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IDENTIFICATION OF IBARRA-MEDINA-KRAWINKLER HYSTERESIS MODEL PARAMETERS USING PARTICLE SWARM OPTIMIZATION ALGORITHM

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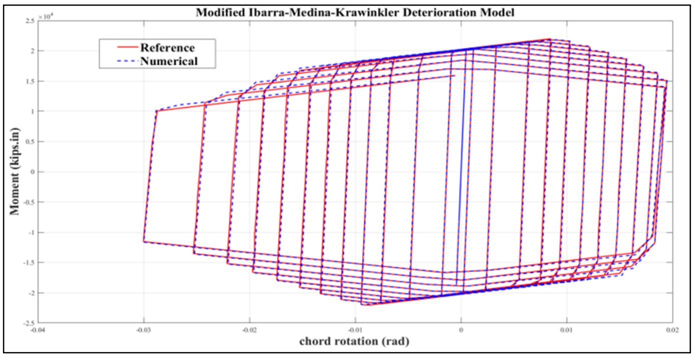
In order to have an accurate evaluation of the performance of the structures and to achieve an optimum structural design against dynamic loading, it is necessary to have analytical models that consider all significant aspects in the behavior of structural materials. The hysteresis curves provide essential information about the dynamic properties that directly contribute to the behavior of the actual structures during an induced seismic load.

Up to this point, a variety of hysteretic models are developed, ranging from simple elastoplastic models to sophisticated models that take into account more complex characteristics of the materials. Each model consists of a few adjustable parameters that can be calibrated to simulate a specific material, and the number of these parameters increase as the models become more accurate. For example, in the case of steel structures, many models that are previously utilized to capture the response do not take into account the effects of material deterioration; even if taken into account, the deterioration is treated separately from the loading history. Bouc-Wen material model is an example of these models. On the other hand, the Ibarra-Medina-Krawinkler deterioration model is one of the models in the literature that considers the deterioration while taking into account the effects of loading history (Ibarra et al., 2005).

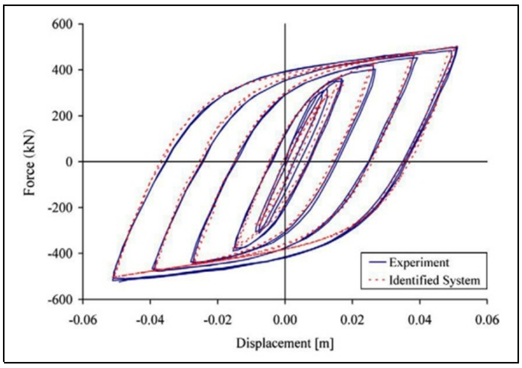
In each case, the parameters of the employed hysteresis model should be calibrated to be applicable for the specific material of the study. The calibration process is usually carried out using classical methods such as Least Squares Mean, Recursive Least Squares, or optimization algorithms known as non-classical approaches. The Particle Swarm Optimization (PSO) algorithm is one of the methods employed in recent studies. In fact, PSO is classified as a part of the wider category of swarm intelligence methods (Kennedy & Eberhart, 1995).

This study aims to utilize PSO method on a structure modeled with modified Ibarra-Medina-Krawinkler (IMK) deterioration model in order to accurately achieve the model parameters and capture the hysteresis response of structure. First, a moment frame with two spans and two floors was modeled in OpenSees. The members were modeled using elastic beam-column elements with concentrated plastic hinges at both ends. The plastic hinges were modeled with zero-length torsional spring elements and IMK material model. The externally applied load F(t) was a record of 15s of the signal $F(t)=t\sin(2\pi t)$ sampled at 0.02 sec. Afterwards, a set of reference values for the plastic hinge model parameters were gathered from the results of Lignos et al. (2011) to achieve a reference structure hysteresis response curve. Then, the parameters were set to their default values, and the model was linked to MATLAB in order to re-evaluate the parameters and re-capture the hysteresis response, this time using PSO algorithm. The best parameters were extracted from the numerical model, which had the highest compliance with the reference data.

An example of the results of PSO algorithm is shown in Figure 1-a which indicates that the identified parameters and the corresponding hysteresis curve is in a satisfactory alignment with the hysteresis curve obtained from the reference model. The accuracy of the model can be compared with Figure 1-b which presents the result of a similar study carried out by Charalampakis & Dimou (2010) using Bouc-Wen model, without concerning any stiffness and strength degradation.



(a) Modified IMK model of this study



(b) Previously used Bouc-Wen model (Charalampakis, 2010)

Figure 1. Comparison between the results of this study and previous studies.

Because of the accuracy of the results of Figure 1-a, an emphasize should be made on the superiority of PSO algorithm, as no other method could have been used to deal with such a complicated hysteresis model. Table 1 summarizes the identified values for the model parameter in each trial and error of PSO algorithm. As presented, the mean relative error between the reference values and those achieved by PSO is limited to 8.88% throughout the whole process. It is concluded that, because of the inherent capability of PSO algorithm in dealing with local optimal solutions and its ability to efficiently move towards the global ones, the exploration and exploitation stages are thoroughly satisfied. This has resulted in a comprehensive search around the global solution within the feasible search domain.

Table 1. Identification results from simulated data analyzed.

parameter	reference value	run1	run2	run3	run4	run5	mean error (%)
McMy	1.1	1.100	1.098	1.100	1.099	1.099	0.078
LS	10	10.722	10.550	9.108	8.139	10.417	8.884
LK	1	1.014	1.003	1.008	1.000	1.004	0.564
LD	0.5	0.524	0.497	0.563	0.533	0.471	6.050
th_Pp	0.01	0.0098	0.0100	0.0097	0.01	0.01	1.219
th_pN	0.01	0.0097	0.0100	0.0097	0.01	0.01	1.493
th_pcP	0.12	0.1062	0.1287	0.1106	0.1180	0.1229	6.133
th_pcN	0.12	0.123	0.120	0.117	0.121	0.120	1.213
ResP	0.3	0.318	0.297	0.264	0.304	0.330	6.052
ResN	0.3	0.287	0.341	0.252	0.291	0.292	7.852
th_uP	0.2	0.191	0.192	0.199	0.206	0.224	4.812
th_uN	0.2	0.204	0.188	0.196	0.197	0.196	2.612

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