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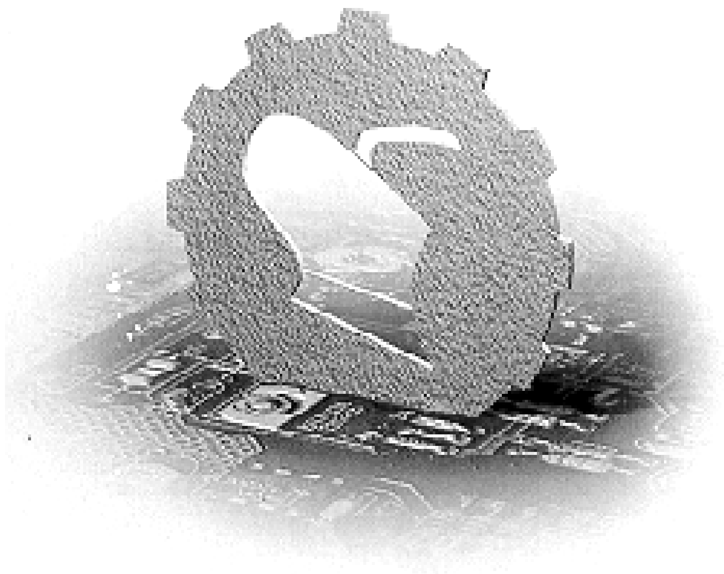

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HIDRAULIČKI SIMBOLI - DEO IV: RAZVODNI VENTILI

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Sažetak: Mehanizacija mnogobrojnih proizvodnih procesa i operacija u savremenoj primarnoj poljoprivrednoj proizvodnji, transportu, skladištenju i pratećoj prehrambenoj prerađivačkoj industriji teško se može ostvariti bez automatizacije. U najvećem broju slučajeva, proizvodna efikasnost i ekološka održivost zahtevaju, između ostalog, preciznu kontrolu toka energije u okviru primenjenih instalacija, radnih mašina, uređaja i mehanizmima. Sa gledišta teorije automatskog upravljanja, elementi angažovane tehnike, mašine, uređaji i mehanizmi, mogu predstavljati objekte upravljanja. Kontrolisano usmeravanje i optimalno dostavljanje određene količine energije željenim objektima upravljanja po pravilu je veoma retko uniformno, jer mora biti usklađeno sa vremenski nepredvidivim promenama zahteva proizvodnog procesa ili operacije. Potrebna energija može se preneti prema potrošačima u poljoprivredi primenom odgovarajućih mehaničkih, električnih, pneumatskih ili hidrauličkih sistema, kao i njihovim sadejstvom. Svi postojeći tipovi sistema prenosa energije imaju izvesne prednosti i nedostatke, uz zajednicki zahtev za odgovarajućim upravljačkim elementima. U fokusu ovog rada su grafički simboli upravljačkih ventila hidrauličkog prenosa energije (snage) i upravljačkih signala, označeni kao hidraulički razvodni ventili, ili hidraulički razvodnici.

Ključne reči: *hidraulika, razvodni ventil, sistem, šema, poljoprivredna tehnika*

[*]Autor za korespodenciju. E-mail adresa: epetrodr@agrif.bg.ac.rs. Rad je deo aktivnosti projekta broj TR-31051: "Unapređenje biotehnoloških postupaka u funkciji racionalnog korišćenja energije, povećanja produktivnosti i kvaliteta poljoprivrednih proizvoda", Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije.

UVOD

Od početka industrijske revolucije, neadekvatni i nedovoljno kontrolisani razvoj tehnologije i njenih posledica na okolinu, kao i ogroman priraštaj stanovništva, dovode savremenu poljoprivrednu proizvodnju sve bliže krajnjim granicama njene održivosti. Uprkos opštem planetarnom porastu broja stanovnika, u razvijenom delu sveta je na raspolaganju sve manje prvenstveno manuelnih radnika, što zahteva intenzivnu i sveobuhvatnu primenu poljoprivredne tehnike u oblasti poljoprivredne proizvodnje.

Zbog izazova kojima je sve oštrije izložena, savremena tehnika u poljoprivredi se neprekidno usavršava. Razvijaju se potpuno nove mašine, uređaji i instalacije, uz istovremeno poboljšavanje njihovih postojećih konstrukcija, kao i samih proizvodnih procesa i operacija u poljoprivredi. Hidraulički sistemi prenosa snage i upravljanja zauzimaju izuzetno važno mesto u poljoprivrednoj proizvodnji. Pri tome se ne sme izgubiti iz vida da se oni nezaobilazno usklađuju i kombinuju sa odgovarajućim pneumatskim, mehaničkim i električnim/elektronskim sistemima.

Imajući u vidu izuzetnu složenost velikog broja ugrađenih hidrauličkih komponenti i komplikovanu prostornu (3D) dispoziciju odgovarajućih hidrauličkih sistema u okviru savremenih poljoprivrednih instalacija, mašina, uređaja itd., oni se po pravilu predstavljaju paraleleno na dva načina. Sa jedne strane se koriste odgovarajući radionički crteži pojedinačnih elemenata i sklopni crteži komponenata, uz istovremenu primenu simboličkog predstavljanja komponenata prilikom šematskog prikazivanja hidrauličkih sistema u celini ili nekih njihovih podsistema. Standardizacija simbola hidrauličkih komponenata je od izuzetno velike važnosti u svim granama tehnike, kako bi se obezbedilo razumevanje hidrauličkih šema i razmena znanja, tehničkih sredstava i tehnologije od strane stručnjaka koji potiču iz najrazličitijih govornih i obrazovnih regiona i zemalja.

Zato je ovaj rad formulisan u obliku četvrtog (IV) nastavka serije posvećene hidrauličkim simbolima, usmeren ka simbolima jedne specifične podgrupe hidrauličkih upravljačkih komponenti – hidrauličkim razvodnim ventilima ili kraće nazvanim hidraulički razvodnici. Po sadržaju, ovaj rad predstavlja logičan nastavak prethodna tri rada publikovana u časopisu Poljoprivredna tehnika, koji su takođe posvećeni simbolima komponenti hidrauličkih sistema. U prvom (uvodnom) delu su prikazani opšti simboli, oznake mernih instrumenata i indikatora [7]. U drugom nastavku serijala su predstavljeni simboli pumpi i izvršnih elemenata, te ukratko opisani njihovi osnovni tipovi, karakteristike i namene [8]. Treći tematski nastavak po istom pitanju je fokusiran na hidrauličke simbole upravljačkih elemenata hidrauličkih sistema, odnosno različitih tipova i konstrukcija hidrauličkih ventila [9]. U ovom, trećem radu o simbolima hidrauličkih komponenata, obuhvaćena je većina najvažnijih standardnih u praksi najčešće primenjivanih hidrauličkih ventila, ne samo u savremenoj poljoprivrenoj tehnici nego i u drugim tehničkim oblastima.

Zahvaljujući nizu specifičnosti i raznolikosti konstrukcija, funkcionalnih principa, operativnih svojstava, složenosti, proizvodnih i eksploatacionih troškova i namene, koje ih suštinski razlikuju i izdvajaju od ostalih hidrauličkih tipova i konstrukcija ventila, u tekućem (četvrtom) nastavku su prikazani simboli hidrauličkih razvodnih ventila, ili kraće, hidrauličkih razvodnika.

Kao i u prethodna tri, u ovom nastavku je prikaz simbola hidrauličkih komponenti od interesa pripremljen poštujući važeće međunarodne standarde najvišeg (ISO) ranga [1], [2] i [3], prateći i forme njihovog predstavljanja u tehničkim publikacijma slične namene, kao što su npr. [6] i [10].

SIMBOLIČKE OZNAKE HIDRAULIČKIH RAZVODNIH VENTILA

Tabela 1 prikazuje osnovne slovne oznake koje se primenjuju za obeležavanje broja i vrste priključnih vodova i radnih položaja hidrauličkih razvodnika. Ove oznake se na odgovarajućim šemama upisuju uz kvadrat (kvadratni simbol) koji predstavlja normalni (neaktivirani) položaj razvodnika. Ostali kvadratni simboli predstavljaju aktivirane položaje.

Tabela 1. Slovne oznake priključaka u hidraulici.

Table 1. Letter designations of hydraulic connectors.

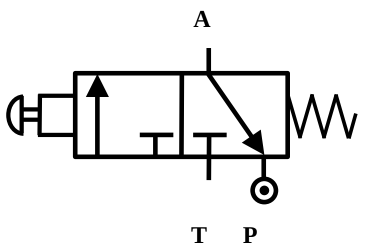
Opšte oznake broja položaja i priključaka razvodnika: n/m	
n	Broj priključaka.
m	Broj radnih položaja razvodnika, jednak broju kvadratnih simbola.
Primer:	Oznaka **4/3** označava razvodnik sa **4** priključka i **3** radna položaja.
Oznake priključaka razvodnika	
	**Primer:** Razvodnik **3/2**, sa **3** priključka i **2** radna položaja, koji se aktivira tasterom (dugmetom). U normalni položaj ga vraća opruga. Normalni (neaktivirani) položaj razvodnika na slici je prikazan kvadratom desno. U ovom slučaju, taj položaj održava dejstvo opruge. Kvadrat na levoj strani prikazuje aktivirani položaj razvodnika, koji se ostvaruje sa pritisnutim tasterom postavljenim sa leve strane razvodnika.
P	Ulazni priključak potisnog voda pumpe (engl. *pump*).
T	Priključak cevovoda za odvod tečnosti ka rezervoaru (engl. *tank*).
A, B, C	Izlazni priključci radnih vodova, koji vode ka potrošačima.
X, Y, Z	Priključci upravljačkih vodova.
L	Priključak pomoćnog voda - odvoda prodrlog ulja iz komponente.

Tabela 2. Opšte oznake običnih (prekidačkih - „ON/OFF“) hidrauličkih razvodnika bez oznaka načina aktiviranja.

Table 2. General symbols of basic „ON/OFF“ hydraulic directional control valves, without designation of activation.

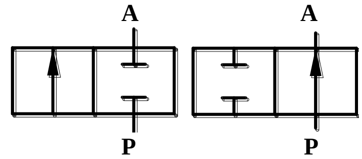
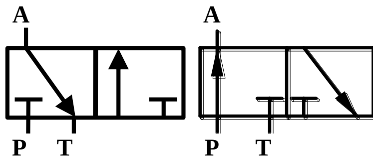
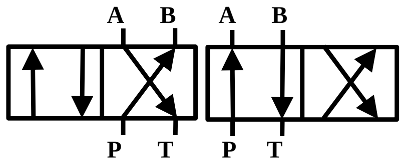
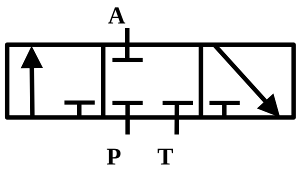
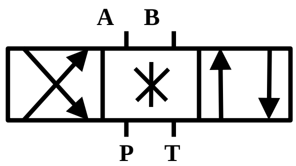
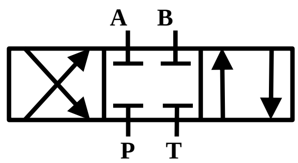
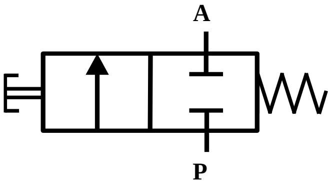
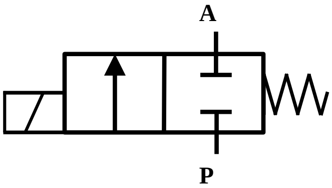
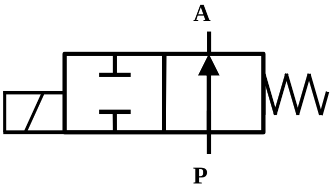
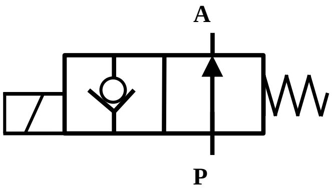
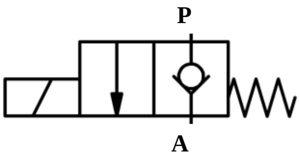
	**Hidraulički razvodnik 2/2:** - normalno zatvoren ventil (levo) i - normalno otvoren ventil (desno).
	**Hidraulički razvodnik 3/2:** - normalno zatvoren ventil (levo) i - normalno otvorenventil (desno).
	**Hidraulički razvodnik 4/2**
	**Hidraulički razvodnik 3/3**, normalno zatvoren.
 	**Hidraulički razvodnik 4/3** Postoje različite konstrukcija ovih razvodnika. U opštem slučaju, razvodnici u centralnom položaju mogu blokirati protok fluida, ili usmeravati tokove radnog fluida u različitim pravcima i smerovima. **Primer** normalno zatvorenog razvodnika 4/3: U normalnom položaju razvodnika (centralni kvadrat), zatvoren je protok u svim vodovima.

Tabela 2 prikazuje opšte oznake običnih (takozvanih prekidačkih – *engl.* „ON/OFF“) hidrauličkih razvodnika bez oznaka načina njihovog aktiviranja.

Razvodnici iz ove podgrupe hidrauličkih ventila omogućavaju dva stanja toka radne hidrauličke tečnosti na svojim priključcima: „**ON**“ - otvoreno i „**OFF**“ - zatvoreno.

Tabela 3. Simboli hidrauličkih razvodnika 2/2 sa prikazom načina aktiviranja – 1. deo.

Table 3. Symbols of hydraulic directional control valves 2/2, with presentation of the activation method – part 1.

Hidraulički razvodnik 2/2 sa ručnim aktiviranjem	
	*Normalno zatvoreni razvodnik 2/2. Aktivira se i pri tome otvara manuelno, a u polazni položaj ga vraća opruga i pri tome ponovo prekida protok.*
Elektromagnetni hidraulički razvodnici 2/2 sa potisnim elektromagnetom za aktiviranje	
	*Normalno zatvoreni razvodnik 2/2. Otvara se elektromagnetnim aktiviranjem. U normalni položaj ga vraća elastična opruga i ponovo zatvara, prekidajući protok.*
	*Normalno otvoreni razvodnik 2/2. Zatvara se elektromagnetnim aktiviranjem. Elastična opruga vraća razvodnik u normalni položaj i ponovo otvara ventil.*
Hidraulički razvodnici 2/2 sa sedištem i potisnim elektromagnetom za aktiviranje	
	*Normalno otvoreni razvodnik 2/2. Elektromagnetno se aktivira pomoću potisnog EM-a, a opruga ga vraća u normalni položaj i pri tome ponovo otvara. Ovi razvodnici u aktiviranom položaju zatvaraju protok radne tečnosti u jednom smeru.*
	*Razvodnik 2/2, normalno zatvoren za protok radne tečnosti u jednom smeru. Elektromagnetno se aktivira i pri tome otvara, a elastična opruga vraća razvodnik u normalni položaj.*

Hidraulički razvodni ventili tipa 2/2, koji imaju dva radna položaja i dva priključka, ali različite načine aktiviranja i usmeravanja toka radne tečnosti, prikazani su u tabeli 3, organizovanoj u dva dela zbog prostornih ograničenja.

Tabela 3. Simboli hidrauličkih razvodnika 2/2 sa prikazom načina aktiviranja – 2. deo.

Table 3. Symbols of hydraulic directional control valves 2/2, with activation method presented – part 2.

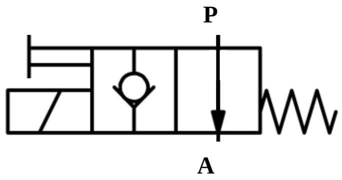
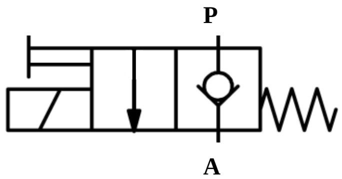
Hidraulički razvodnici 2/2 sa sedištem i mogućnosti ručnog i elektromagnetnog aktiviranja	
	*Normalno otvoreni razvodnik 2/2. Može se aktivirati manuelno ili elektromagnetno. U aktiviranom položaju zatvara protok u samo u jednom (na slici) ili u oba smera, u zavisnosti od konstrukcije. U normalni položaj razvodnik vraća elastična opruga i pri tome se on ponovo otvara.*
	*Razvodnik 2/2, normalno zatvoren za protok u jednom (na slici) ili oba smera, u zavisnosti od konstrukcije. Aktivira se manuelno ili elektromagnetno, pri čemu se omogućava slobodno proticanje radne tečnosti, a elastična opruga vraća razvodnik u normalni položaj.*

Tabela 4 prikazuje hidrauličke razvodnike tipa 3/2, sa 3 priključna voda i dva radna položaja, sa ručnim aktiviranjem.

Tabela 4. Simboli hidrauličkih razvodnika 3/2 sa ručnim aktiviranjem – 1. deo.

Table 4. Symbols of hydraulic directional control valves 3/2, with manual activation – Part 1.

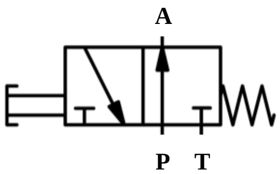
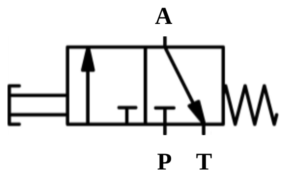
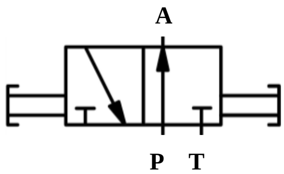
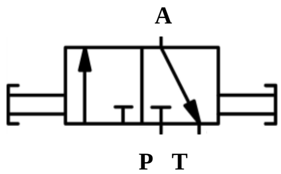
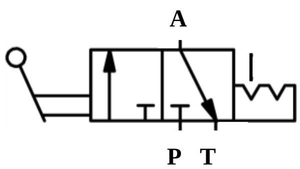
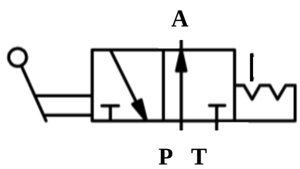
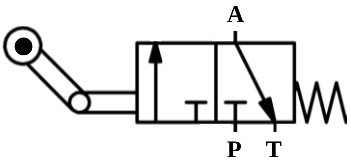
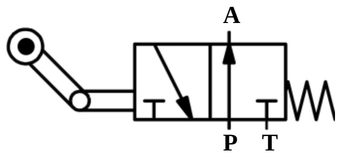
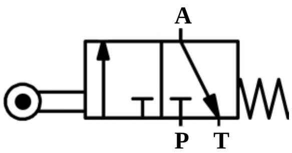
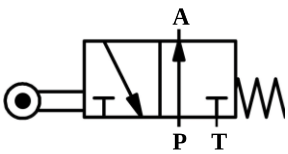
Hidraulički razvodnici 3/2 sa ručnim aktiviranjem		
		*Razvodnik sa manuelnim aktiviranjem, a u normalni položaj ga vraća elastična opruga.*
		*Razvodnik sa manuelnim aktiviranjem i deaktivi-ranjem.*
		*Razvodni ventil 3/2 sa ručicom za aktiviranje i uskočnom letvom za zadržavanje položaja.*

Tabela 4. Simboli hidrauličkih razvodnika 3/2 sa ručnim aktiviranjem – 2. deo.

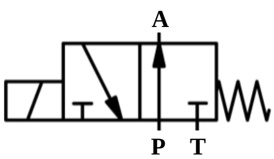
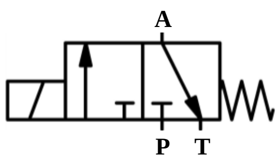
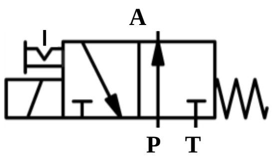
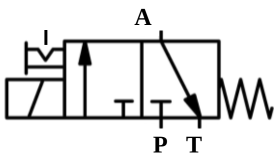
Table 4. Symbols of hydraulic directional control valves 3/2, with manual activation – Part 2.

	*Razvodni ventil 3/2 sa polugom za manuelno aktiviranje i oprugom za vraćanje u normalni položaj.*
	
	*Razvodni ventil 3/2 sa valjkom (točkom) za manuelno aktiviranje i oprugom za vraćanje u normalni položaj.*
	

Pored konstrukcija hidrauličkih razvodnih ventila 3/2 sa ručnim aktiviranjem, u poljoprivrednoj tehnici široku primenu nalaze i razvodnici sa elektromagnetnim aktiviranjem. Njihovi simboli su prikazani u tabeli 5.

Tabela 5. Simboli hidrauličkih razvodnika 3/2 sa elektromagnetnim aktiviranjem.

Table 5. Symbols of hydraulic directional control valves 3/2, with electromagnet activation.

		*Elektromagnetni razvodni ventili 3/2 sa oprugom.*
		*Elektromagnetni razvodni ventil 3/2 sa dodatnim ručnim aktivatorom sa uskočnom letvom za zadržavanje položaja.*

Grafički simboli hidrauličkih razvodnih ventila 4/2, sa četiri priključka i dva radna položaja, predstavljeni su u tabeli 6. Klasifikovani su prema načinu (metodu) aktiviranja i načinu regulisanja protoka (zatvarački ili proporcionalni).

Tabela 6. Simboli hidrauličkih razvodnika 4/2 – 1. deo.

Table 6. Symbols of hydraulic directional control valves 4/2 – part 1.

