EXPERIMENTAL STUDIES ON THE DYNAMIC BEHAVIOUR OF AGRICULTURAL SEMITRAILERS WITH A SUSPENSION SYSTEM AT THE HITCH

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Abstract. *In order reduce the shortcoming determined by the vibrations and shocks transmitted by semitrailer to tractor it aims at improving the suspension system at tractor seat and trailer's axles level and in the same time particular constructive solutions for semitrailers with elastic suspension system at the hitch. The great variety of constructive solutions used for semitrailers with a suspension system at the hitch has motivated the interest in theoretical and experimental research of effects (favourable or not) of these solutions. The paper presents the results obtained further to experimental researches regarding the dynamic behaviour of tractor + semi-trailer system, where the semi-trailer is endowed with a suspension system (leaf spring) at hitch level, in three constructive variants.*
Key words: *tractor, agricultural semitrailer, hitches suspension, dynamic behaviour, vibration*

INTRODUCTION

Unlike the transport activities effected in other economic fields, the agricultural transport displays several particularities determined mainly by the character of the agricultural production and by the special conditions in which the agricultural works are effected.

The current tendency for the transport of agricultural products consists in resorting to the system made of *farm tractor* and *semitrailer,* during the last years there having taken place the spectacular diversification of the semi-trailers from the constructive point of view and the increase of the transport capacity (up to 24 ton). The moving along of the aggregate mainly occurs upon rugged roads and uneven terrain, when spatial undulating movements of the system appear, which exert their influence both upon operator (driver) and upon the integrity of the transported materials, the durability of certain elements and subassemblies, the stability and the functional parameters.

A characteristic of the tractor-semitrailer transport systems is that by means of the trailerhitch a significant part of the semitrailer load is transferred upon the tractor body, this way determining the increase of the adherent load of the tractor and, implicitly, the increasing of the tractor traction force. Due to this connection there are transmitted upon the tractor, dynamic loads and vibrations which proceed especially from the vertical component parts of the interaction forces between the trailer wheels and the road. This process stands for a negative effect, which must be diminished or even removed.

The axles of the agricultural semi-trailers are provided with classical suspension represented by leaf type springs longitudinally disposed, set between the underframe and the axle. In guise of new element in the construction of the agricultural semi-trailers of high capacity, there has been noted the introduction of elastic suspensions in the semitrailer hitch, realized as leaf type springs. Such solutions have been practiced by several companies of worldwide recognition: PONTHIEUX, ORENGE, DUCHÈSNE, BRIMONT, DEVES, LEGRAND, (France), TEBBE (Germany), and others. It is characteristic for all these suspensions upon the hitch the fact that the elastic element, even though it is built under different shapes and set under different positions, represented by the leaf type spring.

According to the placing upon the hitch as for the gripping device of the semi-trailer, the suspension may be transversally set under the frame of the gripping device (fig. 1) or longitudinally upon the hitch, behind the gripping device (fig. 2) or in front of the gripping device (fig. 3)

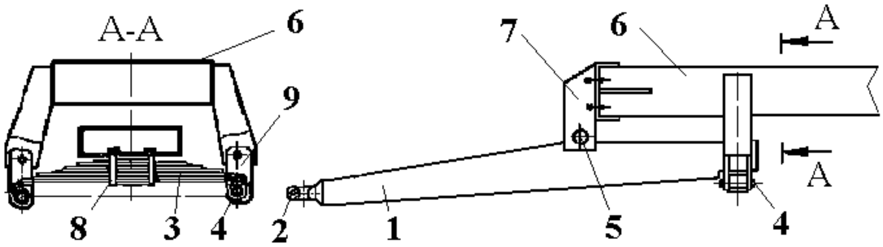

Figure 1. Hitch with the suspension transversally set (PST): 1 - hitch; 2 - tow-rope hoop; 3 - leaf type spring; 4 - elements for fixing the chassis spring; 5 - spring bolt; 6 - chassis; 7 - hitch support; 8 - elements for fixing the spring; 9 - support

