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(73) Patenthaver: **Deutsche Bahn AG, Potsdamer Platz 2, 10785 Berlin, Tyskland**

(72) Opfinder: **Witthuhn, Martin, Hörgenbachgerstrasse 5, 85777 Fahrenzhausen / OT Viehbach, Tyskland**
Pohl, Steffen, An der Schäferwiese 18, 81245 München, Tyskland

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **Fremgangsmåde til at påvirke og begrænse langsgående dynamiske kræfter i et togsæt**

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A METHOD FOR INFLUENCING AND LIMITING LONGITUDINAL DYNAMIC FORCES IN A TRAIN SET

The invention relates to a method for influencing and limiting longitudinal dynamic forces in a train set having locomotives that are distributed in the train set and configured to transfer driving and braking forces to the train set, wherein the locomotives are connected to one another via a main air duct of the train set and via a communication connection.

Trains are braked using pneumatic brakes. A brake command issued by the locomotive, by means of an indirect brake, is initiated by venting the main air duct (HL). The pressure drop in the HL propagates in the train. Once the pressure drop reaches the cars, the pressure in the brake cylinders will be increased to a target value within a predetermined period of time. This period of time (brake development time) is specified in international regulations (UIC). This braking system is practical and safe for the regular train length (approximately 700 m) over decades.

If it is desired to operate longer or heavier trains, further traction units, which are distributed over the train set, will be required as a function of the route (gradients) (e.g. because the traction performance of a traction vehicle is insufficient and due to the minimum braking strength of the screw coupling, the towing hook and the towing bar).

Appendix A of DIN EN 50239 addendum 1 (version of May 2008) describes typical examples of the multiple traction use consisting of a guiding traction vehicle (FTZ) and one or more guided traction vehicles (GTZ).

The response behaviour of the pneumatic brake as described above, as well as the initiated braking operation (via radio remote control) of the GTZ may lead to the generation of increased longitudinal pressure forces. These increased longitudinal pressure forces may occur when the kinetic energy (= ½ m x v^2) stored in the train causes cars that are not yet being braked or that are braked only to a lesser extent to run onto cars that are already being braked. This effect is increased in cases in which the brake command transferred via radio to the GTZ is not received due to interruptions of communication from the GTZ, whilst the GTZ continues with traction power switched on to push against the cars already being braked in front of it.

In the case of a combination of unfavourable operating conditions (e.g. heavy, unbraked cars push onto lightweight braked cars), and if this occurs along a track curve, it may occur that the lightweight cars are “pushed out” and derail. In connection with the running safety of freight wagons, the tolerable longitudinal pressure forces are therefore determined in a defined track curve according to the UIC information sheet 530-2.

What is known is a train control system on the basis of radio connections that is provided for a control unit and a number of remote units (US 4 582 280, US 4 553 723). The system includes a protocol for establishing a radio connection between the control unit and the one or more units, which prevents any of the units in the system from processing communications or commands from other units in other train units or communications or commands that might come from units in the train system, but are destined for other units. In order to avoid the simultaneous transmission of a number of units of the system on a common transmission channel, a hierarchy of transmission channels is provided. Within the context of this hierarchy, the system ensures that messages with the highest priority are transmitted first. The control system provides for a coordinated control of the air brake function on the train.

In certain applications it may also be desired to operate, at least temporally, a train set made up of a number of train segments, each segment including at least one locomotive and a number of cars. Such train segments may be connected to each other at a nodal point and may be operated together or may be separated. A typical train requires a continuous brake line that connects all of the locomotives and cars along the train. In the case of a segmented train, the brake line would typically be connected between the last car of a preceding segment and the next locomotive of the subsequent train segment. The connecting and disconnecting of the brake hoses lead to considerable workload.

US 5 383 717 describes the use of an auxiliary locomotive that is used for temporally supporting the train whilst negotiating a gradient. The auxiliary locomotive is here equipped with a head-of-train unit (HOT unit), and the car immediately in front of the auxiliary locomotive is equipped with an end-of-train unit (EOT unit). The guiding locomotive is also equipped with a HOT unit. The brake line of the auxiliary locomotive is separated from the rest of the train, so that the auxiliary locomotive can connect or disconnect from the train set more quickly. The EOT unit communicates with the HOT unit of the auxiliary locomotive and with the HOT unit of the guiding locomotive, so that the auxiliary locomotive is enabled to operate its brakes on the basis of a mirror image of the master brake pressure as seen by the EOT unit.

