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Constructional Characteristics of the Agricultural Tractors at the Beginning of the 21st Century

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Preliminary note

Through implementation of new technological innovations from the area of the motor vehicles, the agriculture tractor became highly sophisticated vehicle-machine. Tractor engines are equipped with the common-rail fuel injection system, four valves per cylinder and variable geometry turbocharger, and fulfil rigorous ecological standards regarding the air pollution. Continuously variable transmission enables selection of the optimal transmission speed according to working conditions. Besides very accurate adjustment of three point-hitch drawbar, electro-hydraulic control system enables more additional functions. Significant improvement was obtained at ergonomics of operator's working place conditions. Computer control systems are going to take over more and more functions, not only in operating, but also in tractor diagnostics. The utilization of recycling materials, bio-fuel and biodegradable lubricants represent high level of ecological manufacturing as well as tractor operating level. High level of tractor sophistication due to built in computers and electronics requires adequately educated operator.

Konstrukcijske značajke poljoprivrednih traktora na početku 21. stoljeća

Prethodno priopćenje

Ugradnjom najnovijih tehničkih dostignuća s područja motornih vozila poljoprivredni traktor je postao visoko sofisticirano vozilo-stroj. Traktorski motori opremljeni su common-rail sustavom napajanja gorivom, razvodnim mehanizmom s četiri ventila po cilindru, turbokompresorom promjenjive geometrije i ispunjavaju stroge ekološke norme glede onečišćenja zraka. Kontinuirano-varijabilna transmisija omogućuje i osigurava odabir optimalnog stupnja prijenosa shodno radnim uvjetima. Elektro-hidraulički sustav nadzora i upravljanja trozglobnom poteznicom osim preciznijeg podešavanja omogućuje i veći broj funkcija. Ergonomski uvjeti u kabini traktora su gotovo na razini luksuznih automobila. Korištenje recikličnih gradbenih materijala, te bio-goriva i biorazgradivih maziva pokazuje visoku ekološku razinu kako pri izradi, tako i pri korištenju traktora. Visoka sofisticiranost traktora uz sve veću primjenu elektronike i računala iziskuje i tehničko-informatički educiranog rukovatelja.

1. Introduction

Tractor represents the most important machine in agriculture designated to pull and power variety of different agricultural machines and implements applied in complex technological operations of agricultural production. In many countries about 40 to 45 % of the total agricultural machinery investment is related to tractors [1]. The constructional characteristics of the tractors used in high-developed countries in the last 30 years have been significantly changed. The West European and North American farmers require modern, so called high-tech tractors, equipped with the latest technical innovations that can provide high productivity and effectiveness. More and more attention has been given to ergonomic characteristics of the tractor, as well as tractor influence to environment. On the contrary, most Asian, African, South American and even some East European farmers demand low-priced tractors. The number of these tractors is very significant in the market of the stated countries, but clearly such low price brings outdated technology. In Croatia, the number of low-priced tractors is also significant, which is understandable considering the very low average farm size of approximately 3,0 ha. Insufficient arable land per farm is the main cause of non-rational and economically justified exploitation of the tractors in Croatia [2]. In West-European countries the necessary tractor power for the farms up to 100 ha is 2 kW/ha, and for larger farms is 1,1 kW/ha [3]. If these data are compared with Croatian where almost every

average farm owns a tractor with minimal engine power in amount of 26 kW, it is evident that it can't be exploited rationally. Since the Croatian goal is joining European Union, increase of middle sized farm number is expected which means that these farmers will need and buy tractors with built in up to date technical innovations. If Croatian farmers wish to compete with EU farmers they will be forced to equip themselves with up to date tractors and farm machines. For this reason this paper describes constructional characteristics of modern tractors that are currently on the market.

