III INTERNATIONAL CONFERENCE
TRANSPORT SYSTEMS TELEMATICS TST`03

ZESZYTY NAUKOWE
POLITECHNIKI ŚLĄSKIEJ 2003
TRANSPORT z.51, nr kol. 1608

dynamic block - sections,
interval-based train control systems, GPS

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INTERVAL – BASED TRAIN CONTROL MODEL AND ITS RESEARCH

Proposed is a structure for interval-based train control which is promoted by application of GSM-R and navigation systems (like GPS, GLONASS, Galileo). Train control is modeled by applying MatLAB software, for traffic with dynamic block-sections when the tailing train is being controlled with data of the heading train.

BADANIA ITS I MODEL STEROWANIA RUCHEM POCIĄGU BAZUJĄCY NA ODSTĘPACH

Proponuje się opartą na odstępach strukturę sterowania pociągiem, która powstała w oparciu o zastosowanie GSM–R oraz systemów nawigacji (typu GPS, GLONASS, Galileo). Sterowanie pociągiem jest modelowane przy zastosowaniu oprogramowania MatLab, dla ruchu ze zmiennym odstępem blokowym, w którym kolejny pociąg jest sterowany danymi pociągu poprzedzającego.

1. INTRODUCTION

In the vicinal outlook all the automatic line block systems, based on fixed block-sections, will be changed with interval-based train control systems that implements cab's automatics set up (distance to the heading train automatic regulatory system), which should uninterruptedly receive information on the heading train trajectory (coordinates, speed) and completeness. This information can be obtained by applying radio communications- GSM–R. It is proposed to use services of navigation systems like GPS, GLONASS or Galileo for real-time train positioning (measurement of speed and coordinates).

Radio communication system, navigation systems have already been in operation (GSM-R, GPS, GLONASS) or must get in use in the nearest future (Galileo). All the mentioned systems are described in literature [1, 5, 6, 7, 9].

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In the article we propose a structure of interval-based train control system, which is based on the usage of GSM–R and navigation systems. Train control is being simulated with a software package MatLAB, for the traffic with dynamic block-sections, when tailing train is being controlled with a data of the heading train.

2. INTERVAL-BASED TRAIN CONTROL

In order to implement so called moving block-sections it is needed to have all the information in the trains about the real-time location and movement speed for each train. Such data can be obtained from navigation systems like GPS, GLONASS or Galileo. The latter is still being developed and should have start operation only on 2008 [3].

In order to refine precision of positioning it is purposeful to apply new differential technologies of satellite navigation (that is, in precisely defined locations reference receivers are being placed and due to availability of satellite orbital Keplerian Elements [4] it is possible to calculate precisely the distance between the reference receiver and the satellite. By using differences between measured and calculated distances it is possible to define and transmit to moving receiver the errors of signal reception [2]. Such reference receivers would be purposeful to place in stations.

For completeness of the rolling stock and for calculation of the trains coordinates, positioning receivers must be implemented in the front and end of the rolling stock.

Obtained information with their coordinates trains send by the help of GSM–R communications to the central control station where all the received information about running trains is being processed, and control signal is formed based on the obtained data and at the same time sent through the same GSM–R communications channel to the controlled train. Namely this signal shifts the traction of a rolling stock.

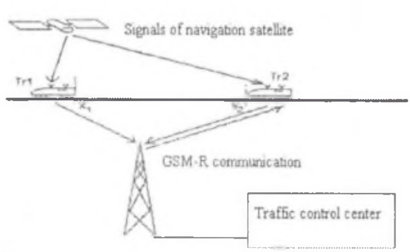

Fig.1. A structure of trains control: Tr1 – uncontrolled train; Tr2 – controlled train; x_1 – tail coordinates of the uncontrolled train, in meters; y_2 – controlled train head coordinates, in meters

An interval-based train control model was developed by using software package MatLAB (see Fig.2).

