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USING FUZZY LOGIC IN ORDER TO DETERMINE CUTS' OUT SPEED FROM WAGON RETARDER - PRACTICAL EXPERIMENTS

The paper presents practical experiments of tuning a fuzzy logic system for determining cuts' out speed from wagon retarder (i.e. first braking position) when „shooting to target" at a marshalling yard. The present paper is a follow-up and a conclusion for previous researches focusing on searching for a method of determining out speed of a retarder, mainly for free runners. In the current paper the results of experiments for bad runners out speed are also presented. Described process of fuzzy logic system tuning can be used at any marshalling yard, also with single or double-position retardation.

WYKORZYSTANIE LOGIKI ROZMYTEJ DO WYZNACZANIA PRĘDKOŚCI WYJAZDOWEJ ODPRZĘGÓW Z HAMULCA TOROWEGO – DOŚWIADCZENIA PRAKTYCZNE

Artykuł przedstawia praktyczną realizację strojenia systemu fuzzy logic wyznaczającego prędkość wyjazdową odprzęgów z hamulca torowego (tzw. pierwszej pozycji hamowania) przy „strzale do celu" na grawitacyjnej górce rozrządowej. Niniejszy artykuł jest kontynuacją i uwieńczeniem uprzednich prac, które dotyczyły znalezienia metody wyznaczania prędkości wyjazdowej z hamulca, głównie dla odprzęgów lekkobieżnych, a obecnie przedstawiono również wyniki prac dotyczące wyznaczania prędkości wyjazdowej dla odprzęgów ciężkobieżnych. Zaprezentowany proces strojenia systemu fuzzy logic może być zastosowany na dowolnej górce rozrządowej, także z jedno- lub dwupozycyjnym hamowaniem.

1. INTRODUCTION

Presented results have been achieved on the basis of the research carried out at a marshalling yard in two stages: the I stage February-April 2003 focused on loaded cuts, while the II stage February-June 2004 focused on empty cuts. The results of researches from 2003

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have been presented during the last year TST conference and they are presented in [4]. As a result of these researches an algorithm has been made on how to identify a marshalling yard and a process was developed of adjusting the parameters of the system generating out speed from the first position retarder on the basis of identification results. The system generating out speed from the first position retarder contains fuzzy logic inference unit for each siding track and can be applied at any marshalling yard. In order to achieve this result, it was necessary to examine a behaviour of different types of cuts in a turnout zone and as well as in the sidings area. The following values have been measured:

- pushing speed of a train V_1
- IN-speed into the first position retarder V_2
- OUT-speed from the first position retarder V_3
- IN-speed into the second position retarder V_4

Moreover, the hypothesis of correlation between cut's kinetic energy before first position retarder and energy loses in a turnout zone after the first position retarder have been proven. It has also been determined which parameters, on the basis of collected measurement data, have loaded or empty cuts, as from the operator's point of view there are only these two categories of cuts.

The measurement system and the process of researches are presented in [4].

2. DATA ANALYSIS

During the whole measurement period data for over 640 cuts has been collected. These data was sorted by a cut type and by siding track. For each cut a characteristic energetic parameter PV has been calculated in a zone before the first position retarder:

$$PV = f(V_1, V_2) \tag{1}$$

where:
PV – energetic parameter;
V_1 – rolling down speed of cut determined by the identification device;
V_2 – IN-speed into the first position retarder;

Also loss of speed in turnout zone after first position retarder DV has been determined:

$$DV = f(V_3, V_4) \tag{2}$$

where:
DV – loss of speed in turnout zone after the first position retarder;
V_3 – OUT-speed from the first position retarder;
V_4 – IN-speed into the second position retarder;

The characteristics for groups of empty and loaded cuts have been determined. From the physical premises it can be concluded that bad running cuts lose more energy in the turnout zone, so they should also act this way in the zone before the first position retarder. The analysis of individual classes of cuts confirmed this assumption was true.

3. IDENTIFICATION PROCEDURE OF A MARSHALLING YARD AND ADJUSTMENT OF A SYSTEM GENERATING OUT SPEED FROM THE FIRST POSITION RETARDER

A procedure of identification of an object (marshalling yard) and adjustment of a system is a set of actions allowing to generate out speed from first position retarder for "shooting to target from the first braking position". It is important to underline, that identification of an object and adjustment of the system is more sophisticated for empty cuts than for loaded ones.

