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A novel computational inverse technique for load identification using the shape function method of moving least square fitting

Jie Liu, Xingsheng Sun, Xu Han *, Chao Jiang, Dejie Yu

State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, College of Mechanical and Vehicle Engineering, Hunan University, Changsha 410082, PR China

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ABSTRACT

Based on shape function method of moving least square fitting (SFM_MLSF), dynamic load is identified. The time domain of load is discretized and the local load is approximated by SFM under LSF. With this local domain moving, whole load is described. The response matrix is formed through assembling the responses of shape function loads in all local domains and the forward model is established. The regularization is adopted to overcome the ill-posedness of load reconstruction. Compared with Green's kernel function method (GKFM), SFM_MLSF approximates load more smoothly, so the ill-posedness is improved. Numerical simulations demonstrate the efficiency of SFM_MLSF.

1. Introduction

Nowadays in many practical engineering problems, such as structural strength analysis, health monitoring and fault diagnosis, and vibration isolation [1–5], the knowledge of dynamic loads acting on a structure is always required. Once exact dynamic external loads are obtained, it is possible to apply various advanced methods to ensure the reliability and safety of engineering structures and to satisfy the requirement of modern industry and national defense. Generally speaking, an input load can be directly measured by a force transducer located in the load transfer path. However, the structure may block the use of a force transducer since the transducer would be destroyed or it may change the system properties. Thus, in some cases, such as a tall building subjected to wind loads, an offshore platform subjected to ice loads and a vehicle subjected to exciting forces from the road, it is usually difficult or even impossible to measure dynamic loads directly, which leads to the booming development of the theory of load identification.

The technique of load identification, a crucial indirect method to obtain dynamic loads, is to solve an inverse problem through the dynamic characteristics of system and the measured responses of structure. There are mainly two classes of identification techniques, namely frequency-domain and time-domain methods [6]. Research on the methods in frequency domain is early and relatively mature. These methods are to determine spectrums of excitation loads via the relationship between the frequency response functions of investigated structure and the spectrums of responses measured during operation, or to calculate the characteristics of modal forces through modal coordinate changing [7–9]. Moreover, on the basis of the kinetic equation, methods formulated in time domain mainly depend on the relation between loads and system responses to obtain the time history of loads [10–14]. Compared with frequency-domain methods, methods in time domain can identify various types of loads including impact loads, and the identified results have clear physical meaning and relatively higher accuracy. As a result, time-domain methods have a good prospect in engineering.

In recent years various methods for solving the inverse problem associated with indirect force measurement in time domain have been proposed. Liu and Han [15] used Green impulse or Heaviside step function to discretize the dynamic response equation of the system to identify dynamic loads. Mao et al. [16] solved the inverse problem of force identification through establishing an exact force identification model based on an idea of precise time-step integration method for Markov parameters. Yan and Zhou [17] proposed a genetic algorithms-based technique for impact load identification through which the impact load identification problem in time domain is transformed to a parameter identification problem. Law et al. [18,19] adopted time-domain methods to widely research on the moving load identification in the practical problems. Mitra and Gopalakrishnan [20] handled the problem of impulse load identification in the elastic wave propagation of

* Corresponding author. Tel.: +86 731 88821478; fax: +86 731 88823945.
E-mail address: hanxu@hnu.edu.cn (X. Han).

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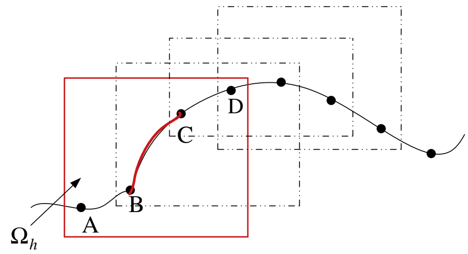

Fig. 1. Supported domain of dynamic load between two adjacent sampling points.

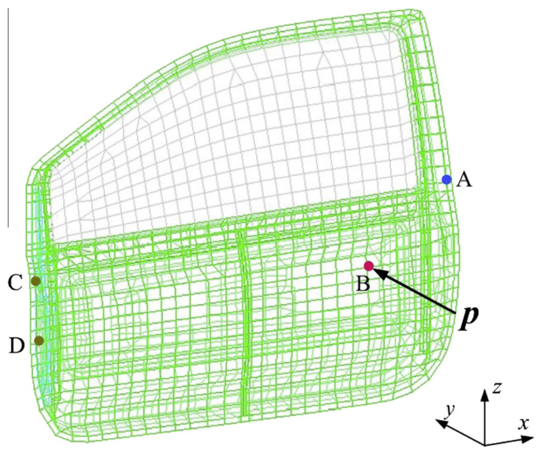

Fig. 2. The finite element model of a simplified door of some passenger vehicle.

