MEMBRANE SHELL FINITE ELEMENT FOR TEXTILE FABRIC MODELLING NUMERICAL AND EXPERIMENTAL ASPECTS

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1. Introduction

Structures made from technical fabrics become more and more popular. Design of such structures is difficult as not only geometric non-linearity, but also very special constitutive modeling is necessary. Usually the finite element method is used in the design process. Typical commercial software can not be applied in this case, as typical membrane elements can not properly express behavior of fabric threads during deformation.

There is several constitutive models which can be used in such calculations (see [1], [2]), but most of them can not be applied in commercial FEM systems. Additionally, usually they can be used for only one type of constructive modeling of threads behavior: non-linear elastic, viscoelastic or viscoplastic. Proposed in [3] the dense net model of a technical fabric can be used with all three mentioned before approaches. It is also applicable for the three node triangle [4], and for four node isoparmetric membrane shell finite elements [5].

The idea of the dense net model is relatively old, but in the paper new, practical aspects of its application will be discussed.

2. Experiments for dense net model identification

To perform calculation of any structure it is necessary to know its material properties. A technical fabric is build from at least two very different materials (threads and coating) and has different properties in different directions which additionally can change in deformation process. National standards require only very simple tests [6] which are not enough to describe the fabric behavior in FEM calculations. The type of constitutive description depends also from the type of calculations which is going to be performed (e.g. nonlinear elastic formulation is enough in the initial stage of design, viscoelastic must used in long time behavior investigations, while in extreme loadings calculations the viscoplastic approach seems to be the best). The laboratory equipment for technical fabric test must enable recording of time, displacements and forces. A standard strength machine must be equipped in a special support system, and must guarantee good accuracy and frequency of recorded results. For creep and shear tests special stands which will be presented during conference are necessary. Generally for identification of warp and weft threads the uniaxial tests are the most often performed. The bi-axial tests are difficult and their results are hard in application to constitutive identification. During conference examples of such tests will be presented and their advantages and drawbacks will be discussed.

3. Numerical aspect of dense net model application

3.1. Identification

After experimental tests identification of threads and coating properties is necessary. Pure experimental data are usually not applicable as for the rheological models calculation of the time derivatives of strains is necessary. The least squares method is the most often used numerical tool on this stage of research. The author experience in identification of non-linear elastic, viscoelastic and viscoplastic models for a warp and weft will be presented. The numerical methods of verification of identification results will be also given.

3.2. Introduction of identification results into FEM calculations

In the FEM calculations of textile structures self-constructed or commercial software can be used. From that second group only systems which enable the user subroutines introduction can be selected (e.g. MSC.Marc or Abaqus). In such subroutine the dense net model describes the constitutive relations for a typical membrane shell element. The modeling by triangle elements is easier as the directions of threads families can be univocally determinate by the edges of an element. For the four node isoparametric membrane elements more complex calculations are necessary [2]. The main problem in calculations ob membrane-cable structures is determination of initial balanced configuration. This process is well known as the form-finding and is supported by special software [7]. The most important type of loading for light structure like a hanging roof is the wind loading. Due to complex shape of a roof only expensive test in an aerodynamic tunnel can give proper distribution of the wind pressure and suction. In the initial stage of design the approach proposed in [8] can be used. Very often not only static but also nonlinear dynamic calculations are necessary.

5. Calculation example

In year 2009 (for the 100th anniversary of erection) reconstruction of the Forest Opera in Sopot is planed. The theatre will be covered by the new hanging, textile roof supported by two over 100 m span steel arches. The author is involved in the roof design process. Necessary experiments and most of the calculations of the cable-textile part of the roof were performed in Gdansk University of Technology. In numerical calculations of the new roof the dense net model with different types of constitutive models was used. Some problems the form-finding of climatic loadings determination will be presented during conference.

6. References

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