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Active tilting tested as JNR plans narrow gauge speed-up

Competitive pressures have forced Japanese National Railways into renewed efforts to raise the speed of limited expresses on its 1 067 mm gauge lines, especially on routes with severe curvature

DEVELOPMENT of the shinkansen has tended to overshadow efforts to improve the performance of Japan's 1 067 mm gauge limited express trains. While construction of more standard gauge lines was in prospect, the incentive to raise speeds on the narrow gauge was lacking. Now that shinkansen construction has come to an end — at least for the time being — commercial pressures are mounting to lift the maximum speed on the narrow gauge above the 120 km/h ceiling that has applied since 1968.

The last attempt to raise narrow gauge speeds dates back to 1973 when Series 381 limited express EMUs were introduced on the 252 km run from Nagoya to Nagano. This line cuts across the central mountain range of Honshu and curvature is severe, so Series 381 car bodies were mounted on rollers that allowed up to 5° of pendular tilting in curves.

The intention had been to operate Series 381 at a maximum speed of 130 km/h, with speeds through curves raised by 20 to 25 km/h. Thus the standard restriction of 65 km/h for a 300 m radius curve would be replaced by a special limit of 85 km/h for tilting trains.

It did not work out as planned. Signalling restraints kept the maximum speed down to 120 km/h, while tilt nausea made it necessary to issue travel sickness pills to passengers. Today, the 277 cars of Series 381 operate the Nagoya — Nagano service (among others) at a commercial speed of around 75 km/h, barely adequate to meet competition from roads that are continually being improved.

Targets set for the latest drive to cut narrow gauge journey times, and the steps being taken to achieve them, were set out by Yasuji Yukawa, Deputy Director of JNR's rolling stock design office, in *Japanese Railway Engineering* (Vol 24 No 2 p16). Maximum speed is to be 130 km/h (120 km/h through pointwork), and speeds through curves are to be 25 km/h above the standard limits for non-tilting stock. In the longer term, it may be possible to lift the maximum speed to 160 km/h.

Standard speed limits through curves (without turnouts) on JNR range from 110 km/h for radii between 1 200 and 1 600 m down to 65 km/h at 300 to 400 m. If the targets are met as planned, a 600 m radius curve will be taken at 115 rather than 90 km/h, allowing a substantial improvement in running times on curved routes. At present Series 381 traverses curves 15 to 20 km/h faster than the standard limits.

A new system of active tilting has been developed and tested that should allow the curving performance of Series 381 to be improved. Fig 1 shows the revised arrangement in which the pendular tilting is assisted by an air cylinder, converting it into an active rather than a passive system. The maximum tilt angle is now limited to 5° as JNR has found that it is not necessary to compensate fully for cant deficiency, confirming the results of tests carried out by British Rail in 1983-84 (RG 11.84 p870).

Another aspect of BR's work on tilting that is mirrored in Japan is acceptance of the need to tilt the body before the start of the transition curve. This is particularly important in allowing people who are standing up to keep their balance when curvature is changing.

To achieve this, JNR uses the ATS (automatic train stop) inductors associated with each signal as markers. Details of curvature throughout the line are programmed into the tilt command controller, which also knows the precise location of ATS inductors. The command controller identifies each ATS inductor in turn, and measures the distance run to the next transition curve by counting axle revolutions. It is thus a simple matter to initiate tilt shortly before the transition curve commences, and likewise to start reducing the tilt as the end of each circular curve approaches.

As Fig 2 shows, there are also accelerometers mounted at the front and rear of the car body which ensure that the tilt controller does not try to impose excessive lateral forces on the passengers. Otherwise, the tilt controller acts according to the profile of line curvature stored in the command controller.

Various control modes were tried out, and the experimental active tilting was put briefly into revenue service. These trials confirmed the need to minimise the rate of tilt by starting ahead of the transition curve and completing the tilting process somewhat after the end of the transition.

