PERIODICA POLYTECHNICA SER. TRANSP. ENG. VOL. 21, NO. 3, PP. 239–245 (1993)

EXPERIMENTAL RESEARCH OF CAR STEERABILITY BY MEANS OF RANDOM STEERING INPUT

Wiesław PIENIĄŻEK

Cracow University of Technology
PL 31–155, Poland

Received: Nov. 10, 1992

Abstract

The paper deals with the results of experimental research of transient pseudo open-loop response with steering random input.

Several basic characteristics are presented. In the second part of this paper, the system gain yaw rate response to steering wheel input from experiment was compared with the result obtained by calculations of theoretical one for the two degres of freedom simple flat model with dynamical parameters calculated on the basis of data from other experimental tests, i.e. steady-state circular test.

Keywords: steering, transient response, random input.

1. Introduction

The road-holding ability of cars is a most important part of active vehicle safety. Any given vehicle together with its driver and prevailing environment forms a unique closed-loop system. The task of evaluating road-holding ability is therefore very difficult because of the significant interaction of these driver-vehicle-road elements each of which is complex in itself.

A complete and accurate description of the behaviour of road vehicles must necessarily involve information obtained from a number of tests of different types.

Primary object of those tests is to determine the transient response behaviour of the vehicle characteristic value and functions in the time domain and frequency domain considered necessary to characterize the transient response of the vehicle.

Important criteria in the time domain are the following:

- time lags between steering-wheel angle lateral acceleration and yaw velocity,
- response time of yaw velocity and lateral acceleration,
- yaw velocity gain,
- lateral acceleration gain,

- overshoot values,
- TB factor.

In the frequency domain we can evaluate:
- the variation in frequency of the gain with respect to steering-wheel input of the lateral acceleration and yaw rate responses,
- the variation in frequency of the phase angle with respect to steering-wheel input of the lateral acceleration and yaw rate responses.

The criteria in the frequency domain are determined during straight line tests at a constant speed and by using steering-wheel amplitude which generates a lateral acceleration within the linear range of operation of the vehicle.

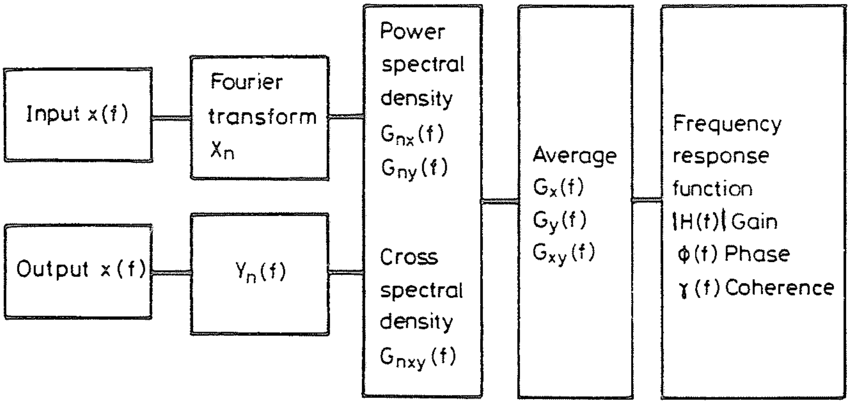

Fig. 1. Data processing flowchart

The results of data processing and analysis are shown in *Figs. 2* and *3*.

2. Experimental Tests and Results

The experimental tests were carried out with the methodology described in international standard ISO 7401 [1], and technical report ISO/TR 8726 [2].

The small car with front drive and load axle-distribution 577/557 kg was tested.

The data processing was conducted according to the above mentioned technical report. This process is summarised in the flowchart in *Fig. 1*.

