21000 TONNE HEAVY HAUL TRAINS ON THE ERMELO-RICHARDS BAY LINE

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Synopsis The article reviews philosophy and design of 200 wagon 20800 tonne trains on the Ermelo- Richards Bay line. Purely technical parameters are examined together with those which build driver confidence through correct feel. The importance of high fidelity information on train dynamics phenomena for advanced driver training is discussed.

1. INTRODUCTION

As commissioned in 1976, ruling gradients were 1 in 66 in both directions. Six diesel locomotives hauled 76 rotary dump wagons loaded to 18« tonnes/axle. In 1979 increased traffic and expected growth prompted replanning of the operation. Formation and bridges permitted 26 and 28 tonnes/axle for wagons and locomotives respectively, but coupler force and power demand were critical. Rugged topography demanded careful investigation of train dynamics because substantially higher train length and tonnage were anticipated. Drivers should nevertheless not perceive their task complexity to have increased significantly. Theoretically tractable and subjective parameters which influence feel and perceptions had therefore to be integrated.

2.0 BROAD DESIGN PARAMETERS

2.1 Environment

Descending gradients predominate in the loaded direction. Service is intense, with heavy coal and general freight trains totalling thirty per day per direction. The maximum speed of heavy trains is 80 km/h and average line side signal spacing is 1,9 km. Fluent trainhandling is thus essential. Imbalanced ascending and descending ruling gradients were economically attractive because they required easing only ascending gradients against loaded trains.

2.2 Optimization criteria

Locomotive adhesion was limited to24-25 %, to inhibit longitudinal dynamic disturbances. Locomotive axle configuration had to be simple. Quasi-static coupler forces in the range 1500-1600 kN economically optimise ruling ascending gradients, but only limited dynamic forces could be accepted on top of such high forces. Knuckles and yokes fail at around 2300 kN, so the worst dynamic augment would therefore have to be less than 50 %. Reliable information on train action, plus advanced driver training to high standards was thus required.

2.3 Train length

Spoornet fits Association of American Rail- roads direct release brakes to air braked freight wagons. For the terrain and train size envisaged, no other system offers adequately fast response. When controlled from a single drivers brake valve, response degrades significantly beyond 200 wagons. Nevertheless, it was economically attractive to maximise train length within this constraint. Longer trains also average gradients over a greater length, and so respond more slowly to gradient changes. A train length of 200 wagons was therefore judgementally preferred.

2.4 Driving feel

During operation of the original scheme, response to topography and handle-ability parameters were perceived to restrict potential train size. The author therefore took to driving personally to experience first hand which parameters are pertinent, how they interrelate and how a driver plans his task. This enabled train handling design to enhance driver confidence and extend perceived ability. Driving feel is dominated by braking characteristics. Composition brake blocks are a prerequisite to achieve substantially constant friction coefficient. The lowest brake ratio consistent with stopping ability is preferred to widen the braking force modulation range. The economic advantage of avoiding empty/loaded changeover equipment was elusive because the new design rotary dump wagons have the high load tare ratio of 4,15:1. By exploiting the smoothness of composition brake blocks and lowering brake ratio to the limit, it was found just possible to accept single capacity brakes. Braking distances between line side signals are typically 600-1200m.

2.5 Electric braking contribution.

Electric braking is arguably the greatest single contributor to train handling feel. It is a synthesis of the characteristics of the electric brake and the ratio of electric braking to friction braking. When descending long gradients the range within which total braking force may be modulated must at least match the range within which total brake force demand varies. Adequate electric braking must be available down to very low speeds. The design adhesion of 22% and extended range down to 15km/h, provide the optimum characteristics, but wet rails can be troublesome.

2.6 Wheel thermal loading

Short turnaround time demands relatively high speeds on descending gradients, which requirement conflicts with short braking distances and thermal limits on wagon wheels. This trade off was optimised by including electric braking as a balancing factor. At a wagon axle load of 26 tonnes it was necessary to use relatively high carbon rim-quenched cast steel wheels with a nominal thermal rating of 12-13 kW per wheel. Had higher wheel thermal loading been risked to reduce electric brake rating, trains would feel "sticky" when traversing short flatter portions of long descending gradients.

2.7 Energy dissipation

An energy dissipation balance conveniently checks correct brake system performance over the design speed range. It demonstrates the high risk of wagon wheel thermal damage if authorised descending gradient speed restrictions are exceeded when the electric brake is on its constant power characteristic. Whilst electric brake rating usually assumes equal ascending and descending ruling gradients, the situation is complex when descending gradients are steeper than ascending gradients. In this case the difference is large, being 1 in 160 ascending and 1 in 66 descending. For the Ermelo-Richards Bay line, the required electric braking capacity proved to be a significant determinant of traction motor rating. In braking, electrical and mechanical inefficiencies work to advantage, and it was therefore possible to specify a slightly higher rating for braking than for hauling. The traction motor ratings specified could not be met by existing SATS locomotives, and it became necessary to design a new class of electric locomotive, the 11E. It is rated at 3,9 MW in traction and 4,5 MW in electric braking. The substantial electric brake rating has proven valuable in building up driver confidence because it minimizes the negative attributes of direct release brakes.

