Discussion

C. E. Tack. The authors have done an excellent piece of investigation and have added to our knowledge of the factors which affect wheel-rail adhesion. While the paper concerns itself primarily with methods of improving adhesion to increase the usable tractive effort of locomotives, the same problem faces the train operator during braking.

The writer's company has investigated wheel-rail adhesion as a by-product of its brake-development program. Extensive road tests of off-tread brakes very quickly spotlighted the fact that rail contaminants were transferred from the rail to the treads of the wheels, and continued rolling occasionally resulted in tenacious, low-friction insulating films on the wheel treads. The end result is low wheel-rail adhesion and occasional impaired signal shunting.

If a method or material can be found which will improve electric signal shunting and adhesion, it surely will have a ready market, provided it is economical and practical to use.

The present paper discusses methods to destroy organic films. If inorganic films also are removed we can subscribe to the use of the proposed rail conditioner, not just to improve locomotive tractive effort but to improve braking and signal shunting as well. Our experience in conducting brake tests leads us to believe that some approach other than chemical is necessary to interrupt or destroy the inorganic films. Our tests confirm and augment the authors' findings that abrasion or polishing is effective.

The use of a continuously dragging tread-cleaning shoe has been tried on certain self-propelled cars and has proved effective in removing loose material from the wheel tread. The tenacious films referred to are not removed by such a tread-cleaning shoe. We have found it necessary to do a moderate amount of braking on the wheel tread in order to remove or interrupt such films. Our service tests indicate tread braking, amounting to at least 1/4 of the total braking effort, is required.

Concurrent with our development work, a large Western railroad has been conducting a series of laboratory and field tests in an effort to improve locomotive tractive effect and reduce or eliminate the need for sanding, since sanding has a number of disadvantages, including high annual cost. These test results showed a significant increase in wheel-rail adhesion when the wheel treads were conditioned by light tread-braking action. One series of tests indicated an average adhesion value of 20 per cent for clean dry wheels and rail, while under identical conditions, the addition of light tread-braking action increased the average adhesion to 27 per cent.

In another group of tests where breakaway torque was measured on one axle of the locomotives, the dry rail and wheel had a breakaway torque of 4000 lb-ft while the wheels which were conditioned by brake-shoe action had a breakaway torque of 5400 lb-ft. This represents an improvement of 35 per cent.

These results generally concur with our findings in a large number of field tests of ASF combination tread and rotor brakes, under a wide range of weather conditions where improvement of 30 to 40 per cent in the average coefficient of wheel-rail adhesion was noted.

The technique of using a light tread-brake application to improve train and locomotive performance is well known. The first formal work to come to our attention was that of Brown-Boveri in Switzerland. Most railroad operating men are aware of the practice of locomotive engineers to "warm up the wheels" of a train by a light brake application if they encounter a poor rail condition and must take a drag up a grade or contemplate a fairly heavy speed reduction. This is the basis for our development of the combination brake.

A serious consideration of these techniques is recommended, and if any railroad believes that an examination of the brake-test results obtained by the writer's company would be beneficial to them, we will be very happy to make them available.

Again, the writer wishes to compliment the authors, not only for the paper which they have presented, but for the work which they have done in a field which should offer cost-reduction possibilities to the railroads.

R. L. Wilson. The authors are to be complimented on an excellent paper and on an important addition to the information available on the subject of wheel-rail adhesion. Furthermore, they have attempted to do something about one of the basic causes for variations in adhesion by proposing means other than sand for voiding the oil film.

1 Product Engineering Manager, American Steel Foundries, Hammond, Ind. Mem. ASME.

4 Vice-President, Engineering Dept., Brake Shoe & Castings Division, American Brake Shoe Co., Mahwah, N. J. Mem. ASME.
We have all been aware of the importance of adequate adhesion, both to traction and to braking. The following is a description of some of the adhesion tests at our laboratory and some observations made during road tests which it is believed will be in general agreement with, and supplementary to, this paper.