Unfortunately, here too, the radio connection between the EOT unit and the HOT unit of the guiding locomotive may be interrupted when the train drives along a curve or through a tunnel. Other circumstances may also cause a less effective operation of the brakes between the train and the auxiliary locomotive. Moreover, there is no coordination between the driving force of the locomotives of the train and the auxiliary locomotive, so that deleterious forces may be generated between parts of the train.

What is known is a control system for segmented brake lines in trains, which include at least one first and one second train segment with a brake line (EP 1 064 181 B1). The train control system advantageously includes a first control subsystem for installation in a locomotive of the first train segment and a second control subsystem for installation in a locomotive of the second train segment, both systems communicating with each other for controlling the braking of the train and/or the driving force. In addition, the system includes a third control subsystem for installation in a car that is adjacent to the end of the train of the first train segment, which subsystem includes at least one pressure transducer for detecting the brake line pressure and at least one control valve for controlling the brake line pressure. All of the control subsystems communicate with each other.

Moreover, systems are known wherein the route recorded in a route atlas or the route determined via GPS is included in the speed control of a train (DE 198 41 246 A1, DE 199 12 640 A1, DE 198 17 783 A1).

All of the known systems with a brake layout according to UIC in train sets with cars having side buffers have the following features in common:

- a control of a train set having a number of locomotives, which takes into account speed and track radii with regard to the driving and braking pressures under consideration of admissible longitudinal dynamic forces, is not possible

- in the case of an interruption of the communication between the individual units of the train set, in particular in the case of trains having a train length of more than 700 m, an unconditionally safe train operation has so far not been possible, so that the train set may at times have to be braked down to standstill.

The invention is based on the object of ensuring compliance with admissible longitudinal forces in a train set also in the case of an interruption of communication between the locomotives in heavy and/or long trains, so that no inadmissible derailing risk can develop.

According to the invention, this is achieved according to patent claims 1 to 11.

On straight route sections, a train set may tolerate higher longitudinal pressure forces without derailing than in areas with tight radii. Further, a train set may also tolerate higher longitudinal pressure forces without derailing due to the friction values of the usual braking facilities (block brakes), which are lower at higher speeds.

To this end, the sections, on which an operation with distributed multiple traction is desired, are divided into route sections which in turn are divided into classes. The classes specify how the train set has to behave in this section in the case of a radio interruption.

At least two classes have to be specified:

- Class 0: in these route sections, a braking operation has to be triggered by all of the locomotives in the train set in the case of a radio interruption within a period of time of 0 to 3 seconds, 3 to 5 seconds or 18 to 30 seconds;

- Class X: in these route sections, no autonomous reaction of the locomotives is required in the case of a radio interruption. Monitoring the main air duct for detecting brake requirements for switching off the traction performance of guided locomotives is sufficient.

Further classes may be defined for the behaviour of groups of trains which, under comparable circumstances (such as e.g. a brake requirement), have a comparable longitudinal dynamic behaviour. Here, characteristic time windows are assigned to these groups of trains, within which an autonomous reaction to radio interruptions has to be carried out. The admissible time windows are here established also as a function of brake development times according to UIC 540, which for brake position P amount to 3 to 5 seconds and for brake position G amount to 18 to 30 seconds.

The classification of the route sections is stored in a database and is available to all locomotives that operate in trains with distributed traction. Whilst traveling, the current speed and the current position are determined by each locomotive. The speed is determined via wheel set transmitters or radar devices, the current position is determined from a combination of a GPS receiver and, for bridging reception gaps, an odometer. The location information is compared on each locomotive with a database with the classification of the route sections, and in this way the currently applicable class is determined. In the course of this, the position of the guiding locomotive is referenced, at which the distance between the respectively guided locomotive and the guiding locomotive is taken into account. Thus, all the locomotives are capable of responding to a radio interruption as a function of the class at the same time in the same way. Optionally, the locomotives can read the route classes for the route section ahead via stationary balises. The balises are located, in the case of a change to a more critical class, ahead of the corresponding route section to such a degree that all of the locomotives set up in the train set will pass the balise even before coming up to the corresponding route section. In case the locomotives determine the classification of the route section ahead via balises, the distance between locomotives, which is known from the train configuration, will be used for determining the route position, from which onwards all of the locomotives have passed the balise and the new classification is known. The classification will only be effective from this position onwards.

The classification of route sections is carried out as a function of the track radii of the respective route section.