The controlled train Tr2 receives (see Fig.1) information from the traffic control center on the speed and real-time location of the first train Tr1. Tr2 also receives information both on its own speed and location in real-time. By knowing this data it is possible to calculate safe distance which must be kept between the trains. Train Tr2 is being controlled by a difference

ΔS between desired S_{pag} and real S_{real} distance between trains. The desired distance is defined depending on the speed of the controlled train.

$$\Delta S = S_{pag} - S_{real} \tag{1}$$

Where $S_{pag} = l_{st} + l_{ats} + l_0$. $l_{st} = \frac{v^2}{2a}$ - is breaking distance for the train Tr2, in meters, and v - is a speed of the train Tr2, in m/s; a – is breaking velocity for the train Tr2, in m/s^2; $l_{ats} = kv$ - is reserve, in meters; k – control system reaction time plus breaking delay duration; l_0 - is selected safe distance such that the trains should not come too close to each other in a case of emergency, in meters; S_{real} - is defined by the selected navigation system.

Depending on the positive or negative road difference ΔS is changed the traction of the controlled train.

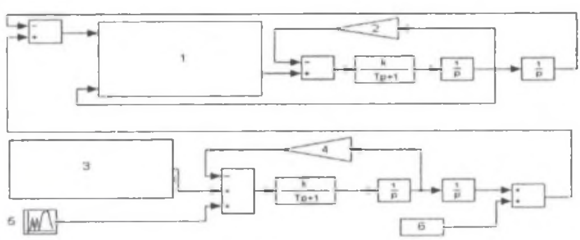

Fig.2. A model of two trains running one after other: 1 – a block for control of the controlled train traction; 3 – a block for control of uncontrolled train; 2 and 4 – appropriate resistance forces influencing the controlled and uncontrolled trains; 5 – interference influencing the uncontrolled train (like curves, bad road and so on); 6 – the initial difference of trains distance

The model contains two integrators. By integrating velocity, the obtained result is speed, speed's result is distance. Train breaks have their own peculiarity therefore it is denoted in the model by the transfer function of the trains breaking system:

$$W(p) = \frac{k}{Tp+1} \tag{2}$$

Where $k = \frac{1}{Q}$ (Q – a mass of the controlled rolling stock, in kg); T – trains time constant, in sec.

Characteristics of the process running in the block No.1 is shown in Fig.3. The train is being controlled the following way. For the first, parameters of the characteristics are defined:

Condition first: $S_{nz} > v_{max} 3T$; where S_{nz} – is insensitivity zone, in meters. By using this formula the efficient width of insensitivity zone is selected. This formula was obtained by applying features of a periodic chain (transitional process settle down during the time, equal for three time constants T).

Condition second was derived after demand for the controlled train to keep the distance between trains ΔS :

$$\Delta F = Q\frac{2\Delta S v_1^2}{(x_1 - y_2)^2} \tag{3}$$

Condition third does not permit to increase or to reduce the traction more that permitted:

$$\begin{cases} F_{max} > F_n + \Delta F \\ F_{min} > F_n - \Delta F \end{cases} \tag{4}$$

Where F_n - is a nominal traction, in N; ΔF - traction variation, N. [2]

