WCCM

ABSTRACTS

Volume I

FIRST

World Congress on Computational Mechanics

International Association for Computational Mechanics

September 22-26, 1986

Held at

THE UNIVERSITY OF TEXAS AT AUSTIN

Organized by
The University of Texas at Austin
and
George Washington University
through
THE TEXAS INSTITUTE for COMPUTATIONAL MECHANICS

MODELING OF CYCLIC PLASTICITY OF STRUCTURAL STEELS

Masaru MINAGAWA
Research Associate

Takeo NISHIWAKI
Professor

Nobutoshi MASUDA
Associate Professor

Musashi Institute of Technology,
28-1, Tamazutsumi 1 chome, Setagaya-ku, Tokyo 158, JAPAN

When structures are subjected to complicated fluctuating loads due to earthquakes, wind storms, waves and so on, stresses beyond the elastic-limits of steels break out in members or parts of them repetitively. In this case, even if the structures do not collapse, it is expected that the hysteretic effect reduces the load capacity or deformability of such a structure from the level predicted in design. Because such problems are very important and fundamental for structural design, the authors have investigated the effect of loading histories on mechanical properties of steels which are important structural materials, and have accumulated experimental data.

Petersson & Popov Model (P.P. Model)[1] has the grounding in the multi-surface plasticity theory and has an advantage that only a few tests are required to make up fundamental functions representing material properties.

The final purpose of this investigation is to complete an accurate hysteretic model to predict elaso-plastic behaviors of steel structures or members subjected to external forces in excess of those amount. In this paper, a stress-strain model based on P.P. Model is studied with the emphasis on the evaluation method of hysteretic effects.

In P.P. Model, hysteretic stress-strain behaviors are represented by the concept of expansion, reduction and movement of state surfaces in the stress space. Each surface is defined by a surface size function K, by which the size of each surfaces is expressed, and a vector $\{\alpha\}$ indicating its central coordinates. In order to introduce the hysteretic effects to stress-strain relations, K and $\{\alpha\}$ are changed with the progress of loading histories. The degree of hysteretic effect is described by accumulative equivalent plastic strain $\bar{\varepsilon}_p$ and increment of equivalent plastic strain $\bar{\varepsilon}_{pi}$. The surface size function is defined according to the following equation, introducing K_a, K_b and W which are the functons of $\bar{\varepsilon}_p$ and $\bar{\varepsilon}_{pi}$.

$$K = W \cdot K_a + (1 - W) K_b \qquad (1)$$

where K_a is the surface size in the case where no hysteretic effect is and K_b is that in the case where the hysteretic effect is stationary. The weighting function W represents the change in the surface size function from K_a to K_b due to loading histories and is evaluated by means of numerical calculation. K_a and K_b which are referred to as Fundamental Surface Size Functions (F.S.S. Functions) in this paper, are key functions for evaluating the surface size function in any phase of loading.

In this paper, basing on experimental results, accumulation of equivalent plastic strain in the process of repetitive loading is accomplished in the following way consistent with results of measurements ; the accumulative equivalent plastic strain is evaluated under the assumption that the plastic strain beyond the preceding plastic strain amplitude is effective.

Characteristic features of stress-strain relations for steels under repetitive loading conditions are as follows ;

(a) the disappearance of yield plateau in the successive hysteteric loading processes when unloading is applied on yield plateau,

(b) the change in degree of Bauschinger effect when unloading is taken place in strain hardening region.

It seems to be a necessary condition for a stress-strain model compatible with experimental results that the model may represent these features. In N.M.M. Model, to get better compatibility with experimental results, the surface size function K_{ab} , which is a surface size function at the start point of strain hardening for virgin material, has been introduced as a F.S.S. Function in addition to K_a and K_b. Following the introduction of K_{ab}, W_1 and W_2 is defined as weighting functions. The function W_1 expresses the phenomenon that stress-strain curve changes continuously from the virgin stress-strain curve, which is characterized by yield plateau and strain hardening, to the smooth curve, on which Bauschinger effect is characteristic, and W_2 stands for the cyclic softening or hardening following the progress of loading histories. These two functions are peculiar to each materials.

Since the model is baed on the assumption that the stress-strain relations on the certain loading path or unloading path is determined by means of accumulative equivalent plastic strain $\bar{\varepsilon}_p$ at the start point of the loading or unloading, material properties can be estimated by a combination of a monotonous tension test and several tension-compression tests each including only one reversed point.

Elasto-plastic FEM analyses are performed. Fig.1 shows an example of stress-strain curves predicted by N.M.M. Model and that gained by an experiment. Close agreement between calculated and experimental stress-strain relation over all strain paths is obtained. Thus N.M.M. stress-strain model proposed by the authors is capable of predicting the actual hysteretic behaviors of steel with high accuracy.

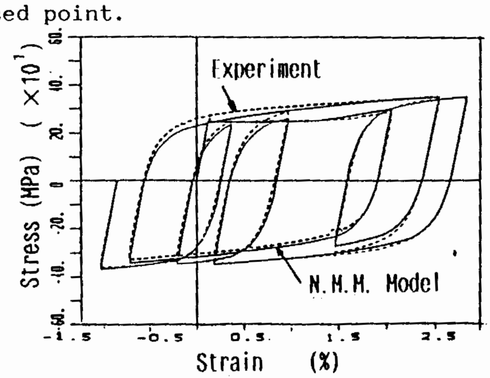

Fig. 1 Comparison;Experiment and calculation.

(Reference) 1.Petersson H. and Popov E.P.: Constitutive Relation for Generalized Loadings, Proc. of ASCE, Vol.103, No.EM4, pp.611-627,1977.

NSM.1 - NONLINEAR SOLID MECHANICS I

Bass Lecture Hall
"Solution Algorithms for Fractional Derivatives," Joe Padovan; University of Akron, U.S.A.

"Finite Element Analysis of Shear Localization in Rate and Temperature Dependent Solids," Jeffrey LeMonds; Brown University; and A. Needleman; SRI International, U.S.A.

"Modeling of Cyclic Plasticity of Structural Steels," Masaru Minagawa, Takeo Nishiwaki and Nobutoshi Masuda; Musashi Institute of Technology, Japan

"Crash Simulation of a Convoluted Box Beam with a Nonlinear Finite Element Code," Hai Wu, Han Wang and Kin Yeung; Ford Motor Company, U.S.A.

"Nonlinear Analysis of Trusses by Energy Minimization," Sadaji Ohkubo and Yasuo Watada; Ehime University, Japan

"An Algorithm of Contact Problems for Forming Process of Thin Plates - A Numerical Analysis for Seaming Process of a Can," Masao Ishinabe; Toyo Seikan Group, Japan