Mechanical Testing at Facility for Accelerated Service Testing

Walter L. Piotrowski, OAO Corporation, Beltsville, Maryland

Test operations are being conducted on the 7.7-km (4.8-mile) Facility for Accelerated Service Testing loop at the Transportation Test Center. The 9000-Mg (10 000-ton) test train operates 16 h/d at an average speed of 67 km/h (42 mph). The goal is an accelerated service test of track and rolling stock to determine comparative performances, wear rates, and maintenance and life-cycle costs. The consist is composed of 90 rail freight cars prepared in accordance with test specifications. Of the 90 test cars, 76 are available each day for testing. At least 1 year of test operations is planned. Four cars are removed daily from the consist for a 24-h period of test measurements and data collection. Inspection and gauging of components common to all cars occur every 22 d. Measurements of specific test components are made in accordance with the objects of each experiment. All measurements will be repeated at least five times during the test period so that a wear rate can be established for each component. The components involved in these experiments include wheels, journal roller bearings, adapters, trucks, springs, center plates, side bearings, brake shoes, wear plates, and couplers. The experiments and test measurements on each component are described.

TEST OPERATIONS

The operation of a compressed life-cycle test installation of track and rolling stock has begun at the Transportation Test Center near Pueblo, Colorado. The emphasis at the 7.7-km (4.8-mile) closed-loop track—the Facility for Accelerated Service Testing (FAST)—is on accelerated wear and fatigue tests of track and mechanical components. This will be accomplished by the continuous operation of a 76-car, 9000-Mg (10 000-ton) train over the FAST loop configuration, 16 h/d, at an average speed of 67 km/h (42 mph).

The nature of freight car and component test facilities and testing in revenue service and the need for rapid accumulation of car distance traveled place severe limitations on the usefulness of different mechanical tests. FAST will provide an opportunity for the comparative testing with respect to wear and fatigue life of freight cars and their components under near-actual conditions. In addition, FAST testing can be achieved in a relatively short time under controlled conditions.

Rolling stock will be tested in an accelerated-service manner to determine relative performances, wear rates, and maintenance and life-cycle costs. The tests will simulate, in a limited environment, the service life of a typical open-hopper car and will evaluate the in-service deterioration of its components.

The FAST consist is composed of 90 railroad freight cars prepared in accordance with test specifications. Of the 90 cars, 76 are available each day for testing. The test train is approximately 1.6 km (1 mile) long and weighs about 9000 Mg. Power is supplied by four GP-38 locomotives of 1 500 000 W (2000 hp) each. The consist includes three 63-Mg (70-ton) piggyback cars, 90-Mg (100-ton) tank cars, three hopper cars with specially fabricated trucks, three bathtub gondolas, and sixty-three 90-Mg open-hopper cars. Except for the 63-Mg piggyback cars, which contain loaded trailers, and six of the tank cars, which are run empty, all cars are loaded to the 119.3-Mg (131.5-ton) maximum gross mass allowed for 90-Mg freight cars in interchange service.

The testing environment includes a limited amount of available trackage that is oval shaped. The consist is operated so that the resulting component wear is equalized at all locations on the test cars. Every other day, the train is turned to compensate for wheel wear and asymmetric forces, and on alternate days, the locomotives are moved from one end of the consist to the other to vary the leading axle. Thus, the train travels clockwise around the loop one day and counterclockwise the next. Operating speeds are controlled, and the cars will remain unchanged during the test.

Each car is on a 22-d shop-inspection and data-collection cycle. Every day, a block of four cars is removed from the front of the consist for test measurements and data collection, after which the cars are reinserted at the rear of the train. During the 22 d between measurement cycles, the cars migrate from the rear to the front of the train. Some measurements are required at shorter intervals and are taken in the field. Others are taken into the shop every second, third, or even fourth cycle.

The car components being tested include trucks, center plates, side bearings, wheels, journal bearings, bearing adapters, springs, couplers, wear plates, and brake shoes. The object of each experiment is to compare the performances of various designs of a particular car component and determine the most cost-effective.

MATERIALS

The most commonly used material in the construction of freight cars and their components is steel. Steels are generally classified by their significant alloy components and by the method of processing; i.e., worked (wrought) or unworked (cast). The strength of steel is increased by the presence of particular other elements, the most important of which is carbon. Carbon increases steel strength without significantly decreasing ductility. Manganese, phosphorus, sulfur, copper, silicon, chromium, and molybdenum are also commonly used.

