MECHATRONIC CONTROL OF THE IMPLEMENT LINKAGE OF AGRICULTURAL TRACTORS¹

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INTRODUCTION

Progress in the technology and automation field causes continual changes regarding requirements for agricultural tractors. In order to improve technical solutions as well as to meet expectations of customers many tractor manufacturing firms applied numerous mechatronic systems (devices) in their products. One of these units is a system controlling the work of an amounted implement.

Three-point linkage of implements is a sub-assemble unit serving to link an implement or machine with a tractor. Depending on requirements for agricultural implements the appropriate control systems of the implement's operation are applied. Automated control of implement operation is realised through an automatic control of hydraulic jack of the implement linkage. The present control of implement linkage applied in agricultural tractors is realised mechanically or more and more frequently electronically.

CONSTRUCTIONAL SOLUTIONS

In a mechanical system the forces in the links are measured with help of spring elements. Displacements of these elements, proportional to the forces occurring in them are compared with the set values, and through the links transmitted to a mechanically controlled hydraulic control valve, which controls the oil flow to a hydraulic cylinder. The position of the implements is determined by a cam mounted on the hydraulic jack shaft (Fig. 1) [5].

¹ The problem presented above is a fragment of a bigger complex topic in the scope of KBN (State Committee for Scientific Research, in Poland) research project no. 7T07C 02514 being just in elaboration, entitled: "Modelling and Automatization of the working processes of computer controlled tractor/implement systems".



Fig. 1. Diagram of a mechanical system of a hydraulic jack control [5]

In a mechatronic system the force values in the links and the position of the implement linkage are converted into electrical signals through appropriate transducers (sensors). These signals are transmitted to a central controlling unit (controller). The required values (for example: a force in the implement linkage) are set on the control console as electrical values and are transmitted to the controller which, on the basis of software sends control signals to an executive subsystem i.e. to an electrohydraulic valve (Fig. 2) [1].



Fig. 2. Diagram of an electronic system of a hydraulic jack control: 1 – hydraulic pump, 2 – electrovalve, 3 – hydraulic cylinder, 4 – central control unit (controller), 5 – force sensor, 6 – position sensor, 7 – control console [1]

A force sensor is an integrated analogue transducer, which utilises the Villary effect (magnetoelasticity), where the course of magnetic stream lines is changed, when the measurement bolt is subjected to the force action. (Fig. 3) [1, 2]. The change of this magnetic stream induces voltage in an appreciated coil, which then is amplified and transmitted as the output signal. This sensor uses a polarised method for measurements of the direction of force.



Fig. 3. Force sensor: a) course of field line in the non loaded state, b) in the loaded state [1]

For the determination of the implement position, a sensor is applied, where the movable ferromagnetic core rests on the cam of the hydraulic jack shaft. This core is located inside the coil and its movement causes the change in coil inductance. In Fig. 4 the characteristics of the sensors are shown [1].



Fig. 4. Characteristics of the sensors: a) force, b) position [1]

Field experiments were carried out in order to compare the functioning of both the implement linkage control systems.

FIELD EXPERIMENTS AND THEIR RESULTS

A tractor with the engine power of 28 kW was used for the field experiments, which was equipped with a mechanical system of implement linkage control. The tractor was additionally equipped with a Bosch electronic control system (EHR), which could control the hydraulic jack alternatively with the mechanical system. The EHR system was mounted in such a way that the constructional dimensions of the implement linkage system has not been changed, however in the hydraulic circuit an electrohydraulic valve was incorporated. The automatic strength and positional control of the implement linkage system was possible through the selection of mechanical or electronic option of the system. Signals of the measured values utilised for the electronic control served also as input signals for the measuring and registering apparatus. During the utilisation of the mechanical system for the control of the implement linkage the electronic system was supplied electrically in order to assure the operation of the sensors and to acquire the measured signal's quantities for recording them. Besides, the measuring and registering system on the tractor determined also: real speed, angular velocities and driving moments of the wheels as well as the fuel consumption by the engine [3].

With the help of a three-point linkage of an implement a mounted cultivator was connected to the tractor. The nominal working depth of the cultivator was 20 cm.

The experiments were carried out on a non-homogeneus soil, with a sandy loamy structure. Each passage was carried out at the speed of 1.5 m/s approximately through the section of 20m length. The apparatus registered the measured quantities with the frequency of 100 Hz, giving about 1,500 samples of the measured quantities per one passage.

The exemplary time courses of changes of the implement working depth a_n and the resultant pull force P_u during automatic mechanical and electronic control are shown in Fig 5.

The obtained in this way samples of observed values (signals) were subjected to statistical analysis [4] i.e. point estimation. The exemplary results are shown in Table 1.

Control	registered	Arithmetic	Loaded	Standard	Coefficients	
system	quantities	mean.	variance	deviation	variation	asymmetry
mechanical	a_n (cm)	19.28	15.73	3.97	20.58%	-0.64
	P_u (kN)	5.49	3.43	1.86	33.71%	0.12
electronic	a_n (cm)	19.48	1.13	1.06	5.48%	-0.25
	P_u (kN)	6.35	1.32	1.14	18.01%	0.22

 Table 1. The results of the point estimation of the registered values



Fig. 5. Courses of values at automatic control: a) mechanical, b) electronic; 1 - required working depth of the tested implement, 2 - real working depth of the tested implement, 3 - the resultant implement resistance force

The analysis of the registered courses of the implement working depth quantities and implement resistance force by means of automatic control of an implement linkage has shown that during mechanical control the maximal amplitude of the implement working depth a_n was 16 cm, and the pulling force $P_u = 7.83$ kN. Whereas with the electronic control these values were $a_n = 6.74$ cm $P_u = 5.76$ kN respectively.

SUMMARY

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The analysis of the experiment results showed that electronic system more precisely controlled the mounted implement operation considering the agricultural requirements and operating conditions. Therefore the electronic system should be used on all the new manufactured tractors regardless of the magnitude of their engines.

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SUMMARY

In this study the experiment results of agricultural implement mounted on the rear three-point linkage by means of automatic control of this linkage by a mechanical or electronic system were presented.