

### PLASMA-SPRAYED RAIL COATINGS TO CONTROL WHEEL/RAIL FRICTION

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#### Summary

Plasma-sprayed coatings applied to the railhead are being examined for their potential use in controlling wheel/rail friction. The Association of American Railroads, in collaboration with the Oregon Graduate Institute (OGI), has conducted large-scale testing of SAE 1080 steel/nylon coatings on coupons and rails using track laboratory tests and the rolling load machine at OGI. A 12-foot coated rail was also tested under heavy axle loads at the Transportation Technology Center, Pueblo, Colorado.

The goal of this study is twofold: to seek ways of improving traction by increasing friction on the rail top, and to reduce rail gage face wear by reducing friction on the rail gage face. Results from small-scale experiments to increase friction were not sufficiently promising to justify full wheel/rail tests. In contrast, tests clearly showed that steel/nylon coatings deposited on rail steel could give fully acceptable low levels of friction (about 0.1) with moderate durability.

Important findings from the small-scale tests include:

- ◆ The SAE 1080 steel/nylon coatings that are plasma-sprayed onto the railhead give very low levels of friction.
- ◆ At this time, the 1080 steel/nylon coatings do not have sufficient durability to allow their implementation in revenue track.
- ◆ There is evidence that thinner coatings using nylon with stainless steel may give improved durability.
- ◆ No other coatings studied showed enough promise to merit large-scale testing.

The successful development of low friction coatings would eliminate the need for conventional grease as rail lubrication. Although the use of grease can result in acceptably low friction, it is difficult to control its spread once applied. It can be difficult to maintain track-side applicators as well. The use of coatings would also eliminate ballast contamination and environmental damage associated with the liberal use of grease.

#### Suggested Distribution:

- Research and Development
- Maintenance of Way
- Track Maintenance
- Safety



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## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR), in conjunction with the Oregon Graduate Institute (OGI), is examining the potential use of plasma-sprayed coatings applied to the railhead to control wheel/rail friction. Large-scale tests of SAE 1080 steel/nylon coatings were performed on coupons and rails, using track laboratory tests and the rolling load machine at OGI. A 12-foot coated rail was also tested under heavy axle loads at the Transportation Technology Center's (TTC) Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. There were two objectives of this study: to reduce gage face wear (a major cause of premature rail replacement) by reducing friction on the rail gage face, and to improve traction by increasing friction on the top of the railhead.

Most work used SAE 1080 steel (similar to rail steel) coatings as carriers for the friction modifiers. Work focused on four areas:

- ◆ *Producing steel coatings with rough surfaces to act as reservoirs for grease, enabling less frequent grease application.* The coatings did not remain rough enough under rolling loads to give grease retention.
- ◆ *Reducing friction by using coatings containing lubricants such as copper and graphite.* The addition of copper to SAE 1080 steel coatings did not significantly modify friction. Steel/graphite coatings were difficult to deposit reliably.
- ◆ *Increasing friction by using high-friction materials, either in pure form or laid down in a carrier metal on the rail.* Inconsistent friction results were found and coating durability was generally poor.
- ◆ *Reducing friction by using low-friction polymer coatings deposited on a metal substrate on the rail.* This system gave the most promising results in

small-scale test, achieving very low friction levels and moderate durability.

Exhibit 1 summarizes the coatings studied and the results achieved.

**Exhibit 1. Summary of Small Scale Tests on Trial Friction Modifying Systems**

<b>Objective: increase friction on the rail top</b>	
<b>System</b>	<b>Comments</b>
Stainless steel in 1080 steel	High friction coefficient found but durability poor
Titanium in 1080 steel	High friction coefficient found but durability poor
Pure metals	Inconsistent friction and durability results

  

<b>Objective: decrease friction on the gage face</b>	
<b>System</b>	<b>Comments</b>
Nylon on 1080 steel	Very low friction achieved Moderate durability
Kynar on 1080 steel	Low friction achieved Moderate durability
Nylon/solid lubricants on 1080 steel	Added MoS or graphite had modest effects on friction and durability
Copper in 1080 steel	Little effect on friction Low durability
Graphite in 1080 steel	Difficult to lay down Low durability at high loads and creepages
Roughened 1080 steel	Steel did not stay rough to act as reservoir

Although early laboratory results showed two or three very promising avenues of research, ultimately it was not possible to define a friction modifying system that could reliably cope with wheel/rail conditions on heavy haul railroads. The problem remains one of ensuring adequate durability. The project will be reviewed in early



1997 to assess the potential for making significant improvements in durability.

### PLASMA SPRAY TECHNIQUE

Coatings were produced using a high-energy plasma spray system designed to feed material in wire or powder form. With this technique, small particles of molten material are propelled onto the sample using the spray gun. The particles solidify quickly on impact and a dense coating is gradually built up. The wire and/or powder used controls the composition of this coating. Spray parameters were adjusted to optimize the microstructure of the coatings, which were generally less than 0.04 inch thick.