Ferritic steels of a given hardness or hardenability have the same tensile strength, whether cast or wrought, regardless of the alloy content. For design purposes involving tensile and yield properties, wrought and cast steels can be reliably interchanged. Cast steels do not show directional properties. The longitudinal properties of wrought steels are slightly higher than those of cast steel, but the transverse properties are lower by an amount that depends on the degree of working. If the directional properties are averaged for wrought steels, the values obtained are comparable to those for cast steels of similar composition. Resistance to wear and corrosion, machinability, and hardenability of cast and wrought steels are also similar.

COMPONENTS

Trucks

The railroad freight car is supported by a truck at each end, which also provides for the attachment of wheels and axles. A body center plate at each end of the car rests on a truck center plate.

The conventional freight-car truck weighs about 4500 kg (10 000 lb) and is a three-piece arrangement with cast-steel frames and bolsters. The truck components include center plates, side bearings, springs, snubbers,

wheels, axles, journal bearings, and bearing adapters. On some trucks, the brake rigging is integral with the truck.

Three different types of commonly used standard trucks and four different types of limited-use trucks are being compared. One of the standard trucks is 63 Mg; the others are 90 Mg. Three of the types of premium trucks are conventional three-piece arrangements with cast-steel side frames and bolsters. The fourth type, a 90-Mg truck, was fabricated of two side frames and a bolster with a secondary spring group in a somewhat conventional arrangement, but it also has a tie between the side frames and is equipped with hydraulic snubbers. Pads directly over the side frames carry the vertical load, and the truck pivots on a conventional center plate that does not transmit vertical loads.

A minimum of three cars are involved in each truck-test program to fulfill statistical requirements. At 44-d intervals, wear is measured within 0.025 mm (0.001 in) on those truck components exposed to it, including friction castings, bolsters, side frames, gibs, and stops. At 88-d intervals, hardness is measured at maximum localized-wear points on the same components.

Center Plates

The center plate about which trucks swivel not only functions as a pivot, but also normally transmits the mass of the entire car body into the truck structure. (Center bearing is a general term used to designate the whole arrangement and the functions it performs.) The body (male) center plate is attached to the underside of the car body and rests on the truck center plate. The truck (female) center plate is either attached to the top side or cast integral with the truck bolster. The center pin (king bolt) passes through both truck and body center plates, but does not really serve as a pivot. The truck turns about the bolt, but the stress is absorbed by the center plates.

The body center-plate surfaces can be cast or forged from a variety of steels and the bowl bearing surfaces can be modified by local hardening. Center plates of cast-steel truck bolsters have a manganese or carbon-steel wear liner applied before the bolsters are assembled into the trucks.

The center plate on 90-Mg freight cars is normally 35.6 cm (14 in) in diameter, but 40.6-cm (16-in) diameter center plates are also used. The nominal static load on these center plates is 56.2 Mg (62 tons) at a unit pressure of more than 6.9 MPa (1000 lbf/in^2). Rocking occurs at critical speeds, and it is not uncommon to have a center-plate reaction on 90-Mg cars of three times the static mass.

The experiments being done on center plates consist of comparing 35.6 versus 40.6-cm diameter center plates, unlined versus lined truck center plates, and standard versus manganese car-body center plates. Center-plate performance is being measured on 27 cars at 44-d intervals. Wear is measured on both truck and body center plates at eight locations on the plate. Surface hardness is determined at the locations showing maximum wear and on a nearby unworn portion of the plate surface.

Side Bearings

The center plate normally carries the mass of the car body into the truck structure, but when the car is tilted, as on a curve or during rocking, part of the mass is carried on the side bearings. Side bearings are attached to the bolsters of both the car body and the truck, on each side of the center plate, to prevent excessive rocking. The upper (body) side bearing and the lower (truck) side bearing are sometimes merely large flat surfaces. Other types of side bearings use rollers, springs, and friction elements to maintain constant contact and control the relative movement between body and truck.

The side bearings of the body are the upper pair of two side-bearing assemblies and are attached to the car-body bolster. The body side bearing is generally a flat plate, sometimes covered with a renewable, wear-resistant, hardened-steel wear plate through which loads from the car body are transmitted to the side bearing of the truck. Body side bearings are usually manufactured from medium-high-carbon rolled steel and heat treated for proper hardness.

Truck side bearings can be large flat plates, blocks, rollers, or elastic units. They are attached to the top of the truck bolster, under a corresponding bearing that is attached to the car-body bolster. Side-bearing housings are generally manufactured from high-carbon, high-manganese rolled steel.

