Development of Ecologically Sustainable Green Products Usable in the Agro-Sector as a Result of Innovative Technical Education

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Abstract: Growing concern of carbon dioxide emissions, greenhouse effects and rapid depletion of fossil fuels raise the necessity to produce and adopt new eco-friendly sustainable alternatives to the internal combustion engine driven vehicles. For this reason, in the last decade, electric vehicles have become in some way widespread, principally because of their negligible flue gas emissions and lesser reliance on oil. Although electric cars were introduced many years ago, agriculture electric vehicles have recently gained attention. The world of agriculture has changed, small specialized farm utility vehicles are now used for a specific purpose, and in several cases they have an electric engine.

In our research, we focused on the design and preparation of a prototype the variable, multifunctional ecological electric loader, which would be dimensionally adapted to the needs of use in greenhouse, interior growing halls, as a result of research by students of innovative dual technical education with effective support of their teachers.

The research deals with specifically the solution of aluminium welding by the TIG method, because the prototype frame is the welding of aluminium parts.

The result of our research was the design and construction of a prototype of a smaller electric loader, which meets demanding quality parameters (performance) and environmental attributes (reduced noise and almost zero emissions) for work in greenhouses.

The benefit of our research is the design and actual implementation of a prototype of a different ecological “green” electric loader, which is still missing on the market in the agricultural sector and is the output of creative innovative technical education in the environment of secondary vocational schools

Keywords: Sustainable agriculture, ecological electric cars, TIG method, innovative technical education

1 Introduction

During the last few years changes have been made in the agriculture sector, passing from the use of large tractors to the use of small and efficient vehicles [1, 2]. Electric vehicles are widely used in agricultural enterprises that adopt organic farming methods as they are completely ecological, they do not pollute, and at the same time have the power necessary to perform challenging tasks; they are very strong, have high performance, are very narrow and have a unique towing capacity [2–4].

A new trend in agriculture is the development of multifunctional, variable, small-sized electric vehicles that can also move in the interiors of greenhouses and growing halls [1, 3, 5, 6].

As a result of changes in the requirements in agriculture, there was a need to pay attention to the design of such design solutions for electric vehicles, respectively loaders that would be smaller, with the required performance, but more adaptable and adapted for use in interiors, e. g. greenhouses or growing halls. In addition to the required power [3, 4], reduced noise and unwanted emissions are required compared to traditional agricultural transport equipment [7–10].

Based on the above, we focused in our research on the design and preparation of a prototype of a smaller loader, the specification of dimensions and parameters are presented in the experimental part of the paper.

Frontal loaders are used in agriculture, but also in other industries [5, 11, 12]. The front loader [3, 13] is actually designed and ready for production, including a drawing document for a prototype of an electric vehicle, specifically an electric tractor. This electro tractor serves to teach high school students. Its advantage, besides being environmentally friendly, is that it does not disturb other students while driving during lessons [14]. Its use is, of course, wider. We are preparing other equipment for its use in soil cultivation e.g. in a greenhouse or foil field.

In our research, we relied on our own several years of experience, which we gained in various design and subsequent implementation of prototypes of multifunctional universally usable electric vehicles, as a cooperation of members of the research team. In this paper, we present the sequence of individual steps in the design of a multifunctional ecological loader (in the Autocad program) in a new dimensional version (smaller and better usable dimensions), applicable especially for mobility needs in greenhouses and interior halls in the agricultural sector.

2 Literature review and problem statement

According to Mitrenga (2011) [8] a growing population and the impact of climate change represent clear challenges for the agricultural sector. In [2, 11, 12] mention in their research contributions that the adapting agricultural machinery, e. g., raising the use of electric vehicles (EVs) , is one way of meeting such challenges. In [3] although interest in EVs and sustainable farming is becoming ever stronger, in practice the usage of EVs still remains at a relatively low level.

Demands for decarbonization represent a major environmental challenge in todayˇs fuels-based economies. According to [6] and [11] state the following in their contribution: electric mobility, despite the related challenges, is seen as a promissing way of reducing carbon intensity of transport systems.