2. Characteristics of certain tractor components

2.1. Engine

At the beginning of the new century the leading tractor manufacturers presented models with new engines that comply with the European Euro II standards, i.e. American Tier II standards [4]. Mentioned standards are related to the decrease of the allowed emission level of air pollutants in exhaust gases of diesel engines such as NO_x, HC, CO and soot particles. Considering tractor's engine allowed air pollutants level, they shall be even more rigorous, demanding engine development aimed to decrease of the exhaust gases emission and fuel consumption. Almost all new two-axle tractors are powered by direct fuel injection diesel engine with integral combustion chamber. These engines are characterised by significantly lower internal losses than engines with indirect injection combustion chamber. Instead of conventional in-line or rotary high-pressure fuel injection pumps with separate fuel injection lines, new engine generations with common-rail and injector-pump fuelling systems enable significantly higher injection pressure [5]. The first tractors with common-rail system appeared in 2002 [6]. Common-rail system is characterised by central high-pressure pump and common delivery line for all injectors with fuel under constant high pressure [7]. Injectors with built-in electromagnetic valves enable very accurate fuel delivery as well as multi-phase injecting. This system provides pressure of fuel injecting above 1500 bar enabling thus more complete combustion and better utilisation of the fuel energy and less environment pollution.

Contrary to the common-rail system with central high-pressure pump, the pump-injector system has separate pump and injector for each cylinder. This solution avoids injection lines and non-avoidable pressure losses. Described system enables pressures above 2000 bars improving fuel combustion, producing thus more power while decreasing fuel consumption and air pollution [5]. At both described systems electromagnetic valves are controlled by computer that provide optimal moment of fuel injecting. It is expected that further development of tractors shall follow the trend of the road vehicles regarding decrease of the exhaust gases emission, so tractors shall be equipped with engines that comply to the European Euro III, and than Euro IV standards, i.e. American Tier III and Tier IV standards. The most efficient means for decrease of exhaust gases emission and fuel consumption is increasing of fuel injecting pressure. Therefore the increase over 3000 bar in tractor engines is assumed, which is possible to achieve through new performances of high-pressure pumps and injectors.

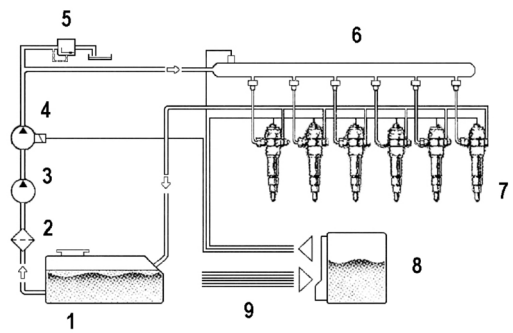

Figure 1. Common rail fuel system:
1. Fuel tank, 2. Fuel filter, 3. Charge pump, 4. High pressure pump, 5. Pressure limiter, 6. Common rail, 7. Nozzles, 8. Electronic control unit, 9. Sensors

Slika 1. Common rail sustav ubrizgavanja goriva:
1. Spremnik goriva, 2. Pročistač goriva, 3. Niskotlačna pumpa, 4. Visokotlačna pumpa, 5. Sigurnosni ventil, 6. Centralni vod, 7. Brizgaljke, 8. Elektronička upravljačka jedinica, 9. Senzori

New engines have increased number of valves from two to four per cylinder (two suction and two exhaust valves) [8] which doubled the area of the fresh air inlets and exhaust gases outlets means significant decrease of the resistance in circulation and enable efficient exchange of operating medium. Therefore the amount of remaining cylinder combustion products are reduced to minimum. Increased number of valves contributes to better cylinder air filling and thus better combustion and increased engine's efficiency. Electro-hydraulic valve control enables the distribution mechanism omitting and accurate computer control of valve position.

Classic turbocharger has become standard part of the tractor. The main disadvantage of conventional turbocharger is insufficient air pre-compressing at lower engine revolutions. Decrease of tractor engine revolutions is possible not only by decreasing the amount of injected fuel but also by overloading the tractor. New generation of turbocharger with variable vanes geometry enables changing the inlet angle of exhaust gases entering turbine rotor. Turning the vanes of the turbine stator enables optimal air pre-compressing

according to working conditions. This action performs the membrane controller connected to the Ventury pipe in the turbo-compressor outlet. Described device even prevents occurrence of unpleasant noise caused by high inlet exhaust gases velocity. Optimal degree of air pre-compressing provides decreasing of fuel consumption within the entire operating range [9]. To achieve even more efficiency in air recompression there is a possibility of built-in two turbochargers. Further means to decrease pollutants emission is to build in recirculation system of the exhaust gases, which significantly decreases the percentage of the soot particles.

