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Discussion

Modelling of force–velocity hysteresis in smart fluid dampers

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Magnetorheological (MR) and electrorheological (ER) fluid dampers have been widely researched over the past few decades. Whilst such devices can offer an elegant means of providing semi-active damping, their nonlinear behaviour has hindered their practical deployment. A central issue is the hysteresis that is observed in the force versus velocity response, as illustrated in Fig. 1. A recent article in the *Journal of Sound and Vibration* [1] attributed this hysteretic behaviour to the compressibility of the operating fluid, and proposed a hydraulic model of this behaviour.

The modelling of this hysteresis using hydraulic concepts was first proposed by Sims, Stanway, and colleagues in the late 1990s [2,3]. This earlier work has been widely cited by the authors of [1] in their other work, but reference [1] appears to have overlooked the earlier literature. Consequently, the present discussion article will briefly describe our perception of the development of this modelling approach.

Ref. [3] proposed that whilst the quasi-steady behaviour can be modelled using a Bingham Plastic approach, "… it is the fluid's compressibility and inertia that are the main contributors toward dynamic effects". Consequently, the lumped parameter model shown in Fig. 2 was proposed, where the bi-linearity of the spring was due to the slightly unusual damper design. The spring stiffness was initially predicted based upon the fluid bulk modulus, and was then updated in line with experimental data.

Ref. [4] extended the earlier work to consider a more general solution for ER and MR dampers. The model shown in Fig. 3a was proposed, which has the same form as that used in the later work of Ref. [1] (Fig. 3b). Furthermore, [4] developed an identification procedure that did not require the lengthy process of parameter optimization based upon the output of time-domain models. One difference between Ref. [1] and the earlier work of Sims et al. [4] is that Hong et al. derived values for the spring stiffness based upon the fluid compliance or bulk modulus. However, this method was adopted in the earlier article [3], albeit for a through-piston device that did not include an accumulator.

To summarize, it is encouraging to see that some consensus is now emerging on how best to tackle the force–velocity hysteresis of ER and MR dampers, but it should be noted that this approach was developed several years ago by the research group at the University of Sheffield.

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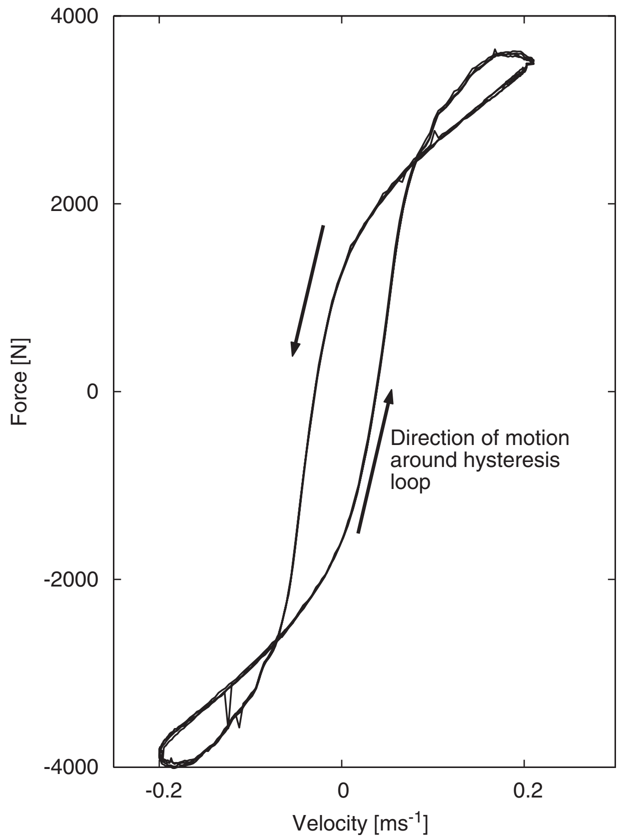

Fig. 1. Hysteresis in the force–velocity response of smart fluid dampers. The response is shown for an ER damper operating at ± 8 mm, 4 Hz sinusoidal mechanical excitation, with an electric field of 4 kV/mm.

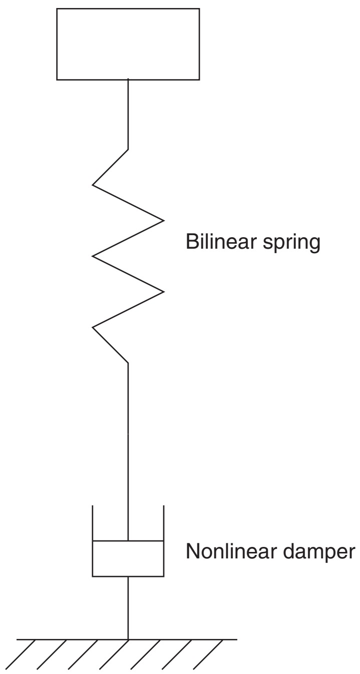

Fig. 2. Early lumped parameter model of fluid compressibility [3].

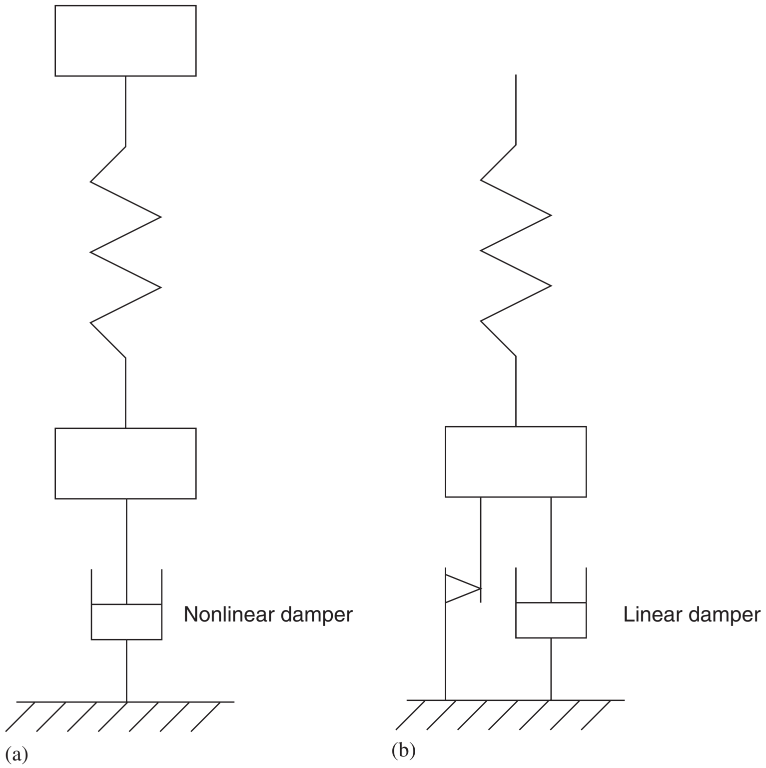

Fig. 3. General model of fluid compressibility: (a) Sims et al. [4] and (b) Hong et al. [1].

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