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Janusz DYDUCH[1]
Mariusz BUŁAWA[2]

AN APPLICATION OF THE STRATEGY „LEADING TO THE TARGET" TO MODULATION OF WAGONS SPEED IN MARSHALLING YARD

The paper presents the system of modulation of wagons speed in the process of shunting. The system is an implementation of the 'leading to the target' strategy, that is based on two fundamental elements: controlled point retarders located along the marshalling track and its control that reduces kinetic energy of running wagons in the way that the shunted wagon arrives with proper speed to wagons standing on sorting siding. The trials of the system are carried on in Poznan Franowo marshalling yard now.

REALIZACJA STRATEGII "PROWADZENIE DO CELU" W SYSTEMIE REGULACJI PRĘDKOŚCI WAGONÓW KOLEJOWYCH NA STACJACH ROZRZĄDOWYCH

W niniejszym artykule prezentowany jest system regulacji prędkości odprzęgów w trakcie rozrządzania. System ten stanowi wdrożenie strategii „Prowadzenie do celu", opartej na dwóch podstawowych elementach: sterowanych hamulcach torowych usytuowanych wzdłuż toru docelowego oraz ich sterowaniu zapewniającym zmniejszenie energii kinetycznej jadących odprzęgów tak, że rozrządzany odprzęg dochodzi z odpowiednią prędkością do wagonów stojących na torze docelowym. Badania tego systemu są realizowane obecnie na stacji rozrządowej Poznań Franowo.

1. INTRODUCTION

In the process of wagons shunting it is necessary to modulate the speed of running wagons in order to assure safe reaching a right place on the marshalling track. Generally, the retarder devices are controlled in the way that the wagon(s) reach the requested place on the about 500-700 m long track with the proper speed, typically below 1,5 m/s. Taking into consideration the variety wagons (number, type and technical condition of vehicles) with different rolling and aerodynamic resistance, and because of variability of weather condition,

[1] Institute of Transport, Warsaw University of Technology, Koszykowa 75, 00-662 Warsaw, jdy@it.pw.edu.pl
[2] TENS Ltd, Jana z Kolna 26C, 81-859 Sopot, M.Bulawa@tens.com.pl

control is made in strongly non-deterministic conditions. Additionally, a location of retarder devices directly limits possibilities to influence a wagons movement. Typically used solutions, based on 'fire to the target' method are sensitive on occurrence of disturbances and the supplementary remedies are needed, for example pushing-down devices.
Presented solution is an implementation of "leading to the target" strategy, based on reducing kinetic energy of wagon by turning on and off point retarders, located along whole way of running wagon.

2. THE KINETIC MODEL AND CONTROL TASK

A. THE KINETIC MODEL

On the marshalling track, equipped with point retarders and axle sensors (Fig.1) a wagon moves, that both mass and axle spread are known (Fig.2).

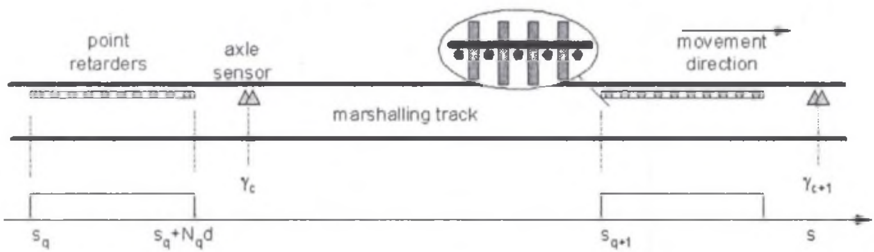

Fig.1. Location of point retarders and axle sensors along a marshalling track

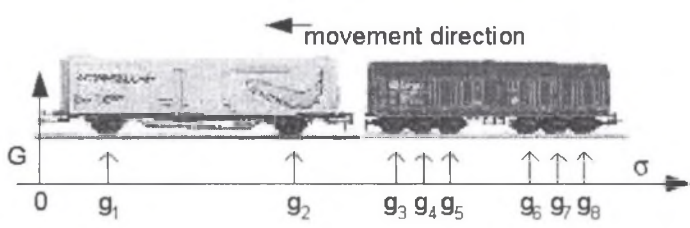

Fig.2. Axle spread of wagon(s)

The passage of a wheel of wagon above the axle sensor gives the actual speed v_i and position of wagon s_i. The identification model presented below [5] can be used in order to estimate on-line the kinetic parameters of running wagons.

