Modeling Asymmetric Hysteresis Inspired and Validated by Experimental Data

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Abstract. Asymmetric hysteresis challenges modeling. This study takes a small step by putting forth a method to capture asymmetric hysteretic restoring force as inspired and validated by a set of carefully designed and collected laboratory experimental data. The extended Masing model for symmetric hysteresis is generalized; all nonlinear parameter identification using the experimental data is carried out using multilayer feedforward neural networks.

Introduction

Experimental data plays an important role in this study. It first reveals the subject of this study, asymmetric restoring force. The challenging asymmetric hysteresis needs a definition.

Definition 1 (asymmetric hysteresis in restoring force) *When displacement $x(t)$ has the same amplitude in both the positive and negative directions, the differences in restoring force $r(t)$ between loading/reloading and unloading in the positive and negative directions of $x(t)$ are not the same for all $x(t)$. We name this asymmetric hysteresis in terms of restoring force.*

Mechanical asymmetry in a structure, device or mechanism is the cause for the asymmetric restoring forces in this study. [1] quantifies a measure for loading rate-dependency and concludes that the responses are *rate-independency* dominant. To model the asymmetric hysteresis, the rate-independency hints the possibility of applying the classical Preisach operator with two benefits. First, the classical Preisach model probably is the most general rate-independent hysteresis models. Next, we will adapt the extended Masing model [2], a subset of the classical Preisach model [3], for asymmetric hysteresis. Our objective is to explore the possibility of generalizing the existing extended Masing model. Since the extended Masing model has a concise format for symmetrical hysteresis, we wonder if another concise format would be achieved for asymmetric hysteresis.

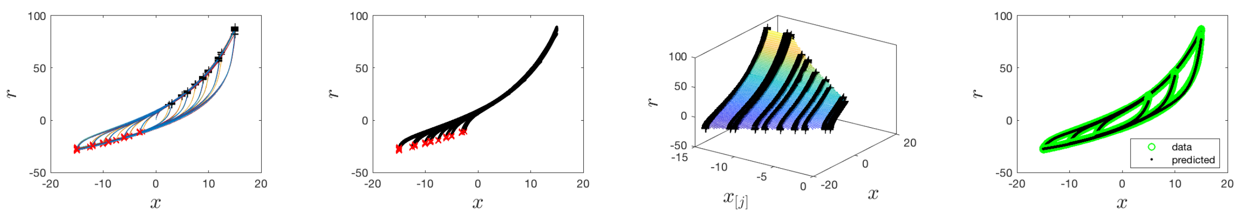
Results and Discussion

We conjecture that, for an asymmetric extended Masing model, we could have two *implicit functions*:

$$\text{all reloading curves:} \qquad f_l\left(\frac{x - x_{[j]}}{2}, \frac{r - r_{[j]}}{2}\right) = 0 \tag{1}$$

$$\text{all unloading curves:} \qquad f_u\left(\frac{x - x_{[j]}}{2}, \frac{r - r_{[j]}}{2}\right) = 0 \tag{2}$$

Formulations for the corresponding *explicit functions* are then obtained and identified using multilayer feedforward neural networks (FFNNs) with three hidden nodes each. Sample results showing data versus model predicted hysteresis are given in Fig. 1.



(a) raw data (b) raw reloading data (c) existence of an explicit function of (b) illustrated (d) validation of two FFNNs for reloading and loading

Figure 1: Sample results showing (a) experimental data versus (d) model predicted hysteresis

References

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