TECHNOLOGY DIGEST
Timely Technology Transfer

LASER GLAZING TO REDUCE RAIL WEAR

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Summary

The Association of American Railroads in cooperative studies with Argonne National Laboratory has been studying the use of laser glazing to reduce wheel/rail friction and thereby decrease rail-gage face wear. The process is intended to replace the use of conventional grease lubrication which is difficult to apply consistently well.

Key results from the study include:

- The layers are very hard, over 700 Brinell compared with normal rail hardnesses in the range of 300 to 380 Brinell.
- In laboratory tests using a rolling-load machine with typical wheel loads, the layers have given average static and dynamic friction values in the range of 0.14 to 0.33. In contrast, untreated rail gave values from 0.38 to 0.51. Good grease lubrication gives a wheel/rail friction of about 0.2.
- After more than 60,000 wheel passes at 39 kips vertical load, there was no evidence that the hard laser layers had cracked or deteriorated. However, the roughened rail surfaces produced by the laser had imprinted the rolling-load machine wheel. This may indicate accelerated wheel wear in service.

The work has demonstrated that a laser beam can be used to produce thin (0.04 inch) and very hard layers (over 700 Brinell) on the rail surface. The layers have considerably different properties from the parent rail material, and this, with the high hardness, reduces friction between the wheel and rail without the use of conventional grease lubrication. Although very hard, the laser-hardened layers have proved to be very durable under realistic wheel loading in the rolling-load machine.

Association of American Railroads
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Suggested Distribution

☐ Planning & Analysis
☐ Maintenance of Way
☐ Maintenance Planning
☐ Track Maintenance

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INTRODUCTION AND CONCLUSIONS

The Association of American Railroads, with Argonne National Laboratory, is investigating the use of laser glazing to decrease rail wear by reducing the natural level of wheel/rail friction.

The traveling laser beam can heat the rail surface to temperatures above 1,650 degrees Fahrenheit in a fraction of a second. The rapid cooling which follows leads to the formation of a thin layer on the rail surface which has considerably different properties from the parent material. In particular, it has the potential to give reduced wheel/rail friction without lubrication. If achievable in service, this reduced friction will reduce rail wear. Key results are:

- The layer is thin (about 0.04 inch), but very hard (about 720 Brinell, compared with a normal rail hardness of 300 Brinell).
- The layer has given reduced friction in laboratory rolling-load machine tests using realistic wheel/rail contact conditions.
- There is no evidence that the layer has cracked or deteriorated under the high contact stresses imposed by the 60,000 wheel passes in the rolling-load machine.
- The laser layers indented the test wheel. Indentation may not be a significant factor in service applications, but it may indicate potentially accelerated wheel wear.

LASER GLAZING OF RAIL

In laser glazing, a traveling laser rapidly heats the rail, producing very high temperatures in a thin layer, which may be molten at the surface. Cooling of this layer is also very rapid, and this leads to a thin (about 0.04 inch) but very hard surface layer on the rail. The layer is typically two to three times harder than the parent rail.

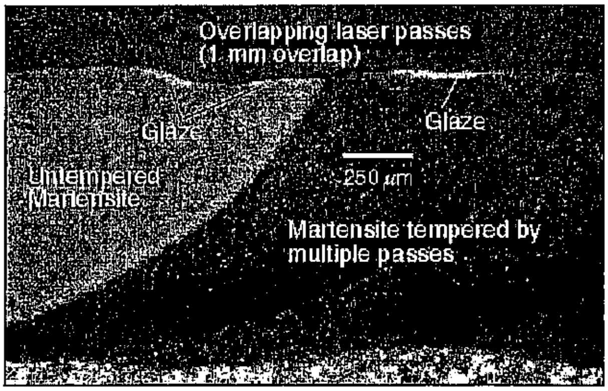

Exhibit 1. Section through a Laser Rail Sample, Showing the Amorphous and Martensite Layers on the Parent Rail Steel

The layer can be in two parts, shown in Exhibit 1. At the surface, the hot molten area rapidly solidifies to form a thin layer which may have an amorphous, that is, non-crystalline, atomic structure. Below this, there is a martensite layer which forms when the hot, but still solid, rail cools fast enough to avoid transforming to the normal rail-steel structure. Both layers are hard and resistant to plastic deformation in rolling contact. This lack of plastic deformation should be reflected in a decreased coefficient of friction, and hence a reduced rail-wear rate.

Early work examined the formation of glazed layers using carbon dioxide (CO_2) and neodymium-doped (Nd:YAG) lasers. Results showed that both lasers were capable of forming hard layers on the rail surface. But the CO_2 laser gave a pitted surface, and required a matte coating to increase the power absorbed. For this reason the Nd:YAG laser was used in subsequent work.

TEST PROGRAM

An Nd:YAG laser was used to produce two areas at the center of the running surface of a 136 RE standard rail. The areas were each 0.75 inch wide by 4 inches long, and 4 inches apart.

