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O PEWNEJ MOŻLIWOŚCI PRAKTYCZNEGO ZASTOSOWANIA STATECZNOŚCI TECHNICZNEJ STOCHASTYCZNEJ

ON A CERTAIN POSSIBILITY OF PRACTICAL APPLICATION OF STOCHASTIC TECHNICAL STABILITY

Niniejszy artykuł prezentuje spojrzenie na definicję stateczności technicznej stochastycznej (STS) oraz jej użycie w symulacji zarówno modeli matematycznych wagonów kolejowych, jak i samochodów. Zaprezentowano użycie STS w badaniu modelu matematycznego wagonu kolejowego w aspekcie jego stateczności poprzecznej. Przedstawiono również możliwości wykorzystania stateczności technicznej stochastycznej w badaniu modelu matematycznego samochodu.

Słowa kluczowe: *stateczność techniczna stochastyczna, stateczność poprzeczna, model matematyczny, samochód, wagon kolejowy.*

This article gives an overview on the definition of stochastic technical stability (STS) and its use in simulation of railway car as well as motor car mathematical models. It presents how the STS was used to examine the mathematical model of railway car in aspects of its lateral stability. It also presents possibilities of using the STS to examine mathematical model of motor car.

Keywords: *stochastic technical stability, lateral stability, mathematical model, motor car, railway car.*

1. Introduction

The purpose of this paper is to give an overview on the possibilities of using stochastic technical stability (STS) in analyses concerning the behaviour of mathematical models in different conditions.

2. Definition of stochastic technical stability - assumptions

We have the following set of stochastic equations $x(t) = f[x,t,\xi(t)]$ *. For the stochastic process $f(0,t,\xi(t))$ and $t \geq 0$ there is $P\{\int_0^T |f(0,t,\xi(t))| dt < \infty\} = 1, \ \forall T > 0$. There is also a stochastic process $f(X,t,\xi(t))$ hat fulfills the Lipschitz condition for another process $\eta(t)$.

As a result there is only one solution [$t=t_0$, $x(t_0)=x_0$], which is a stochastic process.

2.1. Definition of stochastic technical stability

There are two areas in En: ω – finite and open, Ω – finite and closed, where $\omega \subset \Omega$. It has been assumed that there is also a positive number ε, where $0<\varepsilon<1$. The definition of STS is: if every solution of *, having the initial conditions within ω, lies within Ω with the probability of 1-ε, then the structure is technically stochastically stable in relation to ω, Ω and $\xi(t)$ with the probability of 1- ε (Fig. 2.1).

$$P\{(t,t_0,\bar{x}_0)\in\Omega\} > 1-\varepsilon \quad for \quad \bar{x}_0 \in \omega \qquad (1)$$

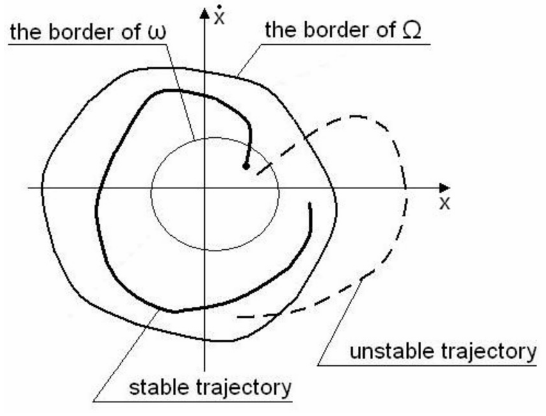

Fig. 2.1. Graphic illustration of stochastic technical stability [3]

The probability of appearance of a wheel set in motion along a straight track was examined. As an occurrence the appearance of three- or four-point contact was considered, for which the instability of the set was assumed. The event of three-point contact between the wheels and the track was examined. Such contact occurs when a set of wheels moves along the Oy_i axis. A four-point contact appears when the wheel set turns around the Oz_i vertical axis. Such a case was analysed in [2] the use of Markov processes.

3. Aspects of stochastic technical stability in the mathematical model of a railway car

STS was used to examine the mathematical model of a railway car (lateral stability). It was presented by E. Kardas-Cinal, PhD, while the basic assumptions were taken from Bogusz definition. The areas of *Ω* adopted for these analyses are presented in Fig. 3.1 and 3.2.

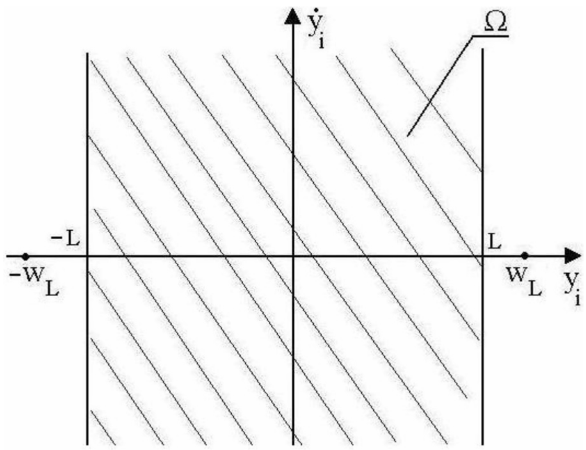

Fig. 3.1. Illustration of Ω for the lateral translation of a railway car [3] $\Omega = \{x : |y_i| \le L\}$

