ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome IV (Year 2011). ISSN 2067-3809

[1.] Boris STOJIĆ, [2.] Ferenc ČASNJI, [3.] Aleksandar POZNIĆ

# THE ROLE OF THE MECHATRONICS IN TECHNOLOGICAL DEVELOPMENT OF THE CONTEMPORARY AGRICULTURAL TRACTORS

**ABSTRACT:**
*In past few decades significant changes happened in the field of technological development of agricultural tractors, leading to great improvements in different aspects of their operation. This is enabled, above all, by introducing of electronic control systems and their wide application in different systems of the tractor. Due to these changes, agricultural tractor has evolved from rough and robust heavy duty machine to high-tech system capable of executing fully new functions and achieving much higher level of overall working results. A few main examples can be named, such as higher energy efficiency, lower emission, higher quality of agrotechnical operations, better soil protection and enhanced working conditions for human operator. New technologies, whose application has led to achieved results, are mostly based on mechatronic systems. This paper will give a basic overview of current achievements and discuss possibilities for future development.*

**KEYWORDS:**
*agricultural tractor, mechatronics*

## INTRODUCTION

*Agriculture recently became area with significant application of high technology. Intelligent systems have been developed and applied enabling efficient agricultural production, contributing at the same time to promotion of ecological and social effects. Contemporary tractor development is in accordance with current principles of agriculture production, which are given through the aim for increase of amount, variety and quality of products, together with the more efficient use of energetic resources and reduction of all kind of negative environmental influences. In this scope there is also tendency for further decrease in the level of the load of the human operator and full automation of the field operations. Contemporary trends in agriculture are also characterized by quality and traceability assurance procedures, including creation of appropriate documents which is demanded by law. Further, there is importance of the issues such as machine park monitoring, telemetry service, error detection and recognition etc. Possibility of tractors and their use to fulfill such demands and follow development trends is given above all by intensive breakthrough of electronic components into all their segments.*

*Numerous electronic measuring and control systems and their integration into already present mechanic and hydraulic components are introduced. In such configuration the data management has a key role in the function realization. This makes contemporary agricultural tractor product comprising great number of mechatronic systems. Many of these can be connected or integrated. Functions they control are e.g. tractor motion, realization and monitoring of agrotechnical operations, communication with environment etc. Despite of interconnection or integration of such systems, this paper is focused mostly on these related to tractor as mobile machine, i.e. vehicle. Necessity of such partial approach is a result of variety and complexity of the topic considered.*

## INTEGRATED CONTROL OF ENGINE AND TRANSMISSION

*Energy efficiency optimization of vehicle powertrain, including mobile machines and tractors, is for a long time subject of intensive activities of researchers and developers. For the power transfer from diesel engine to drive wheels, continuously variable transmission can be seen as one of the most promising solutions. This concept is especially appropriate for the realization of the potentials for working parameters enhancement accompanied by energy efficiency increase. For this to be achieved, one of the key parts is a right use of engine and transmission electronic control.*

System of integrated control of engine and transmission opens further possibilities for optimization, provided appropriate control strategy is used. Such configuration enables work of the engine in the area of low rotational speed, which is accompanied by favorable values of specific fuel consumption. This also gives a higher engine torque while working on actual constant power hyperbole. Lower rotational speed and higher torque as power transmission input values further contribute to energy consumption reduction by enabling transmission to work with higher efficiency. Total fuel consumption can be significantly reduced by utilization of such possibilities. Working load fluctuations, which can be significant, are compensated by control system through variation of fuel amount and transmission ratio. Without such control strategy, engine has to be kept in the area of the high speed in order to keep stability in the non-steady state conditions. The result of this is higher consumption, noise and wear. Paper [9] gives one possible solution for consumption reduction in the way described, ensuring at the same time working regime stability.