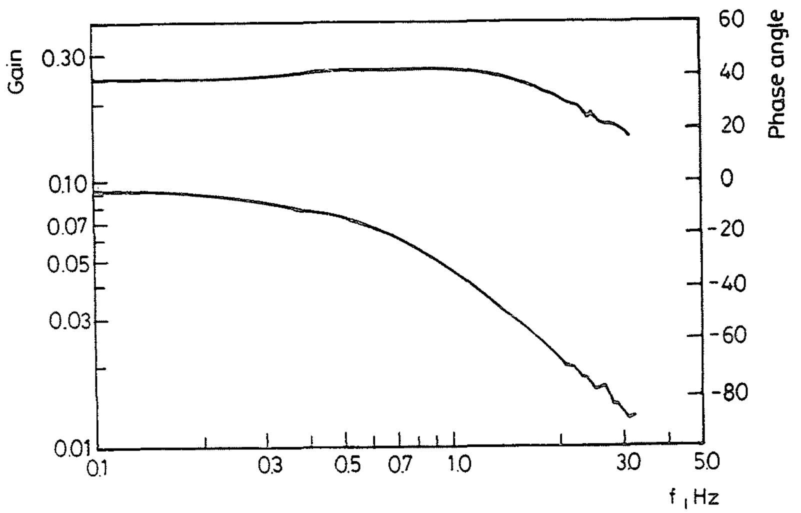

Fig. 2. Experimental gain function

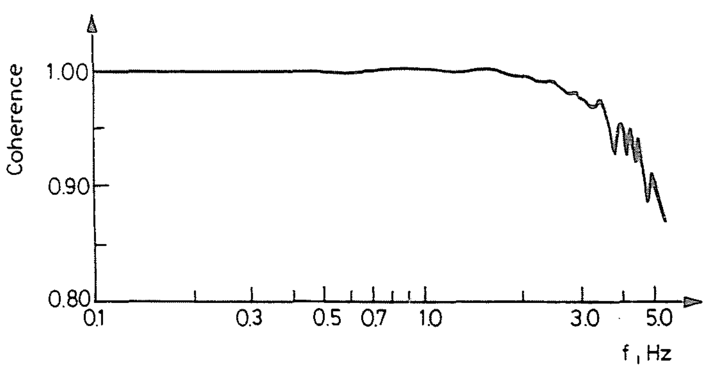

Fig. 3. Experimental coherence function

3. Comparison to Typical Responses Presented in [2]

In *Fig. 4*, we have our gain of transient yaw response in comparison to typical responses for various kinds of cars.

We can see the curve representing the tested car runs little above.

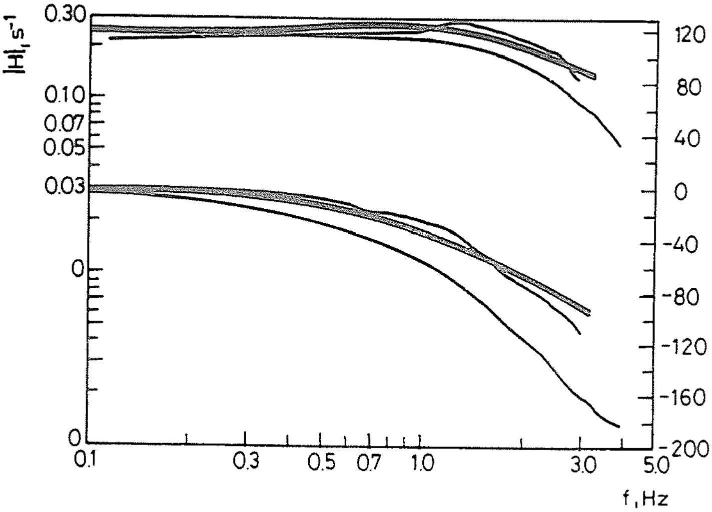

Fig. 4. Comparison of gain functions

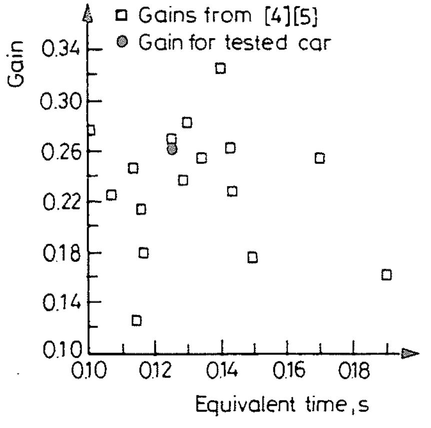

Fig. 5. Comparison of special gain values

Generally, the yaw rate gain is usually flat at lower frequencies up to 'corner' frequency, above which the yaw rate response falls. More pronounced development of a peak is associated with increased understeer.

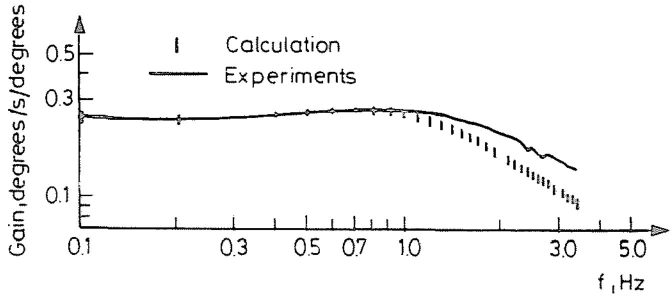

Fig. 6. Comparison of experimental and calculated gain functions

Another factor very convenient for comparison was estimated according to [5]. This is the so-called equivalent time T_{eq}. For the calculation of it, we take a value of the frequency at the point where the phase angle is equal to 45 degrees. For this point, we read off a value of gain and put it into the diagram in *Fig. 5.*

As we can see, the point representing the tested car is placed in the optimum region, among the points for cars which were tested in other research centres.