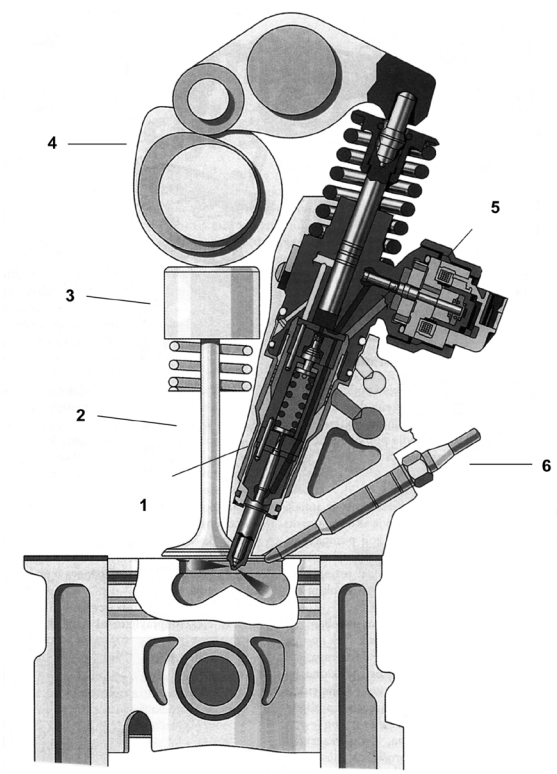

Figure 2. Nozzle-pump system 1. Nozzle, 2. Valve, 3. Cam follower, 4. Cam shaft, 5. Solenoid, 6. Glow plug

Slika 2. Presjek sustava pumpa-brizgaljka: 1. Brizgaljka, 2. Ventil, 3. Podizač ventila, 4. Bregasto vratilo, 5. Elektromagnetski ventil, 6. Grijač

Fuel consumption can be expressed as the hourly consumption in litres or kilograms (L/h or kg/h) or as the specific consumption that represents the fuel consumption per work unit (g/kWh). Common means for evaluation of the tractor engine efficiency is specific fuel consumption, which is at up-to date engines decreased below 200 g/kWh. Modern hi-tech tractor engines have to deliver high torque increase. Approximately twenty years ago a good torque increase was considered to be 20 % while today's engines have torque increase over 50 %. Engine power has been increasing and the limit of standard tractors moved to 220 kW.

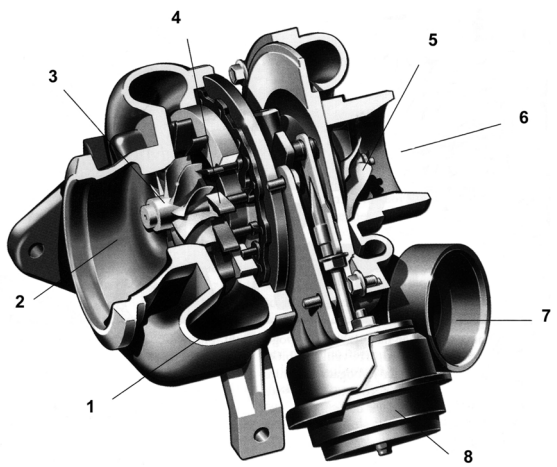

Figure 3. Variable geometry turbocharger (VGT): 1. Exhaust-inlet, 2. Exhaust-outlet, 3. Turbine wheel, 4. Moveble vanes, 5. Charger wheel, 6. Air intlet 7. Air-outlet, 8. Membrane actuator

Slika 3. Turbokompresor promjenjive geometrije: 1. Ulaz ispušnih plinova, 2. Izlaz ispušnih plinova, 3. Turbinsko kolo, 4. Usmjerivačke lopatice, 5. Kompresorsko kolo, 6. Usis zraka, 7. Izlaz usisanog zraka, 8. Membranski regulator