Under normal operating conditions, vertical side-bearing loads will approach three-fifths of the loaded car mass, and, on poor track, this reaction may exceed two-thirds of it.

Many cars are equipped with roller side bearings to overcome the resistance in curves caused by friction at the side bearings. Roller side bearings for 90-Mg freight cars are of the double roller type. Their housings are manufactured from high-carbon, high-manganese rolled steel. Urethane constant-contact side bearings are available for use as replacements for existing double solid-steel rollers.

Some constant-contact side bearings are designed to control truck swivel and are not intended to control car rocking. Others use energy absorption to control the rocking of cars.

The experiments being made on side bearings compare double roller, friction block, and four types of constant-contact side bearings. The measurements are being made on 34 cars at 44-d intervals and include cage and roller wear for double-roller side bearings, permanent set and precompression for constant-contact side bearings, and hardness for all.

Wheels

Freight cars of 90-Mg capacity use 91.4-cm (36-in) wheels. Except for the three piggyback cars, which have 83.8-cm (33-in) wheels, all cars in the consist are of 90-Mg capacity and have 91.4-cm wheels. One-wear, two-wear, and multiple-wear wheels are available in both wrought and cast carbon steel for use on 90-Mg freight cars. One-wear wheels are not intended to be reprofiled; two-wear wheels can be turned at least once; and multiple-wear wheels have sufficient rim thickness to permit turning full flange and tread contours at least twice. One-wear wrought (H-36) and cast (CH-36) steel wheels differ significantly from two-wear wrought (J-36) and cast (CJ-36) steel wheels only in rim thickness.

The type of heat treatment and the carbon content are indicated by a suffix on the wheel nomenclature. Class U untreated high-carbon wheels are intended for general-service use where an untreated wheel is satisfactory. Class C heat-treated high-carbon wheels are intended for light braking conditions and high wheel loads or for heavier braking conditions where off-tread brakes are used, and there are other standards for classes L, A, and B wheels.

The heat treatment for class C cast-steel wheels consists of treating the rim only. The heat treatment for wrought-steel wheels consists of treatment of only the rim or of the entire wheel. After heat treatment and

quenching, the wheels are tempered to meet hardness requirements. The contour of the tread and flange is machined and smooth finished for wrought-steel wheels. The tread and flange contours of cast-steel wheels can be machined, ground, or cast.

The experiments being made on wheels compare wrought versus cast, one-wear versus two-wear, treated versus untreated, and standard versus Canadian National (CN) profile on 91.4-cm steel wheels. Thirty-two cars in the consist will be assembled with new wheels, bearings, and the two types of freight-car trucks most commonly used. The test is a symmetrical design; half the test elements are of one design and will be compared to the other half, which are of another design. Half the cars have 35.6-cm diameter center plates; the other half have 40.6-cm center plates. Half the trucks are of one type, and the other half are of another type. The wheels are wrought or cast, one-wear or two-wear, treated or untreated, and have standard or CN profiles. The journal roller bearings are regular or premium. The cars have the same type of truck at both ends, and both trucks have wheels of the same profile, heat treatment, and wear type, but one has wrought wheels and the other has cast wheels. One truck on each car has regular journal roller bearings, and the other has premium bearings. The center plates, brake shoes, roller-bearing adapters, and side bearings are the same for both trucks.

Wheel measurements are being taken on 71 cars at 22-d intervals. Wheel profiles will provide a complete record of flange and rim wear to within 0.25 mm (0.01 in). Wheel hardnesses (Brinell) are being determined at 44-d intervals.

Journal Bearings

At one time, almost the entire American freight-car fleet rolled on plain bearings, the failures of which required setting off cars at about 240 000-car-km (150 000-car-mile) intervals. Cylindrical roller bearings also were used at one time, but are no longer in use on heavy freight cars in the United States.

The tapered, journal roller bearing is now the most commonly used. These bearings have multiple-row designs and are installed on all new freight cars used in interchange service. They are well suited to the support of combination radial and thrust loads, but are limited to freight train speeds. The package type of roller bearing, a grease-lubricated assembly developed for freight-cars, is characterized by its rotating end cap secured to the axle by three cap screws. Roller bearings are designed for a minimum life expectancy of 804 500 km (500 000 miles) of service with a load factor of 80 percent, which is a full rail load in the radial direction for half the distance. The life expectancy represents a statistical reliability of 90 percent.

