Université Lille Nord de France
Pôle de Recherche et d'Enseignement Supérieur

Ecole doctorale régionale Sciences Pour l'Ingénieur
Lille Nord-de-France - 072

Titre : Thermomechanical fatigue of rubbers: prediction of thermo-oxidative aging effects on lifetime

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Description :

Thanks to their mechanical properties, and more especially their capability to undergo large deformations and to dissipate energy, filled elastomers are increasingly used in many industrial fields. Most of rubber components are often subjected to cyclic, multiaxial and non-proportional loadings. Designing and optimization of such components with respect to their lifetime therefore require the development of fatigue criteria to quantify their mechanical strength. For a few years, the renewed interest on this subject has opened up promising work prospects. The main purpose of the PhD thesis focuses on building a lifetime criterion based upon cumulative damage, in the framework of finite strains and accounting for induced self-heating and the subsequent thermo-oxidative aging.

Indeed, a previous work achieved by the welcoming team allowed to set up a criterion based upon cumulative damage. This criterion was validated using biaxial loading paths in torsion tension but also on random type loadings. Another work pointed out self heating during fatigue and a thermomechanical model was developed allowing the estimation of the temperature levels during cycling.

We therefore wish to enrich this thermomechanical model by coupling the effects of self-heating and thermo-oxidative aging induced by temperature. For this purpose, we plan to develop a physically-based constitutive law (based upon the eight chain model for instance) allowing the model parameters to be linked to the chemical degradation kinetics and their effects on the mechanical properties.

Work schedule:

In this project, we propose to introduce physico-chemical aging in the constitutive law in order to enrich the capability of the thermomechanical model developed by our team.

The work will therefore include experimental fatigue tests under multiaxial loadings (tension-torsion, compression-torsion tests) on as received materials but also on aged specimen at different

temperatures and for different exposure times. The material will be a SBR rubber, containing different volume fractions of carbon black.

The prediction of the lifetime will be done on the basis of a thermo-chemo-mechanical model coupled to the damage evolution and taking into account:

Ø Thermomechanical aspects related to self-heating during fatigue

Ø Influence of physico-chemical aging on residual life.

Timetable

1st year: littérature review,, implementation of the experimental protocol, carrying out tests in alternating tension and torsion, measuring kinematic and thermal fields, accelerated aging.

2nd year: combined tensile-torsion and compression-torsion tests, in phase tests and out phase tests. Validation of the criterion. Deepening of the damage approach, including self-heating effects and physico-chemical aging.

3rd year: continuation of the tests. Extrapolation to long aging times (operating temperature) from accelerated aging tests based on the time-temperature equivalence principle. Implementation of the model in a finite element software.

Applicant: Master degree with a good expertise in mechanics of materials. The applicant will have to develop both experimental and modeling aspects. Therfore, the applicant must be motivated showing a deep interest on these 2 aspects. Basic knowledge of polymer physics (or organic chemistery) would be a bonus.