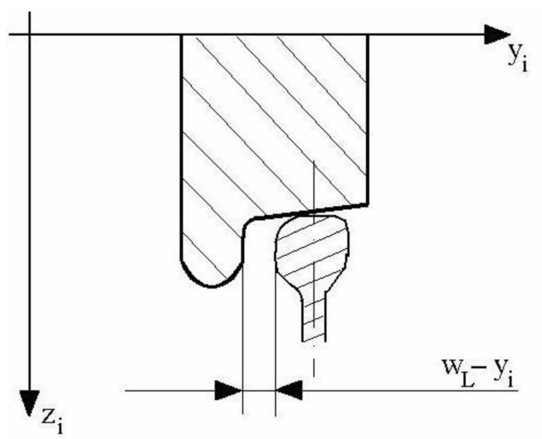

Fig. 3.2. Technical conditions defining the maximum distance L of the set Ω [3]. w_L *– the space between the wheel and the rail head*

4. Aspects of stochastic technical stability in the mathematical model of a motor car

The mathematical model of a car can be analysed using the concept of technical stochastic stability, where the area of the admissible solutions *Ω* is determined by the width of the road (Fig. 4.1). The car model will have a disturbed geometry of the car body resulting from a collision and then repair. We shall investigate stability for nominal and disturbed geometric and mass parameters of the car body.

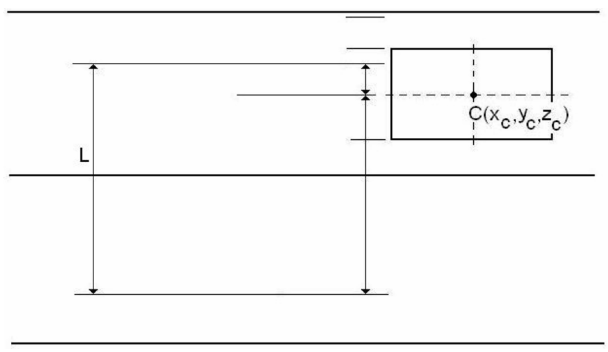

Fig. 4.1. The maximum (admissible) width L of the set Ω between the mass centre of the car model and the roadside: Source: authors'own research

For such assumptions the examination of technical stochastic stability can be conducted for the mathematical model of a car whose motion is disturbed by the irregularity of the road. A method similar to that used in [3] can be employed to determine the probability at which the car motion trajectory will remain in the presupposed area (the width of the road). Some relationships will be obtained between the disturbances of the car body geometry and mass and the stochastic technical stability examined in the process of simulating car mathematical models.

Disturbances resulting from the road appear in the form of irregularities which, according to the assumptions, are the stochastic process. The road is the area of definitivity here, whereas in stochastic signals it is time. The third domain is the wavelength of the road irregularity and, respectively, of the frequency. Thus the disturbances of the road for *v*=const can be easily transformed into a signal, which is the kinematic constraint of the car mathematical model (the transformation of the stochastic process into a stochastic signal). The same wavelength extorts a different frequency for a different car speed.

The change in the geometry and mass disturbances and their influence on the stability of a car motion will be examined. An analysis will be carried out of the probability with which the trajectory of this motion will remain within the area of admissible solutions *Ω* (specified width within which the car can move within the road width). In the research we shall assume that the same interactions apply to the steering wheel.

For a real object, car stability is defined by the ISO 8855:1991 standard and it is as follows:

- Non-periodic stability – stability characteristic at a prescribed steady-state equilibrium if, following any small temporary disturbance or control input the vehicle will return to the steady-state equilibrium without oscillation.
- Neutral stability – stability characteristics at a prescribed steady state equilibrium if, for any small temporary disturbance or control input, the resulting motion of the vehicle remains close to, but does not return to the motion defined by the steady-state equilibrium.
- Oscillatory stability – oscillatory vehicle response of decreasing amplitude and a return to the original steady-state equilibrium.
- Non-periodic instability – an ever-increasing response without oscillation.
- Oscillatory instability – an oscillatory response of ever-increasing amplitude about the initial steady-state equilibrium.

As can be seen from the above definitions, we can directly relate the stochastic technical stability of the car mathematical model to the stability defined by the ISO 8855:1991 standard. So, the research being conducted will not be wholly commensurate with the above definitions of the ISO 8855:1991 as it will be an attempt to find the probability with which the trajectory of a car mathematical model in motion, under the accepted assumptions, will remain in the presupposed area of admissible solutions.

However, the answer concerning the lack of stability for model analyses is different from the one defined by the ISO 8855:1991 standard, as it does not provide for a random approach to the phenomena, although the results can be used for various types of analyses. It seems, indeed, that both 'stabilities' have similar criteria when considering the mathematical model and the real object as a mechanical system.

5. Conclusions

The examination of stochastic technical stability of a car mathematical model will allow us to assess of car stability after crash and repair in the aspect of passenger car stability. Research will be conducted with the use of the simulation results. The results will be presented in further publications. They can also be used to control the technical condition of a car.

6. References

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