At present, the agricultural sector requires variable ecological, small electric multifunctional vehicles that can move in enclosed areas of greenhouses, with reduced noise and high performance [12].

Thus, electric vehicles are seen as one means of contributing to sustainable transport policy [2, 15]. From a usability perspective, e-mobility has made significant advances over the past years. According to [7-9] a new trend in agriculture is the development of small multifunctional electric vehicles, which can respond to the requirements of the agricultural sector, i. have small variable dimensions, low noise, high performance and excellent mobility, especially in the interiors of greenhouses and growing halls.

In our research work, attention was also focused on the issue of transfer of research results into innovative technical teaching in the environment of secondary vocational schools [15–17]. By combining dual teaching, the results of research in the development and implementation of prototypes of an electric loader with additional equipment were realized as an implementation output of the work of students and their teachers.

From the above it is clear that in our research we focused on the design of such a prototype eco loader, which would be universally applicable in agriculture in interior applications and would satisfy the requirements in the agro-sector, as existing models are structurally more massive and do not allow trouble-free handling e.g. in greenhouses and smaller halls. In our own design, we have applied the experience from previous successful outputs in the form of actually made prototypes with emphasis on their functionality, versatility and environmental friendliness, thus responding to the current requirements of the agricultural sector.

We assume that for the successful implementation of a smaller series production of our proposed multifunctional ecological loader, it will be necessary to perform a more detailed analysis (SWOT) to set the production efficiency and variable production of additional equipment.

3 The aim and objectives of the study

The aim of the paper is to show the possibility of a design solution of the loading bucket of an electric tractor as a student simulator. Gradually, there were demands to develop additional attachments such as a bucket, a high-lift platform, etc., so that students could improve their skills as a result of an innovative dual technical education.

The following objectives have been set to achieve the goal:

– design of a small multifunctional ecological front loader, dimensioned for indoor use using a visualization program (AUTOCAD);

– implementation in the preparation of our proposed prototype of a small ecological electric front loader;

– transfer of the results of our research into cooperative dual technical education – involvement of students of the selected vocational school in solving the research task, so that they are effectively involved in solving the needs of practice and for better employment in the labor market.

4 Materials and methods

In our research work – in the construction design of a small ecological multifunctional front loader, methods were

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used, which we present below. Materials - aluminum alloys - were used to make a prototype of a small front loader. The characteristic mechanical, physical and chemical properties of these aluminum alloys are presented in more detail in Tables 1, 2 and in Fig. 6.

4. 1 Preparation of construction drawings

In the first phase - preparation of project documentation - construction drawings in the AUTOCAD program - with the possibility of visualization of the overall prototype of individual components of the front loader. At the same time, additional devices to the multifunction loader were designed and visualized.

4. 2 TIG welding of aluminium components

We applied the TIG method, arc welding using a non-melting tungsten electrode in an internal atmosphere, to join individual aluminium parts and components. Mechanical, physical and chemical properties of used aluminium alloys are characterized in Tables 1, 2.

4. 3 Construction of a prototype of a multifunctional front loader

The finalization of our research consisted in the implementation of the proposed multifunctional front loader, different in size and mobility from commercially produced similar electric loaders.

In our research, we focused on the application of the principles of innovative technical education (e. g. cooperative teaching, cooperation on the design processing of project documentation, visual animations) of secondary vocational school students by implementing the principles of dual education.

5 Results of research

5. 1 Preparation of construction drawings - in our research work

The first attachment designed was a bucket. This bucket was designed as a possible design solution for an existing prototype electric vehicle. The proposal demonstrates the improvement of the existing [5] selected parameters as well as the extension of the usability of the vehicle in practice.

At the beginning, we designed the elements and parameters of the loader body and then we designed the loader body as a whole. The next step was to design a loader bucket with attachments to and equipment’s to the loader body. When designing the front loader drive, we proposed to use two HG200S actuators [7, 13]. To attach the actuator to the arms, the TIG eyes are welded [4] at the weld location of the first and second parts of the arm, into which the grooves of the actuator will be attached and connected by means of a pin.