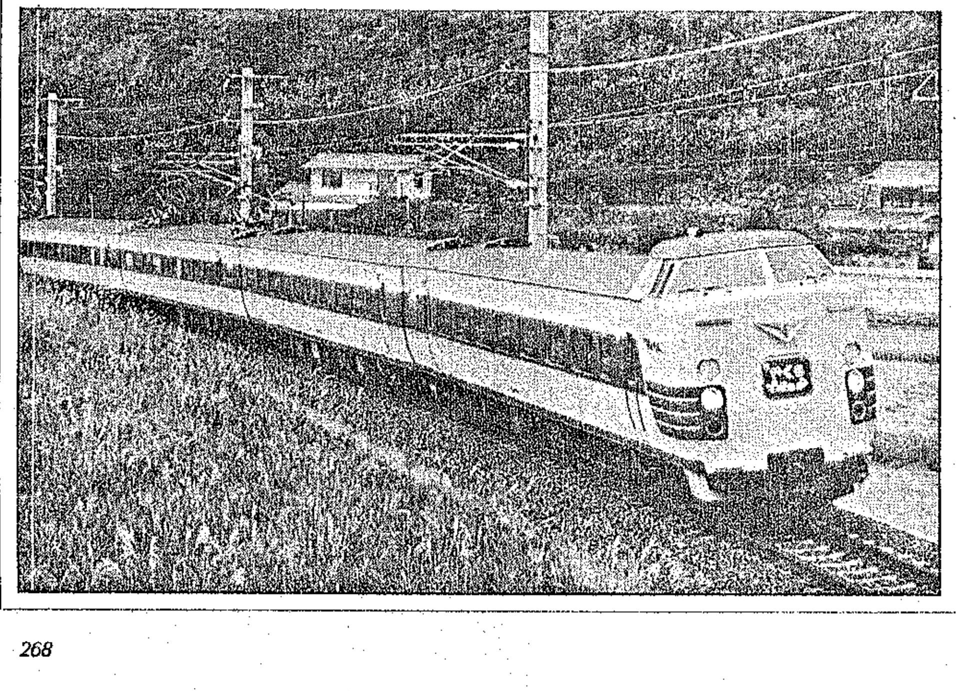
It was also confirmed that passengers felt most comfortable when cant deficiency was only partially compensated. In other words, the passengers evidently prefer to feel some lateral force when rounding a curve, possibly because it is in line with their expectations.

Active suspension

Servo air cylinders were also used experimentally on a Series 381 car as vertical and lateral suspension elements. They were connected in parallel with the secondary air springs with the specific aim of suppressing body vibrations in the 1 to 3 Hz range.

Static tests on one bogie confirmed that the introduction of these active suspension elements reduced the magnitude of vertical and lateral body vibrations by as much as one-third at the resonant frequencies. One car of a

One of JNR's Series 381 trainsets introduced in 1973 has been equipped with active tilting equipment which allows curving speeds to be increased by up to 25 per cent above the limit set for non-tilting trains



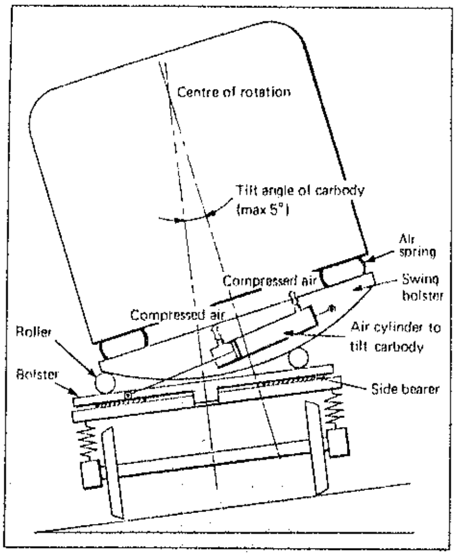


Fig 1. Active tilting is achieved economically by adding an air cylinder to assist the existing pendular tilt mechanism

Series 381 train was fitted up for running trials, which demonstrated that lateral body vibrations could be halved (there was not sufficient compressed air capacity to have an active vertical suspension in use simultaneously).

However, problems did occur with the active lateral suspension when running through curves, and more work is needed to develop this technique before it can be applied generally.

Wheel/rail forces

Running faster through curves tends to increase lateral forces exerted on the track, and some improvement was needed in this area before curving speeds 25 km/h in excess of standard limits could be accepted.

Three prototype bogies were manufactured for use under the Series 381 tilting coaches. These incorporated self-steering wheelsets with a revised tread profile and primary suspension that was soft longitudinally, reduced body/bogie rotational resistance, lightweight construction and a shorter wheelbase.

Running trials with these bogies confirmed that self-steering wheelsets gave the best results, reducing the lateral force exerted by the bogie on the high rail in a 400 m radius curve by about 1 000 kg.

Another approach was to reduce the unsprung mass by such means as hollow axles, lighter axleboxes with rubber primary suspension, and lighter braking elements. Running trials showed that a 20 per cent reduction in unsprung mass was possible, with beneficial effects on the track.

Better braking performance

The original intention to run Series 381 trains at 130 km/h had to be abandoned back in 1973 because braking performance at the higher speed was not adequate to cope with the stopping distances allowed by existing signals and ATS inductors. This requires that the train must be brought to rest from full speed in 600 m on level track.

In seeking to improve braking performance to match the higher speeds now proposed, the first step was to introduce a tread cleaning device which had the effect of raising adhesion by 20 per cent.