2.8 Train action

Bar couplers offer a good compromise between providing sufficient slack to pick up trains whilst also controlling harsh slack action. The new 104 ton wagons are therefore bar-coupled in semi-permanent pairs. When traversing a crest, the gradient component of those wagons which are already over the crest can augment the tractive effort of head end locomotives. The resultant high force may fail a coupler near the middle of the train. For short ascending gradients, kinetic energy is imparted ahead of the rise, so that low tractive effort can be exerted after the crest. After long ascending gradients, tractive effort is modulated to accelerate the train at no more than 2-4km/h/minute until it is sufficiently far over the crest. The new wagons are fitted with standard friction drawgear. Under high compressive forces they are sensitive to the rate of change of electric braking force, which above a threshold level may induce objectionable wave action. The problem is contained by modulating electric braking gently, but constant friction drawgear will be fitted during maintenance.

2.9 Holding brake

Because descending gradients are steeper than ascending gradients, the locomotives' independent brake alone cannot hold a train whilst recharging the automatic brake after stopping on a descending gradient. The latter accelerates a train against full electric braking to authorised speed before the automatic brake can be fully recharged. It was therefore necessary to provide a separate holding brake function. This is essentially a retaining valve which shuts off the brake cylinder exhaust on each wagon and so holds the train positively on descending gradients whilst recharging the automatic brake. A separate holding brake pipe is connected through the trailing locomotives to the first 100 wagons. Trains are not stopped without good reason on descending gradients, because the holding brake apply/release cycle takes at least 20 minutes.

3.0 THE INTEGRATED DESIGN PACKAGE

After assessing all inputs, it was concluded that trains of 200 new design 104 tonne rotary dump wagons could be worked on a strengthened line. Descending gradients could be retained, but ruling ascending gradients against loaded trains were eased to 1 in 160. The trains would be hauled by four new design six-axled locomotives of 28 tonnes/axle. This gives a trailing load of 20800 tonnes, a locomotive consist mass of 672 tonnes, and a train length of 2500 m. The new wagon and locomotive designs were designated respectively CCL-5/7 and class 11E.

4.0 THE TRAIN DYNAMICS INSTRUMENTATION VEHICLE

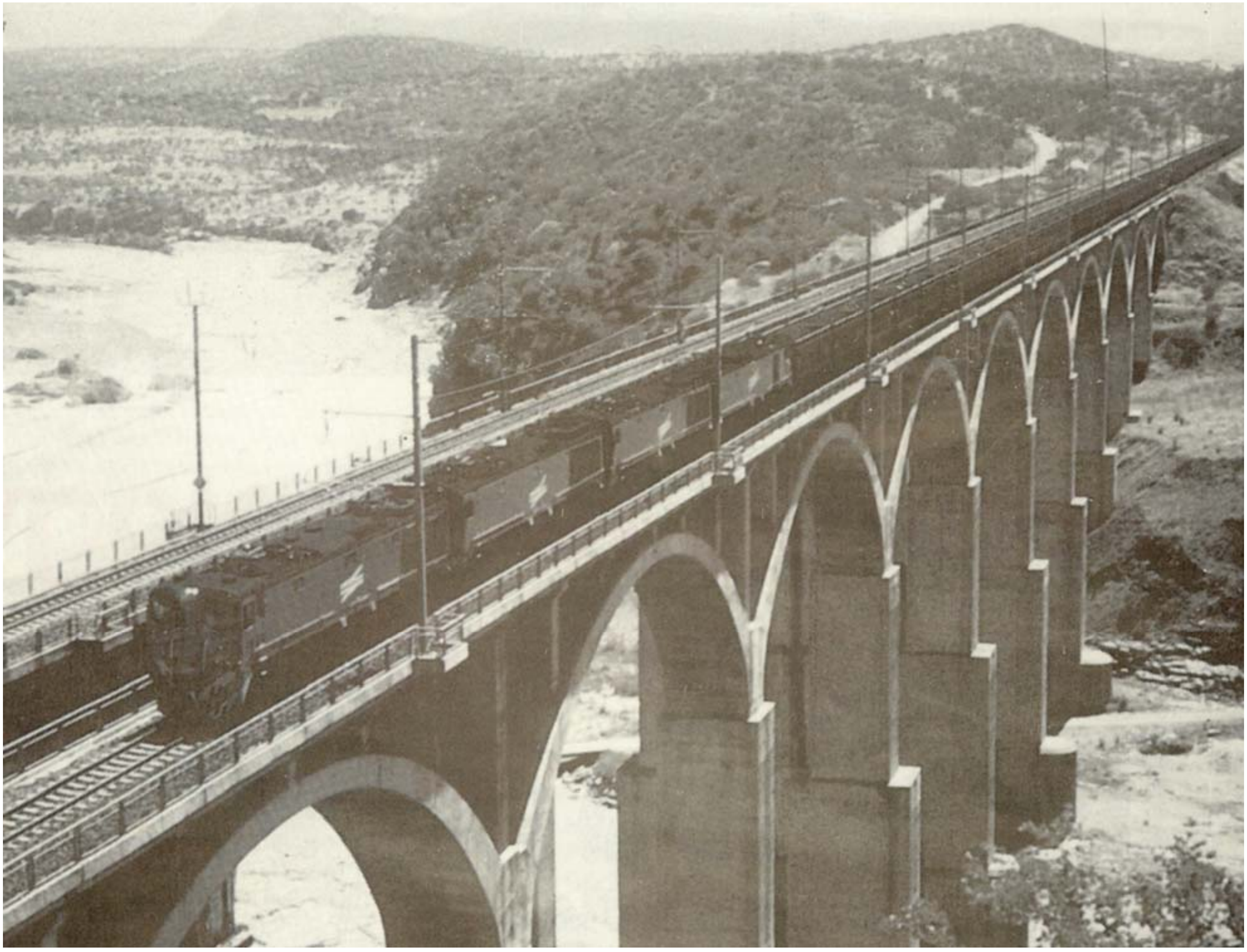
Spoornet's train dynamics instrumentation vehicle measures, processes and displays, in real time, train dynamics phenomena transmitted from outstations at five locations in a train. It employs a digital telemetry system using a single fibre optic cable to monitor coupler force, drawgear behaviour, wagon acceleration and brake system pressures. Locomotive control manipulation and local variables may also be monitored. Time frame recordings are triggered when selected variables exceed preset limits. CRTs display the train moving on the line profile, plus eight selected channels, to the driver so he may drive with real time train dynamics information. This facility was used to accurately assess train action phenomena and use it to train drivers to handle critical situations. The ability to acquire accurate data on in-train phenomena and the understanding of train handling feel enabled a fluid, energy saving driving style to be developed and to be transferred to drivers during advanced training.