According to importance of the powertrain system, its further technological development can be expected, which also includes introduction of new concepts. Utilization of the in-wheel concept can be expected as one of development trends. For the realization of such system a hydrostatic power transmission can be used. Still, since introduction of electric and hybrid-electric powers in tractors is highly probable [1, 2], electric wheel hub motor concept could be utilized in series vehicles, and not only in research and investigation.

Individual motor for each wheel enables, as compared to centralized power, enables several advantages, such as:

- there is no mechanical connection between powered wheels; therefore optimal values of torque, wheel slip and rotational speed can be determined for each wheel for current working or driving conditions; on agricultural surfaces this contributes to optimal utilization of adhesion and enhancement of tractive properties, fuel consumption reduction, better soil protection and reduction of tire wear; on hard surfaces, vehicle dynamic performance characteristics can be optimized and therefore active safety of nowadays high-speed driving tractors improved;
- individual control of torque and rotational speeds enhances drive ability and maneuverability of the tractor.

For realization of advantages named, appropriate control system is required that utilizes adequate control strategy. One concept, that should be realized, is descried in the paper [7]. In this concept, a cyclic communication of control software with sensors and actuators via CAN-bus is provided. On the basis of the driver input and information about dynamic state of the system, appropriate values of hub motors control parameters are determined.

## TRACTOR DRIVING AND BRAKING SYSTEMS

One of the main problems in the exploitation of agricultural machinery is deteriorating influence of normal and tangential forces through which the vehicle acts on the soil. These forces lead to soil compaction, which has a numerous negative impacts. Soil protection from compaction has been significant research topic for a long time. It is a complex phenomena still leading to unanswered questions and therefore offering potential for further improvements in this topic. A possibility for the more significant prosperity in this field could be seen in utilization of the system of the tractor chassis control according to the values of the soil parameters that are in connection with the compaction phenomena. Such possibility is above all connected with the development of the sensor technology and data management. One possible way is to develop a system that can monitor soil humidity as key compaction parameter [4]. Together with the information on tire penetration depth acquired by laser sensor [13] giving an insight into soil stress state, this could be used for the control system for automatic tire inflation pressure regulation and its optimization as the function of soil compaction parameter values.

Due to impact of the tire inflation pressure onto the numerous exploitation characteristic of the tire and tractor itself [3], integration of the system for automatic tire inflation pressure regulation could contribute to enhancement of many parameters such as:

- energy efficiency and realization of the tractive forces through adapting tire characteristic to the current soil conditions;
- driver comfort, through impact on tire vibrational characteristics;
- active safety of the tractor on public roads through impact on tractor dynamics performance characteristics;
- reduction of the tire wear and damage possibility, etc.

When the track mechanism is used for realization of the tractor motion, there is a possibility for enhancement of their characteristics e.g. by optimizing of vertical load distribution. This is achieved by active suspension of the wheels as described in [6]. This paper introduces innovative concept of mechanical configuration and hydraulic suspension that enables optimal contact of the track with the soil through the actions of the control system. This ensures optimal performance characteristic of the tractor in a tillage as well as enhanced maneuverability and driveability while driving on the curved trajectory.

Due to increased speeds of tractors, their braking system has been significantly enhanced. Introducing of control systems such as ABS is, however, not yet to be expected. Electronic control still has an application in the braking action, through the driver assistance systems. One of them is uphill start assistance.

*The other can act while driving downhill towing a trailer, having function of "jack-knifing" prevention [14]. Risk of such event exists when driver tries to decrease speed without using brake pedal, but only through gas pedal release and transmission ratio increase. Then the wheel slip is increased so much that lateral adhesion is almost lost and therefore driveability and stability of the towing train is endangered. This phenomenon is especially pronounced for the case of continuously variable transmission, widely used today, due to their possibility of fast reaction on the driver input.*