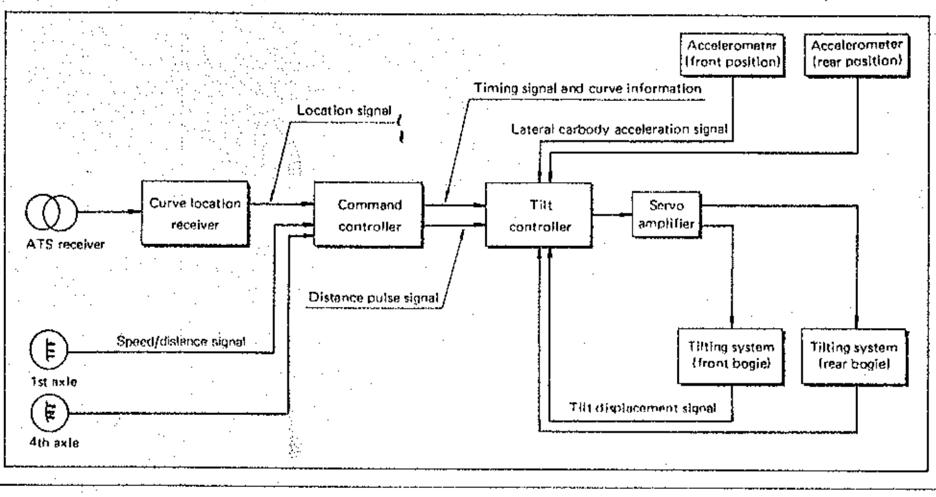
The next stage was to fit electronic wheelslip detection and correction. This works by reducing air pressure in the brake cylinders when wheelslip is detected, and then making a two-stage re-application. Braking pressure is adjusted according to the speed of the train and the load as measured by the air springs.

These improvements in braking were assembled on a Series 583 limited express set, and trials were carried out with adhesion reduced by water sprayed from the front of the leading car. Stops were made successfully from 130 km/h in less than 600 m.

JNR is now in a position to introduce 130 km/h services on 1 067 mm gauge lines with curves traversed 25 km/h faster than the standard limit. This involves either retrofitting the Series 381 fleet with active tilting, new bogies and improved brakes, or building a new series of trains incorporating these features.

In spite of well publicised financial difficulties, JNR speeded up most limited expresses on March 16. Technical developments which will further improve its competitive position are being actively pursued. □

Fig 2. Signals from the ATS equipment initiate the tilting, which is limited by accelerometers



Essais d'inclinaison active de la caisse, tandis que JNR prévoit d'augmenter la vitesse sur son réseau à voie étroite. *Les pressions de la concurrence ont poussé la Société Nationale des Chemins de Fer Japonais à renouveler ses efforts pour augmenter la vitesse des trains dans les courbes. Des vérins pneumatiques ont été utilisés expérimentalement pour améliorer la performance d'inclinaison de la caisse des trains de la Série 381 qui est sortie en 1973, tandis que des suspensions actives ont également été essayées. Les modifications de bogie destinées à réduire les forces entre les roues et les rails et le contôle électronique du freinage destinés à réduire la distance de freinage font partie de l'effort pour pousser la vitesse maximale de 120 à 130 km/h et peut-être même jusqu'à 160 km/h*

JNR prüft Aktivneigung des Wagenkastens im Rahmen der Beschleunigung auf dem Schmalspurnetz. *Durch Druck der Konkurrenz sehen sich die Japanischen Nationalbahnen gezwungen, die Fahrgeschwindigkeit von einigen Schnellzügen auf ihrem Streckennetz von 1 067 mm Spurweite und besonders auf Strecken mit starken Krümmungen zu beschleunigen. Druckluftzylinder wurden versuchsweise für die Wagenkastensteuerung in den 1973 eingeführten Zügen der Serie 381 eingebaut, und weitere Versuche mit Aktivfederung laufen. Änderungen der Drehgestelle zwecks Minderung der Radkräfte und elektronische Bremsen zwecks Verringerung des Bremsweges sind Teil eines Projektes für die Beschleunigung der Höchstgeschwindigkeiten von 120 auf 130 km/h und später vielleicht bis auf 160 km/h*

Los ferrocarriles nacionales japoneses realizan pruebas de inclinación de la caja con elementos activos para aumentar la velocidad en las lineas de via estrecha. *Las presiones ejercidas por la competencia han estimulado a los ferrocarriles nacionales japoneses a poner en juego esfuerzos renovados por aumentar la velocidad de algunos expresos en las lineas de 1 067 mm, especialmente en rutas con curvaturas severas. Se han utilizado cilindros neumáticos experimentalmente para mejorar el comportamiento de la caja inclinable de los trenes de la Serie 381 introducidos en 1973, a la vez que se han ensayado también suspensiones activas. Las modificaciones de los bogies para reducir las fuerzas entre la rueda y el carril y el control electrónico de los frenos para reducir las distancias de parada forman parte de la campaña para aumentar las velocidades máximas desde 120 hasta 130 km/h y, posiblemente, hasta quizás 160 km/h*