An integral part of the construction of the front loader is the drive stroke unit, so we also focused on the actuators. In addition to the description of existing types of loaders, we show the solution of one of the possible design solutions of the front loader body with a prototype of a commercial electric vehicle with demanded technical parameters.

The final parameters of our proposed the actuator are: maximum stroke of 120 mm, which results in a basic length of the actuator, which will be 280 mm and when fully extended, its length will be up to 400 mm.

At the same time, in our research work, we paid attention to aluminum welding ability by the TIG method, because the prototype frame is the welding of aluminum parts.

According to [3] defines loaders as self-propelled belt

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or wheeled machines with an integrated front-mounted load-bearing structure that allows grabbing and carrying loads (bucket, forks, bale pliers).

Bulk loads are picked up, mined or disengaged by moving the machine forward [8]. The movement of the work carrier can grasp the piece load. The load is transported over a short distance by moving the entire machine and storing them at one time or gradually by spraying the boom or tilting the bucket into the specified position [9, 17].

From this definition, it follows that the loader is primarily designed for handling loads or bulk materials [1, 2] we can divide them into small and large front loaders.

According to (CIME) articulated loaders (Fig. 1) [19] are popular with many farmers, especially those engaged in animal production in places where conventional manipulators do not fit. Due to the need to move in narrow spaces, small dimensions and articulated steering are an indisputable advantage, and even with these relatively small size machines, we can achieve good hour performance [6].

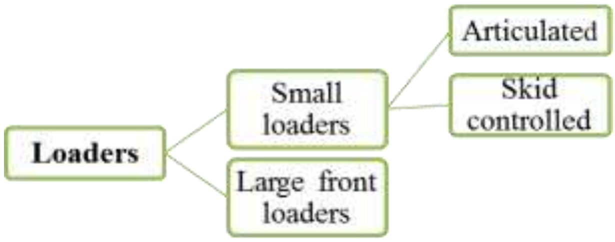

Fig. 1. Types of loaders

Typically, these loaders are equipped with engines up to 100 horsepower. Machines are simple and are often without a cab. Load control is also simple; the drive is mostly hydrostatically designed. The weakness is the lower stability of the machines when cornering, due to articulated steering [18]. In the Fig. 2 [19] we shoved standard skid steer loader.

Nowadays, these loaders are no longer used, but have been very popular in agricultural operations. The advantage of skid steer loaders (Fig. 3) [19] is their stability and dexterity. On the other hand, the disadvantage can be greater tire wear due to shear steering and less ground clearance due to low centre of gravity [18]. The front loader we can see in the Fig. 4 [1]

Fig. 2. Articulated loader [19]

Fig. 3. Skid steer loader [19]

Fig. 4. Front loader [1]

The tractor front loader construction consists of a bracket attached to a tractor for loader attachment and a self-propelled loader with linear hydraulic motor and other hydraulics components [12, 17].

Different types differ mainly in loader size, lifting force, lift height and equipment [6]. The tractor's hydraulic equipment is used to operate the front loader. Tractor frontal loaders extend the use of tractors on a farm and thus reduce their direct cost per hour of operation. A short installation and disassembly time allows you to use the tractor as required.

According to [18], these machines include large single-purpose front loaders, most commonly articulated and designed to handle large volumes of material, powerful engines and large bucket sizes.

An electro tractor has an important environmental role. Because it is equipped with a non-combustion engine and does not discharge combustion into the air, it has been involved in the project "Clean Mobility for a Better Environment in Czech Canada". The prototype of this electric tractor was designed by students of the secondary vocational school in Dacice and was first introduced in Slavonice in June 2014. Students of the field of car mechanic and repairer of agricultural machinery mainly attended the construction.

The prototype has already been awarded the E.ON Energy globe award 2015 (2^{nd} place), an extraordinary award at the Technical and Educational Consortium Olympics at the VSTE Ceske Budejovice and the amper fair 2015 in Brno in the category of commercial vehicles (1^{st} place).