## AUTOMATISATION OF TRACTOR GUIDING AND IMPLEMENT CONTROL

*Automatization of the tractor guiding and realization of working tasks as well is a field where recently greatest development of mechatronics and automatic control systems has happened. As a result, this is probably an area with the most intense development in contemporary tractors. Regarding tractor together with the coupled implement, full automatization of the field work is state of art. There are also aftermarket systems available that can be integrated into tractors originally not equipped with such solutions. This state of development is enabled through wide application of the control systems on different systems of tractor and implement and their networking, through use of different navigation systems and through developing appropriate software solutions as well. When tractor operates in the conditions of low reception of navigation satellite signal, or when there are additional requirements for the precision of guidance, laser sensors are used. There are also laser and ultrasound sensors detecting the position of individual plants or their parts [11]. Further development of this system will contribute in enabling mechanical weed control.*

*It is necessary to design automatization systems in user-friendly way, in order to enable user to fully exploit their potentials, but also to avoid possible user resistance should the complex learning procedure be needed to be able to use the system.*

*Tractor work in the field is characterized by a series of actions periodically repeated. For example, when the tractor comes to the end of the field and turns around to begin a new row, there are operations such as: lifting, turning and setting the plough down; turning power take-off, differential lock and all-wheel drive off and on; control of the engine and transmission to change speed, etc. Electronic control system can automatize such procedures in order to decrease level of operator load and therefore to increase productivity and work quality. This can be realized through programming of operations to adapt automated work to individual needs. Such automatization requires networking of control systems of engine, transmission and hydraulic system and their common control. Beside all this, navigation system data can be use to automatically turn tractor around at the end of the row. Utilization of navigation system data is also basis for precise guiding the tractor along the path required. This provides numerous advantages, such as [15]: getting precise position of the tractor and implement or the next row; reduction of row overlap; reduction of human error possibility; lower level of operator training required, etc. Result of all this is productivity and quality increase, as well as consumption reduction of the fuel and other materials such as fertilizers or pesticides.*

## SUSPENSION SYSTEM AND VIBROISOLATION

*Although elastic wheel suspension is getting more and more involved in the tractor chassis, protection of the operator from the harmful impact of the vibrations (according to EU directive 2002/44/EEC) is still mainly done of the basis of seat and/or cabin suspension. Semi-active and active system can give best results for wide spectrum of excitation frequencies. Semi-active systems are characterized by the possibility of damping control, usually done by controlled cushion valves or by use of magneto-rheological fluids. Active systems use actuators that give force / displacement output according to excitation. Paper [10] describes a concept of active suspended seat with pneumatic actuator. Significant property of the system enabling its use is low energy consumption. This also enables system to use its own energy source instead of being coupled with that of the tractor, which gives a possibility for aftermarket use on arbitrary tractor model. For determining of excitation parameters acceleration and displacement sensors are used. Air spring stiffness is controlled by electro-pneumatic valve for regulation of active air volume. Control algorithm must take into account that excitation has continuous spectrum, which makes the task of proper vibroisolation more demanding.*

## OTHER SYSTEMS

*Besides mechatronic systems of tractor as vehicle, which are the main topic of this paper, other systems should also be briefly mentioned for their importance. Amongst them there are different communication systems enabling the transfer of data used for control and monitoring. For networking of electronic system components and local data exchange and management CAN-bus system is used. Communication of tractor and implement electronic via ISO-bus connection enables further automatization of work and tractor control according to implement requirements (concept called „implement-controls-tractor“).*

*Wireless data transfer to greater distances has importance for the teleservice. This assumes transfer of diagnostic parameters to remote server computer, including use of internet [12], used for planning of maintenance operations as needed according to the system state. This way system faults can be prevented, which is especially important by high specialized mobile machines, for their standstill can cause bigger problems such as e.g. logistic chain break [8]. Data acquired serves also for establishing of required documentation.*

*At the end an important role of the mechatronic in the tractor hydraulic system should be mentioned, because of great influence it has on the agrotechnical operations. Many of achievements described above also would not be possible to realize without it.*

