Time-independent and time dependent Finite Element Analysis for coverage of solar temperature influences acting on laminar cylindrical tanks made of thermoplastic material

In proof of stability und service ability for plastic cylindrical constructions with outdoor installations it is necessary to take account for the temperature influences due to sun exposure. The explanation lies in the extreme temperature dependence of the thermoplastic materials as well as in the forced actions because of disabled temperature expansions.

For the verification of stability of the investigated plastic components computer aided calculations for example with help of the Finite Element Method are applied for the investigation of temperature behavior. FEM is a numeric procedure permitting modeling and calculation of structures and construction elements, which cannot or were insufficient described via analytical simulation techniques. Currently calculations are performed under time independent boundary conditions with different simple temperature scenarios in order to give statement of long term stability with solar exposures. Thereby small areas of high mechanical stresses are obvious at the edges of material parameters. These differences in the response of the material are unrealistic because the distribution of the temperature due to solar radiation in the plastic component is continuous.

In the context of the research project the higher surface temperatures of the tanks are calculated with the software INSEL with reference to the solar radiation. We considered the outside temperatures and the radiation conditions for the hottest day in Germany in the last 100 years. The surface temperatures were saved for every minute of the investigated day and transferred to the Finite Element program NASTRAN in a suitable manner. The founded results were checked of plausibility and compared. During the second step of work time dependent thermal calculation were started to investigate the temperature behavior inside the cylindrical wall. These calculations were performed on a volume mode and considered the heat conductivity and thereby the time dependent expansion of the temperature in the plastic material. At the inside wall of the tanks neither a constant media temperature nor a time dependent air temperature are pretended. The difference is controlled by the convection boundary condition and so it is possible to simulate the filled and unfilled configuration. With help of the results output at different times of the day and different cardinal directions we were able to describe and verify the basic effect within the tank wall.

In the further course of the research project coupled thermo-mechanical calculations are performed for different times of the investigated day. For the filled and unfilled configuration of the tanks different mechanical exposures (filling, depression etc.) and actions due to temperature differences can be noticed. The results of these calculations are compared and the basic effects are discussed and explained. For the surface temperatures as well as for the controlling design points linear in sections distributions of the temperature were derived which take account for the nonlinear results in a very accurate way. The distributions are transferred to plate models and different design relevant calculations were executed. The comparison of the approximate laminar models with the detailed volume models shows the precision and the limitations of the suggested procedure. The final methodology can be easily reproduced and implemented in nearly every calculation tool.

The developed document gives approaches for the structural engineer how to act with the load case „sun exposure and radiation“ for outdoor installations of thermoplastic tanks. Furthermore it induces an improved measurability by a third party. The designed proposal for solution provides a clear approach for to-be handling of specified difficulties in a uniform and established way.

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