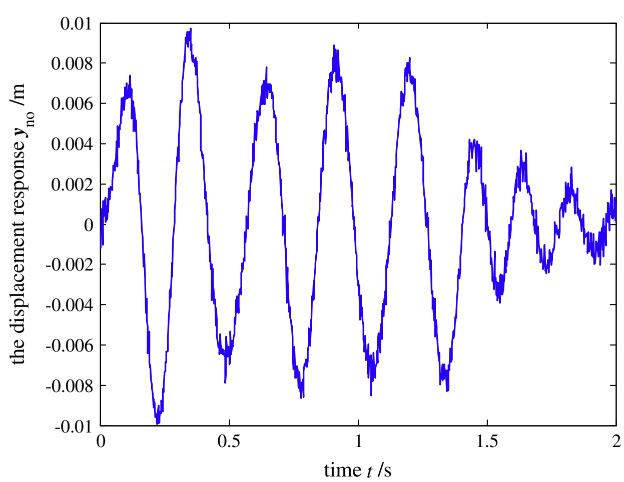

Fig. 3. The displacement of Point A in *y*-direction.

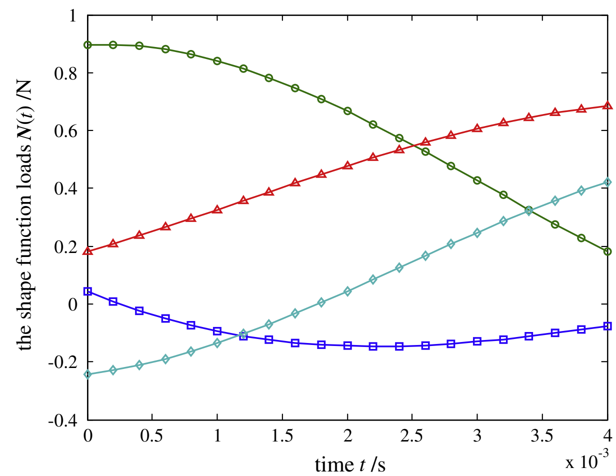

Fig. 4. The curves of the shape function loads. (Δt = 0.004 s).

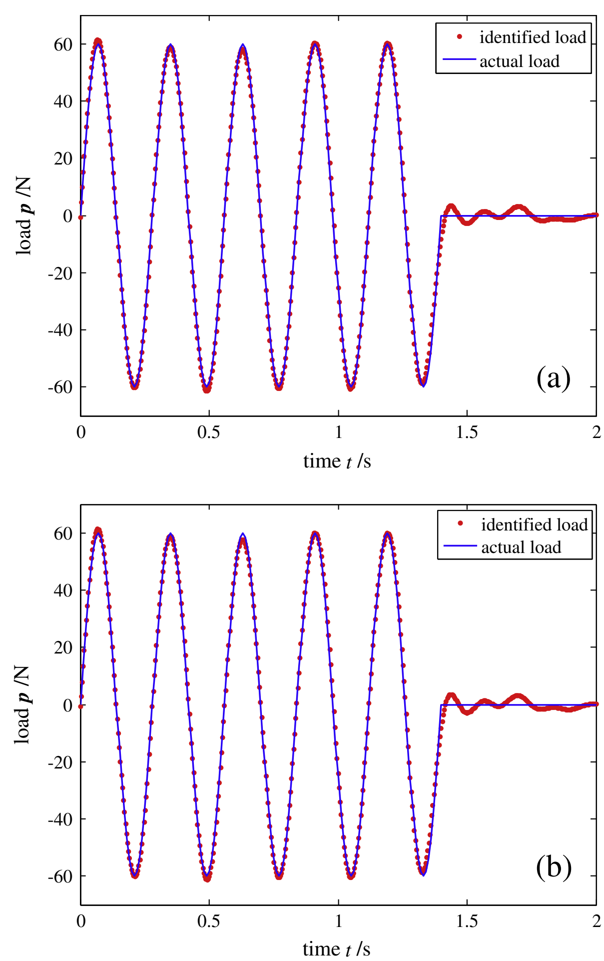

Fig. 5. The identified result of the dynamic load (Δt = 0.004 s) (a) GKFM (b) SFM_MLSF.

1-D connected waveguides by the means of a novel wavelet based spectral finite element. All of these time-domain methods mentioned above lay the solid foundation for the advancement of dynamic load identification. At the same time, some of the methods in time domain are based on the discretization of time domain [21–25]. As the sampling time interval decreases, the dynamic load is approximated more exactly and the identified results are more accurate, but the scale of corresponding matrices is quite great. This not only increases the amount of computations, but also makes the ill-posedness of the kernel matrix more serious. Therefore, with regard to the sampling time interval, the ill-posedness of the kernel matrix and the approximation accuracy of the actual dynamic load contradict with each other. It is definitely hard to select an optimal sampling time interval to balance the contradiction between them.

In this paper, in order to resolve the contradiction above, a novel method is proposed to identify dynamic load in time domain according to the thought of discretized field variables by the finite element method (FEM) [26]. Firstly, the whole time domain is discretized into lots of intervals. The actual dynamic load in each interval is described through the linear combination of some basis functions, which is the least square approximation of the actual load at the sampling time points in the local domain, and the shape