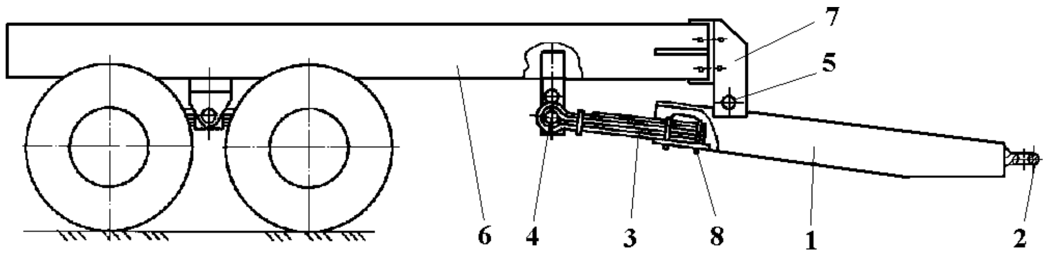

Figure 2. Hitch with the suspension longitudinally set under the gripping device (PSLA): 1 - hitch; 2 - tow-rope hoop; 3 - leaf type spring; 4 - elements for fixing the chassis spring; 5 - spring bolt; 6 - chassis; 7 - hitch support; 8 - elements for fixing the spring to the hitch; 9 - spring support

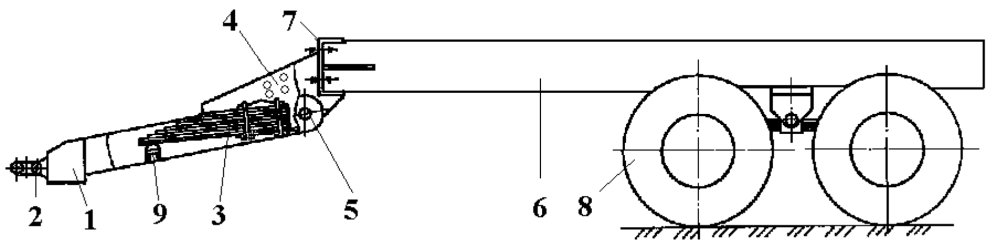

Figure 3. Hitch with the suspension longitudinally set in front of the gripping device (PSLR): 1 - welded hitch; 2 - tow-rope hoop; 3 - leaf type spring;4 - body for connection and adjustment; 5 - spring bolt; 6 - chassis; 7 - hitch support; 8 - wheels; 9 - bearing cross rail of the spring

EXPERIMENTAL RESEARCH

In order to study the influence of the hitch suspension upon the dynamic behavior under the real moving along conditions of the transport system tractor – semi-trailer, there have been carried out research resorting to a device including measure transducers placed upon the system according to the scheme offered in figure 4.

The research have been carried out in a comparative manner, making use of semi-trailers variants equipped with 4 constructive types of hitches: three variants with hitches equipped with elastic suspension (in the variants presented in figures 1, 2, 3) as well as a variant with rigid hitch (of a regular construction).

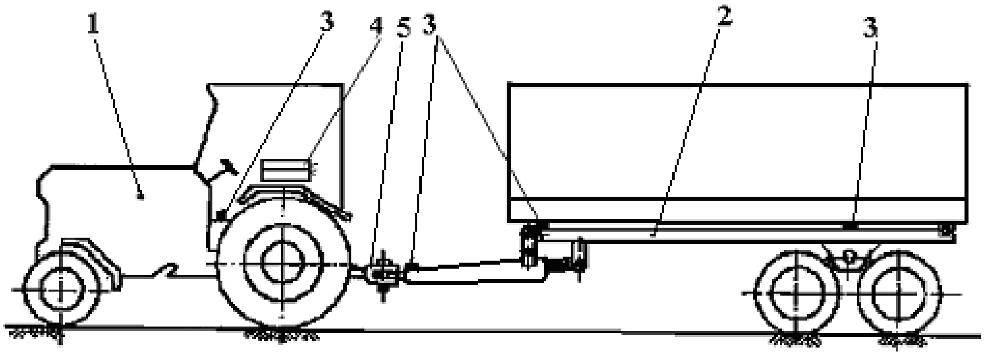

Figure4. Scheme of the system and placing of the technical device necessary for recording the terrain signals: 1 – wheeled tractors U 650 M (power of 65 CP); 2 – semi-trailer (total mass 9300 kg); 3 – acceleration transducers; 4 – acquisition and signal processing device; 5 –transducer for measuring the traction force.

The testing of every type of aggregate tractor-semi-trailer has been carried out under similar conditions, upon two types of road (concrete and arth road road) with values of the irregularities height h_0 and of the irregularities length (step) *L* within the limits offered in Table 1.