2.2. Transmission

In the middle eighties appeared tractors whose maximum velocity exceeded standard of 30 km/h, while in nineties 40 km/h became standard for higher power level tractors. At the beginning of 21st century appeared tractors with maximum velocity of 50 km/h and it seems it could become new standard. Some manufacturers even offer special models of tractors with maximum speed over 60 km/h [8]. Tractors with the maximum velocity over 40 km/h must have brakes on all four wheels. Regarding to further increase of the maximum tractor speed, it is expected that tractors shall have anti-block breaking system (ABS) that reduces negative influence to steering and dynamic stability of the tractor.

The increase of total speed range, as well as the demand for higher number of speeds in the main operating range (5-15 km/h) and greater number of crawler speeds (below 1 km/h) brought to drastic increase of speed number from 4-5 in the sixties to more than 40 at the end of the 20th century [10]. Besides the increased number of speeds, the gearbox had to be a completely synchronized enabling speed changing under the full load. Conventional gearboxes could no longer satisfied all demands so development went to step-less gearbox providing tractor operation at the limit of the engine power at the required speed and shifting under the load. Earlier attempts were by the hydrostatic and hydrodynamic transmission but due to great losses in hydraulic gearboxes the idea was withdrawn.

Mentioned disadvantages have been solved by invention of continuously variable transmission (CVT) with power-split which is combination of mechanical and hydrostatic transmission that achieved acceptable efficiency and retained advantages of hydraulic transmission [11]. This transmission enables the power transfer from engine to planetary gearbox through central (solar) gear. Planetary gearbox provides distribution of the engine power to mechanical and hydrostatic section. Hydrostatic parts are contained of hydraulic pump and two hydraulic motors of the new generation, which means that maximum tilt angle of piston is increased from 30˚ to 45˚. This provides better efficiency and wider speed range coverage. Hydraulic pump is driven by planetary gearbox and according to the piston tilt transmits more or less oil to the hydraulic motors, which therefore altering motors revolutions, which are transmitted to shaft for integration. In mechanical section, the remaining engine power is transmitted through gears to power integration shaft where it integrates with the power transmitted by hydrostatic section. At tractor start-up only hydrostatic transmission is engaged and with speed increase mechanical section of transmission is more and more engaged until it is completely mechanical at the highest speed. With this technique it is possible to obtain optimal tractor speed and drawbar power in certain working conditions without need for shifting [12].

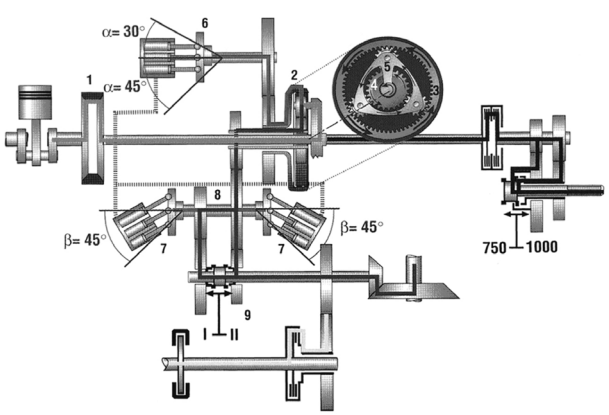

Figure 4. Continuously variable transmission (CVT): 1. Torsional vibration damper, 2. Planetary gear set, 3. Ring gear, 4. Sun gear, 5. Planet carrier, 6. Hydraulic pump, 7. Hydraulic motor, 8. Collecting shaft, 9. Travel range selector

Slika 4. Kontinuirano varijabilna transmisija: 1. Prigušnica torzije, 2. Planetarni diferencijal, 3. Vijenac s unutarnjim ozubljenjem, 4. Centralni (sunčani) zupčanik, 5. Nosač planeta, 6. Hidropumpa, 7. hidromotor, 8. Zbirno vratilo, 9. Izbornik područja brzina

