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*marshalling yard, modulation of wagons speed, leading to the target*

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# AN OPTIMIZATION OF THE „LEADING TO THE TARGET" METHOD

The paper presents an approach to the optimisation of the 'leading to the target' method, which is used by the system of modulation of wagons speed. This optimisation assures high level of safety and high capacity of marshalling yard by eliminating the phenomenon of catching up and collisions of wagons running on the marshalling track.

# OPTYMALIZACJA METODY „PROWADZENIA DO CELU"

Zaprezentowano koncepcję optymalizacji metody „prowadzenia do celu" wykorzystywanej w systemie regulacji prędkości odprzęgów na stacji rozrządowej. Proponowana optymalizacja zapewnia wysoki poziom bezpieczeństwa oraz wysoką przepustowość stacji rozrządowej dzięki eliminacji zjawiska doganiania się i zderzeń odprzęgów na torze docelowym.

## 1. INTRODUCTION

The system of modulation of wagons speed in the process of shunting, based on „leading to the target" method is examined [3, 4, 6]. Safe reaching by a wagon to the right place on the marshalling track is the object of the control. The control is performed in strongly non-determined conditions because of the variety of wagons (number, type and technical condition of vehicles) with different rolling and aerodynamic resistance, and because of variability of weather conditions. The possibility of interactions between running wagons, especially when one wagon catches up another one, what could lead to the dangerous situations, is another issue. The aim of the optimising concept and its implementation presented below is improving safety of shunting and capacity of marshalling yard.

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## 2. OPTIMIZATION PROBLEM

The object of optimisation is to determine the way of controlling of wagon's energy and retarder systems parameters (boundary kinetic trajectories), which ensure:

1) Reaching by wagon requested place $s_d$ with specified default energy $E_d$ and speed $v_d$
2) Eliminating phenomenon of catching up and crashing wagons running on the marshalling track

The both conditions are independent and could be examined separately.

### 2.1. CHOICE OF TRAJECTORY

The control should assure that wagon reaches requested place with minimal speed and minimal risk of stopping before reaching proper place. The area of permitted kinetic energy of wagon $O_i$ requested to reach point $s_d$, is limited by to boundary trajectories (Fig. 1).
The lower boundary trajectory reflects the energy lost during the free movement of wagon, the upper one reflects the capability of energy absorption by retarder devices located along marshalling track.

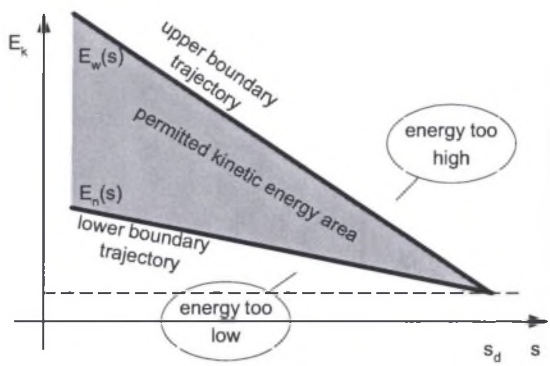


Fig.1. The permitted kinetic energy area

Size of permitted kinetic energy area for a wagon depends on:

1) Rolling resistance during the free movement of wagon (all retarder devices off) – the lower boundary trajectory $E_n(s)$
2) Quantity and location of retarder devices – the upper boundary trajectory $E_w(s)$

In the permitted area there are many trajectories, which assure the target reaching. Between allowed trajectories we could distinguish the three ones:

1) „Minimal speed" - equivalent of the boundary $E_n(s)$, for which the time period needed to reach the target place, is maximal.
2) „Maximum speed" - equivalent of the boundary $E_w(s)$, for which the time period needed to reach the target place, is minimal.

3) „Maximum safety - equivalent of the boundary $E_b(s)$, which is located exactly between the trajectories $E_n(s)$ and $E_w(s)$. In fact, because of non-deterministic conditions, the risk of not reaching the target point or an unsafe collision with standing on the track wagons is minimal for the trajectory $E_b(s)$, which assures the largest safety margin.