## CONCLUSION

*On the basis of literature research, this paper gives a presentation of the current state of mechatronic systems application in agricultural tractors, together with the consideration of the possibilities for future development. Due to versatility and wideness of the topic treated, the paper is focused mostly on these parts of tractor making it a vehicle. Therefore other important electronic and mechatronic systems found on contemporary tractors are not covered. From the same reason closer and more detailed technical description of the systems mentioned is also not given.*

*It can be concluded that mechatronic systems have led to high level of tractors technological development, which is a general trend in overall agriculture production as well as in other fields of human activities. Optimal integration of mechanical, hydraulic and electronic systems enables exact process control, which is a basis for all advantages achieved this way. The main amongst them to be mentioned are saving of all kinds of resources and improvements in productivity, quality, environmental protection and working conditions, etc.*

*As basic features of future trends, further development of sensors and intelligent data management systems can be anticipated. These can be e.g. picture processing, sensors for measuring soil parameters such as soil humidity or electrical conductivity etc. Such development contributes to precise farming, because of the possibility to adapt working process to the local needs and specifications. Data acquired can also be utilized for creation of required documentation.*

## REFERENCES

[1] Aumer W., Lindner M., Geißler M., Herlitzius T.: Elektrischer Traktor: Vision oder Zukunft?, Landtechnik 1/2008, s.14-15

[2] Časnji F., Stojić B.: Razvoj hibridnih elektro-dizel traktora, Traktori i pogonske mašine 13(2008)4, str. 43-48

[3] Časnji F., Torović T., Muzikravić V.: Energetska efikasnost traktora, Monografija, Univerzitet u Novom Sadu, Fakultet tehničkih nauka, 2009.

[4] Drücker H., Zeng Q., Sun Z., Roller O., Schulze Lammers P., Hartung E.: Bodenbearbeitung mit sensorischer Erfassung der oberfl ächennahen Bodenfeuchtigkeit, Landtechnik 4/2009, s.272-275

[5] Freimann R.: Gerät steuert Traktor, Landtechnik 3/2003, s.166-167

[6] Geischeder R., Rainer J., Haller C.: Aktiv gefedertes Gummigurtbandlaufwerk mit automatischer Auflagekraftoptimierung, Landtechnik 3/2010, s.170-173

[7] Geissler M.: Entwicklung, Implementierung und Verifizierung der Steuerung und Regelung für einen elektrischen Einzelradantrieb, diplomski rad, TU Dresden, 2010.

[8] Göres T., Harms H.-H.: Datenmanagementsystem für den Teleservice bei mobilen Arbeitsmaschinen, Landtechnik 5/2007, s.328-329

[9] Harms H.-H.: Potenziale integrierter Motor- und Getriebesteuerungen, Landtechnik 3/2010, s.164-166

[10] Himmelhuber F.: Die aktiv geregelte Luftfederung für den Traktorsitz - Ein Mikroprozessor steuert die Kennlinienanpassung in Fahrersitzen, Landtechnik 3/2006, s.132-133

[11] Holpp M.: Automatisches Lenksystem für Traktoren im Obstbau, Landtechnik 3/2008, s.148-149

[12] Scheufler B.: Intelligente Technologien im Landmaschinenbau, Landtechnik 6/2001, s.396-397

[13] Sommer C., Lebert M., Jaklinski L., Jasinski B.: Bodenschadverdichtung - Strategien und Techniken zum physikalischen Bodenschutz, Landtechnik 2/2003., s.94-95

[14] Wiegandt M., Harms H.-H.: Traktoren automatisch bremsen, Landtechnik 4/2003, s. 248-249

[15] www.deere.com, September 2010

## AUTHORS & AFFILIATION

[1.] Boris STOJIĆ,
[2.] Ferenc ČASNJI,
[3.] Aleksandar POZNIĆ,

[1-3.] FACULTY OF TECHNICAL SCIENCES NOVI SAD, SERBIA


ACTA TECHNICA CORVINIENSIS
– BULLETIN of ENGINEERING
ISSN: 2067-3809 [CD-Rom, online]