Steps of identification procedures and adjustment of a control system:

3.1. COLLECTING OPERATORS' KNOWLEDGE

Operators' knowledge (their experience) has been collected using questionnaires. They included values of out speed from the second position retarder given by individual operators for different cuts depending on a cut type, free length of destination railway tracks, direction and power of wind, atmospheric conditions (ambient temperature and rain).

Operators can set on a console out speed from the second position retarder of a range between 1.5 to 3.0 m/s with a pitch 0.5 m/s. This range is wide enough to assemble loaded cuts allowing speed regulation in the whole range of free length of a siding track up to 500 meters. Operators, using available buttons of 1.5, 2.0, 2.5, 3.0 m/s are able to safely shoot loaded cut not exciding allowed speed of 1.5 m/s and so they have much better experience with these cuts. In case of empty cuts an operator has to (using his own experience) set an out speed using "loose" button in order to achieve out speeds exciding 3.0 m/s. As an example, an empty cut by temperature above zero and windless conditions should be loose from the second position brake with a speed of 5.0 m/s in order to pass 500 m, that is to the end of a siding track. These data is estimated and does not reflect determined settings on the operator's panel, that is why it is preliminary information for setting empty cuts.

3.2. CORRECTION MEASURES

As it has been mentioned before, there are difficulties in accurate setting for the second retarder when controlling an empty cut – out speed can be precisely set on the console up to a maximum value of 3.0 m/s, which is usually too small for an empty cut going to the further part of a siding track. Therefore a correction measurements are made using a portable radar device, making experiments with empty cuts on the arbitrary chosen lengths 500m, 400m, 300m and for check purposes on 200m and 100m, measuring out speeds from the second retarder. Using a parabolic interpolation of speed for other lengths, collected data allows to precise a fuzzy model for empty cuts.

3.3. DIVIDING TURNOUT ZONE INTO FANS OF SIDINGS

It is arbitrary suggested to divide the turnout zone into 8 fans of sidings, four tracks each. Turnout zone has a configuration where external tracks have the longest arches, therefore in external fans of sidings rolling frictions are the highest. There are the highest corrective coefficients for an external fan and the lowest ones for an internal one. For measuring purposes are chosen these tracks from the fan (one of four), for which rolling frictions are the highest (number of arches, the smallest arch radius). It is a kind of grouping (joining) tracks of similar characteristics. The goal of this activity is to reduce the number of measurements to minimum.

3.4. MESUREMENTS OF TURNOUT ZONE

Measurements within turnout zone give in–parameters for this part of a model, which infers the behaviour of a cut in turnout zone. These measurements include: pushing speed of a cut, IN-speed of a cut into the first position retarder, OUT-speed from the first position retarder and cut IN-speed into the second position retarder. These parameters are set for tracks selected according to rules described in 3.3. The parameters are membership functions depending on increase of kinetic energy before the first position retarder (that is the number of membership functions, their shape and rules from knowledge database built during the tests).

3.5. DEFINING THE STRUCTURE OF A FUZZY MODEL

In order to create a control model a programming environment Matlab was used together with an additional tool (being a component of Matlab) - Fuzzy Toolbox. The model consists of two parts: the first one concerns siding tracks (operators' knowledge, measurements for siding tracks zone), while the second part concerns a turnout zone (measurements before and after the first position retarder), stored in accordingly fis1 and fis2 files. These files are stored in Matlab internal format with ".fis" extension, they include membership functions and rules of a fuzzy model. They are the basis for building an independent (from Matlab) fuzzy control application in the form of fuzzy.dll library.

3.6. IMPLEMENTATION OF AN ALGORITHM GENERATING OUT-SPEED FROM THE FIRST POSITION RETARDER IN THE FORM OF "FUZZY.DLL" LIBRARY

A figure nr 1 below (Fig.1.) presents the structure of a fuzzy system generating OUT-speed from the first position retarder V_{ho}. The V_{ho} speed is analytically determined on the basis of arguments received from the fuzzy model. V_{kier} is being generated in the part of the model described in fis1 file (operators' knowledge, siding tracks zone). Arguments g' (modified gravitational acceleration) and $d_{strefy\_rozjazdowej}$ (length of a turnout zone) are constant parameters. An argument w (run parameter) is also generated in fis1 file (this is not visibly marked on Fig.1.). An argumnet c (effect coefficient of cut kinetic energy before the first position retarder) is generated in the part of a model described in fis2 file.