2.3. Hydraulics

Through decades the hydraulic hitch control and three-point hitch drawbar were carried though mechanical-hydraulic system which are, even today, mostly used on older and low-priced tractors. These systems mechanically measure value of the tensile force and the position of the three-point hitch drawbar levers, where given data are transmitted to the control valve through leverage within the system. At the beginning of the eighties of the 20th century, company Bosch has manufactured electronic-hydraulic hitch control for tractors (EHR) that was adopted by almost every tractor manufacturer [13]. The implementation of the electronics in control devices, sensors and executable elements has opened up new possibilities in control of hydraulic hitch of tractors [14]. Figure 5 shows tractor equipped with electronic-hydraulic hitch control system. The control of the EHR system is carried out with electronic control unit with the connections for reception of the input and transmission of the output signals.

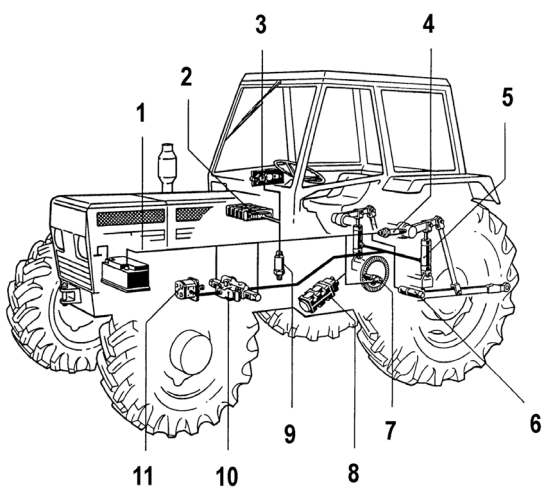

Figure 5. Digital Electronic-hydraulic Hitch Control System: 1. Power supply, 2. Electronic Control Unit, 3. Control panel, 4. Position sensor, 5. Hydraulic lift cylinder, 6. Draft sensor, 7. Inductive speed sensor, 8. Radar sensor, 9. Pressure sensor, 10. Hitch contlol valve, 11. Hydraulic pump

Slika 5. Digitalni elektronički upravljačko-nadzorni sustav: 1. Vod napajanja sustava, 2. Elektronička upravljačko-nadzorna jedinica, 3. Rukovateljeva upravljačka ploča, 4. Senzor-osjetnik položaja, 5. Podizni cilindar, 6. Senzor vuče, 7. Senzor brzine vrtnje kotača, 8. Mjerač brzine kretanja (RADAR), 9. Senzor pritiska, 10. Kontrolni ventil, 11. Hidraulička pumpa

Input signals arrive from different sensors (draft force, lever position, system's oil pressure, tractor velocity, etc.) and are filtered and processed by analogue-digital converters at control panel before input to the processor of the control unit. Separate lower capacity memory unit carries out storage of temporally needed input data, while software used for control functions are stored in the processor with multiple programmable memories. Output signals are transmitted to the control valve electro-hydraulic converter that directs the oil flow for lifting and lowering of levers. The efficiency of the control system is evaluated by delay time for reaction of the control valve, which has to be below 0,5 seconds. Appropriate software support for control unit and additional sensors can also control the front three-point hitch drawbar. Additional advantages of the EHR system are control of tractor wheels slip and vibration damping during transport with mounted heavy implements.

At heavy jobs like ploughing, it is hard to avoid excessive tractor drive wheels slip. However, when wheel slip exceeds limits of 25-30 % very negative consequences like excessive soil compaction, increased fuel consumption and less efficiency occur. A lot of methods for tractor wheels slip preventing and control have been explored but only the EHR system proved as reliable solution. Determination of the tractor drive wheels slip value requires two signals, one to determine real tractor velocity and the other for theoretical velocity. Actual speed is measured by radar sensor based on Doppler effect principle, while theoretic speed measures the sensor on the gearbox shaft outlet. Calculation of the slip performs the control unit and in case of the increase above the default limit (approx. 30 %) it gives the signal for lifting of the three-point hitch drawbar decreasing thus draft force. As aftermath of control system action reduction of the tractor drive wheels slip occurs.