Table 1. Characteristics of the irregularities of the experimental roads

Road type	h_0	L
	[mm]	[m]
Concrete road	10…20	3…5
Earth road	20…30	0,15…0,3

Table 2. Performances of the aggregate tractor + semi-trailer in the PSLR variant

Road type	Speed [km/h]	Parameters							
		$\ddot{z}_{t\,max}$ mm/s^2	$RMS_{\ddot{z}t}$ mm/s^2	$\ddot{z}_{p\,max}$ mm/s^2	RMS_{zp} mm/s	$\ddot{z}_{rf\,max}$ [mm/s^2]	$RMS_{\ddot{z}rf}$ mm/s^2	$\ddot{z}_{rs\,max}$ mm/s^2	$RMS_{\ddot{z}rs}$ mm/s^2
Concrete road	11,9	5,18	1,632	5,3	1,47	4,49	1,248	0,56	0,184
	11,8 *	6,16	2,269	5,12	2,206	5,37	1,719	0,7	0,218
	26,3	8,2	2,815	7,8	2,27	8,54	2,393	0,73	0,264
	16,9*	5,68	2,25	6,8	2,441	5,75	1,996	0,69	0,243
Earth road	10,5	5,71	2,204	7,46	2,391	5,18	1,826	1,33	0,62
	8,4	4,9	2,022	7,04	2,423	4,2	1,7	0,96	0,403
	6,9	4,79	1,99	5,7	2,123	4	1,49	0,96	0,29

*braking

In the framework of the experimental research there have been effected 28 experiments during which there have been realized recordings with the sampling frequency of 500 Hz. The results of the signal processing obtained within the effected tests are centrally presented in the tables 2 … 5, the significance of the notations being as follows:

$\dot{Z}_{tmax}$, RMS_{zt} - maximal amplitude of the vertical acceleration, measured at the tractor floor and, respectively, the average square root of these accelerations;

$\dot{Z}_{pmax}$, RMS_{zp} – maximal amplitude of the vertical acceleration, measured on the hitch and, respectively, the average square root of these accelerations;

$\dot{Z}_{rfmax}$, RMS_{zrf} – maximal amplitude of the vertical acceleration, measured at the front transverse cross bar and, respectively the average square root of these accelerations;

$\dot{Z}_{rsmax}$, RMS_{zrs} – maximal amplitude of the vertical acceleration, measured at the back transverse cross bar and, respectively, the average square root of these accelerations;

Table 3. Performances of the aggregate tractor + semi-trailer in the PR variant

Road type	Speed [km/h]	Parameters							
		$\ddot{z}_{t\,\max}$ mm/s^2	RMS_{zt} mm/s^2	$\ddot{z}_{p\,\max}$ mm/s^2	RMS_{zp} mm/s	$\ddot{z}_{rf\,\max}$ mm/s^2	RMS_{zrf} mm/s^2	$\ddot{z}_{rs\,\max}$ mm/s^2	RMS_{zrs} mm/s^2
Concrete road	11,8	6,16	2,176	4,12	0,996	6,73	1,218	0,93	0,294
	11,8*	5,08	2,056	3,62	0,895	30,75	1,123	1,03	0,364
	23,0	7,52	2,386	6,22	1,524	5,78	2,136	0,91	0,348
	16,9*	5,44	2,045	3,96	1,141	4,6	1,365	1,02	0,327
Earth road	10,9	6,59	2,037	4,54	0,919	4,57	1,273	1,03	0,397
	8,5	4,76	1,997	4,7	0,72	4,05	0,876	0,79	0,326
	7,0	4,31	1,920	2,88	0,688	2,31	0,761	0,75	0,307

* braking

Table 4. Performances of the aggregate tractor + semi-trailer in the PSLA variant