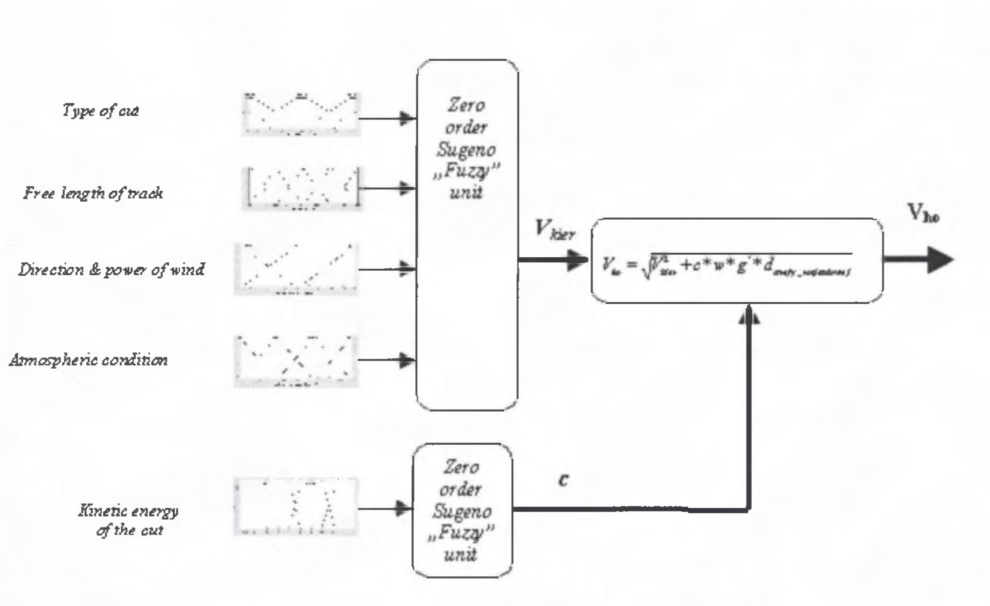

Fig.1. Structure of fuzzy system generating OUT-speed from the first position retarder

4. CONCLUSIONS

On the basis of researches carried out in a turnout zone after the the first position retarder and measurements of cuts' energetic parameters in the zone before the first position retarder it must be said that there is dependence between the cuts' behaviour in these two zones. This means that the cut on slipway before the fist position retarder having a low energetic parameter PV (bad runner cut) will have the same tendency after the first position retarder. The situation looks similar when a cut has a large energetic parameter PV (it is a free runner) in the zone before the first position retarder. It this case, it is also a free runner in the zone after the first position retarder.

Having analysed the measure data, three sub-classes were selected from the class of bad runner cuts and two sub-classes from the class of free runner cuts. The selected sub-classes have been used to build a fuzzy model of kinetic energy losses for a turnout zone. Results of this analysis show that it is possible to "shoot to target" from the first braking position basing on the IN-data such as:

- operators' knowledge determining OUT-speed from the first position retarder executing "shoot to target" from this brake;
- destination track;
- free tracks length;
- atmospheric conditions;
- energetic parameter PV;
- cut class;

"Shooting to target" from the first braking position is in this case limited to shooting to the second position retarder, so that the cut achieves speed coming from operators' knowledge and corrections done by fuzzy logic system.

In order to ensure correct operation of the system generating OUT-speed it is necessary to act accordingly to the following rules during the assemble time:

- reduce pushing speed of a cut;
- stop the assembling in a case when after the free runner cut coming into the almost full siding track there will be a bad runner cut coming into the almost empty siding track;

Important characteristics of empty and loaded cuts when it comes to susceptibility to control the OUT-speed of from the first position retarder are presented in Table 1.

Table 1

Characteristics of cuts

	Free runner cuts (loaded)	Bad runner cuts (empty)
Relative loss of energy in a turnout zone	low	high
Frequency of side hits	low	high
Loss of speed in a turnout zone	low – small dispersion	high – large dispersion
Susceptibility to control the OUT-speed	high	low
Level of risk resulting from setting the OUT-speed 0,5 m/s higher than required	very high	low

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