TECHNOLOGY DIGEST

Timely Technology Transfer

COBALT ALLOY CLADDING TO REDUCE WHEEL WEAR

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Summary

Although Swedish trials indicated that cobalt alloy laser cladding significantly reduced wheel flange wear on wheel types commonly used in European service, tests conducted by The Association of American Railroads (AAR) found no apparent benefit on wheels typically used in North America.

Eight locomotive Class C wheels were treated in Sweden by the originators of the laser cladding process. After an assessment of residual stress and metallurgical examination, four clad wheels and four control wheels were installed on a Norfolk Southern locomotive for tests at the Facility for Accelerated Service Testing (FAST). The locomotive ran for approximately 13,000 miles, and detailed transverse wheel profiles were measured at intervals to assess flange wear.

Key results from the study are:

- The laser cladding process successfully produced a cobalt alloy layer on the wheel flange. The layer was about 0.08 inch thick.
- The bond between wheel and cobalt alloy layer was excellent, with good metallurgical integrity and few inclusions. There was no evidence of the layer debonding from the trial wheels during testing.
- The cladding process produced unwanted residual hoop tensile stress in the wheel rim. This required the clad wheels to be heat-treated once again, to reapply the more normal beneficial compressive stress.
- The cobalt alloy layer wore rapidly on all four wheels, and did not show better wear resistance than the control Class C wheels.
- The contradiction with Swedish findings may be due to the fact that North American Class C wheels are naturally harder and therefore benefit less from laser cladding.

Suggested Distribution:

- ❑ Equipment/Rolling Stock
- ❑ Locomotive Department
- ❑ Car Department
- ❑ Research & Development

Association of American Railroads
Railway Technology Department

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INTRODUCTION AND CONCLUSIONS

Studies by the Association of American Railroads (AAR) on the use of cobalt alloy laser cladding to reduce wheel flange wear failed to achieve results found in Swedish trials (reference 1) which indicated the process significantly reduced wheel wear.

In the AAR study, eight locomotive Class C wheels were treated by the manufacturers of the process. After metallurgical examination and an assessment of residual stresses, four clad wheels and four control wheels were installed on a Norfolk Southern locomotive for trial at the Facility for Accelerated Service Testing (FAST). The transverse profiles of all eight wheels were measured at intervals to assess flange wear. Key results from the study are:

- The laser cladding process formed about a 0.08-inch cobalt alloy layer on the wheel flange.
- The cladding process caused residual tensile stress in the wheel rim, which required the clad wheels to be heat-treated again.
- Metallurgical examination showed a good bond between the wheel and cobalt layer.
- There was no evidence of the cobalt debonding from any of the trial wheels.
- The cobalt layer did not show a better wear resistance than the Class C wheel material.

COBALT CLADDING OF WHEEL FLANGES

Cladding uses a continuous-wave CO_2 laser to heat the slowly moving wheel flange surface and produce a thin molten layer of steel. The cladding powder is introduced into the laser/wheel interface, where it melts, spreads over the wheel surface, and freezes. In these trials the powder was principally cobalt, with chromium and molybdenum as the main alloy elements. The mixing of steel and cobalt alloy may give harder material near the interface, but this is unlikely to extend to the surface of thick alloy layers. The wheel and cobalt alloy material are molten at the interface and produce a very strong metallurgical bond.

Laser surface modification offers several advantages: a fine-grained structure, low layer porosity, good bonding between the layer and substrate, and minimal heat-affected zone size.

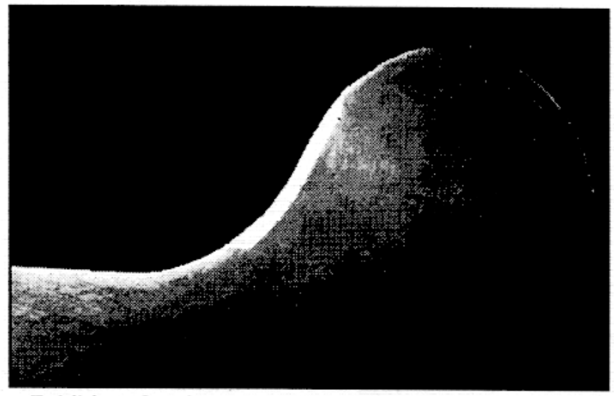

Exhibit 1. Section through a Clad Wheel, Showing a 0.08-Inch-Thick Cobalt Alloy Layer at the Wheel Flange

Exhibit 1 illustrates the thickness of the cobalt alloy layer produced in the trial wheels. A few small inclusions aside, the interface was free of defects. There was no evidence of significant interdiffusion of the cobalt alloy and wheel steel, and no oxide layer or lack of fusion at the interface.

