Accepted Manuscript

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PII: S0749-6419(16)30268-6

DOI: 10.1016/j.ijplas.2016.11.001

Reference: INTPLA 2120

To appear in: *International Journal of Plasticity*

Received Date: 15 August 2016

Revised Date: 17 October 2016

Accepted Date: 2 November 2016

Please cite this article as: Yu, C., Kang, G., Chen, K., A hygro-thermo-mechanical coupled cyclic constitutive model for polymers with considering glass transition, *International Journal of Plasticity* (2016), doi: 10.1016/j.ijplas.2016.11.001.

A Hygro-thermo-mechanical Coupled Cyclic Constitutive Model for Polymers with Considering Glass Transition

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Abstract

Based on the experimental observations to the cyclic deformation of polyamide-6 polymer (PA6) involving a multi-field coupled issue, a new hygro-thermo-mechanical coupled cyclic viscoelastic-viscoplastic constitutive model is constructed to describe the multi-field coupled cyclic deformation of the PA6 within the framework of irreversible thermodynamics. In the proposed model, a new free energy is introduced to obtain the appropriate independent state variables; the thermodynamic driving forces of strain-like internal variables related to the viscoelasticity, viscoplasticity, chemical reaction and glass transition are deduced from the newly constructed free energy and the Clausius-Duhem's dissipative inequality. The spatial and temporal evolutions of temperature and relative humidity are deduced from the first law of thermodynamics and the mass conservation equation, respectively. The Langmuir-type (i.e., non-Fick's) diffusion equation is deduced and a new criterion of glass transition is developed. The glass transition is caused by the intrinsic heat generation of the PA6 during the cyclic deformation. Finally, the capability of the proposed model is verified by comparing the predicted results with the corresponding experimental ones of the PA6. It is seen that the temperature-, relative humidity-, rate-dependent cyclic deformation of the PA6 and the