the client (the Professorship Polymer Engineering at the University of Applied Science, Windesheim), is the high-quality recycling of passenger car tires using devulcanization (Hoogwaardige recycling van banden door devulkanisatie, n.d.). In which devulcanization aims to break the sulfidic crosslinks created through vulcanization, while keeping the main polymer chains as intact as possible (Ghosh, et al., 2023, p. 2).

The current devulcanization process can process 2 kg of rubber an hour. One of the next steps within the project is the upscaling of this process to 20 to 30 kg per hour. This upscaling step is important as it allows for the creation of a Life Cycle Analysis, a step towards a more realistic machine-output ratio and the continuing of other project activities.
This assignment, therefore, aims to provide insight into the steps within the devulcanization process and to inventorize the possibilities and necessities of an upscaled process. The main question therefore follows: *"What scenario of machines, equipment, and connections between machines best fits the needs of the stakeholders for an upscaled devulcanization process that has a capacity of 20-30 kg/hour?".*

The research question was answered using the following central questions and methods (Table 1):

Question	Method
Who are the stakeholders for this devulcanization process and what are their needs?	Semi-structured interviews Informal interviews
How does the current devulcanization process devulcanize the car tire rubber?	Literature review Semi-structured interviews Observations Informal interviews Function analysis
What are possible combinations of machines, equipment and connections, or scenario, that will be able to process 20-30 kg of car tire rubber per hour?	Literature review Semi-structured interviews Observations Informal interviews List of requirements Market research Morphological chart
What scenario would be recommended for a devulcanization process, processing 20-30 kg of car tire rubber an hour?	Process flow diagram Product concept evaluation

Table 1 Main Questions and Methods

The information displayed in the function analysis (Figure 1) uses information obtained from semi-structured interviews, informal interviews observations of the process and information available in the KM Wishlist (Lectoraat Kunststoftechnologie, n.d.).

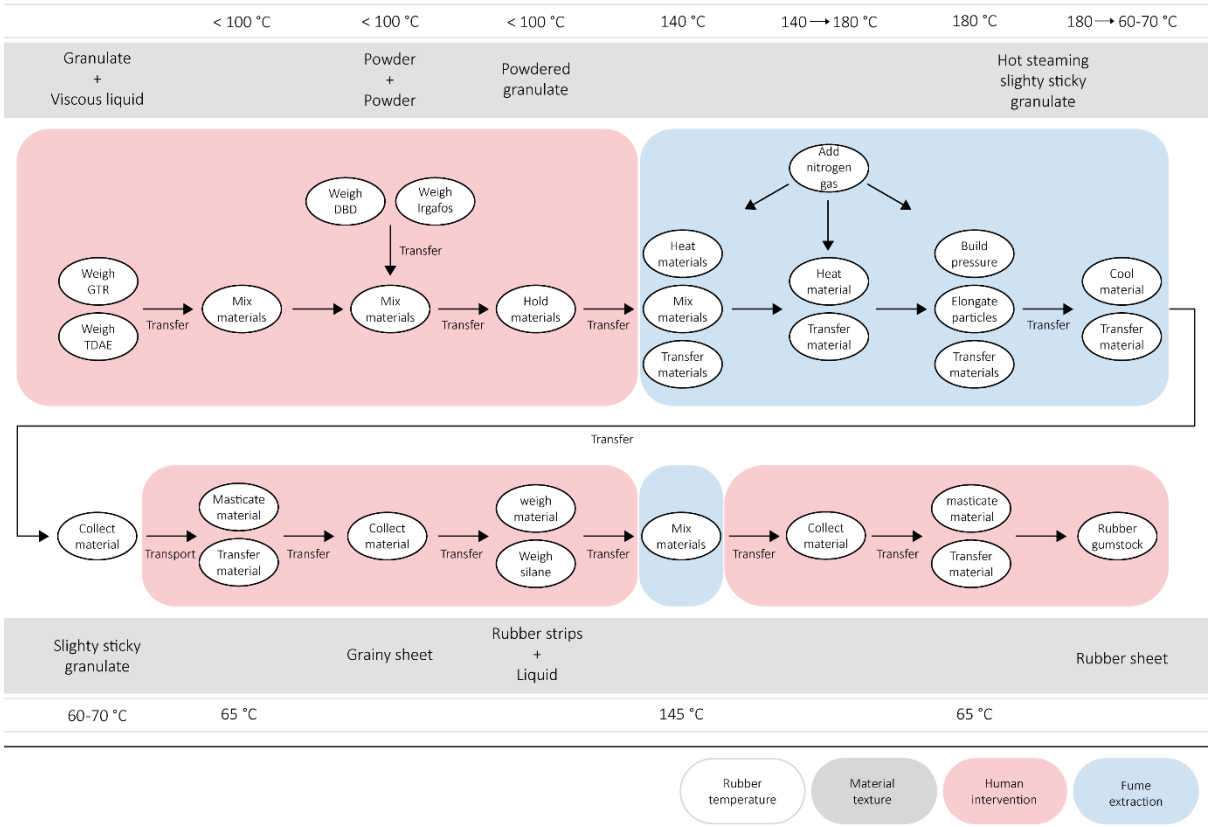

Figure 1 Function Analysis of the Current Process

Using the information from the information from the function analysis, the following process steps were identified:

