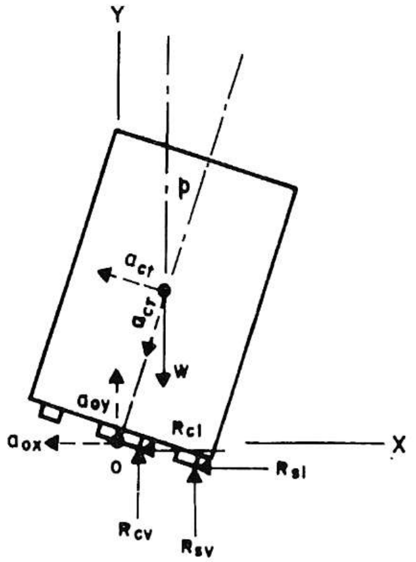

Fig. 10

center plate, a_{ox}, is small, as is the moment about O of the vertical center plate reaction, cR_{cv}. Since cos p can also be considered equal to one for small angles, the two equations can be simplified as follows:

$$F_x = R_{sl} + R_{cl} = \frac{W}{g} a_{ct} \tag{10}$$

$$M_0 = bR_{sv} = \frac{W}{g} r_C^2 \frac{a_{ct}}{h} \tag{11}$$

Combining (10) and (11), an expression is obtained for the total lateral force in terms of the side bearing load:

$$R_{sl} + R_{cl} = \frac{hb}{r_0^2} R_{sv} \tag{12}$$

DISCUSSION

H. I. Dwyer, Jr.[2]

I read the subject paper with considerable interest and enjoyment. Mr. Wiebe has done an excellent job of covering the whole subject of rocking cars in as comprehensive a manner as can be expected in any paper of reasonable length. I can think of little that I could add to the material he has covered.

I have only a few specific comments:

1 In the section "Lateral Resonance," the author has brought out a very good point regarding response of nonlinear damped systems. In such a system, the car body response will be completely different in character, depending on whether train speed is increasing, holding steady, or decreasing. In fact, it is possible for the amplitude to shift abruptly if the train is running at a particular nominal speed and the speed is allowed to fluctuate slightly about this point. Fig.11 shows this phenomenon. It should be noted also that a discontinuity between linear spring rates is the same as a non-linear spring.

2 In the section "Experimental Measurements of Forces and Motions," it is apparent that the author recognizes the importance of dynamic track roughness. It should be pointed out that the practice of defining test track roughness only in terms of low speed measurements can lead to inconsistent results.

3 Also in the aforementioned section Mr. Wiebe's description

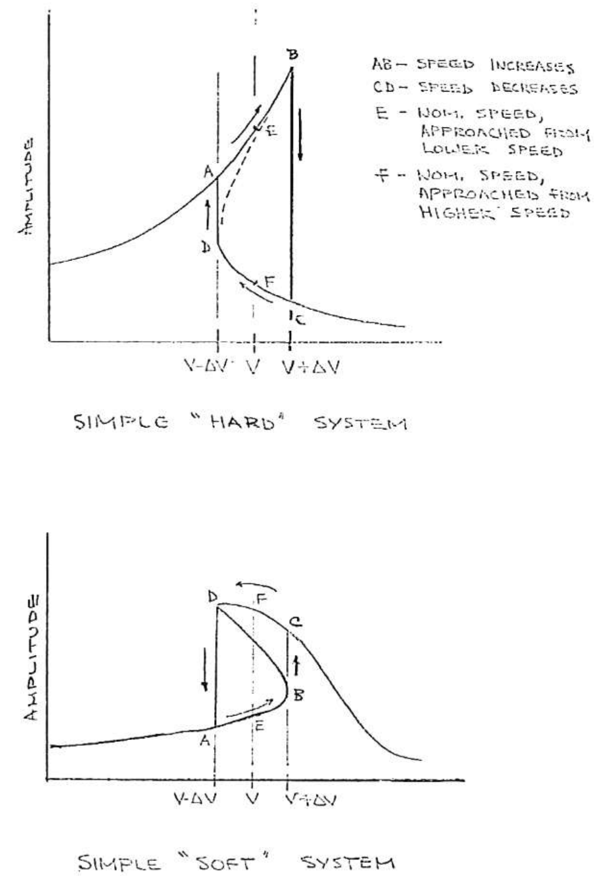

Fig. 11

of the effects of soft track agrees in general with the results of our Battelle simulation.