Road type	Speed [km/h]	Parameters							
		$\ddot{z}_{t\,\max}$ mm/s^2	RMS_{zt} mm/s^2	$\ddot{z}_{p\,\max}$ mm/s^2	RMS_{zp} mm/s	$\ddot{z}_{rf\,\max}$ [mm/s^2]	RMS_{zrf} mm/s^2	$\ddot{z}_{rs\,\max}$ mm/s^2	RMS_{zrs} mm/s^2
Concrete road	12,1	6,41	2,187	7,96	2,948	4,89	1,013	0,52	0,34
	11,7*	4,91	2,087	7,72	3,42	2,79	0,894	0,67	0,228
	23,3	7,77	2,263	12,98	4,515	5,24	1,456	0,72	0,24
	17,3*	5,45	2,215	11,06	3,8	3,98	1,365	0,54	0,272
Earth road	11,3	4,42	1,912	7,96	3,27	2,99	0,937	0,7	0,223
	8,7	4,88	1,933	9,46	3,469	2,22	0,746	0,64	0,356
	7,9*	4,15	1,918	8,72	3,69	2,03	0,657	0,93	0,204

* braking

Table 5. Performances of the aggregate tractor + semi-trailer in the PST variant

Road type	Speed [km/h]	Parameters

		$\ddot{z}_{t\,\max}$ mm/s^2	$RMS_{\ddot{z}t}$ mm/s^2	$\ddot{z}_{p\,\max}$ mm/s^2	RMS_{zp} mm/s	$\ddot{z}_{rf\,\max}$ [mm/s^2]	$RMS_{\ddot{z}rf}$ mm/s^2	$\ddot{z}_{rs\,\max}$ mm/s^2	$RMS_{\ddot{z}rs}$ mm/s^2
Concrete road	12	6,40	2,285	9,04	3,639	5,6	0,988	0,76	0,280
	11,9*	4,95	2,175	8,54	3,745	3,12	0,92	1,31	0,825
	25,0	7,85	2,751	12,14	3,727	5,15	1,809	0,32	0,482
	16,6*	6,12	2,335	12,22	4,047	4,49	1,553	0,29	0,479
Earth road	11,5	5,88	2,14	8,88	3,441	3,7	1,103	0,74	0,298
	9,5	5,12	2,086	7,12	3,336	2,8	0,782	1,02	0,327
	8,2	4,58	1,978	6,8	3,019	1,84	0,6	0,68	0,185

* braking

CONCLUSIONS

Apart from the testing variants on concrete road at high speed moving along (when the moving along speed during the tests was characterized by different values), there has been effected a statistic analysis of the performances of the four types of aggregates tractor-semi-trailer which have been experimented (3 aggregates with semi-trailers with elastic hitch, in the mentioned variants, and an aggregate with rigid hitch).

The analysis of the dynamic behavior of each type of aggregate has been accomplished by comparing the values obtained for the studied parameters, according grades (points) for the studied dynamic performances. This way, for the aggregate whose parameter value indicates a disadvantageous situation there has been granted a single point, and for the other aggregates there have been granted, comparatively, up to 4 points.

The statistics resulted from the even-leveled average of all hierarchisations has enhanced that the best performances (that is a better dynamic behavior for most parameters) have been obtained for the hitch with the suspension longitudinally set under the chassis of the semi-trailer, type PSLA (fig. 2), followed by the hitch variant with the suspension transversally set under the chassis of the semi-trailer, type PST (fig. 1). On the last places there has been classified the hitch with the suspension longitudinally set in front of the gripping device type PSLR (fig. 3) and the rigid hitch (with no suspension).

The results of the research obtained on the basis of the experimental data processing have confirmed the theoretically obtained results upon mathematical models studied in paper, that is a better dynamic behavior of the tractor-semi-trailer system with suspension hitch will be obtained against the tractor-semi-trailer system with no suspension hitch.

It is also to be noted that not any chosen elastic connection (setup variant, type and rigidity of the spring) for the suspension hitch improves the performances of the aggregate, there existing the possibility for the functional characteristics of the system to deteriorate in case of an inadequate choice.

The semitrailers are used in combination with agricultural tractors for transport systems, due to their smaller constructive weight and total length compared to trailers, and particularly due to their positive influence on transport and braking dynamics. This influence is achieved by the contribution to increasing the tractor adhesion load, consequently to the transfer of a part of the semitrailer weight upon the tractor. The semitrailer, having only one axle, has as a second supporting point the coupling devices of the tractor, located at the inferior part of the tractor rear.

In order to reduce the shortcoming determined by the vibrations and shocks transmitted by semitrailer to tractor it aims at improving the suspension system at tractor seat and trailer's axles level and in the same time particular constructive solutions for semitrailers with a suspension system at the hitch.

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