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Experimental investigations of vulcanization and problems during the demolding process by compression molding

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With a self-constructed and automated curing press for compression molding the influencing parameters on vulcanization and especially the demolding behavior are analyzed. In the focus of the measurements are the demolding force and the fouling of the mold after every cycle. The fouling behavior for different sulphur vulcanized compounds has been recorded using a camera with attached borescope, which automatically documents the shape after every demolding process. Discolorations, deposits on the base or side wall area as well as vent plugging has been observed. These effects change over the cycle duration.

Keywords (from 3 to 5 max): mold fouling, demolding problems, sulphur vulcanization, tribology

Vulcanizates are used in many areas, e.g. seals, dampers and tires. In the year 2018 about 245 000 tons of rubber were processed in Germany exclusively for tire production. Almost as much rubber (95 %) was fed into various industry manufacturing processes for the production of other vulcanizate products. [1]

The discoveries of HAYWARD (1838), GOODYEAR (1839) and HANCOCK (1842) laid the foundation for sulphur-based vulcanization. According to WEBER (1902), vulcanization is a chemical crosslinking process. This assumption is supported by the macromolecule theory of STAUDINGER, which was confirmed by MARK at the end of the 1920's. The two possible crosslinking mechanisms (radical and ionic mechanism) that take place between rubber and sulphur accelerator systems were investigated by COLEMAN, CORAN and LAUTENSCHLAGER. [2, 3]

The crosslinking process depends very much on compounding. It is a challenge for the material developer to choose the right recipe components (polymers, activators, accelerators, retarders, filler, softener, silane, processing aids, etc.), because they have a large influence on mixing and vulcanization behavior as well as on the demolding process itself.

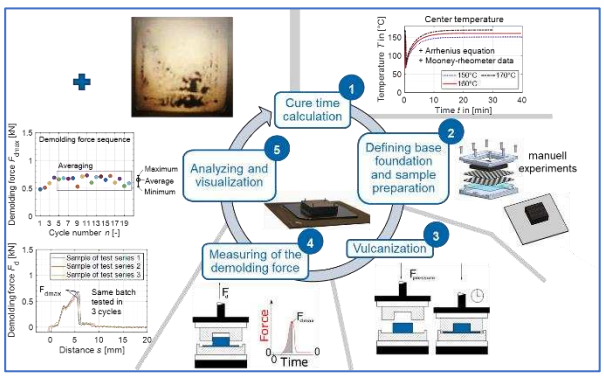

Figure 1: Vulcanization and Demolding process at the demolding test rig with parameter analysis and fouling evaluation

A slow flow rate is advantageous for a good mold filling and then the crosslinking reaction should start fast. The quality of the vulcanizate is directly influenced by the vulcanization and its parameters (time, temperature and pressure). Process parameters affect also the demolding force measurements. In order to achieve the optimal degree of crosslinking and the desired physical properties, the different elastomer recipes, dimensions of the geometry and material thicknesses must be taken into account. The determined vulcanization time ensures an essential crosslinking at the critical area of the vulcanized rubber, because the non-stationary heat conduction results in an anisotropy of the crosslinking over the vulcanizate cross-section.

In order to analyze the influencing variables of the vulcanization on demolding process (force and fouling effects), the self-developed curing press has been optimized and automated in the last three years. A mold temperature control system is integrated and with an adaption the cure temperature curve can be measured for different geometries at the critical point in the cured rubber, so that an individual cure time calculation can be done. For a higher performance and statistical analysis, a robot with a special gripper changes the cured rubber samples and replaces it with the next green sample. The robot activates the test procedure at the test rig and communicates a successful change or an error. The robot also activates the integrated camera system, so that analyses of mold fouling effects after every vulcanization are possible. Various effects have been visualized depending on geometry, compound, process parameters, mold material and coating. Discoloration, deposits on the base or side wall as well as vent plugging will be presented.

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