RESIDUAL STRESS MEASUREMENTS

Because of the high carbon content of the wheels, the manufacturers judged that each wheel rim should be preheated to 750 degrees Fahrenheit before treatment to avoid the risk of cracking. To test the effect of preheat and treatment on residual stress, one wheel was subsequently saw cut from the flange inwards. The saw cut opened 0.0075 inch at a depth of 2 inches, indicating that the cladding process had introduced unwanted tensile residual stresses into the wheel rim.

For this reason, the remaining seven wheels were heat-treated again by Griffin. Saw cutting a further wheel gave a crack closure of 0.009 inch, indicating that beneficial compressive residual stresses had been reintroduced.

Examination of a section from the second cut wheel showed that the cobalt layer was still intact, with no sign of damage, and that the heat-affected zone in the wheel had been removed by heat treatment. The average hardness of the wheel steel was 313 Brinell, while that of the cobalt alloy layer was 368 Brinell.

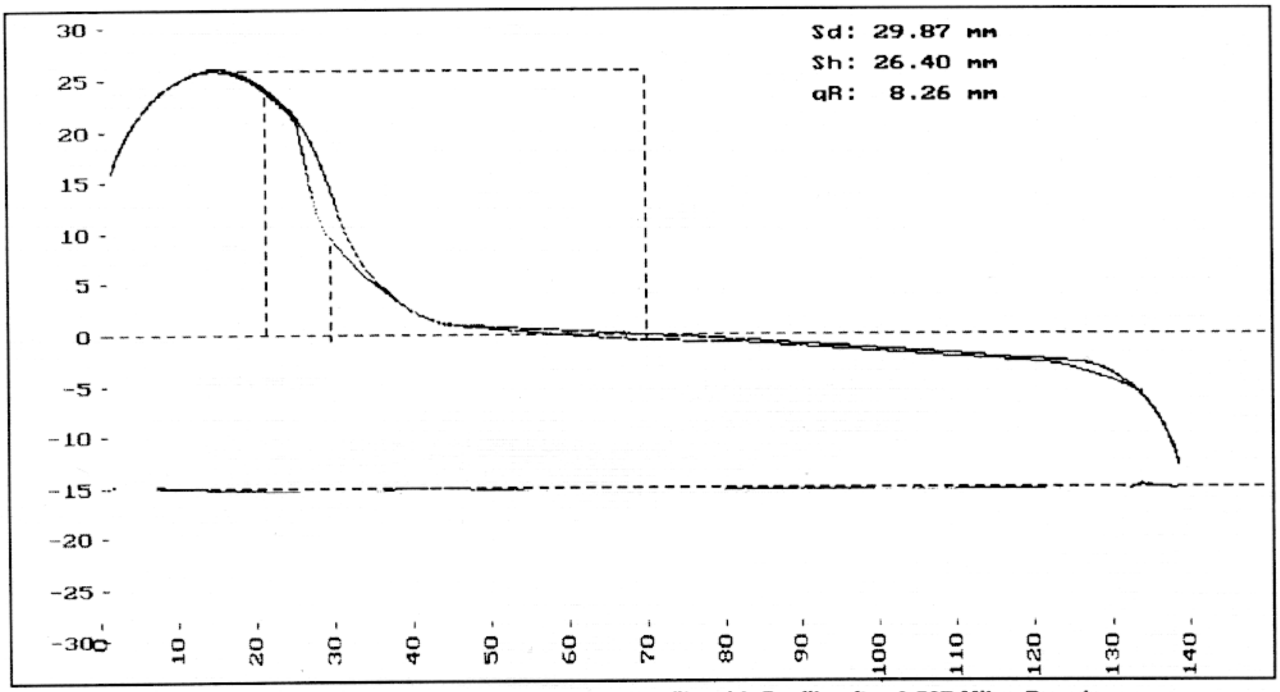

Exhibit 2. Comparison of New Clad Wheel Profile with Profile after 3,567 Miles Running

WEAR MEASUREMENT

The four clad and four control wheels were mounted on Norfolk Southern locomotive NS1355 for testing at FAST. The clad wheels were mounted on the first and third axles from the front, the control wheels on the second and fourth axles. Before running, transverse tread-profile measurements were taken on all eight wheels using a Miniprof measuring system. Further measurements were made at intervals to assess wear, and maximum mileage seen by the wheels was 13,520. Typical new and worn profiles are shown in Exhibit 2.

The locomotive ran in both directions during the trial, and was frequently turned. This is normal FAST practice, and is intended to promote even wear of the locomotive wheels. At the first inspection the control wheels were found to have an incorrect profile. They were turned, re-measured and put back into service. This, and intermittent lubrication applied to the FAST rails, made interpretation of wear results more difficult.