During the tractor transport with mounted heavy implements, especially on a field or a country road, it can cause a vibration of the entire tractor causing very dangerous occasional loss of the front steering wheels with the surface due to temporal unloading of the wheels. One of the possibilities of the EHR system is an active damping of these vibrations. To locate the vibrations and activate the system, no additional sensors are necessary, because draft force sensors can do that. When a tractor transporting a mounted implement is idle and hitch is in the lifted position, sensors of the draft force emit signal proportional to the tool's weight to the control unit. The vibrations that occur during tractors driving EHR sensors measure dynamic part of the force, which is approximately proportional to the variations of the tool induced forces. In that case the increase above the pre-set limit, the control unit activates the damping system that lowers the pressure in the cylinders taking over thus the considerable part of the vibrations.

3. Ergonomic characteristics

Since the farmer spends most of his working hours on the tractor exposed to different, mostly unfavourable conditions, manufacturers spent considerable amount of time to assure farmers appropriate comfort and safety ambience in their tractors. The noise in the tractor cabin has been more and more decreased, and at some up to date tractors it achieved the level of 70 dB (A), which can be compared to the noise in the luxury passenger cars. Those results were achieved due to manufacturing the cabin in a form of the sealed module, elastically mounted on the tractor, choosing the high quality insulation materials and built in several compartments between the engine and the cabin. Besides the noise, the most common cause of the professional diseases of tractor operators is vibrations. At older tractor generation, vibrations problem was solved only by operator's seat suspension. These older seat versions had passive suspension not very efficient for the operator vibration protection. Modern tractor seats manufactured according to medicine expert's suggestions have active suspension assuring less vibration [15].

Figure 6. New generation of tractor seat
Slika 6. Traktorsko sjedalo nove generacije

New tractors have significantly improved operator vibration protection also by some other measures (picture 7) like cabin suspension, front shaft suspension and vibration damping at the three-point hitch drawbar via the EHR system [16]. Some tractor manufacturers offer self-levelling operator's seat regardless of the tractor inclination. The newest solution is self-levelling cabin mounted on four hydraulic cylinders with position sensors. When tractor is inclined due to field slope or

ploughing in furrow, cylinders provide levelling the cabin when the difference reaches 40 cm.

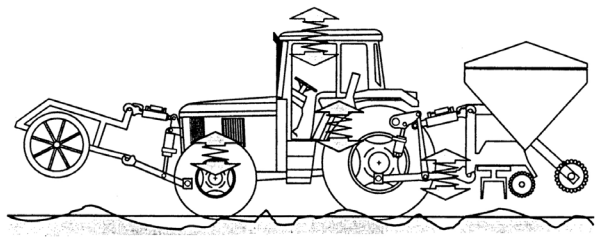

Figure 7. Vibration damping system
Slika 7. Sustav prigušenja vibracija

New cabins provide good all around view by placing the exhaust pipe and air filter along the cabin roof support. Many up to date tractors have so called ”steep nose” means engine cover inclination towards front shaft enabling thus operator better view of the implements on the front three-point hitch drawbar. Modern tractors have air-conditioned cabin with fine-filtered inlet air, so the tractor operator is protected from dust, engine exhaust gases and even poisonous mist during pesticide application. The air condition is now standard accessory of higher-class tractor. The greater implementation of the electronics operating the large number of tractor functions via switches, keys and buttons really eased operator’s work.

Figure 8. Cock-pit of new generation tractor
Slika 8. Nadzorno upravljački sklop nove generacije traktora

4. Implementation of electronics and computers on tractors

As well as all other fields of human activities, modern agriculture in high-developed countries became unimaginable without implementation of the electronic and computer systems in general and especially on agriculture machines [17]. Increasing implementation of electronics and computers to control the complex mechanical systems like tractors, required new science-expert discipline, mechatronics, that combines knowledge from mechanics, electronics and information science, pointing out the necessity of different technical disciplines integration [18]. Mechatronics include development of electronic components for control of tractor components like engine, transmission and hydraulics as a subsystem and tractor as the system, and for connecting and controlling of tractor-implement system. Each component must have all necessary elements like different types of sensors and actuators that provide automatic execution of all functions.