The adhesion tests in our laboratory were somewhat similar to the laboratory tests described in this paper in that (a) we used a large brake dynamometer and obtained values at full loads between a standard wheel and a regular section of rail, and (b) we took the wheel-tread condition into consideration as well as the rail.

The rail section was clamped in the dynamometer applying head and forced against the wheel with loads from 8000 to 28,000 lb, simulating the wheel-load range from light passenger cars to diesel-electric locomotives. Then a gradually increasing tangential force was applied until a force was reached that gave a sustained skidding between wheel and rail section, as shown by a dial indicator which measured the motion between wheel and rail in thousandths of an inch.

The rail surface was prepared by grinding to a smooth polished surface which measured 4 to 5-microinch finish on a surface profilometer. Tests were made with the rail surface clean and with the rail surface coated by a film produced by rubbing the surface with a cloth that had been used to clean a section of rail head in a main-line track. Two conditions of wheel-tread surfaces were used. One can be described as "rough" and the other as "polished," and both within the range of wheel-tread surfaces encountered in service.

On clean dry rail, the static adhesion was approximately the same for both rough and polished wheel treads. See Fig. 15. The addition of water had little or no effect on the rough-tread adhesion, but appreciably reduced the adhesion with the polished tread.

On rail coated with track film, the dry-adhesion value was appreciably reduced with both the rough and the polished wheel treads. The toughness of the track film as compared with the water film is illustrated by the fact that the irregularities of the rough tread, which were apparently capable of piercing the water film, had only slightly more effect on the track film than did the polished tread.

We did not include the effect of water on the track film, as the addition of water had little or no effect under our test conditions. The film-coated rail surface was not wettable and the small amount of water used was not sufficient to remove the track film.

The percentage of static adhesion during our tests was about the same throughout the range of wheel loads from 8000 to 28,000 lb with some decrease (possibly 15 per cent) as the loads increased.

A few years ago we co-operated in some road tests on electric freight locomotives with a large Eastern railroad where the objective was to determine the effectiveness of automatic sanding for correcting wheel slip. The tests afforded an excellent opportunity for observing variations in adhesion as the trains were heavy and almost no sand was used except as automatically applied for the few seconds required for correction at the instant the wheels started to slip.

Some of the observations we made relating to sanding during that road test may be of interest in evaluating and applying the information disclosed in this paper. We observed the following:

(a) Continuous sanding was actually needed only a small percentage of time, and usually there was considerable distance between points of slippage.

(b) Sanding could be delayed under average conditions until slippage actually started, and still correct slippage if applied quickly, before slip speed exceeded rail speed more than 1 or 2 mph. In fact, many slips were self-recoverable, without sand, until the slip speed had increased 5 to 6 mph above rail speed.

These observations would suggest that the authors might give added consideration to applying the rail conditioner automatically at the instant of wheel slip, for the general condition, and apply it continuously only when the necessity was indicated by frequent recurrence of slippage. This method has been found to reduce greatly the amount of sand required, and it is presumed could be even more beneficial from a cost standpoint in the saving of chemical.

Does this rail conditioner have any chemical effect detrimental to locomotive or track parts? Is there any effect on signals?

AUTHORS' CLOSURE

Both Mr. Tack and Mr. Wilson point out the tremendous importance of adhesion to braking. This is especially true in high-speed passenger and commuter service where equipment design has been limited by the adhesion available. Our investigation was conducted under motoring conditions because we were specially set up to make these measurements. Some measurements, made during electric braking, showed that adhesion limits were roughly the same as for motoring and that the phenomenon was basically the same under motoring or braking, with due allowance for such side effects as weight shift and speed.