The prototype (Fig. 5) is of great interest to the public, especially entrepreneurs, such as gardeners, who would like to use this vehicle in their large greenhouses, because unlike small-sized tractors with a combustion engine there is not much noise and there is no need to solve the problem of ventilating space from a closed glasshouse. Visualization of prototype of ecological small electric vehicle is presented in Fig. 5.

Fig. 5. Prototype of ecological small electric vehicle (own research)

In the Fig. 5 are shown the prototype of ecological small electric vehicle usable in agriculture, e.g.in interior glasshouse.

5. 2 TIG welding of aluminium components – presentation of outputs

Aluminium is a silvery glossy metal, which, given its density ρ=2700 kg.m^{-3}, is among the so-called light metals. This substance has excellent cold formability because it crystallizes in a cubic system with a flat centred mesh. Aluminium has a strength of 70 MPa and the melting point is about 600 °C [6] Another characteristic feature of aluminium is good thermal and electrical conductivity [9].

The properties of aluminium, most of all electrical conductivity and strength, are highly dependent on its purity. Classical production methods can produce a 99.3-99.8 % pure metal [17]. As technically pure electro-aluminium, we refer to 99.5 % pure metal, which is most used for semi-finished products.

By multiple electrolysis, we can achieve Al purity of

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99.99 % and even up to 99.9999 % using special refining methods. Since the production of such aluminium is very expensive, it is produced only for laboratory and other special purposes. Highly adhesive and electrically non-conductive layer of Al_2O_3 oxide about 0.1 mm thick on the aluminium surface, we achieve its corrosion resistance [5, 10].

The density of this layer is ρ=3960 $kg.m^{-3}$ and the melting point t=2250 °C is higher than that of aluminium itself [11, 14]. The following table compares the selected properties of aluminium and low carbon steels (Table 1) [10].

Table 1

Comparison of properties of aluminium and low carbon steel [10]

Properties	Aluminium	Low carbon steel
Density at 20 °C [$kg.m^{-3}$]	2699	7850
Density at melting point [$kg.m^{-3}$]	2380	7000
Melting point temperature[°C]	660	1530
Thermal conductivity [$J.cm^{-1}.s^{-1}.°C^{-1}$]	2.1	0.46
Thermal expansion [$°C^{-1}.10^{-6}$]	23.8	12
Strength [MPa]	80	350

Aluminium alloys - the mechanical properties of aluminium can be influenced by the addition of alloying elements to pure aluminium, resulting in aluminium alloys [13, 20, 22, 23]. From the following Fig. 6, we find that the main alloying elements include magnesium, copper, manganese, silicon and zinc [18].

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The following Table 2, is illustrated containing the chemical alloy distribution of aluminium alloys, gives an approximate percentage of the alloying element content [13].

Table 2

Material composition of aluminium alloys [13]

Shaped alloys	
Al – Cu – Mg	Cu content 3–5 % and about 1 % Mg; have higher strength, are suitable for heat treatment, difficult to weld
Al – Mg – Si	Mg content 1 % and maximum 1 % Si; have higher strength and are corrosion resistant
Al – Zn – Mg	Zn content 3–5 % and Mg 1–2 %; have higher strength, suitable for heat treatment, difficult to weld
Al – Mg	Content 2–9 % Mg; have a lower strength, are corrosion resistant, can be welded
Al – Mn	Mn content 1.5 2.5 %; have a lower strength, are corrosion resistant, can be welded

Weld ability of aluminium [20] explains the ability of the material to achieve the desired properties of the weld joint under certain conditions. Aluminium welding influences several factors, the most important of which is the alumina layer (Al_2O_3) present on the surface of aluminium or aluminium alloys. Since this layer prevents the metallic connection of the base material with the auxiliary material, it must always be removed from the surface of the welded parts prior to welding, but because of its resistance, the removal is very difficult. In order to remove the Al_2O_3 layer, mechanical, physical and chemical detergents are most used [6].