$$\dot{\hat{s}}(t) = \hat{v}(t) \quad t_i \le t < t_{i+1} \tag{1}$$

$$\dot{\hat{v}}(t) = \hat{a}(t) \quad t_i \le t < t_{i+1} \tag{2}$$

$$\dot{\hat{s}}(t) = \hat{v}(t) \quad t_i \le t < t_{i+1} \tag{3}$$

$$\hat{s}(t_i) = s_i \tag{4}$$

$$\hat{v}(t_i) = v_i \tag{5}$$

$$\hat{a}(t) = \hat{a}_U(t) + \hat{a}_g(t) + \hat{a}_Z(t) \tag{6}$$

$$\hat{a}_U(t) = \frac{E_H}{m_b d}\sum_{q=1}^{Q}\sum_{k=1}^{K} u_q(t)\Pi(\hat{s}(t) - s_q - g_k, N_q d) \tag{7}$$

$$\hat{a}_g(t) = \frac{m}{m_b} g \frac{dh(\hat{s}(t))}{d\hat{s}(t)} \tag{8}$$

$$\Delta_i = t_i - t_{i-1} \tag{9}$$

$$\hat{a}_{Zi} = \hat{a}_{Z(i-1)} + \theta_v \frac{v_i - \hat{v}_i}{\Delta_i} + \theta_s \frac{s_i - \hat{s}_i}{\Delta_i^2} \quad t_i \le t < t_{i+1} \tag{10}$$

$$\hat{a}_{Z0} = \hat{a}0 \tag{11}$$

$$\hat{F}_Z(t) = m_b a_z(t) \tag{12}$$

where:

s^(t) – estimation of wagon's position at the moment t
v^(t) – estimation of wagon's speed at the moment t
a^(t) – estimation of wagon's acceleration at the moment t
a_Z^ – estimation of acceleration caused by disturbances
a_Z^0 –initial acceleration caused by disturbances
F_Z^ - estimation of disturbance force
θ_v, θ_s – weight coefficients

B. THE CONTROL TASK

The control should assure that wagon reach requested point with minimal speed and minimal risk of stopping before reaching proper place. In view of variety of wagons (number, type and technical condition of vehicles), with different rolling and aerodynamic resistance, and because of variability of weather condition, control is made in strongly disturbed conditions.

For the track section, when issue of control is under consideration, we can evaluate two boundary curves of loss energy for turn on and off retarder devices – so two boundary trajectories. The lower boundary trajectory reflects the energy lost during the free movement of wagon. The upper boundary trajectory reflects energy and location of retarder devices along marshalling track.

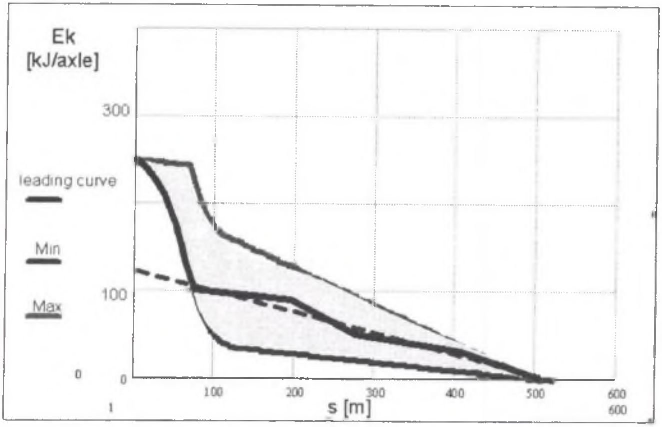

Fig.3. The permitted kinetic energy area and the leading curve

This boundary trajectories determine the area of allowed kinetic energy of wagon(s). There is the risk of not reaching the target point or an unsafe collision with standing on the track wagons if the wagon kinetic energy is out of the area.

One of the possible strategies of control is „leading to the target", in which a trajectory sufficiently distant from boundary trajectories is choosen to leave enough safety margin. In this approach, requirement of precise evaluation of all forces affected a wagon is not so strong. This makes the method resistant to any kind of disturbances of control process.
For implementation of control assuring the proper decrease in wagon's kinetic energy, a "leading curve", appropriate to requested trajectory, could be set . Without going into detail, if the kinetic energy is over the leading curve the retarder devices should be on position ON, otherwise they are OFF.