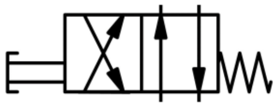
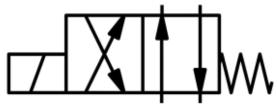
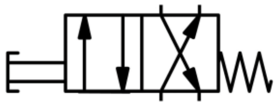
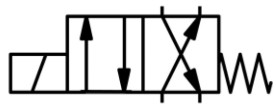
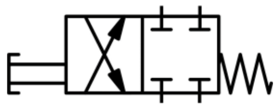
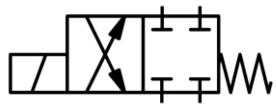
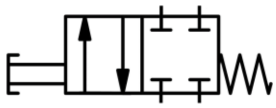
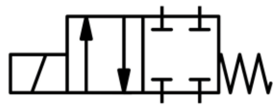
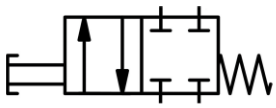
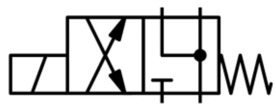
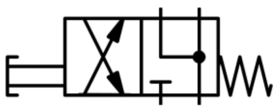
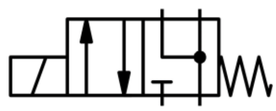
Hidraulički razvodnici 4/2 sa manuelnim aktiviranjem (dugme npr.) i oprugom za vraćanje razvodnika u normalni položaj.	Elektromagnetni hidraulički razvodni ventili 4/2 (aktivira se potisnim EM) sa oprugom za vraćanje razvodnika u normalni položaj.
A B  P T	A B  P T
A B  P T	A B  P T
A B  P T	A B  P T
A B  P T	A B  P T
A B  P T	A B  P T
A B  P T	A B  P T

Tabela 6. Simboli hidrauličkih razvodnika 4/2 – 2. deo.
Table 6. Symbols of hydraulic directional control valves 4/2 – part 2.

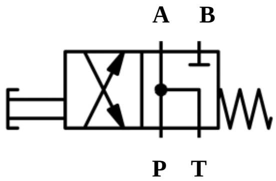
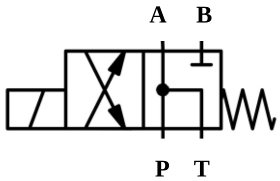
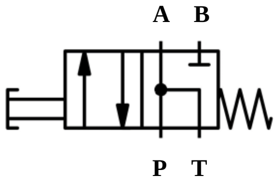
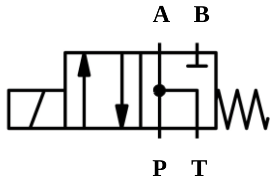
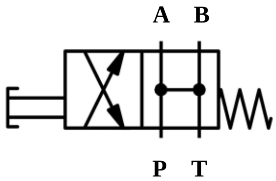
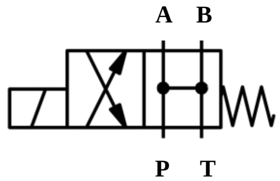
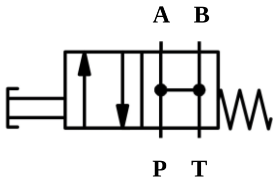
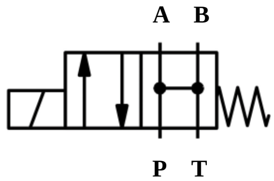
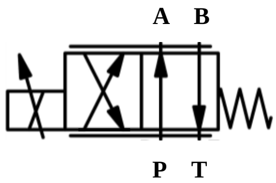
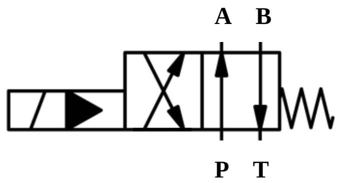
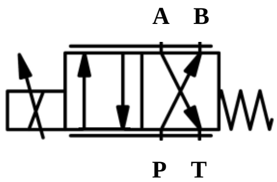
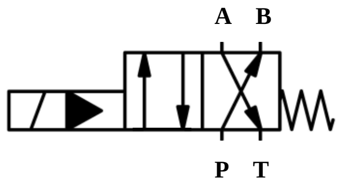
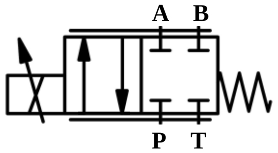
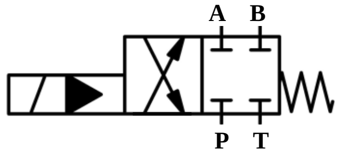
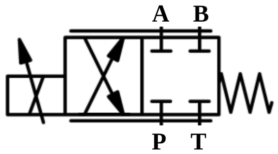
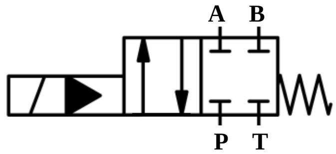
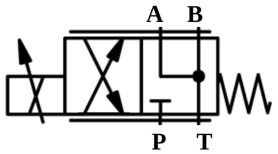
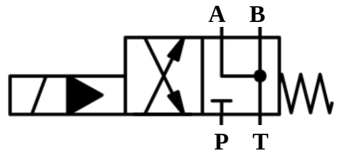
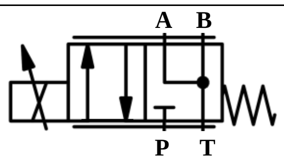
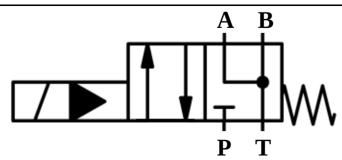
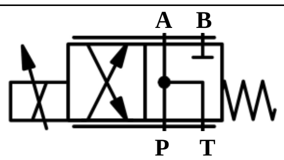
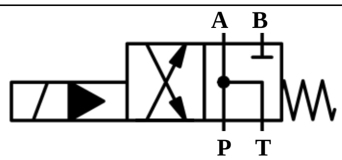
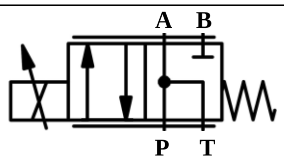
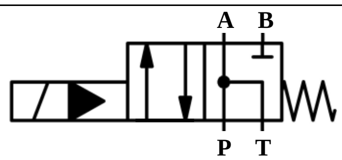
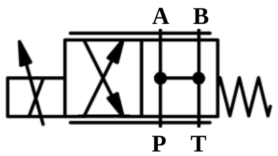
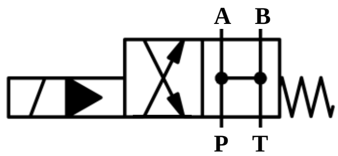
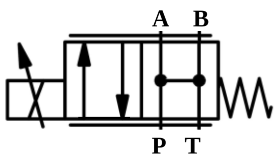
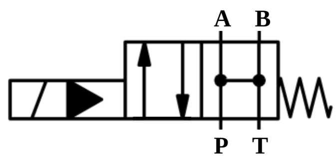
	
	
	
	
Proporcionalni elektromagnetni hidraulički razvodnici 4/2 sa oprugom za vraćanje u normalni položaj.	*Hidraulički razvodnici 4/2 sa dvostepenim aktiviranjem: EM u prvom i hidrauličkim u drugom stupnju. Opruga vraća razvodnik u normalni položaj.*
	
	

Tabela 6. Simboli hidrauličkih razvodnika 4/2 – 3. deo.

Table 6. Symbols of hydraulic directional control valves 4/2 – part 3.

Grafički simboli različitih konstrukcija hidrauličkih razvodnih ventila 4/3, sa četiri priključka i tri radna položaja predstavljeni su u tabeli 7.

Tabela 7. Simboli hidrauličkih razvodnika 4/3 – 1. deo.

Table 7. Symbols of hydraulic directional control valves 4/3 – part 1.

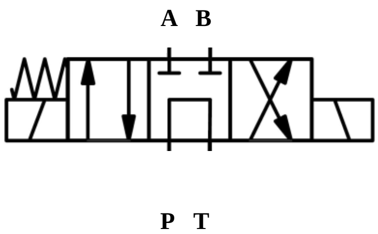
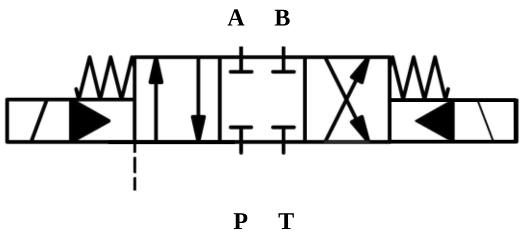
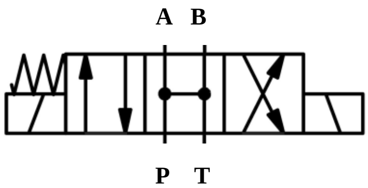
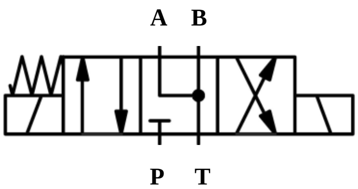
Hidraulički razvodni ventili 4/3, sa dva elektromagneta i oprugom	*Hidraulički razvodnici 4/3 sa dvostepenim aktiviranjem: dvostranim elektromagnetnim aktiviranjem u prvom i hidrauličkim u drugom stupnju.*
	
	
	

Tabela 7. Simboli hidrauličkih razvodnika 4/3 – 2. deo.

Table 7. Symbols of hydraulic directional control valves 4/3 – part 2.

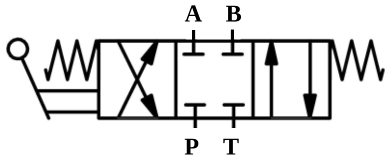
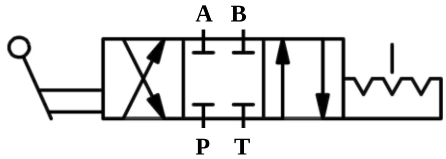
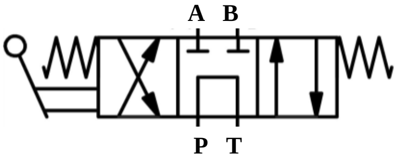
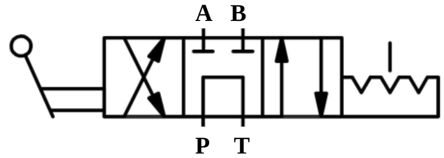
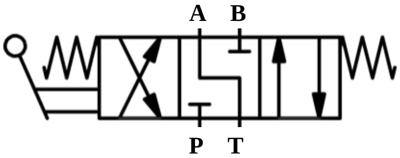
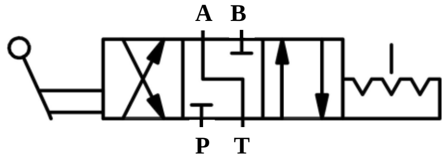
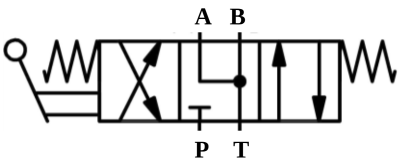
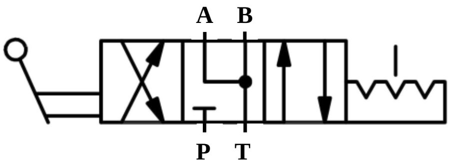
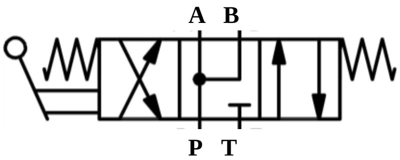
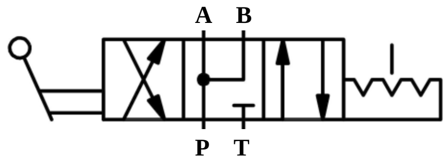
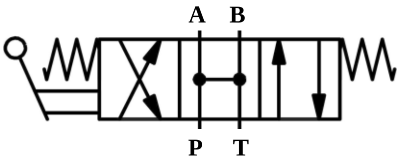
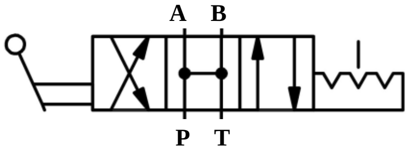
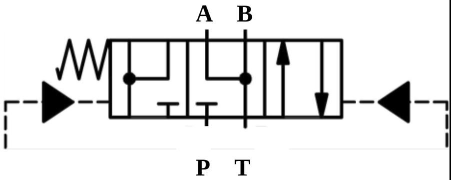
Hidraulički razvodni ventili 4/3 sa ručnim aktiviranjem pomoću ručice i oprugama za vraćanje u normalni položaj (centriranje).	*Hidraulički razvodnici 4/3 sa manuelnim aktiviranjem pomoću ručice i uskočnom letvom za zadržavanje zadatog položaja.*
	
	
	
	
	
	
Dvostrano direktno hidraulički aktivirani hidraulički razvodni ventil 4/3.	
	

Tabela 8. Simboli jednostepenih proporcionalnih hidrauličkih razvodnika 4/3.
Table 8. Symbols of the single-stage proporcional hydraulic directional control valves 4/3.

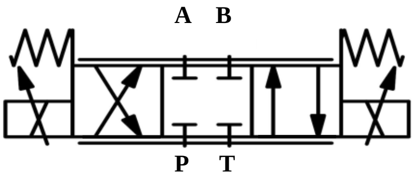
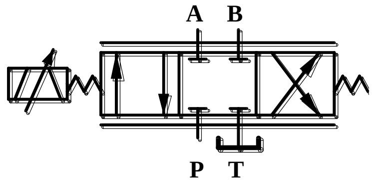
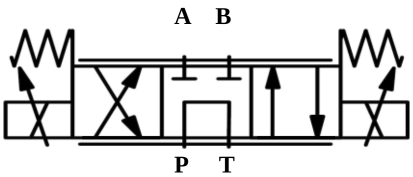
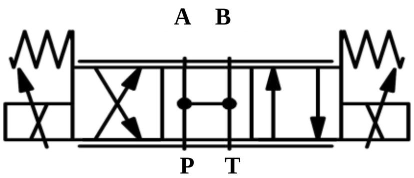
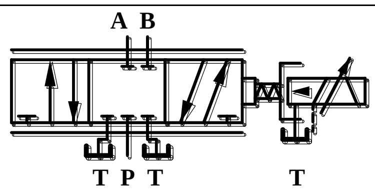
Proporcionalni hidraulički razvodni ventili 4/3, dvostrano direktno aktivirani pomoću podesivih potisnih elektromagneta.	*Jednostepeni direktno aktivirani elektro-hidraulički servo-ventil 4/3. Upravljački element, sa dva vari-jabilna solenoida suprotnosmernog dejstva prihvata upravljački analogni signal, prema kome podešava kontinualnu promenu toka radne tečnosti.*
	
	*Dvostepeni indirektno aktivirani elektro-hidrauli-čki servo-ventil 5/3 sa mehaničkom povratnom Upravljački element, sa dva varijabilna solenoida suprotnosmernog dejstva prihvata upravljački analogni signal, na osnovu koga obezbeđuje kontinualnu promenu parametara toka hidrauličke radne tečnosti.*
	

Tabela 9. Simboli dvostepenih proporcionalnih hidrauličkih razvodnika 4/3 sa manuelnim uključivanjem u prvom stupnju i hidrauličkim aktiviranjem u drugom.

Table 9. Symbols of the two-stage proporcional hydraulic directional control valves 4/3 with manual activation in the first and hydraulic activation in the second stage.

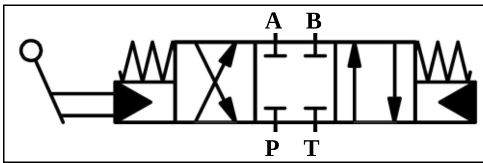
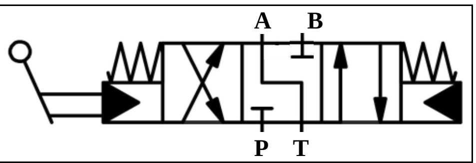
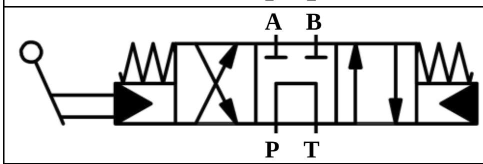
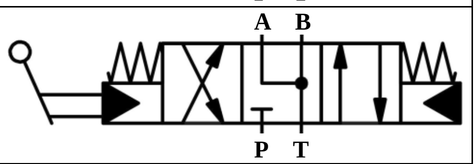
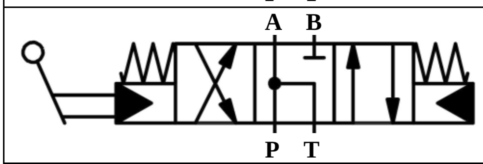
	
	
	

Tabela 8 prikazuje simbole proporcionalnih hidrauličkih razvodnih ventila 4/3 (četiri priključka i tri radna položaja) i sa elektro-magnetnim aktiviranjem (elektro-hidraulički servoventili). Položaj specijalno profilisanog upravljačkog klipa ovih ventila može se kontinualno menjati, omogućavajući kontinualnu promenu strujnih parametara hidrauličke tečnosti.

Simboli dvostepenih proporcionalnih hidrauličkih razvodnika 4/3 sa manuelnim uključivanjem u prvom stepenu i hidrauličkim aktiviranjem u drugom predstavljeni su u tabeli 9.

ZAKLJUČAK

Pojednostavljeno, hidraulika i pneumatika podrazumevaju prenos snage i upravljanja upotrebom tečnosti ili gasa za izvršavanje određenih radnih operacija i procesa, prenos signala itd. [4]. Obzirom na fokus ovog rada, hidrauličke simboličke oznake, treba imati u vidu da se tehnologije zasnovane na njenoj upotrebi koriste u bezbroj svakodnevnih industrijskih okruženja, uključujući i proizvodnju elemenata, montažu i rad najrazličitijih instalacija, mašina i uređaja u okviru poljopriodne tehnike.

Hidraulički sistemi se sastoje od komponenti koje uključuju pumpe, radne cilindre, rotacione hidraulične motore, ventile, creva, spojnice, račve, davače, indikatore, prečistače, zaptivače, rezervoare itd. Prisustvo nekih komponenata je neophodno za sigurno i pravilno funkcionisanje hidrauličkog sistema, dok su druge opcione i koriste se za precizniji rad sistema ili za povećanje životnog veka celog sistema, nekih njegovih delova ili pojedinačnih komponenata delova [5]. Zahvaljujući širokoj lepezi različitih komponenata i sistema uopšte, hidraulika omogućava potiskivanje, povlačenje, podizanje i spuštanje, rotiranje ili držanje praktično svih vrsta tereta. Zbog toga, između ostalog, nalazi široku primenu i u poljoprivrednoj tehnici.

Da bi se pojednostavilo razumevanje funkcionisanja često veoma složenih hidrauličkih sistema, oni se predstavljaju pomoću odgovarajućih šema, a njihove komponente primenom pripadajućih grafičkih simboličkih oznaka.

U ovom radu su predstavljeni grafički simboli hidraličkih razvodnih ventila, kraće nazvanih hidraulički razvodnici, koji čine jednu veoma važnu podgrupu hidrauličkih ventila.

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HYDRAULIC SYMBOLS – PART FOUR: DIRECTIONAL CONTROL VALVES

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Abstract: The mechanization of a wide variety of production processes and operations in modern primary agricultural production, transport, storage and the accompanying food processing industry can hardly be accomplished without automation. In most cases, production efficiency and environmental sustainability require, among other things, accurate control of the flow of energy within the installations, work machines, devices and mechanisms used. From the point of view of the theory of automatic control and regulation, the elements of the engaged technique: machines, devices and mechanisms represent the objects of control. The controlled routing and optimal delivery of energy to desired management facilities is, as a rule, very rarely uniform, as it must have correctlyaligned timing with the current variable requirements of the production or operation process, which often change quite unpredictably over the time.

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The required amount of energy can be transferred to consumers in agriculture through the application of appropriate mechanical, electrical, pneumatic or hydraulic systems, as well as with their combinations.

All existing kinds of energy transmission systems have certain advantages and disadvantages, with a common requirement for appropriate controls. In the focus of interest of this paper are the graphic symbols of the directional control valves for hydraulic transmission and control, designated as hydraulic directional control valves, or shorter, the hydraulic distributors.

Key words: hydraulics, directional control valve, symbol, scheme, agricultural engineering

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SMART SOLUTION FOR SAFE AND LONG-LASTING OPERATION OF AGRICULTURAL EQUIPMENT

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Abstract: Nowadays the increasing of the efficiency of agricultural production and the increasing of crop yields cannot be achieved without modern digital technology and smart machines that are a part of it. With the spread of precision agriculture and the digitalisation next to the power machines the attached equipment is becoming smarter and smarter. Through permanent technological and IT development, it became possible to thoroughly monitor and analyse operating functions and parameters not only for the most important power machines such as tractors, combines and other, but also there are existing solutions for measurement - and related to that a collection and an analyse of data - of specific utilisation parameters for other attached equipment. All of these processed data are essential for making well-considered actions related to the production technology and the machine operating. They help us to gain information about the quality of machine operations of the technology, the environmental factors, or even about the state of attached working equipment and machines.

In this work, the vibration control system as smart solutions on the fail movers will be presented which are effective tools for the utilization of machines, for the precision machine work as well as for prolonging the machine life cycle.

Keywords*: Smart machines, Precision Agriculture, GPS, Data analysing, Vibration Control*

INTRODUCTION

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Precision Farming did become a popular research field since the 1980s. Technologies have been developed all over the world to help the farmers raise crop yields and make agricultural production processes more efficient. This new developments steadily contribute to a higher productivity and show that this technology is very important. Electronic assistance systems, such as autonomous track guidance or section control are state of the art when investing in new machines on crop farms. [3] This technologies are efficient tools to improve sustainability and productivity in farming. Precision Agriculture technologies offer solutions to produce more with less. It is one of the biggest revolution in agriculture [5]. Practically, Precision Agriculture technologies provide farmers with extra sensors which give them more information on how to manage natural variations. [8] It is technical, environmental and management innovation that has come out of the strategic product and technology innovation phase, while the whole management system is sharacterized by continuous renewal and new, higher added value added, [19]. The aim of precision, or site specific agriculture is to handle within field variability with input materials to achieve the highest and sustainable profit. [2] The approach mainly benefits from the development of technologies like GPS, GIS, computer technology, automatic control, remote sensing and advanced information processing [9], [22, 23, 24, 25] , and [28, 29], [30].