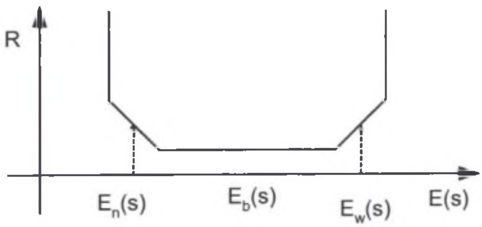


Fig.2. Risk of missing the target point in function of trajectory chosen

### 2.2. ELIMINATION OF WAGONS CATHING UP PHENOMENON

The phenomenon of wagons catching up on the marshalling track, consist in catching up by wagon $O_{i+1}$, moving with speed $v_{i+1}$, wagon Oi which moves with speed $v_i<v_{i+1}$. Typically empty wagon catches up and then hits loaded wagon. As a result empty wagon relays most of its energy to loaded wagon and then we observe unfavourable consequences like a premature stop of the empty wagon or a moving of the loaded wagon with excess of energy (dangerous situation). Elimination of this phenomenon helps to avoid dangerous accidents and also eliminates the need to stop shunting process due to necessity of pushing on.

In order to eliminate this phenomenon it is necessary to choose trajectory of wagons Oi+1 and Oi, which meet conditions (1):

$$t_{d\_k}(O_i) < t_{odsOi,Oi+1} + t_{d\_l}(O_{i+1}); \qquad (1)$$

where:

$t_{d\_m}(O_j)$ – the time period from entrance of marshalling track until reaching the target by wagon $O_j$, using the trajectory $E_m$ ,

$t_{odsOi,Oi+1}$ – the time gap between wagons $O_j$ and $O_{j+1}$ in the moment of entrance of marshalling track.

The fulfillment of the requirement (1) depends on the permitted kinetic energy areas for the wagons $O_i$ and $O_{i+1}$.

In boundary case, when the time period $t_{odsOi,Oi+1} = 0$, the kinetic energy areas should fulfill the requirement (2)

$$E_{n\ Oi+1}(s)/m_{Oi+1} <= E_{w\_Oi}(s)/m_{Oi} \qquad (2)$$

$E_{w\_Oi}(s)$ depends on a number of retarding devices that have influence on the price of the system. So we look for the minimum number of retarding devices meeting the requirement (2).

## 3. IMPLEMENTATION

The algorithms implemented in the SARPO system of speed modulation of wagons in marshalling yard ensure:

1) elimination of catching up wagons on marshalling track
2) selection of the safest possible trajectory

In the moment of entrance of wagon $O_i$ on the marshalling track the following parameters are determined:

1) the permitted kinetic energy area, taking into the consideration: the wagon's $O_i$ parameters, planned point of reaching $s_{d\ Oi}$ and the availability of retarding devices
2) the set of allowed trajectories $E_{k\_Oi}$, k=1..m, consisting of m-number of trajectories, which fulfill the requirements:
   i. $E_{1\_Oi} \equiv E_{w\ Oi}(s)$
   ii. $E_{m\_Oi} \equiv E_{n\ Oi}(s)$
   iii. The force (and acceleration) is constant
3) From the trajectories $E_{k\_Oi}$ one trajectory is selected, which fulfilles following conditions:
   i. Wagon $O_{i-1}$ is not catched up by wagon $O_i$
   ii. The trajectory is closest to the trajectory $E_{w\ Oi}(s)$

Since the control is performed in non-determined conditions, the on-line verification of correctness of chosen trajectory takes place,. The movements of wagons $O_{i-1}$ and $O_{i+1}$ are taken into consideration. The examination of wagon $O_{i-1}$ trajectory is performed in order to prevent catching up and collision. The examination of wagon $O_{i+1}$ movement is performed to verify the possibility of changing the wagon's $O_i$ trajectory to the safer one.
As the result wagon is moving in the safest possible way in order avoiding catching up phenomenon.

## 4. CONCLUSIONS

The presented concept of optimising the „leading to the target" method has been successfully implemented in SARPO system designed for speed modulation of wagons in marshalling yard. The system successfully passed the experimental trials, which proved the efficiency of implemented algorithms.

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