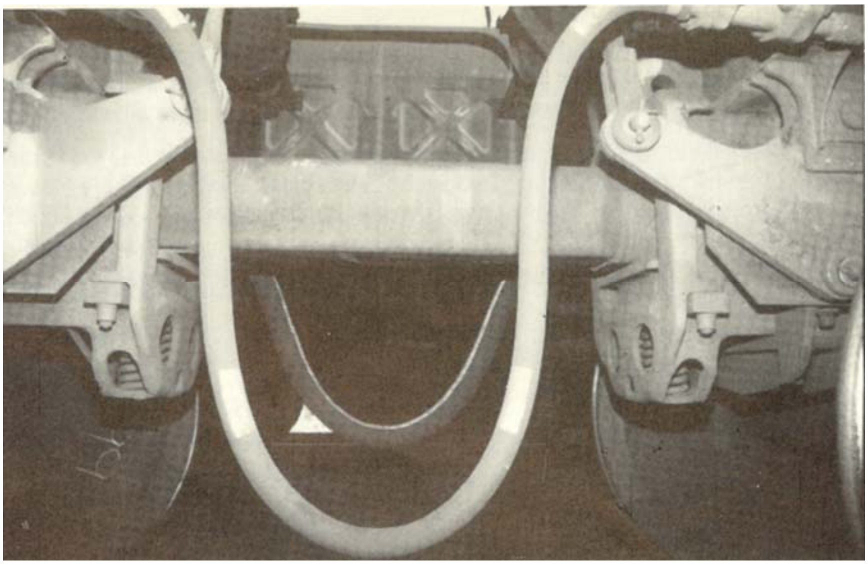
5.0 DRIVER TRAINING

Rational train handling is founded on sound theory plus information on critical phenomena. Drivers distrust aids of mediocre fidelity based on approximate algorithms. Trainee drivers of 200 wagon trains were informed of critical phenomena in their trains via the train dynamics instrumentation vehicle. This is a valuable training technique because the information is always true and credible, but it is complex and suitable only for advanced training. The disadvantage that bungled situations cannot be repeated and refined as with a simulator is countered by cascade training, during which each trainee is accompanied by his successor.

6.0 CONCLUSION

Trains of 200 wagons now operate successfully on the Ermelo-Richards Bay line. Design parameters are structured so that drivers perceive train handling to feel correct. They are confident in their trains and in their ability to handle them. Design performance is safely delivered by very heavy trains over very rugged terrain within tight constraints.





Braking mechanism incorporating the holding brake

CONTRACTORS AND SUPPLIERS

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