MATERIAL AND METHOD

Smart Farming in Agriculture 4.0.

“Smart Agriculture” and “Digital Farming” are based on the emergence of smart technology in agriculture. These technologies are using smart devices which consist of sensors, actuators and communication technology [13].

Digital systems, sensor techniques and technologies, remote sensing on different platforms, artificial intelligence including machine learning and deep learning, and in particular unmanned or quasi unmanned production systems are developing fast, and these are the tool for dynamic sustainability. In the future there will be the integration of these common players into smart transport, smart organisation, and smart landscape management by smart policy making. [12, 15, 16, 20]

The term Agriculture 4.0 should be logical upgrading of Smart and Digital Farming. There is some possibility about how will Agriculture 4.0 impact the supply chain by better using of IT:

– Optimize the inputs (Precision Farming).
– Manage mechanization more efficiently & use of energy resources.
– Enhance crop storage techniques & reduce crop losses.
– Provide better information about market demand & seasonal fluctuation.
– Improve transport & logistics services.
– Optimize retailer stocking & storage (less waste). [1]

The Smart Logistic System, integrated with the ERP (Enterprise Resource Planning), enables application of 4.0 industry approach.

Its intention is to enable same application to agricultural machinery, e.g. for logging the seeding and fertilizing process (lot, operator, date, quantity) and remote diagnostic by using IoT ready systems. The advantages of own production applied utilization of digital information to trace the different materials and automate their handling, are listed following objectives:

– to reduce the material handling;
– to reduce the inventory failures;
– to implement flexibility with discipline;
– to find one place for everything and everything in its place;
– to set a FIFO (First In First Out) rule;
– to implement the material traceability. [17]

Automated data mining and -interpretation is becoming a critical element of agricultural industrial research. [10] Developments in agriculture which mine data and act almost autonomously on basis of these data can be summarized by the term “Agriculture 4.0” [6].

Some Precision Agriculture diagnostic technologies are already highly affordable and thus available to smaller farms thanks to smart phones or tablets and their applications, like in our presented study. Such applications can directly signal a problem on the field or connect to an online service for further probing. [8]

Devices for Precision Farming in grassland

In comparison to its widespread implementation on arable farms, Precision Farming in grassland is used rarely in practical farming. There was some efforts to measure the quantity of harvested grass to, amongst other things generate yield maps. Demmel et al. examined a weighing system in a conveyor belt, mounted at the rear part of a mower. [7] Kumhála et al. used methods to measure forage yield known from choppers or harvesters. They equipped a drum mower with a torque sensor and a curved impact plate (behind a mower conditioner) which was hit by the mowed grass. [14]

Some small smart applications already found their way into practice like a torque sensor for warning the driver if the rotation of the mower and the rotation of tractors power take off (PTO) distinguish too much to give him assistance for an optimum velocity and motor speed.

The Company INO Brezice d.o.o.

A Slovenian company INO Brežice produces a variety of mulching machines, vibrating subsoilers, fertilizer spreaders. Among the company's innovative products are so-called "Smart Solutions" which ensure a safe and efficient operating of their basic products:

- flail mowers by means of continuous measuring vibrations and detecting the outstanding ones,
- fertilizer spreaders and vibrating subsoilers by efficient specific electronic control of operating. [18]

RESULTS

Basic description of INO Vibration Control

The Vibration Control System is a smart solution based on IoT principal, which consists of INO flail mower, sensor, smart mobile device and web application. It offers to the user an online information about working conditions for professional agricultural and communal machines. The main purpose for using INO Vibration Control is to control vibrations on the machine that means flail mower, arm mower or similar (Figure 1.). The sensor is measuring the level of vibrations which are sent to the mobile device. The mobile device stores GPS coordinates, a time stamp and x, y, z axe vibration levels and temperature through all working process for each second.

Figure 1: The position of the vibration sensors on the working machines, actually on the flail mower machine [11].

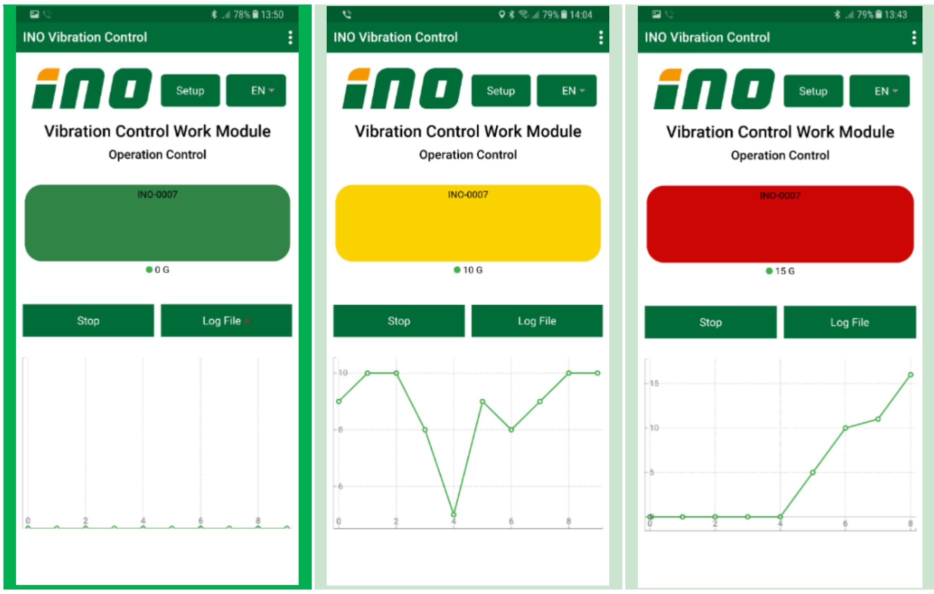
Innovation character

The goal of this system is to control the level of vibrations on flail mowers and consequently also on other machines, used for public utilities and for agricultural land cultivation, where the level of vibration in allowed area is one of the key features for correct, safe and long-lasting operation. Data compilation, collection of information is continued also in the direction of other telemetric information for the purpose of work control on cultivated land, data import from the phone, drawing-up of the surface in online graphic folders and keeping track of various attributes on an individual cultivation area, e.g. number of mowing, amounts of yield, fertilization, quantity, working temperature, speed of movement, location, etc.

Usability and advantages of system are globally as follows:

- control of machine operation,
- control of the operator's work,
- measuring productivity,
- communication between sensor and mobile device without vendor lock limitations
- online vibrations control level to enable safe, long-lasting operation and to decrease the maintenance costs
- mobile application for Android and iOS system

- telemetric data for determination of productivity level of the end user (tractor operator)
- simple Enterprise Resource Planning web based application
- useful analytical synthesis data for the extension of the warranty
- independence from different payable systems,
- saving measured data,



The machine is working in the expected level of vibrations	*The machine has reached the margin value of vibration*	*The vibration level of the machine has been exceeded*

Figure 2: Three level of vibrations, normal, marginal, and excessive, showing on the mobile phone, [11].

The program package is developed for different users:

a) operators-tractor drivers
- alert if the engine hits something
- alert if too high vibrations are on the engine (see Figure 2.)
- alert when low battery

b) supervisors at the desk:
- too high vibrations are on the engine
- engine is working in wrong time and/or on wrong area
- the exact place where the engine is working in the exact time

c) analysts-reporters:
- full report and analyse of working productivity including of working time and stops, working area, vibrations and alerts for each engine, details of surface covering, tracking and so on
- Application with program package without use the sensor, adapted to the buyer's needs (possible all up-mentioned data except vibrations) [21]

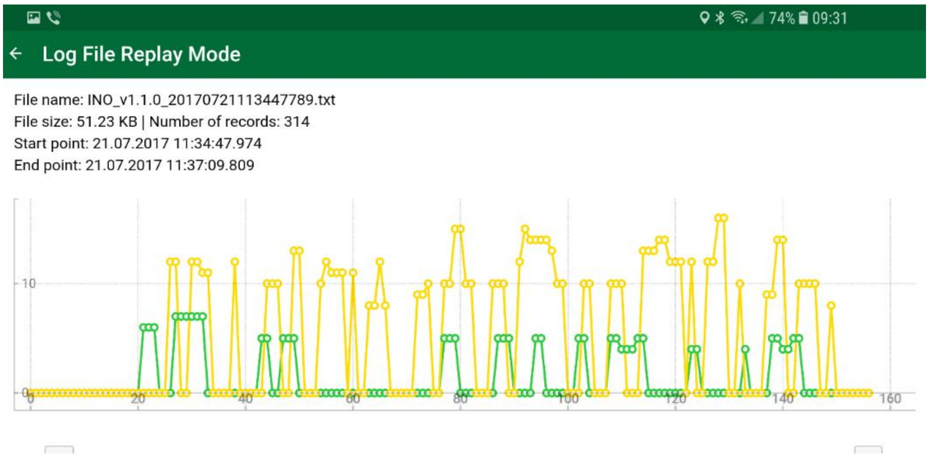


Figure 3: The history of the measured data on the Mobile Phone Screen [11]

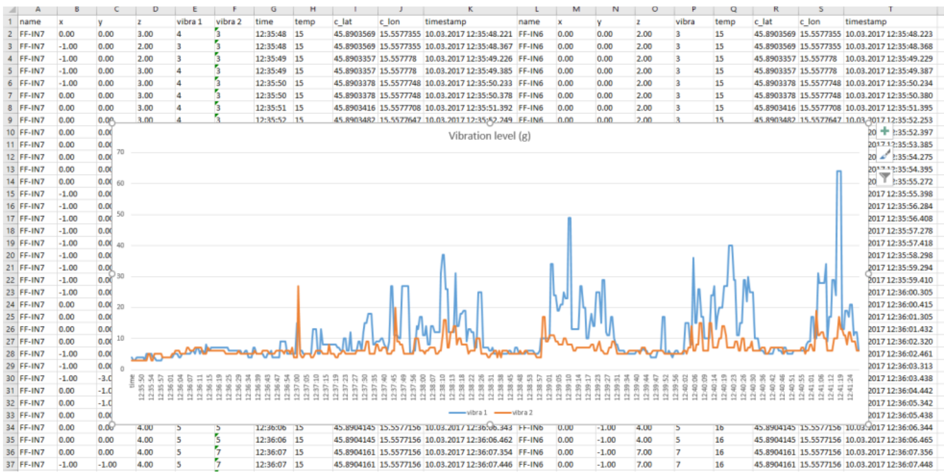


Figure 4: The history of the measured data on the Computer Screen, [11].

The mobile application could provide the user with the next information:
- Emergency SMS service (send SMS with current location to selected contact)
- Send SMS for detection of machine stop (to selected contact)
- Send SMS for excessive vibrations (to selected contact)
- Option for use only as GPS tracking (no INO sensors needed)
- Show on Map for Log Files (with vibration data markers) [21]

The measured sensor data can be stored to the mobile device. The user can read stored data for each second of recording:

GPS coordinates, vibration levels by X, Y, and Z axis, temperature and exact time. Stored data can be exported to another device or computer and later analysed in one of the required applications (for example: MS Excel), or can be viewed directly on a mobile device. (Figure 3., 4.)

CONCLUSIONS

For small, medium-sized, and for the large-scale farm machinery too, the above-mentioned Smart Solutions prove to be beneficial for efficient work, professional utilization of machines, and for minimizing the production and mechanization costs.

A common feature of systems described in this article is that they can be operated independently from the tractor's ISOBUS system. Both, the controller as well as the data collecting interface can be operated autonomously using their own system by means of a mobile phone or tablet device that can be controlled via wide spread accessible mobile application.

It is very important to mention that there are some advantages of IT, but some problems as well. Most significant are those related to putting systems into the operation and fighting with malfunctions. One of specific problem is coupling the tractors and implements by using different stages of ISOBUS. That means, full commercial maturity of compatibility of ISOBUS is still in front of us. [4]

The design of these electrical systems can also be realized by an individual, innovative medium-sized machine manufacturing company, as it is shown in the presented work.

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PAMETNA REŠENJA POLJOPRIVREDNE OPREME ZA SIGURNO UPRAVLJANJE NA DALJINU

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Sažetak: U današnje vreme povećanje efikasnosti poljoprivredne proizvodnje i povećanje prinosa useva ne mogu se postići bez priemne savremenih digitalnih tehnologija i "pametnih" mašina. Sa većom primenom precizne poljoprivrede i digitalizacijom, pored pogonskih mašina, i priključna oprema i mašine postaju sve "pametnije". Kroz stalni tehnološki i informatički razvoj, postalo je moguće detaljno nadgledati i analizirati radne funkcije i parametre, ne samo pogonske mašine, kao što su traktori, kombajni ili druge slične, već i postojeća rešenja koja uključuju merenje i analizu podataka i specifičnih parametara upotrebe za priključenu opremu i mašine.

Svi dobijeni i obrađeni podaci sa sistema mašina su od suštinske važnosti za dobro i uspešno korišćenje proizvodne tehnologije u radu mašine.

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Merni i kontrolni sitemi na mašinama pomažu da se dobiju: informacije o kvalitetu rada mašina u primenjenoj tehnologiji, faktorima životne sredine ili čak stanje i ispravnost rada priključene radne opreme i mašina.

U ovom radu je predstavljen sistem za daljinsku kontrolu i merenje vibracija na mašinama, kao pametno rešenje za pokretače (i uzroke) kvarova koji su efikasno sredstvo za korišćenje mašina, precizan rad i time produženje životnog ciklusa mašine.

Ključne reči: *pametne mašine, precizna poljoprivreda, GPS, analiza podataka, kontrola vibracija*

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EVALUATION OF UNIFORMITY AND WATER CONVEYANCE EFFICIENCY OF SPRAY TUBE IRRIGATION SYSTEM

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Abstract. Irrigation water is one of the limited resources and need to be managed efficiently in order to meet crop water requirement. Thus, water resources have to be utilized in such a manner as to protect and conserve the available water reserves in the most efficient way as possible to prevent unnecessary losses and water wastage. In view of this, the research evaluates the uniformity and water conveyance efficiency of spray tube irrigation system using sixty catch cans at different spacing intervals of 0.5 m x 0.5 m, 1 m x 1 m, 1.5 m x 1.5 m and finally with 2 m x 2 m. The results shows that value of Christiansen's coefficient of uniformity (CU) ranges from 87% to 92%, distribution uniformity (DU) ranges from 79% to 88% and scheduling coefficient (Sc) ranges from 1.13 to 1.27. Efficient performance and delivery of the spray tube irrigation system is envisaged to help cut down operational cost, water losses and to increase crop yield.

Keywords: *Spray tube irrigation, Uniformity, Water, Efficiency*

INTRODUCTION

Historically, early irrigation works were typically implemented to ensure human physical survival. In the absence of large populations, industries and recreation, there was not much competition for water except among neighboring irrigators sharing the same source of water.

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As human activities increases, engineers also build upon improving irrigation system, the chief concern was production of crop according to Clemmens *et al*. [1].

According to Ismail and Ozawa [2] in their research stated that in the arid and semi-arid as well as tropical regions, water shortage is a normal phenomenon and seriously limits agricultural potential. Water is one of the limited resources and need to be managed efficiently in order to meet the crop water requirement.

Thus, water resources have to be utilized in such a manner as to protect and conserve the available water reserves. In irrigated agriculture, this will be made possible through the effective management of water consumption [3].

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed throughout system pipes usually by pumping. It is then sprayed into the air through spray tube so that it breaks up into small water drops which fall to the ground. This has brought about the use of spray irrigation system which evenly distributes the water in a form of spray with the use of spray tubes. In the spray tubes irrigation method, water is sprayed into the air and allowed to fall on the ground surface in a form resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or small holes.

According to Yuan *et al*. [4] sprinkler irrigation systems with poor uniformity results in reduced yields due to water stress as well as water logging which contribute to an increase in the cost of irrigation and other related issues. Modern spray tube irrigation technologies usually convey water through pipes hence resulting in less water wastage. Spray tube irrigation systems seem to have large potential for improving water use efficiency of crops. Spray tube irrigation produces positive yields in relation to water savings and increases crop productivity, but one of the concerns is the uniform distribution, which is the spatial distribution irrigation applied in a regular way throughout the area in which the water is needed. Irrigation uniformity is an important performance characteristic of the spray tube irrigation system and is necessary paramount when evaluating the performance of the system. Spray tubes properly spaced will respond to a relatively uniform application of water over the irrigated area. According to Tim and Zoldoske [5], uniformity is how evenly a sprinkler delivers water over the ground. The distribution uniformity of a system has an effect on the system's application efficiency and on the crop yield [6, 7, 8, 9]. Irrigation systems with poor distribution uniformity experience reduced yields due to water stress and/or water logging [1]. Poor distribution uniformity also increased financial and environmental costs. Nutrients can be leached out of the soil due to excess water being applied to overcome poor irrigation uniformity; this will increase fertilizer costs and pumping costs, and may have environmental impacts if the excess runoff and deep percolation are contaminated with nutrients [8].

The distribution uniformity of an irrigation system depends both on the system characteristics and on managerial decisions [10]. The issue of uniformity and efficiency of spray tube irrigation system has still not been properly addressed mostly with spray tube irrigation system. This duels to the fact that uniformity and efficiency assessment is very important when it comes to crop water management and performance. It is therefore of a paramount interest to evaluate spray tube irrigation systems based on their ability to establish uniformity in water application to identify run times that minimize dry areas.

It is in the light of this that this research was carried out to generally determine the uniformity and water conveyance efficiency of the spray tube irrigation system using different spacing intervals of catch cans.

METHODOLOGY

Field experiments were conducted during the dry seasons from December to February of 2018-2019. at a farmers Farm in the Central Region of Ghana. The experimental area has a semi-arid climate with wet season and hot dry season. Table 1 below shows the soil physical and chemical properties of the experimental site.

Table 1: Soil Physical Properties

Bulk density (g/cm^3)	*Particle density (g/cm^3)*	*Pores %*	*P^H*	*Sand %*	*Silt %*	*Clay %*
1.34	*2.48*	*48*	*5.3*	*75*	*20*	*5*

The land was first cleared with the use of cutlass to give an open space and to enable an easy working field. The grasses and stumps were carried off the farm leaving only soft weeds on the surface of the farm as a mulch to conserve moisture and enable easy installation of the irrigation system. The farm was left unploughed (minimum or zero tillage practices) and leveled.

Installation of the System

The spray tube irrigation system (Figure 1) is made up of the following features that come together to form the system; the pumping machine, two inches PVC pipes (Main pipes), Irrigation spray tubes, The valves (main valve and the spray tube valves), PVC suction intake pipe and the end pegs.

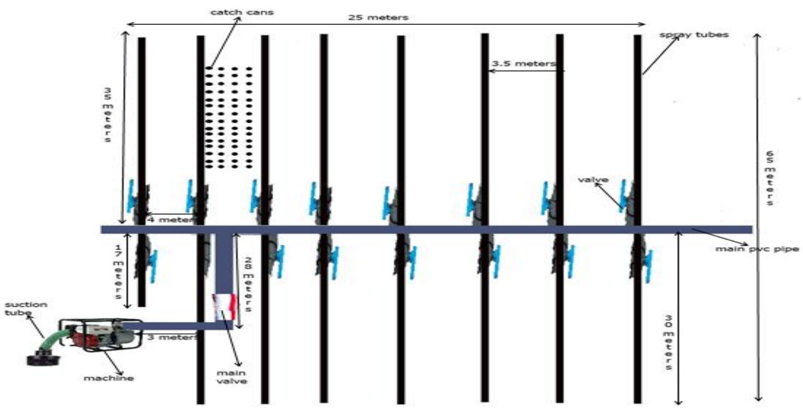

Figure 1: Experimental field layout of Spray tube irrigation system

The source of water was first cleared open to enable the easy implantation of the pump suction intake hose into the water source. The dimensions of the land area were taken to determine the total land size of the area which was 1625 square meters. The suction intake hose with the Strainer fitted was connected to water pump machine and the machine was then connected to the outtake (discharge port) which was step down from the three inches to two inches PVC pipes which is the main pipe. The pump machine applied suction pressure which pulls water from the sources through the suction intake hose to the machine and through the outtake. The pump machine was set to deliver a constant volume of 500 litres per minute and WCE was calculated using the volume of water delivered within one hour at each spacing interval. The outtake was made up of two inches PVC pipe which were glued together to form a long pipe which is the main pipe.

From the out take (discharge port) at a distance of three meters along the main line was a main valve which controls the flow back of water out of the system. The main pipe was curved left at an angle of 90º along the length of farm. At a distance of twenty eight meters, the pipe was also curved rightwards at an angle of 90° across the length of the farm. The valves holes were bored through the main PVC pipe at an interval of 3.5 meters. The valves were fitted to the main pipe with the help of valves rings at both holes of pipe. These valves regulate the movement of water into the irrigation spray tubes. The spray tubes were then connected to the valves with the perforated hole facing upwards. The spray tubes were laid along the farm and pegged at ends of the farm which help them to lie straight along the measured dimension. The pegging was done at an interval of 3.5 meters as the spacing on the main pipe. The ends of the main pipe were closed to create a pressure build up within the spray tube for effective spraying.