4. Comparison to Theoretical Linear Flat Model of Car [3]

Since coherence function is high, i.e. is near unity for practical region of input frequency, the linear model with two degrees of freedom [3] was taken into consideration.

The well-known set of differential equations for the mathematical description of this model is the following:

$$mv\dot{\beta} + (c_{\alpha_1} + c_{\alpha_2})\beta + \left[mv^2 - (c_{\alpha_2} l_2 - c_{\alpha_1} l_2)\right]\frac{\Psi}{v} = c_{\alpha_1}\delta_H ,$$

$$I_z\Psi + \left(c_{\alpha_1} l_1^2 + c_{\alpha_2} l_2^2\right)\frac{\Psi}{v} + (c_{\alpha_2} l_2 - c_{\alpha_1} l_1)\beta = c_{\alpha_1} l_1 \delta_H ,$$

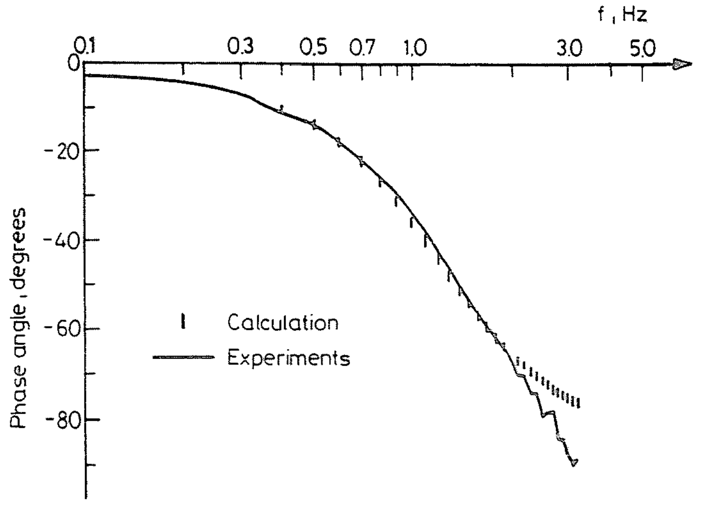

Fig. 7. Comparison of experimental and calculated values

where: m – mass of the car,
v – velocity (80 km/h),
I_z – moment of inertia about z-axis,
l_1 – distance of the front axle from the mass centre,
l_2 – distance of the rear axle from the mass centre,
$c_{\alpha 1,2}$ – equivalent cornering stiffnesses of the axles.

For this model, runs of theoretical gain and phase angle have been calculated. The natural frequency, damping ratio and steerability factor were calculated on the basis of data from steady-state circular experimental test.

These runs are presented in *Figs. 6* and *7* in comparison to analogical curves obtained from experiments (see also *Fig. 2*).

5. Concluding Remarks

The results obtained from experimental tests are generally conformable to the analogical results in other research and science centres.

A comparison of experimental and theoretical results indicates that the flat model with two degrees of freedom seems to be simple (especially for a region of higher frequency, i.e. 1.5 Hz).

In the future, we need to perform experiments on roll angle measurements and consider more complicated models, i.e. with roll. (see, e.g. [6]).

References

1. ISO 7401 (1988) Road Vehicles — Lateral Transient Response Test Methods.
2. ISO Technical Report 8726 (1988) Road Vehicles — Transient Open-Loop Response Test Method with Pseudo Random Steering Input.
3. MITSCHKE, M.: Dynamik der Kraftfahrzeuge, Band C: Fahrverhalten, Springer-Verlag, 1990.
4. ROMPE, K. – HEISSING, B.: Objektive Testverfahren für die Fahreigenschaften von Kraftfahrzeugen, Verlag TUV Rheiland GmbH, Köln, 1984.
5. WEIR, D. H. – ZELLNER, J. W.: The Application of Handling Requirements to an RSV Type Vehicle. *International Automotive Engineering Congress and Exposition*, Detroit, 1977.
6. ELLIS, J. R.: Vehicle Dynamics, Business Books, London, 1969.