Laser area L1 was formed using a defocused round beam which rastered back and

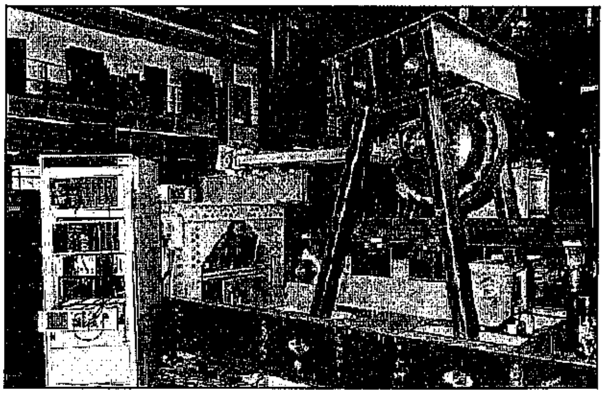

Exhibit 2. Rolling-Load Machine Used to Assess Rail-Layer Friction and Integrity

forth over the 4-inch length. The beam had a width of 0.08 inch, and the raster separation was 0.04 inch, giving a beam overlap of about 50 percent. Area L2 was formed by an elliptical beam which made four passes over the 4-inch length. The beam was 0.2 inch wide, and pass separation was 0.2 inch. These conditions led to minimal beam overlap. For both areas the delivered power measured was about 1 kilowatt.

The 4-inch section between the laser areas was used as the control section.

The rolling-load machine shown in Exhibit 2 was used to assess the integrity of the laser areas, and the effect of the areas on wheel/rail friction. The following test program was used:

- One hundred wheel passes were made at 39 kips vertical load to condition wheel and rail.
- Friction measurements were made in the two laser areas and the control area.
- Forty thousand wheel passes were made at 39 kips, and the rail was inspected visually and using dye penetrant and magnetic particle methods.
- The friction measurements were repeated.
- Twenty thousand wheel passes were made at 39 kips vertical load and 8 kips tangential load, and the rail was again inspected.

Friction was measured at vertical loads between 5 and 40 kips. At each vertical load, the tangential load on the wheel was gradually increased until the wheel began to turn.

The static friction, µs, was calculated as the ratio of the tangential load needed to start the wheel turning to the vertical load. The dynamic friction, µd, was found as the ratio of the maximum tangential load with the wheel turning to the vertical load.

There was great scatter in the measurements made after 100 wheel passes. This made interpretation difficult. It is not known whether the scatter was due to instrumentation problems or inadequate conditioning of wheel and rail. The measurements made after 40,100 wheel passes gave much less scatter and were used to assess friction.

SIGNIFICANT RESULTS

After 60,100 wheel passes, there was no evidence from visual and non-destructive inspection of any cracks in either of the two laser areas. There was little evidence that the slightly raised areas had deformed under the rolling load, and no spalling had occurred.

Because both layers were raised slightly above the rail surface, the mating wheel sur-

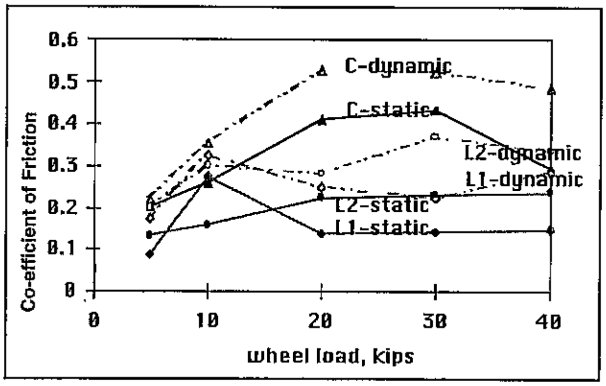

Exhibit 3. Effect of Wheel Load on Static and Dynamic Friction for the Two Laser Layers (L1,L2) and Control Layer (C)

face had become indented with their patterns. Such indentation is unlikely to be seen in service application, but it may indicate a potential wheel wear problem.

The friction measurements made after 40,100 wheel passes are given in Exhibit 3. This shows the effect of wheel load on static and dynamic friction for the two laser layers (L1, L2) and the plain rail control area (C). Exhibit 4 gives the average values of friction over the load ranging from 20 to 40 kips.

The measured friction values varied inconsistently with applied vertical load, but both laser layers gave significantly lower values of static and dynamic friction than did the control area. The values in Exhibit 4 can be compared with a value of 0.2 found typically in track lubricated well by grease.

Layer 1 gave the lowest friction values. This layer was formed using the laser raster which had significant beam overlap. This is expected to have led to more even hardening than that achieved in layer 2, where no beam overlap occurred.

FUTURE WORK

Tests have demonstrated that laser glazing can be used to harden the rail surface and reduce wheel/rail friction. The hard layers also appear durable under typical vertical and tangential loads.

Layer	Static Friction	Dynamic Friction
Laser 1	0.14	0.25
Laser 2	0.23	0.33
Control	0.38	0.51

Exhibit 4. Average Static and Dynamic Friction Found in the Load Range 20 to 40 kips

The work to date has given an increased understanding of the costs associated with laser glazing of rail. It is likely that at least two to three lasers will be needed to glaze rail in track at an acceptable processing speed. The intention now is to examine the cost benefits closely, and also to look at potential barriers to implementation.

If a cost-benefit analysis shows promise and implementation strategies can be developed, further technical work would be needed to refine the process. This would include:

- Defining the optimum form of laser glazing.
- Seeking to reduce further the friction level offered by glazing.
- Assessing the long-term crack and wear resistance of the glaze layer.
- Assessing whether cracking of the glaze layer affects rail integrity.
- Examining the effects of laser rail glazing on wheel wear and damage.

The laser glazing process has real potential to allow wheel/rail friction to be reduced in a controlled manner without the use of conventional grease. If achievable, this will give significant operational and environmental benefits over the use of conventional grease lubrication. The task is to demonstrate that the benefits can be obtained at acceptable cost.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON D.C., 20001