Uniformity Test Experiment

The uniformity experiments were carried out with catch cans (Figure 2) of the same size and diameter. A total of sixty (60) catch cans were used. A portion was selected in between the spray tubes where the experiment was carried out. The catch cans were first distributed evenly in the farm using a spacing of half (0.5) meter by half (0.5) meter interval between the catch cans and it was represented by (S_1). The catch cans were placed with their openings facing upwards to collect the water. The machine was powered and the system was set to run for an hour with a constant pressure 30 psi and discharge rate (500 liters per minute) and after then the volume of water collected in each catch can was measured and recorded. With the same intervals the experiment was repeated three times represented as R1, R2, and R3.

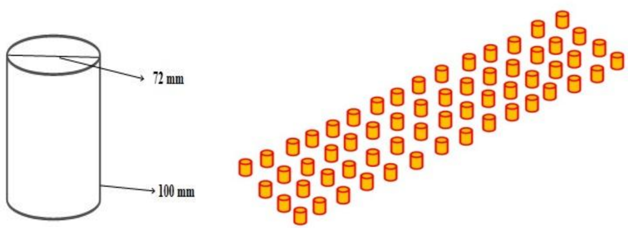

Figure 2: Catch cans layout

The experiment was carried out with the same number of catch cans using the same pressure from the pump and discharge rate but with an interval of one (1) meter by one (1) meter apart represented as (S_2); one and half (1.5) meters by one and half (1.5) meters represented as (S_3) and with a spacing interval of two (2) meters by two (2) meters of the catch cans represented as (S_4). Each spacing was replicated three times denoted as R1, R2 and R3 and the volume water collected in each catch can was measured and recorded.

Christiansen's coefficient of uniformity (CU) was expressed as a measure of the absolute difference from the mean divided by the mean expressed as a percentage below:

$$CU = 100\left[1 - \frac{\sum_{i=1}^{n} |X_i - \bar{X}|}{n\bar{X}}\right] \quad (1)$$

Where is :

X_i - water depth collected from the i^{th} catch can, mm/h;

$\bar{X}$ - mean water depth collected in all catch cans within the area, mm/h;

n - the total number of catch cans in the area under consideration.

The distribution uniformity (DU), proposed by Merriam and Keller (1978) was also computed by dividing the mean low quarter caught in the cans by the average depth caught in all the cans expressed as a percentage. Their equation is as follows:

$$DU = 100\left[\frac{Dlq}{\mu}\right] \quad (2)$$

Where is : DU - distribution uniformity, %

Dlq - mean of the lowest one-quarter of the measured depths, mm.

The scheduling coefficient (Sc) also represents the ratio of area receiving the least amount of water to the average amount of water applied through the irrigation area. This value of measurement is considered very important which enables us to find the critical area in the water application pattern [7].

Mathematically, Sc is defined as:

$$Sc = 100\left[\frac{1}{DU}\right] \quad (3)$$

The entry area of the Catch can is the upwards opened area of the catch can which enables it to trap water that is sprayed up by the spray tube. The wider the entry area, the higher the volume of water that can be trapped and the smaller the entry area, the smaller the volume of water that would be trap by the catch can. The catch cans were cylindrical in shape with an inside diameter of 72 millimeters and a height of 100 millimeters.

The entry area is calculated with the formula;

$$Area = \pi r^2 \quad (4)$$

Water Conveyance Efficiency (WCE)

Water conveyance efficiency is the ratio of volume of irrigation water delivered by the distribution system to the water introduced into the system.This takes into account the conveyance or transit losses and is determined from the following expression:

$$\mathrm{WCE} = \frac{\mathrm{Wf}}{\mathrm{Wi}} \tag{5}$$

Where is:
WCE - water conveyance efficiency
Wf - volume of irrigation water delivered by the distribution system
Wi - water introduced into the system

$$\mathrm{WCE} = \frac{\text{volume of irrigation water delivered by a distribution system}}{\text{water introduced into the system.}} \times 100 \tag{6}$$

Statistical Analysis Results

Data collected was subjected to the analysis of variance (ANOVA) procedure using GenStat Software Statistical tool to investigate whether there were statistical differences in the parameters studied.

RESULTS AND DISCUSSION

Water Distribution Pattern

Water collected in catch cans depicts the water distribution pattern, volume of water (ml) captured in each catch can was measured using a volumetric flask, hence, the pattern of distribution as observed in Figure 3. Water collected was generally higher at spacing interval s_1 and it generally decrease to lower values at s_4 .

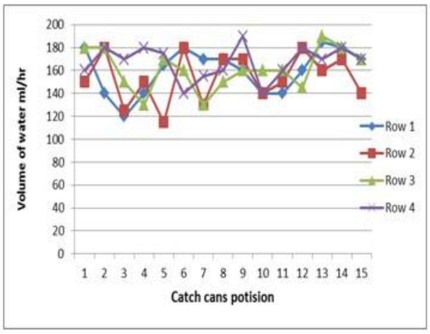

Figure 3a: Water distribution pattern in catch cans at S_1

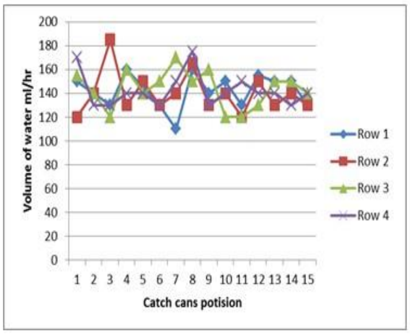

Figure 3b: Water distribution pattern in catch cans at S_2

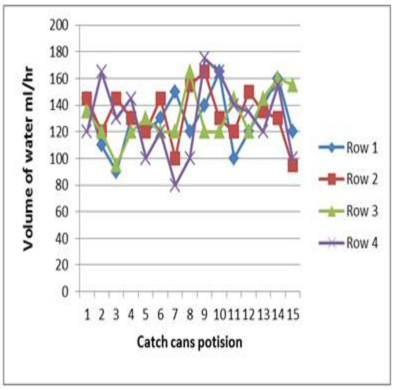

Figure 3c: Water distribution pattern in catch cans at S_3

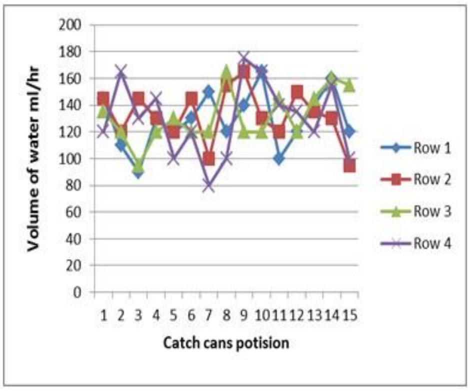

Figure 3d: Water distribution pattern in catch cans at S_4

Figure 3a, 3b, 3c and 3d shows the water distribution pattern where 3a shows the water distribution pattern for S_1, 3b represents the water distribution pattern for S_2, 3c represent the water distribution pattern for $S_3$and 3d represent water distribution pattern for S_4. The mean water distribution in catch can observed in Figure 3a, 3b, 3c and 3d were 160.58 ml, 14 ml, 130.75 ml and 125 ml respectively. As observed in the water distribution pattern curves, generally, catch cans volumes differences in 3a and 3b are very close with higher mean values implying that much water was collected by catch cans placed in these replications. But in 3c and 3d, the mean value decreased due to the wider spacing interval used thereby spreading out the line graph. Spacing interval S_1 relatively collected more water than that of S_2, S_3 and S_4, because majority of its catch can volumes peaked at 180 ml whereas only one catch can had its peak at 180ml in S_2. At S_3 and S_4 catch can volumes are less than 180ml.

These variabilities in pattern of water distribution could be attributed to the differences in spacing interval used for the spray tube as well as wind distortion which usually brings about a reduction in the wetted area [12.13].

Coefficient of Uniformity (CU)

Several researches have been done on uniformity and efficiencies and they vary from irrigation system to irrigation system. Coefficient of uniformity was calculated using Christiansen formula [14]. Analysed data in Table 2 indicates that there is no significant difference within the treatment s_1 coefficient of uniformity (CU) but there exist significant differences between the treatments s_1 to s_4 with the exception of replication three which has no significant differences between the treatments from s_1 to s_4 and this may be as a result of variations in pressure distribution within the spray tubes, wind speed and direction and spray tube spacing.

Table 2: Coefficient of Uniformity

Spacing	*Coefficient of Uniformity (CU)*		
	R1 (%)	***R2 (%)***	***R3 (%)***
S_1	*91.74a*	*91a*	*90a*
S_2	*90.49ab*	*91a*	*89a*
S_3	*86.6ab*	*90ab*	*87a*
S_4	*86.13b*	*87b*	*87a*

Distinct letters in the column indicate significant differences according to ANOVA test (p≤ 0.05).

All the treatments with their replications obtained a coefficient of uniformity ranging from 80% to 95% which is excellent, hence the system supplies water uniformly. Significant differences that exist between treatments may be due to wind speed and direction as well as the layout of spray tube.

With respect to the values obtained above, it is within the satisfactory range. According to Michael [13], a satisfactory uniformity coefficient should be 85% or more. Dwomoh *et al*. [15] also recommended uniformity values under low and moderate wind speed conditions as ranging between 80% and 90%.

Distribution Uniformity (DU)

Distribution Uniformity (DU) results in Table 3 also indicates that there is no significant difference within replications of treatment S_1.

Table 3: Distribution Uniformity

Spacing	*Distribution Uniformity (DU)*		
	R1 (%)	***R2 (%)***	***R3 (%)***
S_1	*88a*	*86a*	*86a*
S_2	*84b*	*85a*	*81b*
S_3	*80d*	*84a*	*79b*
S_4	*81c*	*81a*	*79b*

Distinct letters in the column indicate significant differences according to ANOVA test (p≤ 0.05).

There is no significant difference between the treatments s_1 to s_4 for replication two but there exist a significant difference between the treatments s_1 to s_4 for replication one and replication three. In Table 3, majority of distribution uniformity (DU) falls within the recommended range; 85% and above, and very good ranges (80% and above) with few of them been above 70% which is also good. According to the literature, Solomon (1988), Keller and Bliensner [16], Jorge and Pereira [17] as well as Rain Baird [18] found that the uniformity of distribution ranged from 75 to 85% which is widely accepted. Significant differences in DU were due to the effects of wind and the position of the spray tube holes.

Scheduling Coefficient (Sc)

In Table 5, the analyzed data for scheduling coefficient (Sc) shows that there is no significant difference that existed between the treatment (s_1 to s_4) in replication one but significant differences existed between the treatments for replication two and three.

Table 5: Scheduling Coefficient

Spacing	***Scheduling Coefficient (Sc)***		
	R1 (%)	***R2 (%)***	***R3 (%)***
S_1	*1.13**a***	*1.16**c***	*1.16**c***
S_2	*1.20**a***	*1.18**bc***	*1.23**b***
S_3	*1.25**a***	*1.19**b***	*1.27**a***
S_4	*1.24**a***	*1.23**a***	*1.27**a***

Means with the same letters are not significantly different according to ANOVA test (p≤ 0.05).

The scheduling coefficient of treatment s_4 shows no significant differences between the replications. The values of scheduling coefficient depend on the values of distribution uniformity. Scheduling coefficient value of less than 1.3 is considered as satisfactory according to Yuan *et al.* [4] who conducted their research and concluded a scheduling coefficient (Sc) values which ranged from 1.13 to 1.42 for different pressure and height conditions. The values obtained above for all set of replication falls within the range recommended cited by other authors.

Water Conveyance Efficiency (WCE)

Table 6 below shows the volume of water delivered to the farm at various treatments and their replications. Volumes of water delivered to the field by the irrigation system were measured to be different between parameters observed.

In Table 6, the water conveyance efficiency at s_1 shows no significant differences within the replications, at s_2 there is no significant difference within the replications.

Table 6: Water Conveyance Efficiency

	Water Conveyance Efficiency		
Spacing	***R1 (%)***	***R2 (%)***	***R3 (%)***
S_1	*87**b***	*88**b***	*87**b***
S_2	*97**c***	*98**c***	*95**c***
S_3	*80**ab***	*80**a***	*84**b***
S_4	*77**a***	*83**a***	*79**a***

Distinct letters in the column indicate significant differences according to ANOVA test ($p \leq 0.05$).

But in s_3, there exist significant differences within the replications and in s_4, there is no significant differences within the replications. The table also indicates that, there exist significant differences between treatments ($s_1 to\ s_4$). Water conveyance efficiency of a system take into consideration the amount of water the system can deliver to farm considering all loses that will occur along the transportation channel. Based on the values in Table 6, there exist some variations that are as a result of leakages in the pipe and spray tubes valves [19]. Considering all the efficiencies, the system is good, hence loses are minimal.

CONCLUSION

Uniformity assessment helps the farmer to identify the cropping method to use to maximize crop yield since this help to choose the crop density which is most appropriate and suitable for the available soil water. Coefficient of Uniformity (CU) values ranged from 87% to 92%, Distribution Uniformity (DU) values ranged from 79% to 88% and Scheduling Coefficient (Sc) values ranged from 1.13 to 1.27 obtained for the different spacing used is within the recommended range. Hence the spray tube irrigation system distributed water uniformly. Also, the Water Conveyance Efficiency (WCE) values obtained ranged from 77% to 98% thereby indicating efficient water delivery by the system.

The spacing interval s_1 (0.5 meters by 0.5 meters) performed more satisfactory than the rest of the spacing intervals. Efficient performance and delivery of the spray tube irrigation is envisaged to help cut down operational cost, water losses and to increase crop yield.

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ISPITIVANJE UJEDNAČENOSTI I EFIKASNOST DISTRIBUCIJE VODE KOD SISTEMA ZA NAVODNJAVANJE SA RASPRSKIVAČIMA

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Sažetak. Voda za navodnjavanje je jedan od ograničenih resursa i sa njim se mora efikasno upravljati, da bi se zadovoljile potrebe useva za vodom. Zato se vodeni resursi moraju koristiti tako da se zaštite i sačuvaju raspoložive količine vode na najefikasniji način, i tako eliminišu nepotrebni gubici i rasipanje vode.

U ovom istraživanju se procenjuje ujednačenost i efikasnost distribucije vode sistemom za navodnjavanje sa rasprskivačima pomoću šezdeset uložaka u različitim intervalima rastojanja od 0,5m x 0,5m; 1m x 1m; 1,5m x 1,5m i konačno sa rastojanjem od 2m x 2m.

Rezultati ispitivanja rasprskivača pokazuju da se vrednost Christiansen koeficijenta uniformnosti raspodele vode (CU) kreće od 87% do 92%, uniformnost distribucije (DU) u rasponu od 79% do 88%, a koeficijent zakazivanja sistema (Sc) u rasponu od 1,13 do 1,27.

Predviđene performanse sistema i isporuka vode za navodnjavanje prema rasprskivačima pomažu u smanjenju: operativnih troškova, gubitaka vode, i znatno se povećava prinos useva.

Ključne reči: *navodnjavanje, rasprskivači, uniformnost, voda, efikasnost*

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ASSESSEMENT OF SITTING ANTHROPOMETRY OF MALE AND FEMALE TRACTOR OPERATORS IN ABIA STATE

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Abstract: The anthropometric body dimensions of the tractor operators in Abia state (Nigeria) where studied to obtain a database for their anthropometric body dimensions to enable the designers of tractors and agricultural equipment operated in sitting positions improve on their design in order to optimize their usage, enhance posture and comfort of the users and maximize output. Result revealed that the male agricultural workers have average hand length, hand breadth, arm reach from wall, elbow height, elbow rest height, grip strength, internal and external grip diameters, hand circumference, forearm length and forward grip reach of male agricultural workers are 161.05cm, 49.1cm,143.75cm,38.25cm,19.55cm, 8.65cm, 85.75cm,104.25cm, 24.9cm, 41.6kg, 4.7cm, 7.35cm, 7.35cm, 49.9cm and 75.2cm respectively while in that same order the female agricultural workers recorded 150.55cm,38.9cm,138.6cm, 36.45cm, 18.15cm, 7.2cm, 82.35cm, 100.4cm, 22.25cm, 40.25kg, 4.0cm, 6.7cm, 19.55 and 75.15cm respectively. Also result showed that the sitting height, sitting eye height, sitting shoulder height, hip breadth, knee height, buttock knee length, functional leg length, foot length of the male agricultural workers are 80.75cm, 81.8cm, 68.5cm, 54.0cm, 33.0cm,

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55.8cm, 49.7cm, 65.0cm, 57.05cm, 48.65cm, 95.25cm, 32.55cm, 14.35cm, and 66.05cm respectively; and the female in the same arrangement had 85.8cm, 65.59cm, 65.07cm, 41.38cm, 29.14cm, 49.14cm, 44.97cm, 56.06cm, 47.86cm, 36.58cm, 80.51cm, 27.53cm, 3.35cm and 79.19cm respectively.

Key words: *Anthropometric, dimensions, operators, tractors, sitting positions.*

INTRODUCTION

Engineering anthropometry deals with the application of scientific physical measurement method to human subjects for the development of engineering design standards. It includes static and functional (dynamic) measurements of dimensions and physical characteristics of the body as they occupy space, move and apply energy to physical objects, as a function of age, sex, occupation, ethnic origin and other demographic variables (Sanders and McCormic 1992).

Agrawal *et al.,* (2010) noted that anthropometric body dimensions play significant roles in human-machine interaction and that the overall working efficiency of human-machine environment and resultant discomfort has severe impact while using farm tools and machinery. They also noted that anthropometric dimensions vary considerably across gender, race, age, and that within a particular group, the anthropometry differs due to nutritional status and nature of work, and to achieve better performance and efficiency along with higher comfort and safety to the operators, it is necessary to design tools, equipment and workplaces keeping in view of the anthropometric data of the agricultural workers.

One major reason for low agricultural productivity in some agricultural regions is due to prevalence of traditional method of cultivation and lower mechanization level. Machines or tools manufactured without application of human factors or ergonomic principles are low in working efficiency and most times fail to reduce drudgery and increase discomfort of the operators. Ergonomics is the science which considers human characteristics, expectations and behavior in the design of things mainly used in environment (Sanders and McCormic , 1992). The ergonomic principles or human factors are considered in machine design to enhance effectiveness, efficiency, safety and comfort of the users/operators of the equipment. In most cases, constraints are been experienced in adoption of improved machineries being utilized in other parts of the country; the adopted equipment at times need to be modified before being introduced into other countries or regions to suit agricultural workers of the region for which body dimensions limits of local populations was required. To design any product for human use, engineers have to rely on anthropometric data, otherwise the resulting product may turn out to be ergonomically incompatible (Lewis, 1993; Hastegrave, 1986).

According to Mebarki and Davis (1990), anthropometric dimensions are one of the essential factors in designing machines and device. Gite and Yadav (1989), noted that the design and dimensions of agricultural tools and implements have great bearing on the body dimensions and physical built of the users, requiring compatibility essentially between machine devices and worker body dimensions. Dewangan *et al.,* (2005) suggested that the only way to fulfill this objective is to create database of anthropometric dimensions of the user population.

Gupta et al (1983) observed that most of the anthropometric data in India is limited to male agricultural workers; while it was discovered by Reddy *et al.,* (1994) that about 88% rural women working population is engaged in agricultural sector and stipulated that the value is nearly 50.2% of the total agricultural labour force in India. Dixit *et al.,* (2014) added that due to paucity of female anthropometric data, the anthropometric data of male workers are extrapolated to define women at work whenever necessary. Cox *et al*., (1984) opposed this assumption and said that such an approach is likely to be inaccurate due to obvious anthropometric, physiological and biological differences between male and female subjects. As earlier noted in this review, the body dimensions vary with age, sex, ethnic groups (Sanders and McCormick, 1992). According to Dixit and Namigial (2012),there is considerable difference between the anthropometric data of India and Western population emphasizing the need for generating anthropometric database for agricultural workers as it is not feasible practically to design equipment for an individual sex (male and female).

Based on the foregoing, this study was conducted to generate and analytically compare the anthropometric data of the male and female agricultural workers in the rural areas of south-eastern region of Nigeria. The data so generated will be compared with those of other regions of the western countries for the consideration of ergonomic design of agricultural equipment and machines which will suit the male and female agricultural workers in the study area to enhance effectiveness, efficiency of production, safety and comfort of the users/ operators of the machines.

The placement of different controls in a tractor is a complex task for the designer and requires the anthropometric characteristics of the target population (Yadav *et al*., 2000). The efficiency and comfort of the operator can be improved with properly designed tractor workplace. The dimensions of the seat, location of controls and access/exit provisions are the parameters where anthropometric data can provide help in matching the workplace according to the user's capabilities and to the physiological reach of the operator.

For design purpose, Yadav *et al.,* (2000) stipulated that either one of the boundary value (5^{th} or 95^{th} percentile) or the mean values is used depending upon the dimensional element. Anthropometrically, the authors noted that seat height from foot rest to suit female Indian 5^{th} and 95^{th} percentile population would be within the range of 37.0 to 40.0cm. While in the case of male Indians would be within the range of 41.6 to 47.1cm. If the equipment is to be operated by women, the anthropometric data of the female must be considered in the design along with men anthropometric data. Anonymous (1996) revealed that most Indian tractors are manufactured to suit the anthropometric measurements applicable to the countries where the tractors are designed.

The objective of this research work is to develop an anthropometric database for agricultural field machinery operators in Abia state and any other region with similar anthropometric dimensions for a better design of farm machinery to suit them for safety, comfort and efficient operation in sitting positions.

MATERIALS AND METHODS

Samples for the Study

The samples for the study consist of 400 tractor operators (200 each of male and female) within the age limit of 18- 50 years selected randomly from different areas of Abia states.