SIGNIFICANT RESULTS

At the first inspection (3,567 miles) it was clear that two of the clad wheels had suffered high flange wear. Both wheels were on the left side of the locomotive and had lost about 0.08 inch from the flange (refer to Exhibit 2), about the entire thickness of the cobalt alloy layer. At the next inspection (8,640 miles), the two clad wheels on the right side were seen to have worn more than 0.08 inch at the flange.

Therefore, after just 8,640 miles running, the major part of the cobalt alloy coating had been removed by wear from all four clad wheels. (There was no evidence of the cobalt alloy layer debonding from the wheel substrate.)

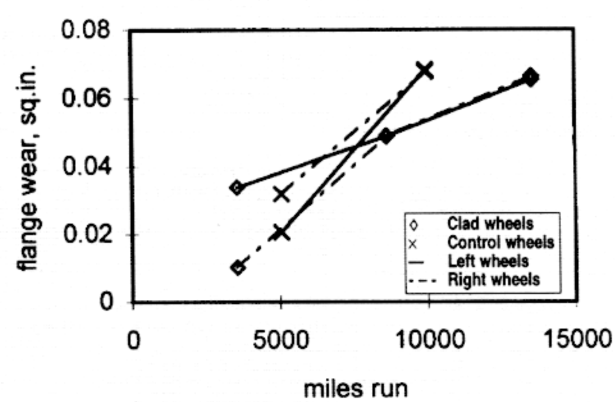

Exhibit 3. Effect of Mileage on Average Left and Right Wheel-Flange Wear

The difference between the new and worn profiles in the flange area was calculated (in square inches) to quantify the wear. It was found that, at low mileage, the left side wheels had much different wear patterns from the right side wheels. Because of this, Exhibit 3 shows the relationship between average left and right wheel-flange wear and miles run.

Exhibit 3 appears to show that after about 7,000 miles the clad wheels have a better wear performance than the control wheels. This may be misleading. First, as already noted, the cobalt alloy layer had all but worn away from the clad wheels after 8,640 miles. Second, the method of operation of the locomotive (turning and reversing), with the initial problems with the control wheel profiles, led to uneven wear of the eight trial wheels.

When a truck traverses a curve, generally the leading wheel set is more likely to run with the high-rail wheel in flange contact. (The trailing wheel set assumes a more radial alignment in curves.) Consequently, flange wear tends to concentrate on high-rail leading wheels. To clarify wear performance, the number of miles each wheel ran as the high-rail wheel of the truck leading wheel set was calculated.

Exhibit 4 gives the average left and right wheel-flange wear as a function of "flange miles," and seems to show that the left and right clad wheels had higher flange wear rates than the left and right control wheels. The cause of the apparent difference in left and right wear rates is unclear.

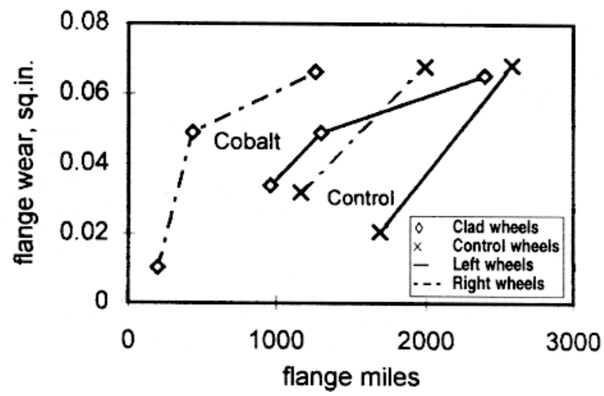

Exhibit 4. Effect of 'Flange Miles' Mileage on Average Left and Right Wheel Flange Wear for the Cobalt and Control Wheels

DISCUSSION

Interpretation of the flange wear data was complicated by the way in which the FAST train was operated during the trial. Intermittent lubrication may have also clouded the results. However, it is clear that the cobalt alloy-clad layer did not significantly reduce wheel flange wear. This result contradicts the findings in earlier Swedish trials.

A possible cause for these contrasting results may be the different wheel steels used in the two trials. The composition of the wheels used in the Swedish trial was not stated, but European wheels are typically softer than the Class C wheels used in these AAR tests, and have lower carbon level. Since strength and carbon content control wear resistance in pearlitic steels, European composition wheels are likely to have a natural wear resistance inferior to North American Class C wheels.

The possibility is that cobalt alloy cladding may improve the wear resistance of typical European wheels, while having little effect on typical North American wheels.

REFERENCE

C. Endberg and A. Blomberg, "Increased wear resistance of laser treated wheels," 11th. Intern. Wheelset Congress, Paris, 1995.

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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