4 In the section "Lateral Instability as a Potential Cause of Car Derailment," the author suggests that break-in of trucks will tend to reduce the derailing tendencies, and also that a rigidly square truck may cause trouble. I am sure that service experience could be used to confirm or refute this idea, but I do not know the answer at this time.

5 The author's statement in the conclusion about the additional energy required for a rocking car is interesting in light of the apparent anomaly that empty cars generally require more locomotive power than loaded cars making up the same weight of a train. As he points out, the energy has to come from somewhere, and the only source is the locomotive. Even cars which are not severe rockers may rock sufficiently to cause a noticeable effect.

S. G. Guins[3]

The author's remarks on the mechanism of derailment are interesting. My own observation of cars on tangent track and rocking to the extent that wheel lift occurs have been that they develop enough lateral force to break the friction at the wheel to rail contact point. Assuming this to happen also on curved track it seems that the trucks should be properly aligned in the curve and that the lifted wheels should descend with their flanges between the rails.

I believe that a more dangerous condition exists at speeds close to resonance or at resonance during the buildup of oscillations when some weight shift occurs from the outside wheels. On entering and negotiating the curve the flange of the leading outside wheel contacts the rail and there is generated the lateral force

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required to turn the truck. Because the car is leaning over on the far side bearings that lateral flanging force may be greater than if the car were upright. It appears quite possible that the ratio of lateral flange force to vertical wheel load may exceed the value of 0.8 frequently given as that necessary to prevent flange climbing and the subsequent derailment of the car on the outside of the curve.

This hypothesis leads to an alternate explanation of the reported reduced likelihood of derailment when the car has been in service for some time. As wheel wear takes place, some of the lateral movement energy is dissipated by moving the car vertically thus reducing available energy leading to increase of lateral forces.

Another possibility is that the friction damping elements become more effective as they wear in so that the build up of oscillations is reduced.

The author is to be congratulated on his work and especially on his analysis of the many effects of rocking other than the obvious one of derailment.

Author's Closure

The author wishes to thank Mr. Dwyer and Dr. Guins for their pertinent comments. With reference to Mr. Dwyer's comment on nonlinearity and car body motion response to varying speed, there are many potential combinations of various lateral motion modes of a car body on its suspension:

1 The motion of the car body with respect to the bolster; rocking about the center plate or separating at the center plate and rotating about a side bearing.

2 The motion of the bolster with respect to the side frame on the spring group; vertical and lateral.

3 The motion of the axles and side frames referenced to the ground or gravity. In addition, varying restraints occur over the motion ranges of each of these named principal modes.

Any mode of motion that is not continuously displayed but is abruptly introduced when the original motion reaches a certain amplitude, such as center plate separation and wheel lift, also abruptly changes the natural response of the system. The most severe possible response or motion condition in this case can be achieved only by accelerating or decelerating from the speed at which the composite of the two motion modes is initiated.

Any device applied to the suspension that is prone to introduce a nonlinear characteristic or emphasize an already existing nonlinear characteristic in the suspension can result in a more severe resonance in actual service than the constant speed performance on a test track would indicate. For example, high friction in the suspension can restrain or actually lock mode (1) until the motion from mode (2) reaches a given amplitude, and then break free, creating a composite motion which no longer responds to the same excitation speed or frequency; or, mode (2) can be locked in place until mode (1) reaches a given amplitude. The resulting lateral car body motion at any constant speed will not acquire a steady-state amplitude but will develop a pronounced beat, which can be illustrated from Mr. Dwyer's Fig. 11 as motion amplitude increasing and decreasing between points B and C. The most severe resonance amplitude from a constant speed excitation, the beat maximums, would correspond to point C. However, a decelerating speed could readily occur in actual operating practice that could drive the motion amplitude to D.