Apparatus Used

The following anthropometric equipment was used for the study:

1. An anthropometer was used in measuring various body dimensions at sitting postures.
2. Weighing balance of 1kg sensitivity and 150kg capacity was used for measuring the body weight of the subjects.
3. Measuring tape was used for measuring lengths and widths of some body parts.
4. Vernier caliper was used for measuring the internal and external grip diameters.
5. Grip strength dynamometer was used for measuring grip strength.

Anthropometric Measurement Procedure/Data Collection

Thirteen (13) anthropometric body dimensions considered useful for design of agricultural equipment/machines operated in sitting position were measured. The standard anthropometric definitions of measurements and techniques used by Pheasant (1986) as applied by Onuoha *et al.,* (2012) were adopted in the study. Prior to the collection of the data, some persons (male and female) were trained on how to take measurements of body dimensions (Oduma, 2017). The process for data collection was properly explained to the trained personnel so as to maintain accuracy in their measurements and to seek full cooperation from the subjects (Agrawal *et al*., 2010 and Dixit *et al.,* 2014). Measurements were taking in sitting postures. In process the subjects were asked to sit with their body vertically erect, while their shoulders and head touch the vertical plane and their feet completely touch the base platform. In all the measurements with anthropometer, the subjects were bare footed. The measuring tape was used to measure waist breadth, waist circumference, foot length, and hand breadth across thump, hand height at metacarpal etc. For every subject, measurements of a given body dimension was replicated for five times and average value of the dimension was taken as the real dimension; this is to avoid error in the measurements.

Data Analysis

The data collected from the measurement was analyzed using range, mean, standard deviation, percentile values (5^{th}, 50^{th} and 95^{th} percentile) and percentages. The percentile was used to adjudge the proportion of a group of individuals who exceed or fall below some possible design limit.

Apart from the mean; the 5th and 95th percentile values of body dimensions were calculated to decide various possible sitting design limits of farm machinery and work place layout to be operated by tractor operators (Agrawal 2010).The percentage was used to determine the percentage difference or variation in the set of data obtained for male and female operators (Oduma, 2017).

The percentile was calculated from the formula suggested by Kothari (2013) as used by Oduma (2017).

$$X = \mu + ZQ \tag{1}$$

Where is: X = Percentile

μ = mean values

Q = standard deviation

Z = constant = -1.645 for 5th percentile; 0 for 50th and 1.645 for 95th percentile

The standard deviation was computed using the expression:

$$S = \sqrt{\frac{\Sigma f(Y-\bar{Y})^2}{N}} \tag{2}$$

Where S = standard deviation

Σ = symbol of summation

f = frequency

Y = measures of body dimensions

Ȳ = mean values of body dimension given as

$$\frac{\Sigma fY}{N} \tag{3}$$

N = number of subjects measured

RESULTS AND DISCUSSION

Table 1. Anthropometric dimensions of tractor Male operators in Abia state

Body dimensions	Male						
	Range				Percentiles		
	Min	max	Mean	S.D	5^{TH}	50^{TH}	95TH
Hand length	15.2	23.9	19.55	3.8	13.30	19.55	25.81
Elbow height	90.4	118.1	104.25	4.9	96.19	105.25	12.31
Elbow rest height	16.7	33.2	24.95	3.3	19.52	24.95	30.38
Hand circumference	15.2	25.6	20.9	1.6	18.27	20.9	23.53
forearm grip reach	59.1	91.3	75.20	0.6	74.38	75.20	76.02
Sitting height	64.2	99.3	81.75	5.1	73.36	81.75	90.14
Sitting eye height	56.8	80.2	68.50	0.3	68.00	68.50	68.99
Sitting shoulder height	44.2	63.8	54.00	5.8	44.45	54.00	63.54
Hip breadth	28.6	37.4	33.00	0.6	36.41	33.00	33.99
Knee height	47.2	64.4	55.80	1.6	53.17	55.8	58.43
Buttock knee length	43.7	70.4	57.05	4.8	49.15	57.05	64.95
Functional leg length	80.3	110.2	95.25	7.0	83.74	95.25	106.77
Foot length	20.6	44.5	32.55	0.8	31.23	32.55	33.87

Table 1a: Anthropometric dimensions of tractor Female operators in Abia state

Body dimensions	**Female**						
	Range				**Percentile**		
	Min	**max**	**Mean**	**S.D**	**5TH**	**50TH**	**95TH**
Hand length	*14.60*	*21.7*	*18.15*	*3.2*	*12.89*	*18.15*	*23.41*
Elbow height	*88.50*	*112.3*	*100.4*	*3.8*	*94.15*	*100.4*	*106.65*
Elbow rest height	*14.20*	*30.1*	*22.25*	*3.1*	*17.51*	*22.25*	*27.00*
Hand circumference	*14.8*	*23.9*	*19.35*	*1.4*	*17.05*	*19.35*	*21.65*
forearm grip reach	*55.2*	*89.1*	*75.15*	*1.2*	*73.18*	*75.15*	*77.12*
Sitting height	*52.4*	*95.1*	*73.75*	*4.9*	*65.59*	*73.75*	*81.81*
Sitting eye height	*52.2*	*78.6*	*65.4*	*0.2*	*65.07*	*65.4*	*65.73*
Sitting shoulder height	*40.5*	*59.7*	*50.1*	*5.3*	*41.38*	*50.1*	*58.82*
Hip breadth	*25.2*	*34.4*	*29.8*	*0.4*	*29.14*	*29.8*	*30.46*
Knee height	*43.4*	*60.8*	*52.1*	*1.8*	*49.14*	*52.1*	*55.06*
Buttock knee length	*39.8*	*68.1*	*53.95*	*3.7*	*47.86*	*53.95*	*60.04*
Functional leg length	*78.1*	*105.3*	*91.7*	*6.8*	*80.51*	*91.7*	*102.89*
Foot length	*18.7*	*40.3*	*29.5*	*1.2*	*27.53*	*29.5*	*31.47*

Table 2: Effect of gender on the anthropometric dimension of tractor operators in Abia state

Sources of variation	DF	Sum of squares	Mean squares	F. cal	F. tab 5%
Gender	1	-70945.01	-70945.01	0.08[NS]	4.21
Body dimensions	13	507137.26	39010.56	0.04[NS]	2.03
Error	13	12051818.57	927062.97		
Total	27	12488010.82			

NS = Not significant

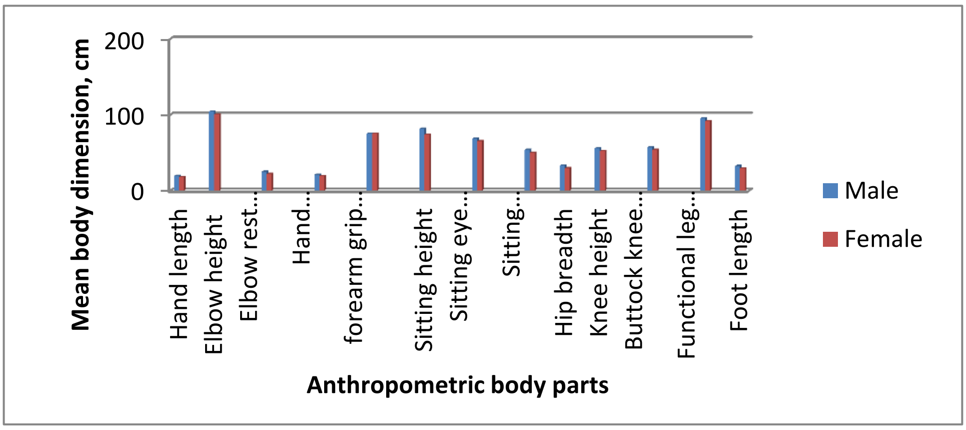

Figure 1: Mean Anthropometric body dimensions of Abia state male and female tractor operators

DISCUSSION

Table 1., and Table 1a., showed the body dimensions of Abia state male and female agricultural workers in sitting positions. Result revealed that the male agricultural workers have average hand length, elbow height, elbow rest height, hand circumference, and forearm grip reach of male tractor operators are 49.1cm, 38.25cm,19.55cm, 8.65cm, and 104.25cm, respectively while in that same order the female agricultural workers recorded 38.9cm, 36.45cm, 18.15cm, 7.2cm, and 100.4cm, respectively. Also result showed that the sitting height, sitting eye height, sitting shoulder height, hip breadth, knee height, buttock knee length, functional leg length, foot length of the male tractor operators are 80.75cm, 81.8cm, 68.5cm, 54.ocm, 33.0cm, 55.8cm, 49.7cm, and 65.0cm, respectively; and the female in the same arrangement had 85.8cm, 65.59cm, 65.07cm, 41.38cm, 29.14cm, 49.14cm, 44.97cm, and 56.06cm, respectively.

Figure 1., revealed the mean body dimensions of the male and female tractor operators in Abia state in sitting position. The figure showed that the mean body dimensions of the male are slightly higher than the female except in the hand length, hand circumference and forearm grip reach where they maintained a very close values of 19.55cm, 20.9cm and 75.2cm respectively for males and 18.15cm, 19.35cm and 75.15cm respectively for female operators. However, the discrepancies in the rest of the dimensions are very infinitesimal and could be ignored in tractor design.

The ANOVA of the effect of gender on the anthropometric body dimensions of Abia state male and female tractor operators (Table 2) revealed that there is no significant difference among the body dimensions of male and female tractor operators, hence P < 0.05. Thus, the body dimensions of the male and female in Abia state do not differ much, therefore, tools and equipment designed based on data collected can effectively be utilized by both male and female agricultural workers within the region, which is in agreement with the study of Agrawal (2010) and also observed by Oduma and Oluka (2017).

CONCLUSION

From the findings made, the following conclusions can be drawn about the study: The mean body dimensions of the male are slightly higher than the female except in the hand length, hand circumference and forearm grip reach where they maintained a very close values of 19.55cm, 20.9cm and 75.2cm respectively for males and 18.15cm, 19.35cm and 75.15cm respectively for female operators. However, the discrepancies in the rest of the dimensions are very infinitesimal and could be ignored in tractor design.

The ANOVA of the effect of gender on the anthropometric body dimensions of Abia state male and female tractor operators revealed that there is no significant difference among the body dimensions of male and female tractor operators, hence P < 0.05.

Recommendation: Based on the above conclusions, it is therefore recommended that study of anthropometric body dimensions should be extended to different geographical regions of Nigeria to guide the engineers or designers of agricultural equipment in designing and manufacturing the equipment to match the users and make them work in good postures and maximize their output.

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ANTROPOMETRIJSKA PROCENA SEDIŠTA TRAKTORA ZA MUŠKARCE I ŽENE U DRŽAVI ABIA (NIGERIA)

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Sažetak: Antropometrijske procene dimenzije korisnika karoserije traktora (muškarci i žene) u državi Abia (Nigeria) su proučavane zbog dobijanja baze podataka za dimenzije karoserije kako bi konstruktori traktora i poljoprivredne opreme bolje dizajnirali mesto (sedište i kabinu) gde operateri rade u sedećim položajima.

Dizajneri traktora tako mogu da poboljšaju svoj dizajn i optimiziju njegovu upotrebu i poboljšaju držanje i udobnost korisnika mašine za najveći učinak u radu.

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Rezultat istraživanja je pokazao da poljoprivredni radnici (muški) imaju prosečnu dužinu ruku, širinu ruku, dohvat ruku od zida, visinu lakta, visinu oslonca za laktove, čvrstoću držanja, unutrašnji i spoljni prečnik držanja, obim šake, dužinu podlaktice i opseg dohvata napred, imao je vrednosti 161.05cm, 49.1cm, 143.75cm, 38.25cm, 19.55cm, 8.65cm, 85.75cm, 104.25cm, 24.9cm, 41.6kg, 4.7cm, 7.35cm, 7.35cm, 49.9cm, odnosno 75.2cm. Istim redosledom parametara, žene poljoprivredne radnice imale su vrednosti: 150,55 cm, 38,9 cm, 138,6 cm, 36,45 cm, 18,15 cm, 7,2 cm, 82,35 cm, 100,4 cm, 22,25 cm, 40,25 kg, 4,0 cm, 6,7 cm, 19,55 i 75,15 cm.

Takođe je rezultat ispitivanja pokazao da: visina sedenja, visina preglednosti, visina kukova, visina kolena, dužina kolena, funkcionalna dužina nogu, dužina stopala muških poljoprivrednih radnika iznosi: 80,75cm, 81,8cm, 68,5cm, 54,0cm, 33.0cm, 55.8cm, 49.7cm, 65.0cm, 57.05cm, 48.65cm, 95.25cm, 32.55cm, 14.35cm, i 66.05cm, respektivno. Kod žena, isti raspored parametara ima vrednosti: 85,8cm, 65,59cm, 65,07cm, 41,38cm, 29,14cm, 49,14cm, 44,97cm, 56,06cm, 47,86cm, 36,58cm, 80,51cm, 27,53cm, 3,55cm, odnosno 79,19cm, respektivno .

Ključne reči: antropometrija, dimenzije, operatori, tractori, sedeće pozicije.

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NUTRIENT RELEASE PATTERNS FROM COMPOST, VERMICOMPOSTING, AND LONG-TERM EFFECT ON SOIL FERTILITY STATUS

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Abstract: The principal aim of this study was to examine the nutrient release pattern from two types of composts and long-term implications on soil fertility status. An incubation experiment was carried out in the laboratory to determine the nutrient release patterns from compost and vermicompost mixed with soil at different application rates of SC30, SC70, SC120 and SV30, SV70 SV120 respectively for 21 days. Initial pre-incubation analysis of the compost material used for the experiment showed that both the compost and vermicompost had high nutrient content. The results further revealed that the different rates of compost and vermicompost application to soil had significant influence on the slow, gradual release process, indicating the long-term effect the organic fertilizers could exert on soil fertility status

Key words*: Compost, Vermicompost, Nutrient release, Soil fertility.*

INTRODUCTION

The natural recycling of organic solid waste through composting is a management technique, which helps to provide balanced nutrients to crop roots and promote growth by augmenting the organic matter content of the soil. Numerous organic sources such as green compost and vermicompost have abundant nutrients that are considered better sources for sustainable crop production by increasing yields and growth of crops.

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Vermicompost refers to an organic fertiliser prepared as the vermicast from earthworms' feeding activity on waste materials mostly of biological origin [1].

It is regarded as one of the best sources of nutrients for plants, and helps to enhance the physicochemical characteristics of crops [2]. Studies showed that vermicomposting does not contain toxic enzymes, thus it is an ecologically friendly organic substance that produces positive effect on the biochemical processes of the soil, enhances soil quality, fertility, mineral content of its structure, aeration, textural properties and tilt thus reducing soil tendency to compaction [3]. Vermicomposting helps to build up water retention capacity of the soil due to its rich organic matter content, promoting nutrient absorption and root growth [4].

Field as well as laboratory experiments are required to evaluate the nutrient availability and efficacy of bio-fertiliser compost and vermicompost derived from oil palm wastes and residues. Such experiments are significant in view of the fact that the nutrient contents of organic fertilisers differ considerably [5].

A number of authors such as Chen, Lin and Yang [6] have focused attention on the potential application of nitrogen derived from animal dung. Granite powder has also been investigated and found to be a good source of slow-release K fertilizer [6]. However, further studies on the potential use of nitrogen from different sources such as compost and vermicomposting derived from palm oil waste in lieu of animal manure are required. Thus the objective of the present study was to determine the nutrient release pattern from two types of composts derived from palm oil waste `and long-term implication for soil fertility status.

MATERIAL AND METHODS

Experimental set up

The research involved an incubation experiment to determine the nutrient release patterns from palm oil waste derived compost and vermicompost. The compost materials used for the experiment were obtained from Malaysian palm oil industry. The soil used was the ordinary sandy soil, which was air-dried, ground and sieved using a 2 mm mesh sieve. The two main organic fertilisers namely compost and vermicompost were used in combination with soil in the pot experiment that were arranged in the incubator in a completely random fashion in triplicate. The treatments consisted of compost (SC30, SC70, SC120 t/ha) and vermicompost (SV30, SV70, SV120 t/ha). The soil was thoroughly mixed with the composts and moistened with 36 ml of deionised water. The potting media were incubated inside the dark growth chamber maintained at 32^{0}C over a 3-week period. Water baths were placed at the bottom of the incubator in order to minimize water losses from the potting media due to excessive evaporation and to control the humidity of the incubator's internal environment. The initial base-line analysis of the composts used for the incubation experiment was carried out using appropriate standard laboratory procedures. The moisture as well as organic matter contents of the compost materials was also determined after drying at 105^{o}C for a 24 hour period. The pH was determined in 50ml water extracts. Total carbon, organic carbon, and nitrogen were determined using Elemental Analyser (Elementa Vario EL).

Extractable nitrogen (NH_4^+ and NO_3^-) was determined in 100ml of 2 mole/l potassium chloride solution. Available P was analysed in ammonium bio-carbonate solution.

Chemical Analysis

The chemical analysis involved preliminary based-line characterization of the compost and vermicompost materials used for the incubation experiment to determine the typical nutrient contents prior to incubation. The properties of the compost and vermicompost examined included total carbon, total oxides of carbon, total and available potassium, total and available phosphorus, total and extractable nitrogen, loss on ignition, water content and pH. Samples were taken from the incubated pots once every week for a time period of 21 days. Each extract from the sampled pots was analysed to determine the concentrations of mineralized N in NH_4^+ -N and NO_3^- -N released from the different combination of treatments, and the mineralized N was estimated as the sum total of NH_4^+ -N and NO_3^- -N each time. The Burkard Scientific Segmented Flow Analyser was used to determine the N in NH_4^+ and NO_3^-.

RESULTS AND DISCUSSION

Pre-Incubation Characteristics of the Composts used

The results of the pre-incubation analysis of the compost materials used for the pot experiment are shown in
. The results of the initial chemical analysis of the composts shown in
revealed that both the compost and vermicompost had high content of nitrate (NO3- N). Since nitrate is generally present in very low concentrations in immature composts, the high concentrations as observed in this experiment is an indication of the stability and maturity of the compost and vermicompost used in this study. The vermicompost was acidic (pH 5.2), with low organic carbon content (25.39%), and high nitrogen content of 1.92% which was above the minimum required for mature compost of 0.6% as reported by Riffaldi *et al.*, [7] and also falls within the normal range of 0.5-2.5% dry weight basis. The acidic nature could be due to the presence of the proton (H^+) in $NH4^+$ which furnishes hydroxonium ions when dissolved in water. The level of acidity is determined by the concentrations of hydrogen ions released during mineralisation of ammonium.
The chemistry of this reaction is depicted in a simple equation as follows:

$$NH4^+ \rightarrow NO3^- + H^+ \qquad (1)$$

Where $[H^+]$ is a proton, which confers acidic properties on the vermicompost and the pH is the negative logarithm of the hydrogen ion concentrations represented by the following expression:

$$pH = -\log [H^+] \qquad (2)$$

And it is defined as the degree of acidity or alkalinity of an aqueous medium.

The pH is a measure of active acidity in the compost material, and the majority of finished composts will exhibit a pH in the range of 5.0-8.5. Generally, a neutral pH is suitable for most applications as revealed in literature. Thus, the pH of the compost (7.16) and vermicompost (5.02) are within the stated values for finished composts.

Although there is no ideal organic matter level for finished composts, because this will normally decrease during composting of wastes, organic matter on dry weight basis of typical finished composts is in the range of 30-70%.

Thus, the results in

indicate that the organic matter content of the compost (46.25%) and vermicompost (37.92%) for the present study are consistent with this range.

Furthermore, the carbon to nitrogen ratio (C: N) for the compost used was 12.01 while that of the vermicompost was 10.56. These ratios could also serve as indicators of the stability of the compost and nitrate availability. Literature studies revealed that composts with high C: N ratios (>30) will likely immobilize nitrate upon application, whereas composts with low C: N ratios (<20) will mineralize organic nitrogen to inorganic, plant-available forms of nitrate.

The C: N ratios from the analysis mean both composts have the potential to mineralize N to meet crop nutrient demand when applied to soil. In addition, if the quantity of N contained in the organic residue is higher than that needed by the microbial biomass, net mineralisation of N will occur with the release of inorganic nitrogen N, but if the amount is the same as the amount needed by the microbial biomass, the net mineralisation will not take place [8].

The foregoing discussion indicates that the quantity of carbon to nitrogen in organic residues such as those of compost and vermicompost used in this study are significant factors influencing the net mineralisation of N or its net immobilization. Furthermore, organic substances with a carbon to nitrogen ratio of below 20 (<20) usually releases mineral nutrient (N) early during decomposition in comparison to those with higher ratios between 20 and 30 (>20). Organic compost with carbon to nitrogen ratio above 30 will result in immobilization at the initial decomposition process. Whitmore [9] noted that the carbon to nitrogen ratio of organic residues is related to the quantity of mineralized N and that the break-even point between net mineralisation of N and its net immobilization can be found between carbon to nitrogen ratios of 20 and 40, which is in line with the results obtained in this study.

Similarly, the moisture content from the analysis; 53.07% for the compost, 77.99% for vermicompost, revealed that both had high moisture content typical of finished composts. Literature review indicated that typical finished compost should have a percentage solids content of 50-60% (50-40% moisture). The high moisture content plays significant role in the mineralisation of organic nitrogen into available inorganic form of nitrate. This is because moisture content coupled with soil temperature influences the rapid decomposition and release of nutrients from composts in the soil. A study by Quemada and Cabrera [10] discovered a strong interplay between temperature and water content in the N mineralisation from surface-applied crimson clover (*Trifolium incarnatum L.)* residues. It was also discovered that the effects of temperature and water content on mineralisation from soil organic matter differ from the effects of temperature and water content on the mineralisation of N for surface-applied residues.