In order to enable tractor and all of its subsystems optimal functioning, the unique control system is necessary to provide it. The ISO-bus system [19] enables efficient communication between the board computer, tractor and implements. Standardization of the system (ISO 11783) ensured universal application, regardless of the tractor or implements manufacturer.

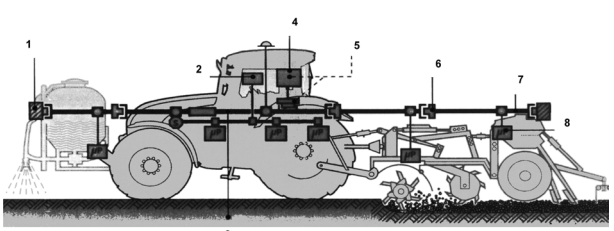

Figure 9. Communication between tractor and implement using ISO Bus: 1. Bus terminator, 2. Tractor internal monitor, 3. Tractor internal Bus, 4. Bus terminal, 5. Data transfer to management computer, 6. Bus connector, 7. Tractor implement Bus, 8. Electronic control unit (ECU)

Slika 9. ISO Sabirnica : 1. Završetak sabirnice, 2. Monitor u traktoru, 3. Sabirnica unutar traktora, 4. Virtualni terminal, 5. Prijenos podataka u centralno računalo, 6. Veza traktor-priključak, 7. ISO sabirnica priključenog stroja/oruđa, 8. Elektronička nadzorno-upravljačka jedinica

The tractor's board computer in the cabin and the implement's electronic control unit provide complete control, work programming and data exchange with the central computer at the farmer's home-office. For every machine or implement tractor's board computer chooses the optimal engine revolutions and transmission velocity significantly saving fuel and also protecting soil structure by decreasing the wheel slip. Working settings of each implement like optimal position and number of power take-off (PTO) revolutions can be chosen according to soil and weather conditions at the time of the operation [20]. The tractor operator already must be properly educated in order to use software and monitor processes performance, entering settings data and manage certain tractor and implements functions [21]. At the same time, electronic-computer systems made operators free of monotonous routine works and significantly reduce the possibility of operator's mistakes that could influence on quality and quantity of work and tractor failures.

Computer control systems are going to take over more and more functions, not only in operating, but also in tractor diagnostics. The computer shall not only detect the failure but it shall inform the nearest authorised service to prepare all necessary parts for repair including term of repair the tractor. Further, it shall forecast tractor's failure and informs the operator-owner on time. All these tasks will be simplified by geographical positioning system (GPS) system, which locates the position of the tractor on-line. It is assumed that in the near future, tractor shall be operated by remote control from the control centre.

5. The tractor's influence on the environment

World wide increased number of tractors caused unavoidable and unfavourable influence to the environment. It is primarily evident in the air pollution due to emission of the harmful substances in exhaust gases, environment contamination by used lubricants, discarded parts and even depreciated tractors and soil damage caused by the tractor wheels compaction. Construction solutions for decrease of the emission of the exhaust gases of the tractor engines are described in the chapter 2.1. Taking into consideration the forecast of crude oil resources decrease and ecological demands, alternative-renewable fuels for engines are more and more explored [22]. Besides increase of bio-diesel fuel application in the EU countries, use of natural gas, biogas, methanol, ethanol, hydrogen and the even electrical drive of tractor are also explored [24]. Serious ecological issue are used lubricants and also their package, which are after spending very often thrown off in the environment. [25] Considering the total world number of tractors and their lubricants demand, we are faced with the enormous quantities, which after been spend should be properly deposited without the harmful consequences for the environment. The application of the biodegradable lubricants, i.e. vegetable lubricants is a promising solution. Spend parts as well as the entire thrown off tractors besides the economical loss endanger environment. The further development of tractors and other agriculture machines has challenging task to make new generation products more appropriate for recycling [27]. In the future, more and more tractor parts shall be manufactured out of biodegradable materials [28].