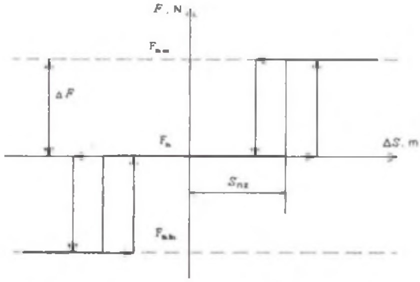

Fig.3. A characteristic for traction control process

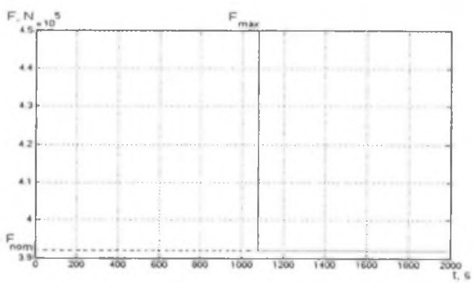

Fig.4. Traction of controlled train

Trains control process is started after having defined parameters of the characteristics. If the controlled train tails from the uncontrolled train in longer distance compared to the insensitivity zone S_{nz}, then the maximal traction is applied. The controlled train should run the F_{max} until the $\Delta S < S_{nz}$ (see Fig.4). When distance difference falls into the limits of insensitivity zone, the controlled rolling stock will be influenced with the nominal traction (see Fig.4). If the controlled train will come closer to the uncontrolled rolling stock within a difference bigger than S_{nz}, the same process will be repeated just with the minimal traction force.

The complete control process is unstable. Constant oscillation is possible. The switch-over period can be regulated by changing width of insensitivity zone and the maximal or minimal traction values. The less is a difference between F_{max} and F_n also between F_n and F_{min}, the frequency of oscillation will go down. [8]

A proper selection for the width of insensitivity zone and traction forces will minimize a number (frequency) to a desired minimum (see Figs.4-6). These characteristics have been obtained for the mass of controlled train Q=1000t, $F_n = 392kN$, $F_{max} = 509{,}6kN$, $F_{min} = 200kN$, force of resistance – $15000 Ns/m^2$, and presuming the uncontrolled train being 5000 meters ahead [8].

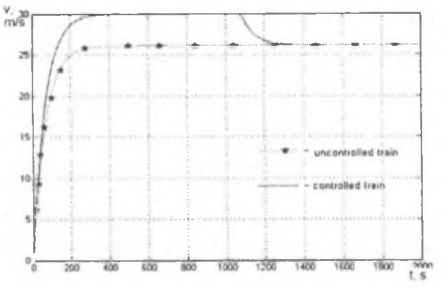

Fig.5. Characteristics of speed variation

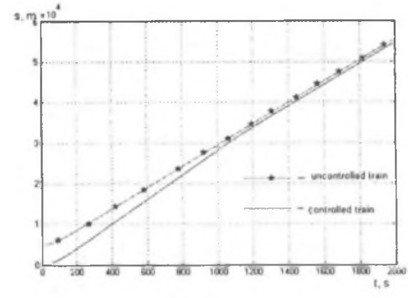

Fig.6. A comparison of controlled and uncontrolled trains resulted road distances

3. CONCLUSIONS

1. By using satellite positioning systems and communication system GSM–R it is possible to implement dynamic block-sections in railway tracks.
2. Dynamic block-sections permits several trains simultaneously running in a single track line with a minimal (that is – optimal in this case) distance, this results increase in throughput capacity.
3. Increase in throughput capacity is a must for most of railways administrations in competitive Euro-traffic market. Alternative well known ways for increasing the throughput capacity are inefficient compared to the proposed dynamic block-sections solution. The proposed solutions does not require huge investments in building the second opposite direction track.
4. Dynamic block-sections permits an efficient way to control completeness of a rolling stock by the help of front and end receiver sets.
5. Depending on the positive or negative road difference ΔS is changed the traction of the controlled train. The switchover period can also be adjusted by changing the width of insensitivity zone.
6. The efficient width of insensitivity zone is defined by phenomenon of transitional process settle down time, equal for three time constants T. Traction force is limited with an expression (4).
7. The traction force switchover process is a constant oscillation as a result of dense traffic, in proposed solution does not mean undesired quality of a process - vice versus, when desired safe distance between trains is down to the minimal, oscillation period is short and switchover happens even more often.
8. Dynamic block-sections solution alone will not answer all the questions of effective operation (for example, in undersea or mountain tunnels because of the well known drawbacks of satellite operation). Therefore there is plenty of room for combined satellite-ground signaling system solutions.

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