Table 1. Typical Nutrient Compositions of the compost and vermicompost prior to incubation

Property	***Compost***	***Vermicompost***
Organic matter (%)	*46.25*	*37.92*
NO3 (mg/kg)	*257.3*	*1407.3*
NH4 (mg/kg)	*0.00*	*82.83*
Total N (%)	*2.23*	*1.91*
Available K (mg/kg)	*3987*	*3680*
Total K (mg/kg)	*5126.67*	*4228.33*
Available P (mg/kg)	*257.1*	*221.6*
Total P (mg/kg)	*5355.02*	*5135.94*
Total Carbon (%)	*26.79*	*20.17*
C/N	*12.01*	*10.56*
Total Organic Carbon (%)	*33.05*	*25.39*
Ph	*7.16*	*5.02*
Water content (%)	*53.07*	*77.99*

Nutrient Release Characteristics from Compost and Vermicompost

The results of the cumulative NO_3-N and NH_4-N release from the compost and vermicompost during the incubation experiment displayed in table 1 showed that the both compost fertilizers used had high content of nitrate (NO_3-N) than ammonium (NH_4^+- N). The higher content of nitrate indicates these are stable, mature and finished composts. In stable, finished composts such as those used for this study, most of the nitrate would be in the organic form; this organic nitrate is only slowly mineralized and made available to plants unlike the NH_4-N and NO_3-N that are immediately made available to plants. Compost and vermicompost from organic materials differ in their nutrient characteristics depending on the nature and type of the material used in composting. According to Amlinger [11] N mineralisation rates of between 5-15% in an incubation experiment as well as 3-5% in a 21-year field experiment were obtained in the first year of compost application whereas Gutser et al., [12] and Passoni *et al.*, [13] noted an N mineralization of between 0-20% and 35-40% respectively. These findings however, cannot be compared because the experiments were conducted on different soils, soil management, and with different types of composts.

Table 2. Cumulative NO_3^- - N and NH_4^+- N release during the incubation experiment

Treatments	***NO_3^-N***	***SE***	***NH_4^+- N***	***SE***	***Total***	***SE***
SC30	*110.7*	*16.05*	*50.5*	*10.6*	*161.2*	*26.65*
SC70	*208*	*30.61*	*50.5*	*16.07*	*258.5*	*46.68*
SC120	*298.5*	*13.79*	*58.3*	*15.37*	*356.8*	*29.16*
SV30	*365.5*	*66.25*	*95.3*	*35.88*	*460.8*	*102.13*
SV70	*882.5*	*223.59*	*158.8*	*50.82*	*1041.3*	*274.41*
SV120	*1225.3*	*120.55*	*122.3*	*11.64*	*1347.7*	*132.19*

(SE = Standard Error)

Nutrient release patterns at different rates of Compost and Vermicompost mixed with Soil

Table 3 shows the mean values of the amount of nutrients released from each of compost and vermicompost mixed with soil at different rates, and the nutrient release patterns are represented in figures 1 and 2 respectively. The results showed that both compost fertilizers exhibited typical characteristic release patterns consistent with all organic-based manures, that is, the nutrient release follow a slow, gradual process as indicated by the graphical patterns.

Table 3. Mean concentration of mineralized N across the days of incubation experiment

	Day 0		***Day 1***		***Day 7***		***Day 14***		***Day 21***	
SampleId	***Mean***	***SE***	***Mean***	***SE***	***Mean***	***SE***	***Mean***	***SE***	***Mean***	***SE***
SC30	*22*	*7*	*13*	*4*	*48*	*7*	*40*	*8*	*40*	*1*
SC70	*36*	*11*	*28*	*11*	*52*	*7*	*71*	*11*	*71*	*6*
SC120	*60*	*9*	*55*	*9*	*69*	*8*	*87*	*1*	*87*	*1*
SV30	*63*	*24*	*93*	*29*	*105*	*13*	*92*	*13*	*107*	*23*
SV70	*173*	*75*	*318*	*120*	*171*	*23*	*177*	*11*	*202*	*45*
SV120	*241*	*39*	*286*	*51*	*259*	*19*	*287*	*4*	*275*	*19*

(SE = Standard Error)

Nutrient release pattern from Soil-Compost combinations (SC)

The graph of the nutrient release patterns in soil-compost treatment is shown in Figure 1. The nitrate mineralisation varied with the application rates as revealed in Figure 1. Note that the error bars overlapped at only one point which suggests that all points except at point day 7 after incubation with respect to treatment SC30 and SC70 are significantly different.

The initial concentration of nitrate was higher at point day 0 than the observed concentration at point day 1 as shown in Figure 1. This could be due to the fact that N mineralisation did not occur prior to this point because it was a gradual, slow process. There was a gradual slow release pattern after day 1 until day 14 when it plateaus throughout the remaining days (Figure 1). The nitrate mineralisation varied with the application rates. Among all the treatments, the treatment which received 120t/ha (SC120) released the highest net mineralisation of N (87.33 mg/kg) at point day 21, followed closely by treatment which received 70 t/ha (SC70) with net mineralisation of 71.33mg/kg at point day 14. The nutrient release for treatment with SC30, 30t/ha peaked at point day 7 where the amount of nutrient released was 47.83mg/kg, but remained constant and immobilized throughout the remaining days 14 and 21 (39.50mg/kg). This result is in line with a study conducted by Adeoye [14] who examined the influence of different EFB composts on oil palm nursery in which the manure was applied at a rate of 4.8g N per plant, it was observed that oil palm empty fruit bunch compost mixed with cow excrement raised the performance of oil palm seedlings.

Also prior study by Danso *et al*., [15] showed that mixing 7.5kg EFB (7500g) compost together with topsoil could substitute the standard mineral fertilization in main nursery stage as the 12-month-old oil palm seedling grows as good as seedlings under normal fertilization methods.

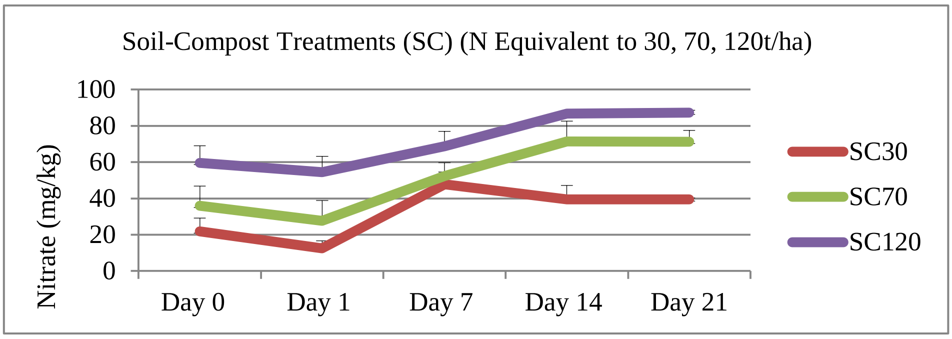

Figure 1. *Nitrate-release patterns during the incubation experiment influenced by soil-compost application rates*

Nutrient release pattern from Soil-Vermicompost combinations (SV)

The graph of the nutrient release pattern from soil-vermicompost combinations across the days of incubation is shown in Figure 2. The error bars are indicated to show significant differences in the characteristics release patterns between the various application rates.

There was an observed marked increase in the concentration of mineral nitrogen in NH_4^+ - N and NO_3- N in the soil-vermicompost application rate of 70t/ha (SV70) that peaked at point day 1 (318.33mg/kg). This could be due to the low carbon to nitrogen ratio of the vermicompost used (10.56).

The result is in line with Tisdale et al. (1990) who observed that organic substances with a carbon to nitrogen ratio of below 20 (<20) usually release mineral nutrient (N) early during decomposition in comparison to those with higher ratios between 20 and 30 (>20). Organic compost with carbon to nitrogen ratio above 30 will result in immobilization at the initial decomposition process.

The nitrate mineralisation in treatments with 120t/ha equivalent to (SV120) was observed to follow a gradual slow release pattern from day 0 after incubation until day 14 where the net peak N mineralisation (286.50mg/kg) occurred as seen in Figure 2. On the other hand, the observed concentration of nutrient released between treatments which received 70t/ha (SV70) and 120t/ha (SV120) at points day 0 and day 1 where the error bars overlapped at the two points for both treatments was not statistically significant. Evidence from literature revealed that the amount of mineral nitrogen released into the soil increased with increase in the rate of application of manures and chemical fertilisers. The gradual slow mineralisation of nitrogen could be due to the low C: N ratio (10.56) of the vermicompost, which is less than 20.

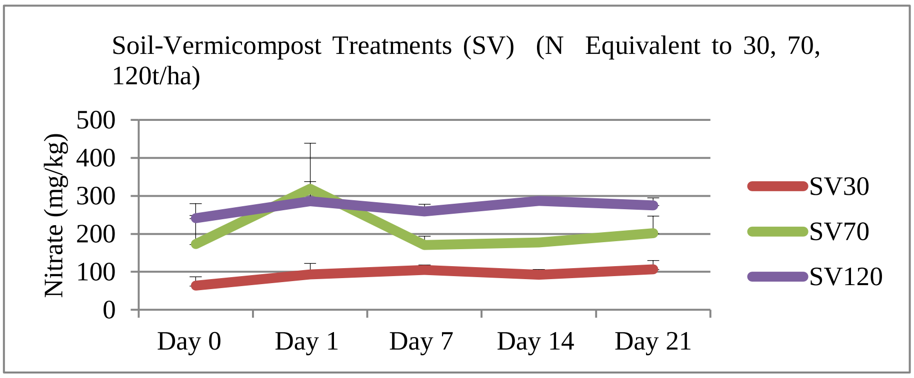

Figure 2. *Nitrate-release patterns during the incubation experiment influenced by soil-vermicompost application rates*

CONCLUSIONS

Soil amendment materials derived from oil palm waste compost and vermicompost in soil growing media have been variously reported in literature to have long-term beneficial effects on the growth and development of the crop by Rupani *et al.*, [16] and Tisdale *et al.*, [17]. The incubation experiment conducted in the laboratory indicated that all treatment combinations (SC and SV) had significant influence on the slow, gradual release of nutrient across the days of incubation. Thus, the use of slow release compost and vermicompost fertilizers could benefit the soil of agriculture both from environmental aspects by maintaining soil structural and textural properties as well as overall health status of the soil, and economic aspect in terms of improved crop yields to farmers in the long run.

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NUTRITIVNE VREDNOSTI KOMPOSTA, VERMIKOMPOSTA I DUGOROČNI EFEKAT NA STATUS PLODNOSTI ZEMLJIŠTA

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Sažetak: Glavni cilj ove studije je bio ispitivanje obrazca oslobađanja hranljivih materija iz dva tipa komposta i dugoročne posledice na status plodnosti zemljišta. Izvršen je eksperiment inkubacije u laboratoriji da bi se utvrdili obrasci oslobađanja hranljivih materija iz komposta i vermikomposta pomešanih sa zemljištem, pri različitim količinama kombinacijama primene SC30, SC70, SC120 i SV30, SV70 SV120, tokom 21 dan. Početne pre inkubacijske analize kompostnog materijala korišćenog za eksperiment pokazale su da i kompost i vermikompost imaju visok sadržaj hranljivih sastojaka. Rezultati istraživanja pokazuju da su različite količine unetog komposta i vermikomposta u zemljište imale značajan uticaj na spor, postepen proces oslobađanja, hranljivih materija, što ukazuje na dugoročni efekat koji organsko đubrivo može da ima na status plodnosti zemljišta.

***Ključne reči**: Kompost; Vermicompost; Ispuštanje hranljivih sastojaka; Plodnost zemljišta.*

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DESIGN AND DEVELOPMENT OF MECHANICAL DRIED CHILLIES COMPACTION MACHINE

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Abstract: Dried chillies are packed in gunny bags non-uniformly in different packing sizes. Dried chilies, being low bulk material occupies large volume, need to be compacted before it is bagged to gunny bags. Conventionally, dried chilies are compacted by labor in the field itself by tying gunny bag to a tripod stand and simultaneous filling of dried chilies and trampling by feet till overall weight of the bag reaches 40-45 kg. Conventional method is highly labor intensive involves drudgery, low productive (3 laborers can compact a quantum of 8 bags per hour) and causes burning sensation to the labor. An attempt has been made to design and develop portable mechanical machine to compact dry chilies and bag. Evaluation of developed machine has been conducted at farmer's field in Guntur district of Andhra Pradesh - India. The capacity of the developed machine was found to be 18 bags/h, technically feasible and economically viable. There is a saving of Rs 9.68 per bag in mechanized compaction and bagging process with an improvement in productivity over 150%.

Key words*: Chilli compaction machine, Power pack unit, Platen, Hydraulic motor, Bulk density, Moisture content*

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INTRODUCTION

Dry chilies are mostly pungent fruits of *capsicum annum L* and *capsicum frutescence* majorly used as condiment or culinary for its pungency, spicy taste, besides the appealing color it adds to the food. It's powder is used in pickles, sauces, ketchup, essences, oleoresins and is an inevitable ingredient in all Indian dishes. The major chilli producers in the world are India, China, Pakistan, Morocco, Mexico, Turkey and Bangladesh. Chilies are mostly grown in all regions of India particularly Andhra Pradesh and Telangana contributing $2/3^{rd}$ of India's total production. Andhra Pradesh alone has a production of 8.83 lakh MT from 2.06 lakh hectares, which accounts for 24 percent of area and 47 percent of production in the country (www.indiastat.com, 2016-2017. statistics). In Andhra Pradesh, major production catchment include Guntur, Prakasam, Krishna and Kurnool districts. About 65% of the total chillies produced in India are exported to Srilanka, Bangladesh, Malaysia, USA, Nepal, Indonesia, UAE and Italy in the recent past (1).

In Andhra Pradesh, dried chillies are usually packed in gunny bags for transportation and storage. It is found that there is no uniformity in the packing size of chillies in the country. Packing material used and the capacity of packages are varying in different states. The size of gunny bag is generally 20-25 kg in North Eastern States and in Punjab (2). In Andhra Pradesh and Tamil Nadu, the pack size is about 40-45 kg. Generally all the farmers use old gunny bags to pack chillies before selling. Only the exporters repack them in new gunny bags sometimes with polythene liners.

Dried chillies, being low bulk material occupies large volume, need to be compacted before it is bagged to gunny bags. Conventionally, dried chillies are compacted by farm labour in the field itself by tying gunny bag to a tripod stand and simultaneous filling of dried chillies and trampling by feet till overall weight of the bag reaches to 40-45 kg.

Conventional method is highly labor intensive involves drudgery, low productive (3 labourers can compact a quantum of 8 bags per hour) and causes burning sensation to the labor trampling the chillies in bag. This paper aims to design and develop a dried chillies compaction machine in order to avoid drudgery in conventional compaction method using labourers and to conduct its evaluation studies.

MATERIAL AND METHODS

Basic principle employed for development of dried chillies compaction machine was hydraulic press to produce compressive force by means of hydraulic fluid using Pascal's principle (3)(4). Thus an attempt has been made to automate the process of press work using hydraulic mechanism in press machine. The inputs and outputs of the control system in hydraulic mechanism are solely mechanical such as reciprocating plunger operated by means of hydraulic components such as actuators to initiate the movement in the form of lever to apply manually so that the compaction of the dried chillies can be achieved in to and fro motion. Furthermore, direction control valves have been implemented to control the directions of piston movements and regulate the same. The principal parameters of the design included the maximum load, the distance the load resistance has to move, the system pressure, the cylinder area and the volume flow rate of the working fluid (5).

Design of hydraulic components

The following assumptions were made in the design of hydraulic components:

Particulars	*Assumption*
Stroke length	*1000 mm*
Inner diameter of cylinder (d_{ci})	*110 mm*
Size of moving platen	*360×360 mm*
Maximum working pressure	*1000 kPa or 1 N/mm^2*
Allowable tensile stress for cast steel cylinder and end plate (σ_{tc})	*80 MPa or 80 N/mm^2*
Allowable tensile stress for piston rod (σ_{tp})	*60 MPa or 60 N/mm^2*
Allowable compressive stress for mild steel for ram (σ_c)	*75 MPa or 75 N/mm^2*
Allowable shear stress for mild steel for hinge (τ)	*45 MPa or 45 N/mm^2*

Maximum capacity of pressing machine (F)

Maximum capacity of pressing machine was determined by multiplying maximum pressure with the contact area of moving platen.

Pressure exerted inside the cylinder (*p*)

Pressure inside cylinder (*p*) was computed by equating to the work done by the cylinder

Thus, $F = (\pi/4) \times d_{ci}^2 \times p$ (1)

$p = 4F/\pi\, d_{ci}^2$ (2)

where d_{ci} is the diameter of inner cylinder, F is the maximum capacity of pressing machine

Design of ram

It is a round bar attached to piston at one end and to moving platen at other end and it moves in and out from cylinder for pushing and pulling operation. Let d_r be the diameter of the ram and maximum force exerted by ram is given as

$\sigma_t = (\pi/4) \times d_r^2 \times p.$ (3)

$d_r = \sqrt{4}\sigma_{tc}/\pi p$ (4)

where σ_{tc} is the tensile stress for cast steel

Design of cylinder

It is the important component of the machine. It develops pushing or pulling force to carry out desired operation using pressurized hydraulic fluid. For the compaction cum bagging machine, a double action cylinder is used which can take power stroke in forward as well as reverse direction. Both forward and reverse stroke was achieved by pumping oil under controlled pressure and flow direction from both oil port of cylinder.

Wall thickness of the cylinder (*t*) can be found out by Lame's theorem (5)

$t = (d_{ci}/2)\{\sqrt{\ }[(\sigma_{tc} + p)/(\sigma_{tc} - p)]-1\}$ (5)

Design of piston rod

Let d_p is the diameter of piston rod.

Force acting on piston rod is given as (F)= $(\pi/4)\times d_{ci}^2\times p= (\pi/4)\times d_p^2\times \sigma_{tp}$

$$d_p = \sqrt{(d_{ci}^2\times p/ \sigma_{tp})} \quad (6)$$

Design of hinge pin

Let d_h is the diameter of hinge pin of piston rod. Load on the pin is equal to the force acting on piston rod and hinge pin is in double acting shear as per procedure stated (6), therefore

$$F = 2\times (\pi/4)(d_h)^2\tau \quad = 70.7\ (d_h)^2 \text{ (Taking } \tau=45 \text{ N/mm}^2) \quad (7)$$

$$d_h = \sqrt{F/70.7} \quad (8)$$

When cover is hinged to cylinder, one can use two hinge pins only diametrically opposite to each other. Thus, diameter of hinge pins for cover $d_{hc} = d_h/2$

Design of flat end cover

Let t_c is the thickness of end cover (7)

Force on end cover is given as $F = d_{ci}\times t_c\times \sigma_{tc}$ (9)

$$t_c=F/(d_{ci}\times \sigma_{tc}) \quad (10)$$

Design of cylinder end cover plate

The thickness t_{ce}, of the end-cover-plate, which is supported at the circumference by bolts and subjected to an internal pressure uniformly distributed over the area as per procedure suggested (6).

$$t_{ce} = k_1 d_{ci}\sqrt{(p/ \sigma_{tc})} \quad (11)$$

where, the coefficient k_1 depends on type of material of the plate and method of holding the edges, the value k_1 is given as 0.44 for cast steel,

Power output of cylinder

Stroke length of piston is L and time required for working stroke is S. Distance moved by piston per second is given as L/S

Work done per second = Force × distance moved by piston per second

= F × L/S

Power of motor

Power of required for motor was determined (8) by the following equation

Pump discharge (Q_p) = Cross-Section Area of Cylinder (m^2) × Working Speed (m/s)

$$= \pi/4\ (d_{ci})^2\times L/S \quad (12)$$

Calculation of displacement of pump

The displacement of the pump was calculated based on a 3- phase induction motor operating at N RPM. Assume a volumetric efficiency of η_v. The pump must deliver sufficient flow to advance the cylinder at the maximum speed, hence displacement of pump was calculated as (D_p)

$D_p = Q_p/N\eta_v$ where, N is motor RPM,

Torque required to drive the pump at system pressure (T) = $D_p.p/\eta_m$ where, η_m is the mechanical efficiency)(9)(10)

Power of electric motor = T (N.m/rad).N (2π rad/rpm) (min/60 s)/ η_e (13)

RESULTS AND DISCUSSION

Physical properties of dried chillies before and after compaction in conventional method

In a conventional method of compaction, a special bamboo tripod stand is formed and erected in the yards and gunny bag was held in between and a person tramples the pods by standing in the gunny bag, to achieve good compaction (11) (Figure 1). Generally, gunny bags used for bagging dried chillies have a diameter of 480±20 mm and a length of 1100 mm. Certain properties of dried chillies before and after compaction and bagging was presented in Table 1. The data indicated that loose bulk density of the dried chillies was low and after compaction, the bulk density increased from 91 to 223 kg/m^3.

Figure 1. Conventional compaction and bagging of dried chillies

Table 1. Certain properties of dried chillies during conventional bagging

Parameter	Before compaction and packing	After compaction and packing
Weight (kg)	20.1±2.2	39±2.2
Bulk density (kg/m^3)	91±14	223±16
Moisture content (%w.b.)	12.35±0.25	12.35±0.25

Determination of maximum force to achieve required compaction

In conventional system, a farm labor of 70 kg body weight approximately tramples the dried chillies in the gunny bags around 35-40 times to achieve the bulk density of 230±5 kg/m^3. Pressure applied on the chillies was calculated as 0.54 N/mm^2 (Approximating force applied as 600 N and area of foot as 0.15× 0.075 = 0.011 m^2 thus pressure applied was calculated as 54545 N/m^2).

Assuming factor of safety as 2, maximum compaction pressure required for design purposes was assumed as 1 N/mm^2 (or 1000 kPa).