Bearings and enclosures are designed either for no field lubrication or for efficient periodic lubrication at a minimum specified interval. Roller bearings with housing end covers that rotate are lubricated at 48-month intervals. Extended-life bearings are designed to go without reconditioning or relubrication for 965 000 km (600 000 miles) or 10 years, whichever comes first.

The experiments being made on journal roller bearings compare three types of regular and three types of premium (extended life, no field lubrication) roller bearings. Measurements are being made on 30 cars of the wheel-test group. Grease loss will be determined within 2.8 g (0.1 oz) by cleaning the bearing exterior and weighing the bearing when the test is completed. The properties of the grease will be determined by conducting a penetration test and by inspecting the grease for foreign matter. Wear on the outer ring is being measured at 88-d intervals and when the bearings are replaced.

Bearing Adapters

The roller-bearing adapter ensures proper seating of a roller bearing in the pedestal type of side frame. The side-frame lugs on either side of the adapter transmit the lateral-thrust loads through the adapter side slots to the bearing cup. The top of the adapter is crowned to evenly distribute the load between the bearing seats. The crown also minimizes the shift in the center of the bearing load as the side frame rocks. Relief grooves in the center and on each end of the bore form the bearing seats that place the load directly over the rollers in the bearing.

Excessive adapter wear can cause improper loading of the bearing raceways, which will result in reduced bearing service life. Thrust-shoulder face wear, which is caused by contact with the end of the bearing outer ring, can result in damage to one or both of the bearing seals.

The experiments being done on bearing adapters compare nonhardened, crown-hardened, and crown-and-thrust-shoulder-hardened adapters. Wear and hardness measurements are being taken on 31 cars at 22-d intervals at all adapter wear points; i.e., adapter crown, thrust shoulder, and relief grooves.

Springs

The bolster spring is the main spring of a car and supports the truck bolster on which the mass of the car body rests. Some cars are equipped with stabilizing springs as part of the friction snubber on the truck. This spring also carries part of the load.

Freight-car truck springs are heat-treated helical compression springs and made of carbon-steel or alloy-steel round bars, by coiling on a preheated mandrel. These springs have inner and outer coils. The D-5 outer coil (carbon spring) has a left-hand winding of 14 cm (5.5 in) outside diameter, and the inner coil (alloy spring) has a right-hand winding of 8.6 cm (3.375 in) outside diameter. An alloy outer spring of the same winding, size, and spring parameters as the carbon outer coil has received conditional approval, but is not in widespread use. The recommended arrangement of D-5 springs for 90-Mg freight cars is 8 each inner and outer coils/spring nest. The solid (fully compressed) capacity per spring nest is 43 000 kg (95 000 lb).

Some newer freight-car trucks use the D-7 long-travel helical compression spring. The outer coil of this spring has the same winding and diameter as the D-5, but its solid capacity is slightly greater. Its total travel is 10.8 cm (4.28 in).

The experiments being made on springs compare D-5 carbon versus D-5 alloy outer springs and D-5 versus D-7 springs. The permanent set of all springs is being measured within 0.25 mm (0.01 in), the spring deflection is being measured within 0.25 mm (0.01 in) for load carrying springs, and the spring rates are being determined for all springs on 34 cars at 44-d intervals.

Snubbers

Standard bolster springs recoil with approximately the same force as that of the shock causing them to be compressed, which results in a periodic vibration of compression and recoil. This action is usually controlled by snubbing springs, friction dampeners, or hydraulic shock absorbers. Some type of mechanical system for preventing the development of harmonic car-body motion is

incorporated in all current truck designs. However, spring group or side-frame snubbing devices are not being tested or considered as a test variable. If installed on any test car received, they were removed or deactivated.

Couplers

Freight-car couplers automatically connect one rail vehicle to another, or conversely, disconnect them. The longitudinal (drawbar) forces at the couplers between cars or between cars and locomotives can be either tensile (draft) or compressive (butt), depending on the operation of the train at the time. Coupler-centering devices maintain the coupler in the center line of draft, but allow it to move to either side when a car is rounding a curve while coupled to another car.

The type E coupler, the basic coupler used in freight-car service, was adopted by the railroads as standard in 1932. It has undergone numerous design modifications, including continued metallurgical refinements to improve the physical properties of the steels used in its manufacture. Couplers made of grades C and E steels have the same chemical composition, but differ in heat treatment, hardness, and strength.