Before the journey, the current train configuration is deposited in the control unit on the locomotives. The train configuration includes at least the following data:

- the position of the individual locomotives in the train set (distance from the guiding locomotive);
- the overall mass of the train set.

In addition, the following data may be deposited:

- the mass distribution over the train set
- the equipment status of the cars (2-axle cars, bogie cars, etc.).

The speed is evaluated in a manner subordinate to the track class. In the course of this, the data of the train configuration is taken into account.

It may be intended to apply the method according to the invention only to trains having a minimum length, so that for example in the case of trains having a length of up to 700 m, irrespective of their speed, no autonomous reaction takes place. In the case of trains over 700 m, both the train length and the speed are included for determining the admissible time, after which an autonomous reaction has to take place. At speeds of less than approximately 40 km/h, a braking operation may in principle be initiated autonomously immediately or with a delay (as a function of the classes of train sets).

Advantages of the invention

- The control of the communication between the locomotives included in the train set is influenced in such a way that the admissible longitudinal pressure forces are complied with at any time over the entire train set (i.e. also in the case of a radio/signal failure);
- the train set will optimally continue to be influenced as a function of the track geometry and of the routing, but also in line with the current speed, taking into account the train configuration also in the case of a radio/signal failure;
- a non-matched reaction of several locomotives within the train set in the case of a radio/signal failure can no longer occur;
- the division into route sections, classes and groups of trains as well as of time windows, which are dependent therefrom, of a necessary reaction as a function of the current location, which is to be carried out before the start of the journey, leads to a braking regime of all locomotives of the train set, which can be controlled in a coordinated manner and which is adapted to the respective route;

- the delayed reaction of the train set enhances the availability of trains with distributed traction because the period of time, within which an autonomous reaction has to take place, is extended, and as a result the possibility to re-establish communication after a radio interruption is enhanced.

Embodiment example

The invention will be explained in more detail below by means of an embodiment example.

In a train set with an overall length of 1000 m, locomotives are set up at the front end and at position 500 m. The train set consists of regularly loaded four-axle bogie cars of a similar design. The train set is controlled from the guiding locomotive via a radio based multiple traction controller. As long as the radio connection between the locomotives exists, all of the locomotives operate nearly synchronously. This relates not only to the traction commands but also to the commands for reducing the pressure in the main air duct for initiating braking operations. Since the brake commands reach the guiding locomotive via the existing radio connection almost without any delay, the pressure in the main air duct will be reduced in two places (position 0 m and position 500 m) almost synchronously, which results in a more uniform response of the brakes of all the cars in the train set. Thus, longitudinal pressure forces are significantly reduced.

In the case of a radio interruption, an almost synchronous control of the locomotives is no longer possible. In the case of a braking requirement from the guiding locomotive, if no further measures were taken, markedly higher longitudinal pressure forces than in conventional trains with a train length of up to 700 m would develop due to the greater train length and the longer run time of the pressure reduction associated therewith, and due to the greater differences in braking the cars which in turn result therefrom.

In the case of radio interruptions, the worst-case scenario has to be assumed that immediately after the start of the interruption of the radio connection, a brake command is issued from the guiding locomotive.

In order to ensure that in this case the tolerable longitudinal pressure forces are not exceeded either, the guiding and the guided locomotives initiate a braking operation in principle autonomously. Since the time of the start of the radio interruption is known both to the guiding and the guided locomotive, a braking operation may almost synchronously be initiated also in the case of a radio interruption.

Due to the concrete train configuration (homogeneous mass distribution, bogie car), the train set may however tolerate substantially greater longitudinal pressure forces without derailing in route sections with large track radii.

For example, all of the locomotives know the current route class via the database of the classification of the route sections and via the current position determined via GPS.

Based on the assumption of a radio interruption and of current class "K", a delayed reaction of the locomotives of e.g. 4 seconds will be admitted. Thus if the radio interruption lasts less than 4 seconds, i.e. if the radio connection is re-established within 4 seconds, there will be no autonomous reaction of the locomotives. Should the radio interruption last longer than 4 seconds, all of the locomotives will synchronously initiate a braking operation. In this case, the longitudinal pressure forces are comparable with those that occur in an existing radio connection.