Important limitation regarding assumption of maximum compaction pressure is that the dried chillies pod should not break while compaction. Hence, compressive pressure for compaction of 1000 kPa was considered for design purposes.

Design of hydraulic components

Maximum capacity of pressing machine

Maximum capacity of pressing machine is determined by multiplying maximum pressure with the contact area of moving platen.

Maximum capacity of pressing machine = 1000×10^3 (N/m^2) $\times (0.36)^2$ = 129.6 kN or 130 kN

Now, pressure inside the cylinder (*p*). Load on pressing machine is equated to the work done by the cylinder

Thus, 130×10^3 (N) = $(\pi/4)\times d_{ci}^2\times p = (\pi/4)\times(70)^2\times p$

p= 33.79 N/mm^2

Design of ram

It is a round bar attached to piston at one end and to moving platen at other end and it moves in and out from cylinder for pushing and pulling operation. Let d_r be the diameter of the ram and maximum force exerted by ram is given as $\sigma_{tp}= (\pi/4)\times d_r^2\times p$.
On substitution of σ_t and p, the value of d_r was obtained.

60×10^3 (N) = $(\pi/4)\times d_r^2\times33.79$

d_r = 47.56 mm or 48 mm

Design of cylinder

Let d_{co} is the outer diameter of hydraulic cylinder and d_{ci} is the inner diameter of cylinder.

Assuming clearance of 20 mm between ram and cylinder bore, therefore, inner diameter of the cylinder (d_{ci}).

$d_{ci}= d_r+$ clearance = 48+15 = 63 mm or say 70 mm

Wall thickness of the cylinder (t) can be found out by Lame's equation

$t = (d_{ci}/2)\{\sqrt{[(\sigma_{tc} + p)/ (\sigma_{tc} - p)]}-1\}$

substituting the values of r_{ci}, σ_t and p,

$t=35\times\{\sqrt{[(80.00 + 33.79)/(80.00 - 33.79)]}-1\}=35\times(1.569-1) = 19.92$ *mm or 20 mm*

Diameter of outer cylinder = $d_{ci} +2t= 70+(2\times20)=110$ *mm*

Design of piston rod

Let d_p is the diameter of piston rod.

Force acting on piston rod (F)= $(\pi/4)\times d_{ci}^2\times p= (\pi/4)\times(70)^2\times 33.79$ = 130039.15 *N*

Force acting on piston rod is also given as$=(\pi/4)\times d_p^2\times\sigma_{tp} = (\pi/4)\times d_p^2\times60=47.13\ d_p^2$

Equating above two gives $d_p = \sqrt{(130039.15/47.13)}$= 52.52 mm or say 52 mm

Design of hinge pin

Let d_h is the diameter of hinge pin of piston rod. Load on the pin is equal to the foce acting on piston rod and hinge pin is in double acting shear, therefore

$F = 2\times (\pi/4)(d_h)^2\tau \quad = 70.7\ (d_h)^2$ (Taking τ=45 N/mm^2)

$130039.15 = 70.7\ (d_h)^2$

$d_h = 42.88$ mm or 44 mm

When cover is hinged to cylinder, one can use two hinge pins only diametrically opposite to each other.

Thus, diameter of hinge pins for cover $d_{hc} = d_h/2 = 44/2 = 22$ mm

Design of flat end cover

Let t_c is the thickness of end cover.

Force on end cover is given as $F = d_{ci}\times t_c\times \sigma_{tc}$

$130039.15 = 70\times t_c\times 80$

t_c=23.22 mm or say 23 mm

Design of cylinder end cover plate

The thickness t_{ce}, of the end-cover-plate, which is supported at the circumference by bolts and subjected to an internal pressure uniformly distributed over the area, is given by Eq. (2) as:

$t_{ce} = k_1 d_{ci}\sqrt{(p/\ \sigma_{tc})}$,

where, the coefficient k_1 depends on type of material of the plate and method of holding the edges, the value k_1 is given as 0.44 for cast steel,

$t_{ce} = 0.44 \times 70\sqrt{(33.79/\ 80)} = 20.01$ mm or 20 mm

Power output of cylinder

Stroke length of piston = 1.0 m

Time required for working stroke = 24 s

Distance moved by piston per second = 1.00/24 (m) = 0.041 m

Workdone per second = Force × distance moved by piston per second

= 130039.15 × 0.041 = 5331.60 Nm

Power output of the cylinder = 5331.60 Nm/s = 5.33 kW

Platens

The platens provide point of direct contact with the object being compressed. Hence, they are subjected to pure bending stress due to an equal and opposite couple acting in the same longitudinal plane. The design consideration is essentially for bending and consists primarily upon the determination of the largest value of the bending moment (M) and shear force (V) created in the beam which was found to be 45 kN/m and 150 kN, respectively. These were computed using the adopted procedure (12).

Bending moment of platen is given as
$M = FL/4 = 130\ (kN)\times 0.36/4\ (m) = 11.7\times 10^6$ N-mm
Similarly, section modulus for a square platen is
$Z = b^3/6 = (0.36)^3/6 = 7.776\times 10^6\ mm^3$
Now bending stress acting upon platen is given as
$\sigma_b = M/Z$, where Y is yield stress (250 MPa)
$\sigma_b = 11.7\times 10^6/7.77\times 10^6 = 1.505\ N/mm^2$.
Factor of safety = Yield stress/ Bending stress = 250 /2.104 = 118.82

Power of motor

Pump discharge = Cross-Section Area of Cylinder (m^2) × Working Speed (m/s)
$= \pi/4\ (d_{ci})^2\times$ working speed (m/s)
$= \pi/4\ (70/1000)^2\times 0.041 (m/s) = 157.78\times 10^{-6}\ m^3/s$
= 0.157 Lps or 9.42 Lpm

Calculation of displacement of pump

The displacement of the pump was calculated based on a 3- phase induction motor operating at 1750 RPM. Assume a volumetric efficiency of 0.70. Note that the pump must deliver sufficient flow to advance the cylinder at the maximum speed,
$D_p = Q_p/N\eta_v = 9.42\times 10^{-3}(m^3/min)/[1750(Rev/min)\times 0.70] = 7.68\times 10^{-6}\ m^3/rev$
Torque required to drive the pump at system pressure:
$(T) = D_p.p/\eta_m$ (Assuming $\eta_m = 0.7$)
$= 7.68\times 10^{-6}\ (m^3/rev)(rev/2\pi\ rad)\times 2\times 10^6\ (N/m^2)/0.7 = 3.494\ N\cdot m/rad$
Power of electric motor = T (N.m/rad).N (2π rad/rpm) (min/60 s)/ η_e
$= 3.494\times 1750\times 2\pi/(60\times 0.7) = 914.28$ W or 0.91 kW or 1.22 HP
= or say 2.0 HP electrical motor was selected.

Design of hydraulic power pack unit

Reservoir capacity: Tank capacity could be between 3 to 10 times of the pump discharge capacity. Thus, a tank capacity of 3 times of pump discharge capacity *i.e*., 30 L was selected. An oil reservoir tank of size 0.45 ×0.38 ×0.38 m was fabricated to hold hydraulic oil. Bottom of tank has sloping, where drain plug was provided. This facilitate removal of all contamination settled at bottom, when oil is drained-out. Further, externally visible oil level indicator was provided. Further, tank was provided with air-breather filler assembly and return line filter. Tank was provided with suction filter and baffle plate to protect pump from sucking heavy or light contamination returning to tank along with exhaust oil.

A relief valve with maximum pressure setting of 2 MPa was provided at delivery side of pump to avoid any pressure build-up. A pump operating without relief valve is bound to cause an accident or damage to system or for itself.

A single manifold block has connection port for connecting pump, exhaust port, and two oil port for cylinder, and on its various ground surface provision to mount the valves. After providing manifold and relief valve, a direction control valve is fitted on it. Oil is filled through filter up to maximum level of oil level indicator.

The technical specifications of dried chillies compaction machine are shown in Table 2 and specifications of components of manifold block are depicted in Table 3. Various components of mechanical dried chillies compaction machine is shown in Figure 2.

Table 2. Technical specifications of the dried chillies compaction machine

Description	Specification
Type	Hydraulic double acting cylinder compaction machine
Stroke length	1 m
Compaction pressure	1000 kPa
Maximum pressure	2000 kPa
Cylinder diameter	110 mm
Piston diameter	40 mm
Moving platen dimension	360 ×360 mm
Power pack unit hydraulic oil capacity	30 L
Dimensions	965 × 920 ×2850 mm (L×W×H)
Capacity of hopper	7 kg
Power	2 HP single phase

Table 3. Specifications of components of manifold block

Component	Technical specifications
Hydraulic suction pipe	Connect thread size G 3/8; shapes (Curve – 73, 29 mm; Straight – 120, 180, 280, 320 mm
Hydraulic return pipe	Connect thread size M12, Shape straight - 120, 180, 280, 320 mm

Figure 2. Mechanical dried chillies compaction and bagging machine

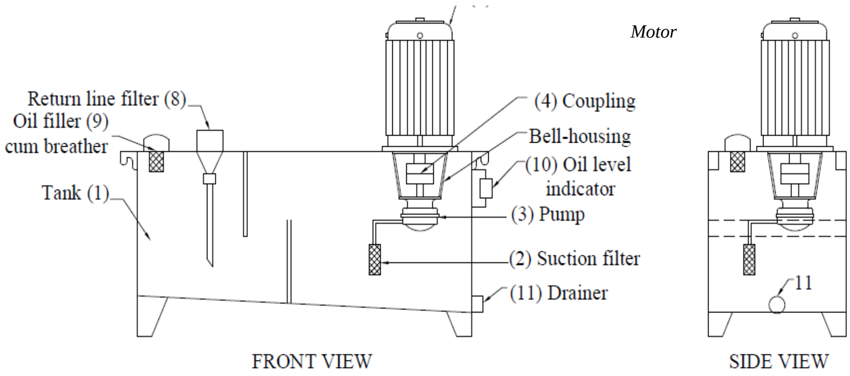

Figure 3. Various components of power pack unit

Performance evaluation of the developed compaction machine

The details of the evaluation of chillies compaction machine was shown in Table 4. Time required for compaction and bagging of dried chillies was recorded to vary from 3 to 3.5 min where as in conventional method, it varied from 8.5-10 min. Average bulk density of chillies compacted in mechanical system was noted as 239.4 kg/m^3 and average compacted weight of chillies was recorded as 42 kg (Figure 4). The capacity of mechanized compaction and bagging unit worked out to be 18 bags/h.

The economic analysis of conventional and mechanized compaction cum bagging of dried chillies shows that the cost of compaction and bagging in conventional system was Rs. 30/ bag of 40-45 kg where as in mechanized system; the cost was worked out to be Rs.20.31 per bag. There was a saving of Rs.9.68 per bag in mechanized compaction and bagging. Total savings in a day of 10 h of working, was estimated to be Rs. 2343. Further, productivity in mechanized system was worked out be 150% over conventional system. Economic analysis suggested that return on investment was worked out to be 70.3% with a payback period of 1.42 years.

Table 4. Evaluation of mechanical dried chillies compaction machine

Parameter	*Mechanical compaction cum bagging method*
Time for compaction and bagging per bag (min)	*3.0-3.5*
Capacity (bags/h)	*18±1*
Breakage of pods	*Nil*
Weight of the bag	*42.0±2.2*
Bulk density	*239.4±7.2*

Figure 4. Compaction of dried chillies in gunny bags using compaction machine

CONCLUSIONS

Conventional method of compaction and bagging of dried chillies is low productive and involves drudgery and burning and day long scorching sensation to the laborers involved. An attempt was made to develop a mechanical compaction machine for packing of capacity 18 bags/h. Evaluation of developed machine has been conducted at farmer's field. Developed machine is technically feasible and economically viable. There is a saving of Rs. 9.68 per bag in mechanized compaction and bagging process with an improvement in productivity over 150%.

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PROJEKTOVANJE I RAZVOJ MAŠINE ZA MEHANIČKO SABIJANJE OSUŠENE ČILI PAPRIKE

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Sažetak. Osušene čili paprike se pakuju (konvencionalno sušenje u polju na vazduhu) u vreće bez nekog određenog oblika u različitim veličinama pakovanja (vreće). Na ovaj način osušene čili paprike imaju veliku ukupnu zapreminu, koju treba smanjiti na manju zapreminu, pre nego što se upakuju u vreće. Tradicionalno se osušeni materijal čili paprika sabija na samom polju gaženjem nogama radnika sve dok ukupna težina vreće ne dostigne 40-45 kg. Ova konvencionalna metoda je radno intezivna, ima malu produktivnost (3 radnika sabijanjem napune 8 vreća/čas), i izaziva snažan neprijatan i nelagodan osećaj ljutine kod radnika.

Dizajnirana je i napravljena prenosna mehanička mašina za sabijanje (kompakciju) osušenog čilija u vreće. Ispitivanje ove razvijene kompakt mašine je obavljeno na polju u okrugu Guntur u državi Andhra Pradesh - Indija.

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Kapacitet ove razvijene mašine je 18 vreća/čas, što tehnički je izvodljivo i ekonomski isplativo.
Ušteda od 9,68 Rs po vreći u postupku mehanizovanog sabijanja i sakupljanja osušene čili paprike ima poboljšanje produktivnosti od preko 150%.

Ključne reči: *Mašina za sabijanje Chilli paprika, pogonski motor, valjak, hidraulični motor, zapreminska težina, sadržaj vlage.*

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KARAKTERISTIKE POWERSHIFT MENJAČA KOD POLJORIVREDNIH TRAKTORA

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Sažetak: Ovaj rad daje prikaz i analizu funkcionisanja jednog od traktorskih sklopova, tačnije transmisije. To se odnosi na tehnološki napredno rešenje menjačkih sklopova kao što je *Full PowerShift*. Ovaj tip menjača je najzastupljeniji trenutno na tržištu jer je menjač bez prekida toka snage. Takođe, biće reči i o proporcionalnom solenoidnom ventilu koji je sastavni deo ove transmisije. Svojom konstrukcijom i funkcijom omogućava specifičnost u promeni stepena prenosa. Promena stepeni prenosa bez prekida toka snage, u transportu nema za posledicu zaustavljanje traktora i promene režima rada motora.

Konkurencija proizvođača za najefikasnijim i najracionalnijim rešenjem uslovila je danas ponudu izuzetno širokog spektra raz8ičitih menjačkih sklopova. Menjački sklopovi sa upotrebom različitih elektronskih elementa daju različite eksploatacione karakteristike. Na taj način formiraju pojedine tipove menjača, koji se u tolikoj meri razlikuju da ih je skoro nemoguće obuhvatiti jednom analizom.

Ključne reči: *Poljoprivredni traktor, Full PowerShift, Neprekidan tok snage, Solenoidni ventil.*

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Projekat: Istraživanje i primenu naprednih tehnologija i sistema za poboljšanje ekoloških, energetskih i bezbedonosnih karakteristika domaćih poljoprivrednih traktora radi povećenja konkurentnosti u EU i drugim zahtevima tržišta. Broj TR-35039. Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije.

UVOD

Zadatak transmisije je da prenese mehaničku energiju na pogonske točkove. Kao rezultat uzajamnog dejsta točkova i podloge, javlja se tangencijalna sila koja dovodi do kretanja traktora. U transmisiji se vrši transformacija obrtnog momenta i promena brzina izlaznog vratila menjačkog prenosnika.

Naziv *Full PowerShift* transmisije potiče od reči (eng. *full*), što treba da ukaže na vrstu menjačkog prenosnika, kod koga se svi stepeni prenosa mogu menjati pod opterećenjem bez prekida toka snage [4].

To obuhvata opseg od prve do poslednje brzine. Promena stepena prenosa po rangu, kod ove vrste menjačkih prenosnika, praktično ne postoji. Stepen prenosa se bira pomoću dugmadi na ručici. Signal se šalje do računara transmisije, koji putem *CAN bus* mreže vrši kontrolu proticanja fluida sa solenoidnim ventilma za vreme kretanja traktora [2].

Savremeni poljoprivredni traktori su vrlo složeni tehnički sistemi u koje se ugrađuje veliki broj elektronskih komponenti koje kontrolišu i upravljaju sa sklopovima traktora. Na taj način se olakšava rad rukovaoca traktora, obezbeđuje sigurnost u radu traktora, postiže bolji efekat i omogućava duži vek eksploatacije traktora odnosno manje je pojava kvarova [8].

Za postizanje potrebne kontrole stanja i rada sklopova traktora, postoje određene kontrolne jedinice, koje od odgovarajućih senzora dobijaju potrebne informacije o stanju i funkcionisanju sistema, pri čemu se svaka nepravilnost, odnosno odstupanje od propisanog registruje. Sve nepravilnosti se beleže i na odgovarajući način prosleđuju i obaveštavaju rukovaoca traktora. Istovremeno kontrolna jedinica šalje odgovarajuće signale izvršnim kontrolnim jedinicama koje služe za upravljanje i rad samog traktora .

Ugradnjom najnovijih tehničkih dostignuća sa područja motornih vozila poljoprivredni traktor je postao visko sofisticirano vozilo. Traktorski motori opremljeni su *common-rail* sistemom napajanja gorivom a kontinualno-varijabilne transmisije omogućavaju i osiguravaju odabiranje optimalnog stepena prenosa shodno radnim uslovima bez prekida toka snage. Elekto-hidraulički sistem nadzora i upravljanja priključnog mehanizma osim preciznijeg podešavanja omogućuje i veći broj funkcija.

MATERIJAL I METODE RADA

Pri izvođenju radova na njivi ili u transportu, rukovaoc traktora za obavljanje pojedinih tehnoloških operacije mora izvršiti više postupaka, što za posledicu ima veći zamor vozača, smanjenu efikasnost u radu i često lošiji kvalitet rada [3]. Zbog mogućih navedenih negatvnosti, savremeni traktori a posebno traktori više klase, opremljeni su sistemom upravljanja priključcima odnosno priključnim radnim mašinama [10]. Aktiviranjem ovog sistema automatski se izvršavaju neki postupci u određenoj sekciji odnosno području.

Osnovne funkcije koje se mogu programirati i kojima se može upravljati su:

- podizne poluge dizanje/spuštanje

- kontrola dubine brazde (gore/dole)
- izbor stepen prenosa (više/niže)
- automatski *PowerShift* (*APS* – aktiviranje/deaktiviranje)
- spoljni izvodi hidraulika (*SCV* - izvlačenje/uvlačenje, aktiviranje plivajućeg položaja i otkazivanje)
- pogon prednjeg mosta (uključeno/isključeno/auto)
- priključno vratilo za pogon pomoćnih agregata (*PTO*- isključeno/uključeno)
- blokada diferencijala- uključeno/isključeno.

Traktori uglavnom pored opisane funkcije elektronske kontrole *ELC*, imaju ugrađene i neke dodatne funkcije koje zavise od proizvođača. Kao bi se realizovale dodatne funkcija primenjuje se monitor performansi *Datatronik* koji je povezan sa *ELC*. Za rad sa transportnim sredstvima primenjena je aktivna kontrola transporta *ATC-Active Transport Control*, kojim se apsorbuju udarci pri transportu i neutrališu pojave "skakutanja".

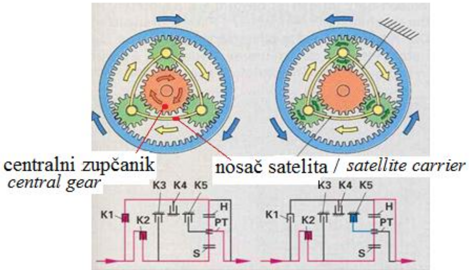
Da bi se održale ravnomerne dubine oranja sa polunošenim plugovima na traktorima, ugrađena je dvojna kontrola (*Dual Control*) kojom se automatski kontroliše ulazak i izlazak plužnih tela iz brazde. Time se održava ravnomerna dubina i na neravnoj površini zemljišta [14]. Dodatna funkcija *Draft Control* kontrola vuče obezbeđuje da plug pri podizanju održava položaj paralelan sa površinom zemljišta [7].

Kod rada sa priključenim vučenim mašinama, primenjuje se sistem odnosno funkcija kontrole vučenih mašina *TIC* (*Trailed Implement Control*) [15]. Pomoću podataka o vučnoj sili, visini mašine i klizanja točkova, dobijenih od određenih senzora, automatski se reguliše dubina rada preko elektronski kontrolisanih elektromagnetnih ventila.

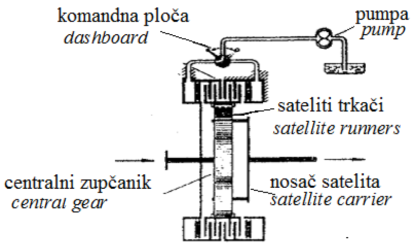
Kontrola protoka ulja na spoljnim izvodima vrši se posebnim sistemom upravljanja solenoidnim ventilima *SMS* (*Spool Valve Menagment System*). Ako se veza uspostavi preko *Datatronik* sistema, može se podesiti i vreme obavljanja određene funkcije [16].

Menjački prenosnik bez prekida toka snage predstavlja osnovni i najznačajniji sklop prenosnika snage. Osnovni zadatk menjača je da pri prenosu snage od motora na pogonske točkove izvrši promenu njegovih parametara: obrtnog momenta i broja obrtaja odnosno ugaone brzine [5]. Osim osnovnog zadatka menjač omogućava_kretanje traktora napred/nazad što se postiže sa i bez prekida toka snage [18]. Menjački prenosnici bez prekida toka snage sa promenom stepena prenosa pod opterećenjem, mogu biti kao:

- *Semi PowerShift* - pojedini stepeni prenosa se uključuju pod opterećenjem.
- *Full PowerShift* - svi stepeni prenosa se uključuju pod opterćenjem.
- *CVT* - imaju kontinualnu promenu prenosa.