Many world scientists, even some in Croatia, has been for long time pointed out to hardly reparable damage of agricultural soils mainly caused by tractor and other machine wheels compaction. Growing plants need soil with certain water and air content ratio, enabling thus roots access to oxygen, water and nutrients supplies. Frequent passing of tractor with implements or machines over compacting soil and sometimes induces hardly reparable changes in the soil that influences growth and development of the plants. One of the most efficient ways to decrease the soil compaction is reduction the number of working operations. Modern tractors with front and rear three point hydraulic hitches and PTO are able to combine appropriate implements and machines integrating thus more operations like tillage, sowing, fertilization and plant protection into the one pass. Soil compaction can be reduced by tractor tyre pressure deflation, usage of lower weight tractors or increasing wheel contact surface by special Terra tyres [29]. Joining of tractor wheels reduce wheel pressure to the soil for almost 50 % because the tractor mass along with the additional wheels mass is distributed to doubled surface. Implementation of the wider tyres obtains similar effect, while extra-wide (Terra) tyres reached 5-6 times greater contact surface and as much lower soil pressure compared to the standard tyres at the same wheel load [30].

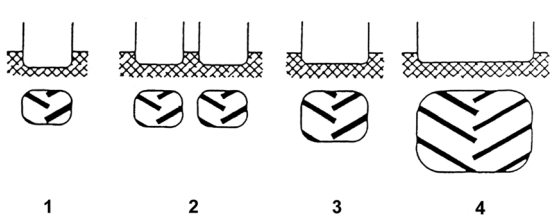

Figure 10. Contact area of different tractor tires: 1. Standard, 2. Dual, 3. Wide, 4. Terra

Slika 10. Kontaktne površine različitih tipova pneumatika: 1. Standardni, 2. Udvojeni, 3. Široki, 4. Terra

Crawler tractors are characterised by lower soil compaction due to greater contact surface in comparison to wheel tractors [31]. Comparison of the caterpillar and wheel soil pressure is shown on the Figure 11. Recently, famous world tractor manufacturers presented

and included into his offer tractors with the rubber caterpillars whose wider application is to be expected. Disadvantage of rubber caterpillars is significantly higher price compared to the tyre wheel tractors and could be efficient only at large farms over 500 ha.

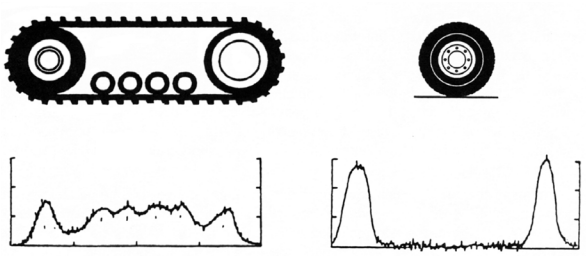

Figure 11. Contact pressure at tractor with rubber belt and wheels

Slika 11. Tlak na tlo kod traktora s gumenim gusjenicama i kotačima

6. Conclusion

Modern agriculture tractors are high sophisticated machines equipped with latest technical innovations. Tractors are equipped with engines with common-rail fuel injection system, four valves per cylinder and variable geometry turbocharger, innovations that have been proved at road vehicles. Continuously variable transmission (CVT) enables selection of optimal speed and draft force shifting under the full load adopting thus various working conditions. Electro-hydraulic three-point hitch control system provides significantly accurate operation and higher number of tractor hydraulics functions. Significant improvement was obtained at ergonomics of operator's working place conditions. More attention has been aimed to environment protection, therefore during tractor manufacturing, new biodegradable and recycling materials are used along with renewable bio-fuels and lubricants. Due to increasing implementation of electronics and computers at tractor control system, operators must be well trained to handle such sophisticated machines.

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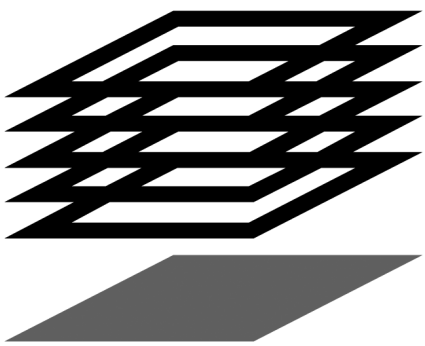

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