Before spraying, all test samples were cleaned, degreased, and grit-blasted to provide a rough surface acting as a key for the SAE 1080 coating. It is important to note that the bonds between the rail, the 1080 steel, and the friction modifier are generally mechanical; this has contributed to insufficient durability.

### LABORATORY TESTING

Initial work to optimize coatings and to test the friction and durability achievable was done at OGI using small diameter (1.4-inch) discs in an Amsler wear machine. The wheel and sprayed rail steel discs were rotated against each other at high contact stresses, typically 177 kips per square inch (ksi), and at creepages usually between 5 and 35 percent. Note that creepage is a measure of the relative sliding between the discs. These very severe conditions were chosen to imitate those on a rail gage face in a sharp curve. Friction was measured during each test, and the coatings were examined periodically for signs of physical failure.

Coatings made of nylon (about 0.0025 inch thick) deposited on 1080 steel (0.02 to 0.04 inch thick) laid on rail steel gave very low friction levels and an encouraging durability. It was decided to concentrate efforts on improving the durability of

these coatings, and to test their performance in more realistic conditions.

### TESTING OF NYLON/STEEL COATINGS

The nylon steel coatings gave initial friction levels below 0.1 in Amsler tests. Typically, tests lasted 10,000 to 15,000 cycles before either the coating debonded or the friction level rose to about 0.25. The spray system was modified to produce coatings on larger samples, and a series of rail and rail coupon-sprayed samples were made for large-scale testing TTC. Types of tests performed are shown in Exhibit 2.

Exhibit 2: Large Scale Tests Used to Study Nylon/Steel Coupons

Test	Description
Track Lab (TL)	Uses 24-inch rail coupon. A 100-ton car rolls back and forth over the coupon at 10 to 15 mph.
Rolling Load Machine (RLM)	Uses 6-foot rail sample. Wheel loaded at 35 to 45 kips rolls back and forth over the rail — either in pure rolling or at high creep.
Facility for Accelerated Service Testing (FAST)	A 12-foot rail was coated and installed in track at FAST for test under heavy axle loads.

During the Track Lab and Rolling Load Machine tests, the coating was applied on top of the rails and coupons. In the FAST test, the coating was applied to the gage face wear scar on the rail. Results are given in Exhibit 3. To aid interpretation, lives-to-failure in the different tests are converted to million gross tons (MGT) of traffic passed. Failure was defined as large-scale debonding of the coating from the sample.



**Exhibit 3: Results of Large Scale Tests on Steel and Steel/Nylon Coatings**

Test	Results
TL1	1080 steel coat lasted 0.12 MGT before debonding from the coupon
TL2	1080 steel coat lasted 0.32 MGT before debonding
TL3	Stainless steel/nylon coat lasted 6 MGT before debonding
TL4	1090 steel coat lasted 0.32 MGT before debonding
RLM1	1080 steel tested in pure rolling at 45 kips lasted 2.2 MGT before debonding
RLM2*	1080 steel/nylon coat tested at varying creepage at 45 kips lasted 0.2 MGT before debonding
RLM3*	1080 steel/nylon coat tested at high creepage at 45 kips lasted 0.24 MGT before debonding
FAST	1080 steel/nylon coat was unharmed at 0.125 MGT (10 train passes). Nylon began to debond at 0.15 MGT. Major debonding of steel coat by 1.7 MGT
* Machine control problems applied high but unknown creepages.	

The principal conclusions from this series of large-scale tests are as follows:

- ◆ Nylon/steel coatings give low friction levels under realistic wheel/rail contact conditions. If durable, the levels achieved would greatly reduce rail side wear.
- ◆ These low friction levels last several MGT in pure rolling conditions, but rise slowly with time if creepage is present.

- ◆ The main cause of failure is debonding of the steel coat from the rail. This is caused by oxide particles and porosity in the coating, and the insufficient strength of the mechanical bond between the steel coat and rail. Once started, debonding tends to spread quickly.
- ◆ There is a trend for thinner steel coatings to last longer. The reason for this is not known.
- ◆ There is an indication that stainless steel may be more durable than SAE 1080 steel as a carrier for the nylon. This may be because its oxides are more resistant to deformation in rolling contact than those of the SAE 1080. (Coatings sprayed in air contain oxides.)

#### **FUTURE WORK**

Testing has shown that coatings can be used to reduce wheel/rail friction; however, sufficient durability has not been achieved. Work will be reviewed in 1997 to assess the potential for modifying the coating process to achieve realistic durability, as well as the possible constraints of an improved process on field use. The practical and logistical problems of field use will also be considered. Future work will depend on the conclusions from this review.

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