The rigid-shank, type E coupler has a flat butt surface that is seated on the draft-gear follower. This arrangement requires a lateral coupler movements to compress the draft gear. This reaction maintains the alignment of cars in pusher service or under dynamic braking conditions and tends to retain the coupler to a centered position on the car.

The type F interlocking coupler does not allow vertical disengagement when mated with a similar coupler and has a support shelf that retains an E coupler in the event of a failure or a pullout. An alignment control on the shank counteracts lateral car forces and coupler jackknifing under butt loading. The type F coupler is available in various shank lengths that allow curve negotiations for longer cars.

The most recently adopted standard freight-car coupler is the E/F coupler. By design, the coupler head is the standard E type, and the shank is the standard F type. It is widely used on longer freight cars.

Some freight cars have a rotary-shank coupler that allows coupled open-top, full-size railroad or mine cars to be unloaded in car dumpers without uncoupling and is widely used in unit train operations transporting bulk material such as coal.

The performance of type E couplers in grades C and E steel is being measured on 9 cars at 44-d intervals. Wear and hardness at all wear points, the permanent sets of the shank length, and butt thicknesses are being measured.

Coupler Shank and Carrier Wear Plates

The coupler shank rests on a carrier whose opening allows the coupler to swing laterally to permit passage of the car around curves. Some coupler-shank designs have a 0.64-cm (0.25-in) thick wear plate on the bottom wall to provide for wear due to contact with the carrier. The material for shank wear plates is spring steel or a suitable substitute, hardened and tempered to prolong its life.

The wearing surface of the flexible carrier on which the coupler shank bears must be long enough and wide enough to cover the full width of the coupler shank in the maximum angled position. Type E coupler carriers are integral with the striking plate. The type F coupler has a spring-supported carrier. Renewable, wear-resistant, hardened-steel carrier wear plates are used on carrier surfaces where wear is greatest.

The experiments being made on shank and carrier wear plates compare J-alloy AR-360, C-1045, and manganese-steel wear plates on 15 cars at 44-d intervals and when the plates are replaced.

The wear depths of both plates are measured near the plate center at the maximum localized wear. The hardness of both plates is measured at the maximum localized wear and where there is no wear.

Draft Gears

Draft gears are shock-absorbing devices designed to receive and dissipate coupler forces without damage to the car structure and lading. The draft gear forms the connection between the coupler rigging and the center sill. It receives the shocks incidental to train movements and car coupling and cushions the force of impact so that the maximum unit stress is within the capacity of the car structure.

Draft gears are not being tested or considered as a test variable. All test cars are equipped with draft gears conforming to the same specifications that require a minimum capacity at a specified level of reaction force.

Brake Shoes

Dynamic braking can be used to control train speed and to brake a train to a low speed, after which air brakes can bring it to a full stop. On most freight cars now in service, braking forces are developed in a single body-mounted cylinder and transmitted to the wheel treads by cast-iron brake shoes through a system of rods and levers. However, some cars are equipped with truck-mounted or composition brake shoes.

Brake shoes are made of a material that will provide friction and shaped to fit the tread of the wheel and held together by a steel backing plate. Composition brake shoes have characteristics considerably different from those of the standard metal brake shoe. The coefficient of friction of composition shoes is relatively constant throughout the entire speed range, but the standard metal shoe has a coefficient that increases as the speed decreases, which results in a tendency of the wheels to slide at slow speeds when a constant braking force is exerted throughout deceleration. The retardation performance of vehicles with composition brake shoes is more closely parallel to rail adhesion than is that of vehicles with cast-iron shoes, because the friction value is more uniform. The composition high-friction shoe develops a higher coefficient of friction than does the cast-iron shoe and allows a smaller force against the shoe to develop the same retarding effect.

The experiments being made on brake shoes compare high-phosphorus cast-iron and three types of composition high-friction shoes. Performance is being measured on 16 cars at 7-d intervals and on 47 cars at 22-d intervals by weighing the brake shoes before, during, and after testing to obtain the rate of wear and the total wear.

BATHTUB COAL GONDOLAS AND TRAILERS ON FLATCARS

The three bathtub gondola cars are being compared with the sixty-six 90-Mg hopper cars in the consist. Trailer-on-flatcar performance is being measured on the three 63-Mg flatcars and compared to that of the 90-Mg open-top hopper cars. Components unique to the gondolas and flatcars, such as king pins, trailer-hitch jaws, and side plates, will be measured at 66-d intervals.

ACKNOWLEDGMENT

This research was sponsored by the Office of Research and Development, Federal Railroad Administration.