- Weighing or dosing the ingredients.
- Mixing the ingredients.
- Dosing.
- Mixing and heating in an extruder under a nitrogen gas environment.
- Cooling the material.
- Masticating the material.
- Weighing the material and the silane.
- Mixing the materials.
- Masticating the material.
- Collecting the material.

With collection, transfer and or dosing operations in between the different processing steps. Additionally, while not a step within the process, fume extraction is an important part of the process as well.

Through literature research, interviews, observations and market research different machine and equipment possibilities were found for the different processing steps. Five concepts were then created using a morphological chart. After the product concept evaluation, one concept was chosen and altered to the stakeholders' wishes. The result is the machine combination that is shown below (Figure 2). Which is an automated devulcanization process that should, in terms of equipment, be scalable to a larger throughput, while maintaining a similar line-up.

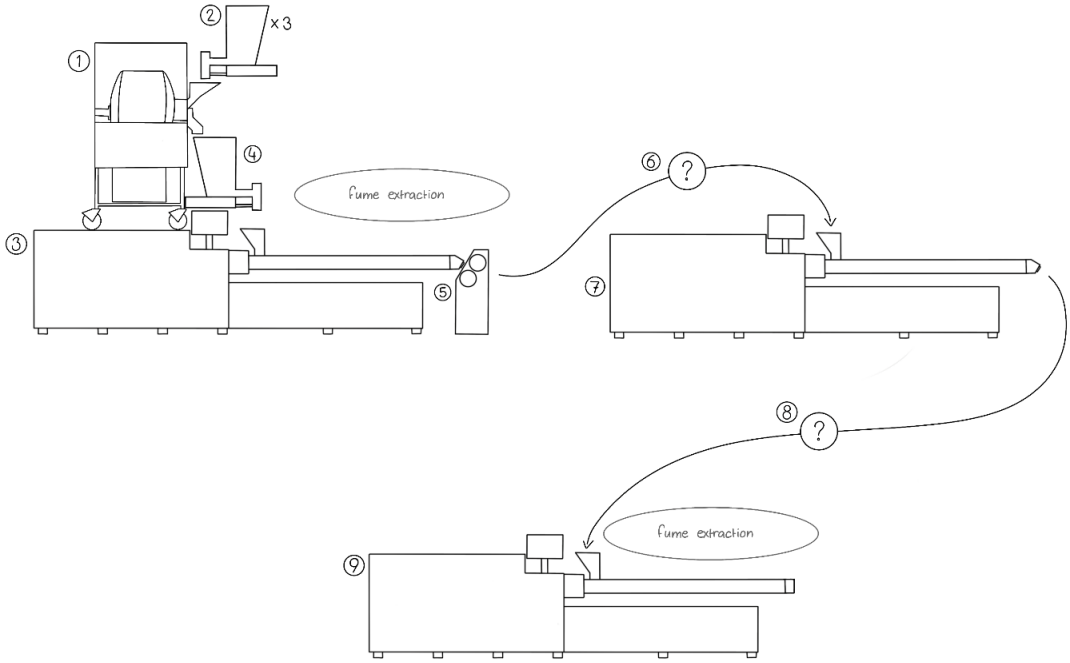

Figure 2 Final Concept Sketch

1. Tumble mixer
2. Gravimetric loss-in-weight screw feeders (dosing technology)
3. 42 mm twin-screw extruder
4. Gravimetric loss-in-weight screw feeder
5. Calender
6. Collection, transfer and dosing section
7. Single screw extruder with gear pump and strainer
8. Collection, transfer and dosing section
9. 42 mm twin-screw extruder with sheeting die

It was concluded that the machine combination shown above best fits the needs of the stakeholders for an upscaled devulcanization process that has a capacity of 20 to 30 kg per hour. Further development would require the following: The determination of material texture and consistency after each processing step. This will allow the determination of proper collection, transfer and dosing technologies. Emissions determination for filter selection and extraction unit. Selection of the proper calender, single screw extruder, gear pump and strainer. As well as the operation time of the dosing technologies and mixer. Determination of the feasibility of using an extruder for silane addition as well as the feasibility of performing silane addition and mastication in the same extruder. The determination of further necessary processing steps. And finally, the determination of the necessity of silane addition as part of the devulcanization process.

References

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