In case a braking operation has been initiated by the guiding locomotive immediately after an interruption of the radio connection, the cars that are not yet braked at all or are braked only to a lesser extent will run onto the front part of the train and will thus increase the longitudinal pressure forces compared to a braking operation with an existing radio connection. These increased longitudinal pressure forces, however, may be tolerated by the concrete train set without an enhanced derailing risk, because it is on the one hand travelling along a route section with large track radii (here route class "K"), and on the other hand the car design and the loading condition as well as the mass distribution in the train set bear a substantially lower derailing risk than in the case of trains with e.g. 2-axle cars and a non-homogeneous mass distribution.

Patentkrav

1. Fremgangsmåde til at påvirke og begrænse langsgående dynamiske kræfter i et togsæt med lokomotiver fordelt i togsættet og konfigureret til at indføre fremdrifts- og bremsekræfter i togsættet, hvor lokomotiverne er forbundet med hinanden via en hovedluftledning i togsættet og via en kommunikations-forbindelse,

kendetegnet ved, at

et spor, hvor togsættet skal køre, på forhånd opdeles i sporafsnit, hvor hvert sporafsnit er tildelt en klasse, som specificerer togsættes adfærd i dette sporafsnit i tilfælde af en afbrydelse af kommunikationsforbindelsen,

hvor i en første klasse, en afbrydelse af kommunikationen udløser opbremsning af alle lokomotiver i togsættet inden for et defineret tidsvindue,

og hvor i mindst en anden klasse, hvor ingen autonom reaktion af lokomotiverne er påkrævet, er det tilstrækkeligt at overvåge hovedluftledningen for at identificere bremsekrav til afbrydelsen af trækkraften af det mindst ene lokomotiv, som trækker,

hvor denne klassificering af sporafsnittene lagres i en database og stilles til rådighed for styreindretningerne i alle lokomotiver i togsættet, og den aktuelle togkonfiguration bestående af mindst positionen af det individuelle lokomotiv i togsættet og den samlede masse af togsættet registreres i hver styreindretning, idet den aktuelle hastighed og den aktuelle position af hvert lokomotiv bestemmes, mens togsættet kører.

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** i den første klasse af sporafsnit udløser alle lokomotiver i togsættet en opbremsning inden for et tidsrum fra 0 til 3 sekunder efter afbrydelse af kommunikationen.

3. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** i den første klasse af sporafsnit udløser alle lokomotiver i togsættet en opbremsning inden for et tidsrum defineret afhængigt af togkonfigurationen, toghastigheden og bremsetider efter afbrydelse af kommunikationen, hvor dette tidsrum er 3 til 5 sekunder for en bremseposition "P" og 18 til 30 sekunder for en bremseposition "G".

4. Fremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** togsættets respektive hastighed bestemmes med hjulsætsfølere og/eller radarindretninger.

5. Fremgangsmåde ifølge et af kravene 1 til 4, **kendetegnet ved, at** den aktuelle position af togsættet bestemmes ud fra kombinationen af en GPS-modtager og – for at udfylde modtagelseshuller - et odometer.

6. Fremgangsmåde ifølge et af kravene 1 til 5, **kendetegnet ved, at** placeringsinformationen for hvert lokomotiv i databasen sammenlignes med den respektive klassificering af det tilsvarende sporafsnit, og den aktuelle klasse bestemmes.

7. Fremgangsmåde ifølge et af kravene 1 til 6, **kendetegnet ved, at** placeringsinformationen henviser til den respektive position for et lokomotiv, der trækker togsættet, ved at tage hensyn til afstanden fra lokomotivet, der trækkes, til det trækkende lokomotiv.

8. Fremgangsmåde ifølge et af kravene 1 til 7, **kendetegnet ved, at** klassificeringen af de respektive sporafsnit forude sendes til lokomotiverne via baliser.

9. Fremgangsmåde ifølge krav 8, **kendetegnet ved, at** afstanden mellem lokomotiverne, som er del af togsættet, kendt ud fra togkonfigurationen, anvendes til bestemmelse af sporpositionen fra tidspunktet, hvor alle lokomotiverne har passeret balisen, og hvor den nye klassificering er kendt.

10. Fremgangsmåde ifølge et af kravene 1 til 9, **kendetegnet ved, at** togsættets hastighed evalueres i forhold til sporklassen.

11. Fremgangsmåde ifølge et af kravene 1 til 10, **kendetegnet ved, at** ud over informationer, som skal registreres i lokomotivernes styreindretninger som en minimumsstandard (positionen af de individuelle lokomotiver i togsættet, den samlede masse af togsættet), registreres informationer om massefordeling over hele togsættet og udstyrsstatus for de individuelle vogne (især vogne med 2-aksler og/eller fire-aksler, bogievogne, etc.).