ON THE ADVANCED THERMAL-FSI APPROACH TO THE THERMO-ELASTIC-FRAGILE CRACKING CAUSED BY THERMAL STRESSES BASED ON THE BURZYŃSKI-PĘCHERSKI CRITERION

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1. Introduction

The present work is devoted to the analysis of yield conditions for glass exhibiting the strength differential (SD) effect [1,2]. The issue of glass materials was brought up, because glass is an important element of our daily life, of which we are aware when e.g. the glass cup with juice is dropped or the view through the window is disturbed because of rupture on the glass. As well known, glass is elastic material, but also very fragile. Glass cracks almost immediately without any earlier plastic deformation. Cracks can occur delayed in relation to cause, which them entails.

Of many thermal properties of glass, interest stopped at rapid-change-temperature-strength, which is associated with thermal expansion and also phenomenon of stresses formation inside the glass. The quantity which characterized thermal expansion is coefficient of thermal expansion [1].

During sudden warming, which is not concentrated, glass withstands 8 times higher temperature changes than during sudden cooling. Explanation of this phenomenon is based on fact, that glass owns much greater value of compressive strength than tensile strength; taking into account the low value of thermal conductivity is easy to understand, that during sudden warming of cold glass, outer layers are pressed, whilst during sudden cooling of hot glass, outer layers are extended (interior of glass is compressed). For this reason, the glass always will crack, when applied to it load will be exceed the tensile strength. Intense and heterogeneous glass heating on whole surface (which can be caused by sun or hot fluid) can lead to emergence of high stresses. This in turn causes thermal shock i.e. the glass cracking due to thermal overload. In CFD solver is obtained field of temperature [3,4] and then imported to CSD solver where stresses fields and strains fields are obtained [4,5].

2. Simulations

In particular in this paper, is investigated influence of pressure sensitive material effort model on equivalent stress of real geometry. Analysis is drawn up with two effort models, mainly Burzyński-Pęcherski and Huber-Misses-Hencky model. The extension of Burzyński condition [6,7,8] is expressed by [9]:

$$\eta_f(\theta)q^2 + \eta_v(p)p^2 = K. \tag{1}$$

where $\eta_f(\theta)$ - Lode angle influence function, $\eta_v(p)$ - pressure influence function, p^2 - volumetric strain energy density $p = \frac{1}{3}(\sigma_1 + \sigma_2 + \sigma_3)$, q^2 - distortion strain energy density $q = \sqrt{\frac{1}{3}[(\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 + (\sigma_1 - \sigma_2)^2]}$, $\sigma_1; \sigma_2; \sigma_3$ - principal stresses.

The Burzyński-Pęcherski is compared with the classical Huber-Mises effort definition during thermal FSI analysis of the glass behavior during artificially induced thermal shock. Models could be used, cause glass is isotropic material. The behavior of different types of glass can be various, because of miscellaneous chemical composition, but general and final effect is the same - rupture of glass. As a model of glass material is used a cold glass cup and as a load hot boiled water. This approach is well known most of people as a cup cracking during the pouring of hot, boiled water. The result is emergence of large temperature gradient, what consequently leads to thermal stresses. Finally CFD conjugate heat transfer analysis has been carried out using commercial software. Then stress analysis was performed with boundary conditions obtained during CFD analysis. The examples of thermal-FSI analysis with Burzyński-Pęcherski criterion was performed in work [10,11].

3. Conclusions

In the paper comparison of material effort models: classic the Huber-Mises approach and the Burzyński-Pęcherski criterion is introduced. Our investigation is performed during one-way thermal-FSI analysis of a glass material. At first CFD conjugate heat transfer analysis has been carried out. Following the heat transfer analysis, stress analysis, in which boundary conditions obtained by CFD analysis, was performed. During the stress analysis, two mentioned equivalent stress definitions were applied and the differences in material effort modeling by them were showed.

4. References

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