Mr. Tack describes the use of a continually dragging clasp brake on the wheel tread to improve adhesion. As he points out, the Brown-Boveri Company of Switzerland has had such good success with their antislip brake design that its application is universal on some European railroads. The abrasion, and consequent heating, destroys the thin films present on the locomotive driving wheels, roughens the surfaces, and provides wear particles which help overcome the track film. This method, when used to overcome a locomotive wheel slip, will permit maintaining about 90 per cent of the normal tractive effort while correcting a wheel slip, in contrast to "power-removal" systems which unload the locomotive from about 50 to 100 per cent for two seconds or longer until the slip is corrected.

The effect of abrasion from tread brakes, however, is greatly lessened in areas of heavy track film. These oil reservoirs and neighboring thin films are the underlying cause of loss of adhesion. A direct attack on these sources is a strike at the cause of low adhesion and will produce the most pronounced effect in correcting it.

The tests which Mr. Wilson describes indicate an effect of surface roughness on filmed and wet rail in contrast to little effect on clean dry rail (45 per cent adhesion). This can be
accounted for by the "Weld-Interlock" Theory of friction which has strong acceptance at present for explaining metal-to-metal friction forces.

If the wheel and rail surfaces had a perfect finish (no asperities on either surface), the peak contact pressure would be in the elastic range and could be determined from the Hertz equations for elastic deformation. For average wheel and rail wear the value would be approximately 75,000 psi. The thin films would generally support this pressure and virtually no "cold weld" would occur. Likewise there would be no asperities, so that no interlocking would occur. The friction coefficient would be virtually zero.

This never actually occurs in practice and there are always asperities. The wheel-rail contact is formed on these asperities. The contact pressures on these microscopic areas are above the plastic flow point of the wheel and rail steel so that flow takes place until enough asperities are engaged to form sufficient area to support the wheel load. As the asperities flow to form the supporting contact area, there is a disturbance of any films that might be present. If these films are fractured, cold weld occurs. The friction will increase as the percentage of contact area in cold weld increases.

As the surface finish becomes rougher, the asperities become higher. In forming the contact area they undergo greater deformation and probably are better able to fracture the films than smoother surfaces thus affording a higher percentage of cold weld. Unfortunately, locomotive and car wheels tend to acquire a high polish under rolling conditions which, as pointed out, may be as smooth as four to five microinches. The advantages of tread brake application in increasing the potential cold-weld area under filmed rail conditions is apparent.

Mr. Wilson mentions that in past tests poor adhesion areas were localized and that many slips were self-correcting under five mph slip speed. We concur in this most heartily. In fact, slips or wheel walks of two or three mph are quite frequent and may account for 90 per cent of all slips under the worst rail conditions. Usually they are self-correcting. If wheel-slip relays which unload the engine have too sensitive a setting, they are a real detriment and cause needless loss of momentum by detecting these slight self-correcting wheel walks.

Extremely poor adhesion areas are localized, usually being confined to wide-gage track on curves, to switches, and to crossovers where heavy oil reservoirs are present to continually supply the films.

As to Mr. Wilson's questions, the signalling was monitored on track where the chemicals were tested. No loss of shunt was recorded during these tests. The chemical did not exhibit a corrosive effect on the rail other than to leave it clean so that initial rusting was accelerated during a rain.

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As mentioned several times, the basic difficulty underlying poor adhesion is the excessive accumulation of heavy oil reservoirs with their consequent films as a result of journal oil losses. Whatever the railroads can do in the way of preventive or corrective maintenance to counteract these reservoirs will pay the greatest dividends in overcoming low adhesion. Correct gaging, better oil seals and oil applicators, and control of overoiling will help immeasurably.

Where high adhesions are required, a direct attack on the reservoir and films is the surest method. If the chemists provide a commercial means of accomplishing this, it will still be wise to continue with the preventive maintenance outlined above.

The authors' purpose will be accomplished if at some future time it is possible for a superintendent to operate his division at a given level of adhesion with complete confidence that his rail and equipment is good for that amount and that his operation will not bog down because of the caprice of nature.