3. IMPLEMENTATION

The „leading to the target" concept is a basis of the SARPO system – a system of speed modulation of wagons in marshalling yard developed and tested now in Poland. The structure of the SARPO system is built around two basic units:

- Trackside devices: point retardes, axle sensors and wheel load sensors
- Distributed control system based on field controllers connected by CAN type extended network and the main controller working under QNX v.4.0 – real-time operating system.

The system performs its principal function – speed modulation of wagons by the implementation of three subsystems i.e:

1. Localisation of wagons subsystem
2. Estimation of wagons' speed subsystem
3. Retarder control subsystem

The determination of wagon's actual position and estimation of speed algorithms are based on the information coming from axle sensors placed on the track every 30 m. The passage of a wheel above the sensor gives the actual speed and position of wagon. That information is given only in discreet moments and a prediction algorithm to determine on-line speed and position is implemented [5].

Speed modulation of wagons relies on control of retarders in the way to assure safe reaching by the wagon the right place. The concept of "leading curve" is implemented [3]. The system tracks the kinetic energy of wagons and minimises the difference between the leading curve and actual kinetic parameters of object. The choice of the leading curve for the object takes into consideration permitted energetic area and the kinetic parameters of object running in front.

4. EXPERIMENTATION

The experimentation has been made in marshalling yard at Poznań Franowo station since September 2003. Some results are given below:

<u>Abbreviations</u>
Ek – kinetic energy of wagon,
Fw – leading curve,
Emax – upper bound of permitted area,
Emin – lower bound of permitted area,
Vo – initial speed of wagon(s),
Vd – speed of wagon(s) at target,
SH – location of point retarders,
Control – control retarders signal

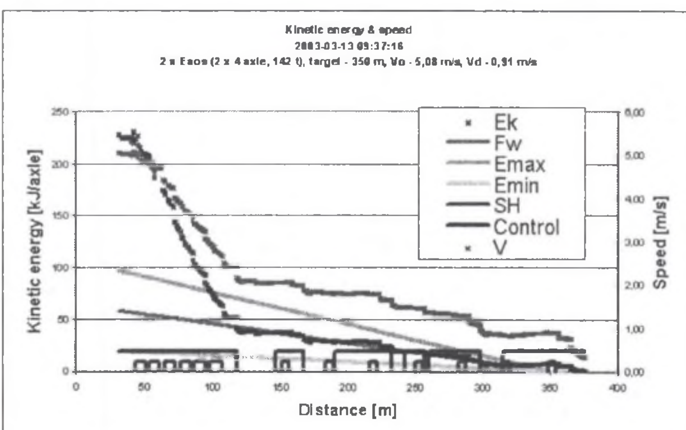

Fig.4. Speed modulation of a loaded wagon

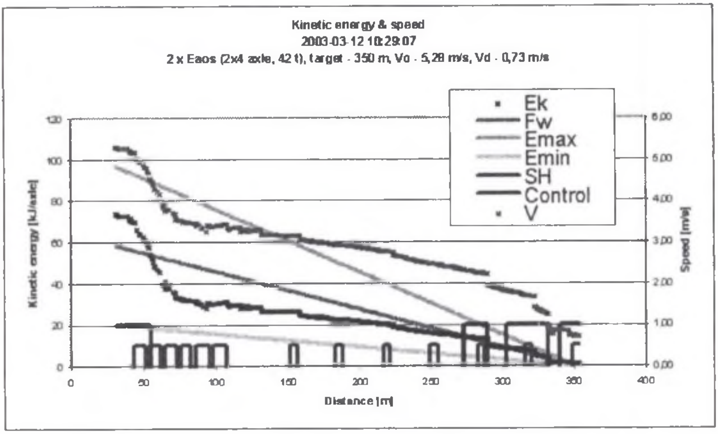

Fig.5. Speed modulation of an empty wagon

An analysis of estimation errors for the proposed concept of identification of kinetic parameters of running wagons [5] and the experimentation results are given in the paper [4].

5. CONCLUSION

The implemented „leading to target" concept is a very interesting solution to improve efficiency of a big marshalling yard as well as a small one. An application of field controllers and CAN type network reduces the wiring and makes the system more reliable. A concept of use of axle sensors to determine the kinetic parameters of running wagons seems to satisfy the needs of tracing the kinetic energy and location of running wagons. The trials that are carried on Poznan Franowo marshalling yard aim at confirming the viability of the system.

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Reviewer: Prof. Andrzej Lewiński