Slika 1. Planetarni prenosnik, [6]
Figure 1. Planetary gearbox, [6]



Slika 2. Šema rada *PowerShift* menjača, [6]
Figure 2. Power Shift transmission scheme, [14]

Prvi prenosnici snage, (*Semi PowerShift* grupa menjača), bili su planetarni zupčanici kod kojih se kočenjem jednog zupčanika dobijao pojedini stepen prenosa i obavljao prenos snage. Planetarni set zupčanika sastoji se od centralnog zupčanika (sunčanik), planeta-setelit zupčanika sa njihovim nosečem i nazubljenog venca, (slika 1.)

Kočenje se vrši tako što se nazubljeni venac planetarnog zupčanika po svom spoljnom obodu ima čvrsto spojene lamele, među koje ulazi set frikcionih lamela čvrsto spojenih sa kućištem menjača [15]. Na ove lamele utiče klip potiskivan pritiskom ulja tako da on vrši kočenje nazubljenog venca. Usporavanjem nazubljenog venca ubrzavao se nosač planetarnog zupčanika i dobijao se jedan stepen prenosa bez zaustavljanja traktora, koji može da se uključi pri različitom broju obrtaja kolenastog vratila motora [17]. Kombinacijom više takvih planetarnih prenosnika u liniju, dobija se menjač bez prkida toka snage, tzv. *Full PowerShift* menjač čija je šema data na slici 2.

Na taj način su poboljšani uslovi rada zbog jedinstvenog i udobnog rukovanja, samim tim je povećana ekonomičnost i produktivnost traktorskog agregata, ali postoje i izvesni transmisioni gubici snage. Ovakve konstrukcije se najčešće susreću kod traktora kategorije 30-60 kW i 60-90 kW.

Traktori kategorije preko 120 kW imaju ugrađene menjačke prenosnike kod kojih se svi stepeni prenosa uključuju pod opterćenjem u okviru jedne grupe brzina [7]. Zbog smanjenja transmisionih gubitaka vratila menjača su poređana po visini kako zupčanici ne bi bili u dodiru sa uljem. Zupčanici u menjaču su sa pravim zupcima, kao bi se eliminisale aksijalne sile i smanjili gubici. Radi ravnomernog prenosa snage dubina zubaca je povećana tako da su uvek tri para zubaca spregnuta [11]. Kontrola i upravljanje na starijim konstrukcijama traktora je hidraulično, dok je kod novih menjača elektro-hidraulično [9]. Na osnovu komande rukovaoca, računar šalje signale za uključivanje spojnice ka solenoidnom ventilu koji otvarju tok ulja ka spojnici [10]. Danas se koriste različite vrste solenoidnih vetila od koji su neki prikazani na slici 3.

Slika 3. Solenoidni ventili, [14]
Figure 3. Solenoid valves, [14]

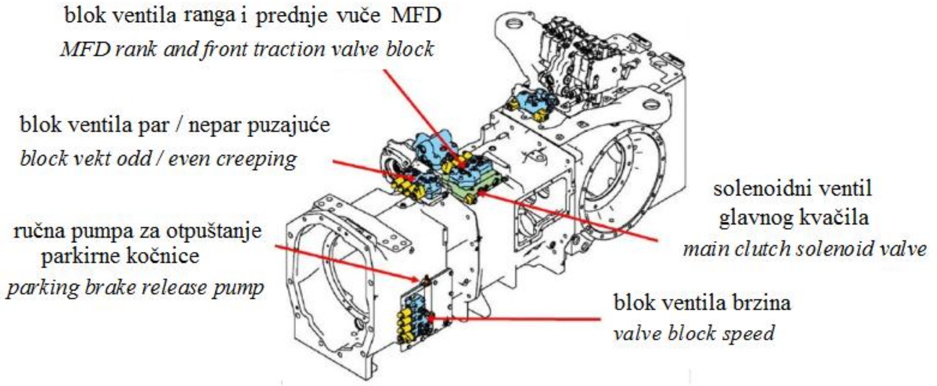
Postoji *PowerShift* transmisija (sa 16+5 stepeni prenosa), sa zupčanicima u stalnom zahvatu i elektronskim upravljanjem uz pomoć proporcionalnih elektromagnetskih ventila sa daljinskim komandama. Drugo, opciono, izvođenje je transmisija *PowerShift* (sa 12+2 stepeni prenosa), sa elektronskim upravljanjem pomoću proporcionalnih elektromagnetskih ventila. Kao ulazni parametar za automatsko upravljanje transmisijom koristi se obrtni moment motora, pa se na taj način ostvaruje postepena i komforna promena stepena prenosa [20].

Treća varijanta transmisije je (sa 24-stepena prenosa) *Power Sunc* transmisija kod koje je kombinovana *PowerShift* i sinhro-tehnologija.

Hidrostatički prenosnici snage u transmisiji traktora obezbeđuju:

- kontinualnu promenu prenosnog odnosa,
- prenos velikih snaga pri malim dimenzijama i masama komponenata,
- mogućnost lakšeg razmeštaja više radnih uređeja,
- preciznost radnih pokreta,
- zaštitu pogonskog motora od preopterećenja i
- lako uključivanje i isključivanje radnih uređaja.

Kompletno kolo za kontrolu transmisije se sastoji od tri sklopa ventila koje čine individualni PWM (*Pulse Width Modulating-PWM*) solenoidni ventili, upravljani od strane modula za kontrolu transmisije. Spojnice koje su kontrolisane PWM ventilima su: spojnice ranga (niski, srednji i visoki); spojnice brzinske sekcije (od I do V stepena prenosa) , hod unazad, spore brzine; spojnica prednje vuče i glavna spojnica kardanskog vratila, (slika 4.).



Slika 4. Položaj blokova ventila na *Power Shift* transmisiji, [6]
Figure 4. Position of valve blocks on Power Shift transmission, [6]

Napajanje ovih ventila kontroliše elektronska kontrolna jedinica, koja sa druge strane prima komande iz kabine preko komande za promenu stepena prenosa ili pedale za postepeno kretanje. Spojnice blokade diferencijala, parkirne kočnice i prednje vuče su kontrolisana preko PCS (*Proportional Current Solenoid*) ventila.

Full PowerShift transmisija svojim nazivom ukazuje na vrstu menjačkog prenosa. Kod ove vrste menjačkih prenosnika svi stepeni prenosnika mogu se menjati pod opterećenjem duž celog opsega od prvog do poslednjeg stepena prenosa. Kod menjačkih prenosnika bez prekida toka snage, izbor stepena prenosa odabira se putem poluge (zaokretanjem na hidrauličnim ventilima), ili putem tastera prikazanih na slici 5.

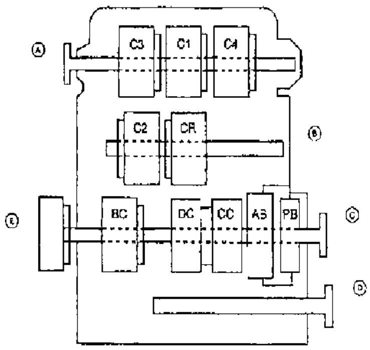
Savremena *Full PowerShift* transmisija kod traktora, koja je danas u upotrebi, (slika 6), otklonjen je nedostatak ranijih *PowerShift* menjača. Drugim rečima, kod *Full PowerShift* transmisije uključuju se svi stepeni prenosa pod opterećenjem bez prekida toka snage [18].

Za razliku od ostalih menjača, gde se svi planetarni prenosnici nalaze u jednoj liniji, novi menjač ima više vratila preko kojih se ostvaruje pogon preko odgovarajućih sa zupčanika [21].

Kod nove transmisije upravljanje se obavlja pomoću elektrilnih signala koji se sa male ručice, postavljene na pokretnoj konzoli sedišta vozača, šalju na solenoidne ventile. Kod starijh generacija transmisije, pomeranjem ručice za izbor stepena prenosa, direktno se zaokretao razvodni ventil, koji je slao ulje u pojedine kočnice planetarnih parova.

Slika 5. Komande za selekciju stepena prenosa, [19]

Figure 5. Display gear selection commands, [19]

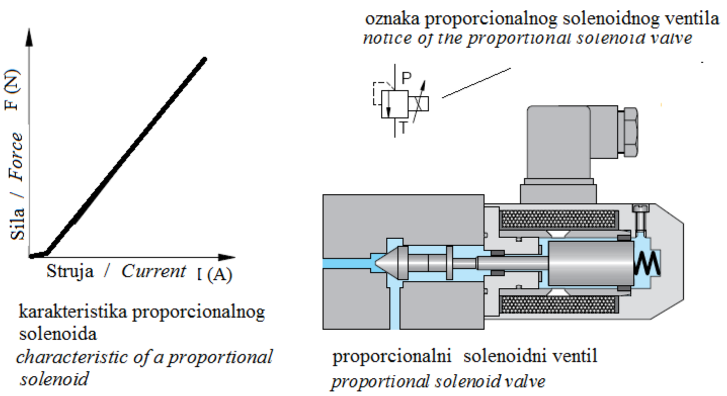


Slika 6. Elementi *Full PowerShift* transmisije, [22]

Figure 6. Elements of Full PowerShift transmission, [22]

PowerShift transmisija se sastoji iz ulazne i izlazne sekcije. Ulazna sekcija sadrži različita vratila za kretanje napred i nazad, postavljena na ulazno i pomoćno vratil(C1, C4, C2 i CR). Izlazna sekcija sadrži kvačila i kočnice na izlaznom vratilu (BC, DC, CC, AB i PB). Broj stepeni prenosa je 16 za hod napred i 5 stepena prenosa za hod nazad. Na drugom kraju izlaznog vratila nalazi se kvačilo i mehaničkog pogona prednjeg mosta (MFWD), a ispod njega vratilo za pogon priključnog vratila traktora. Promena stepena prenosa vrši se pomeranjem komande postavljene na pokretnoj konzoli sedišta, pri čemu se šalje signal određenom solenoidnom ventilu za aktiviranje spojnice.

Proporcionalni solenoidni ventili (slika 7.), imaju oznaku i karaktristike. Ovi ventili omogućavaju da se pri inercijskim opterećenjima izvrši upravljanje uz veliku tačnost, brzinu odziva i maksimalno pojačanje snage.



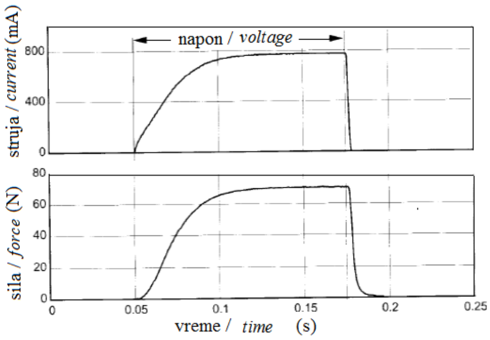
Slika 7. Proporcionalni solenoidni ventil, [14]

Figure 7. Proportional solenoid valve, [14]

REZULTATI ISTRAŽIVANJA I DISKUSIJA

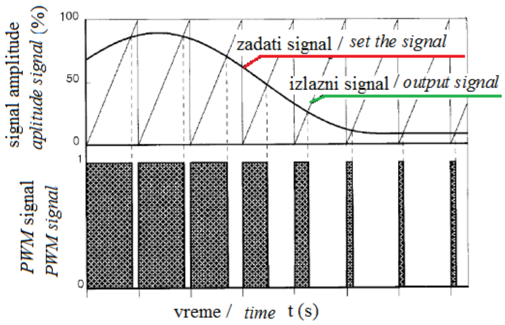
Na grafiku 1. dat je step odziv solenoidnig ventila odnos sile, stuje i vremena. U vremenskom intervalu t=0,05s solenoid je napajan sa jednosmernim električnom energijom. U vremenskom intervalu, t= 0,175s je kolo prekinuto.

Odziv sistema sa aspekta privlačne sile i napona je prikazan na grafiku 1. Primetan je aperiodičan odziv sistema koji se može modelovati diferencijalnom jednačinom prvog reda, sa transportnim kašnjenjem od T=20ms.



Grafik 1. Step odziv solenoidnog ventila, [14]
Chart 1. Step response of solenoid valve, [14]

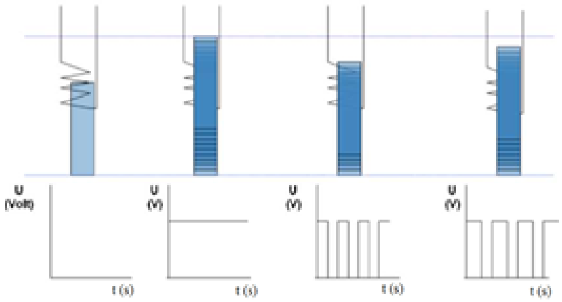
Kao bi se izbegli magnetni uticaji na modulisani signal, upotrebljava se sklop ventila označen *PWM (Pulse Width Modulation)*, a koristi se za izbegavanje histerezisa, pa je signal ove sprege prikazan na grafiku 2.



Grafik 2. Signal regulisan *PWM* vezom ventila, [21]
Chart 2. Signal regulated by PWM valve connection, [21]

Kompletno kolo za kontrolu transmisije se sastoji od tri sklopa ventila koji čine individualni *PWM* (*Pulse Width Modulating-PWM*) solenoidni ventilili, upravljani od strane modula za kontrolu transmisije.

Spojnice koja se kontrolisišu *PWM* ventilima su: spojnica ranga (niski-srednji-visoki), spojnica brzinske sekcije (I, III, V stepen prenosa, hod nazad, puzajuće brzine, parne i neparne), spojnica prednje vuče, glavna spojnica i spojnica pogona prednjeg mosta, prikazani su na slici 8.



Slika. 8. PWM ventili (PWM- pulse with modulation), [14]
Figure 8. PWM valves (PWM pulse with modulation), [14]

Električno napajanje *PWM* ventila kontroliše elektronska jedinica (*eng. electronic control unit*) koja sa druge strane prima komande iz kabine preko komande promene stepena prenosa ili pedale za postepeno kretanje (*eng. inching pedal*). Kvačilo blokade diferencijala , parkirne kočnice i prednje vuče su kontrolisana preko *PCS* ventila. Sa porastom struje u kalemu, proporcionalno njenoj jačini struje (A), pomera se i ventil vezan za solenoid. Prednosti proorcionalnih ventila su :

1. Podesivost ventila :
   - neograničeni podesiv protok i pritisak pomoću ulaznog električnog signala,
   - automatsko podešavanje protoka i pritiska za vreme rada sistema.
2. Uticaj na pogon:
   - automatsko, beskonačno i precizno podešavanje (sila pokreta, ubrzanje, kretanje ili brzina, pozicija ili ugao).
3. Uticaj na potrošnju energije:
   - potrošnja energije može biti smanjena zahvaljujući zahtevima odgovarajuće kontrole i pritiska i protoka.
4. Pojednostavljenje spojeva ventila:
   - proporcionalni ventil može zameniti nekoliko ventila npr. ventil za kontrolu smera menja ventile za kontrolu protoka.

Funkcija i osobine procesa promene stepena prenosa

Svaka promena stepena prenosa se vrši pritiskom na komandu u kabini traktora. Kontroler transmisije "čita" datu komandu i menja matricu spregnutih zupčanika promenom *PWM* radnog cilusa aktivnih i neaktivnih proporcionalnih elektro-hidrauličnih ventila. Kontroler transmisije poseduje memorisanu krivu (vreme/pritisak) za svaku kombinaciju aktivnog i neaktivnog solenoidnog ventila u svakom stepenu prenosa. Elektro-hidraulični ventili propuštaju ulje koji je proporcionalno jačini električne struje dovedene na ventil od strane kontrolera.

Pritisak za svaku spojnicu je kontroliše tako da se uspostavi odgovarajući prelazni pritisak potreban za postepenu promenu stepena i za ravnomeran prelaz sa deaktivnne na aktivnu spojnicu. Ovaj kalibrisani pritisak poboljšava kvalitet promene stepena prenosa i smanjuje nivo buke pri radu transmisije.

Broj obrtaja kolenastog vratila motora i broj obrtaja na izlazu iz transmisije se direktno prate od strane kontrolera transmisije radi eliminacije faznog kašnjenja koje se javlja kada se vrednosti obrtaja prate preko *CAN bus* mreže.

Broj obrtaja kolenastog vratila motora i broj obrtaja na izlazu iz transmisije se direktno nadgledaju od strane kontrolera transmisije radi eliminacije faznog kašnjenja koje se javlja kada se vrednosti obrtaja prate preko *CAN bus* mreže koja prenosi informacije o obrtajima na kontrolni displej. Kao rezultat direktnog očitavanja ostvaruje se kvalitetniji rad spojnice zasnovan na povratnoj informaciji o broju obrtaja kolenastog vratila motora i transmisije.

Elektronsko upravljanje promenom stepena prenosa rezultira u mogućnost:

- programiranja podrazumevanog stepena prenosa za "*power shuttle*" funkciju
- aktiviranja "*autoshift* " funkcije u okviru radnih i transportnih brzina.

Vučne karakteristike traktora

Izbor stepena prenosa vrši elektronska kontrolna jedinica koja preko ventila za kontrolu transmisije omogućava proticanje fluida i na taj način aktivaciju određenih spojnica., odnosno dovođenje u spregu određenog para zupčanika. Često se u literaturi upotrebljava naziv za elektronsku kontrolnu jedinicu kontroler transmisije (*transmission contorller*). Uloga kontrolera transmisije je da u određenom vremenskom periodu izvrši deaktivaciju jednog i aktivaciju drugog seta spojnica. Promena treba da bude obavljena u određenom vremenskom roku, da ne bude duga, kako ne bi došlo do proklizavanja, a isto tako da ne bude spora kako ne bi bila karakterisana udarnim opterećenjima.

Grafik 3. Sila na poteznici u funkciji snage traktora, [1]

Chart 3. Traction force as a function of tractor power, [1] *Full PowerShift* je kvalitetno tehnološko rešenje transmisije za traktore koja je veoma laka za korišćenje. Pomoću samo jedne ručice, džojstika, vrši se meka promena brzina od v= 0 do 40 (km/h) ili bilo koje brzine između. Nije potrebano pritisak na papučicu spojnice čak ni kada se zaustavlja traktor. Jednostavno podesi se željena brzina u radu ili transportu, i motor i transmisija će raditi usklađeno obezbeđujući maksimalno efikasan rad traktora, automatski i brz odgovor na promene opterećenja.

U ovom radu će se prikazati vučne karakteristike traktora R-135 razvijenog u Industriji motora u Rakovici koji je podvrgnut detaljnim ispitivanjima i kao rezultat je prikazan na dijagramu (slika 3). Menjački prenosnik traktora R-135 je proizveden u *ZF PASSAU* Gmbh D-94030 Passau, tip Full PowerShift T 7117 [1].

Sa dijagrama datog na grafiku 3, uočava da tokom rada traktora pod opterećenjem i pri određenoj, zadatoj brzini, kontrolna jedinica prepoznaje opterećenje motora i otpor na poteznici odnosno otpor pri vuči traktora nakon čega automatski usklađuje otpor sa snagom motora i koriguje odgovarajućim stepenom prenosa bez prikada toka snage. Dakle, u slučaju da je otpor manji kontrolna jedinica prebacuje stepen prenosa u viši stepen i obrnuto. U slučaju da je otpor na poteznici veći kontrolna jedinica obezbeđuje da se pod opterećenjem izvrši promena prenosa na niže i obezbedi usklađenost raspoložive snage motora i realnog otpora na poteznici. Tok te transformacije se ostvaruje po višestrukoj krivoj liniji (grafik 3).

ZAKLJUČAK

Traktor sa kontinualno promenljivom transmisijom u eksploataciji ima rad bliže maksimumu izlazne snage i odgovara na svako povećanje ili smanjenje opterećenja, bez obzira na *PowerShift* rang, bez menjanja stepena prenosa. Maksimalni stepen iskorišćenja transmisije dobija se automatskim usklađivanjem broja obrtaja kolenastog vratila motora i prenosnog odnosa transmisije. To omogućava da se pri velikim transportnim brzinama smanjuje broj obrtaja kolenastog vratila motora, u oblasti konstantne snage, a time se smanjuje potrošnja goriva i povećeva stepen korisnog dejistva transmisije. Istovremeno sve radne operacije traktora u eksploataciji sa kontinualnom transmisijom su mnogo lakše i jednostavnije.

Trend proizvođača traktora je uvođenje što boljih i inovativnijih rešenja transmisija, što jasno ukazuje na porast primene hidromehaničkih transmisija. Primetan je rast naprednih rešenja iz godine u godinu kod mnogih proizvođača savremenih traktora posebno kod kategorija traktora od 90 kW do 120 kW.

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CHARACTERISTICS OF POWERSHIFT GEAR OF AGRICULTURAL TRACTORS

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Abstract: This paperwork paper presents and analises the functioning of one main tractor assemblies, precisely the transmission. This includes and it is applied to a technologically advanced gearbox solution such as *Full PowerShift*. This type of gearbox is the most represented currently on the market because it is transmission without interruption of power flow. Also, there will be adequate proportional solenoid valve that is an integral part of the transmission. With its construction and function, it provides specificity in gear changes.

Changing gears without interrupting the power stream, during transportation does not result in stopping the tractor and changing the engine mode due to load and nominal power of machine.

The overrun and in between struggle of manufacturers for the most efficient and rational solution today has led to the offer of an extremely wide range of various gearboxes. Gearboxes with different electronical elements give different exploatations characteristics. In this way, they form differential types of gearboxes, which different so much that it is almost impossible to capture them in a proper analysis.

Key words: *Agricultural tractor, Full PowerShift, Continuous power flow, Solenoid valve.*

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