For chemical removal, a layer of alumina can be removed before starting welding with a pickling and rinsing

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bath or directly during welding, using suitable Al_2O_3-soluble fluxes. Another option is the removal of the Al_2O_3 layer mechanically, for example by a stainless steel machine or hand brush. Once the layer has been removed, welding has to be started immediately since aluminium has high affinity for oxygen, which causes the oxidation layer to recover within a few milliseconds, although a longer time is required to achieve sufficient welding-avoidance thickness [5, 11]. The final way to remove Al_2O_3 is to cleanse the physical arc welding phenomena [10].

Welding of aluminium by TIG (TIG - Tungsten Inert Gas), welding with Tungsten Electrode - TIG is an international acronym for designating the arc welding method with the help of a non-fusing electrode and a protective atmosphere of inert gas [10]. In this welding method, the arc burns between the non-fusing electrode and the base welded material. Since the electrode does not melt, it must be made of a material that resists very high temperatures [5]. This condition is met by tungsten. The tungsten electrode is clamped in the TIG torch using a collet [10]. Fig. 7 shows a schematic representation of the TIG welding method [10].

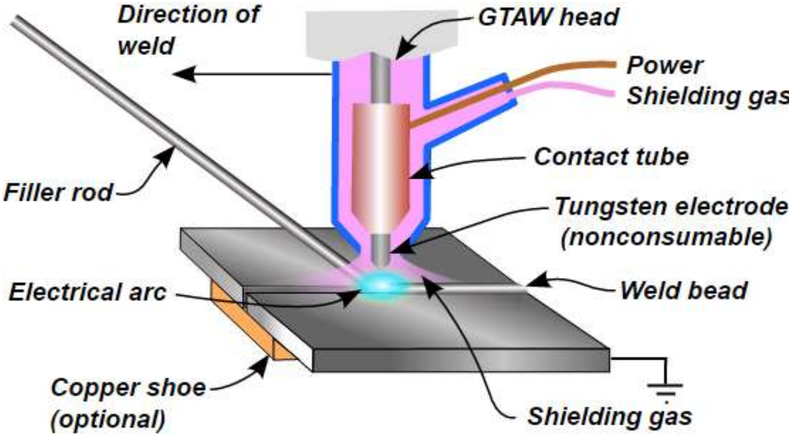

Fig. 7. Schematic representation of the TIG welding method [10]

The welding current is transmitted to the electrode by means of a collet. The internal protective atmosphere creates a gas flowing from the nozzle that is provided with a burner at the welding point. The melt bath is protected by an internal atmosphere from the air and facilitates the ignition of the arc.

Welding can be done without the addition of additive material or addition of additive material. Welding without additional material is accomplished by melting and slitting the base materials in one unit. Welding with the addition of additive material - the additive material is in the form of welding metal wires (rods) having a similar composition to the base material [13].

Ensuring a high-quality welding joint in the event of cloud welding requires the creation of a protection zone of the arc and molten metal from the harmful effect of air. Inert gases (argon, helium and mixtures - do not react with the molten metal) are used to create the protective zone and active gases (carbon dioxide, hydrogen) and their mixtures react with molten metal [15]. Welding methods are manual, mechanized and automated [17].

When welding manually, the welder holds the burner in one hand, the wire in the other hand, and drops it into the bath as needed. Mechanized welding consists in the fact that the welder still holds a burner in one hand, but the wire is fed into the arc by means of a special and motor-driven feeder [4]. The welder, by the button on the burner, controls the wire shift. In automated welding we have a torch in the machine, such as a robot. In this case, the burner guidance and wire addition are controlled automatically [20].

The benefits of TIG welding are as follows [13, 15, 20]:

– the most significant advantage of TIG welding is the excellent control over the welding bath

– TIG can be welded without additional material

– in some cases, we can also use as a feed material a cut or a piece of base material

– high arc temperature, thanks to which we can also weld high-alloy steel

– due to the very narrow temperature field, there is no thermal influence of the base material in such a wide area around the weld

– we can effectively control the heat input into the weld

– use of inert gases ensures excellent welding protection against harmful effects of air oxygen in particular

– TIG can also weld very thin material profiles.

The disadvantages of TIG welding are as follows [5, 6, 10]:

– the greatest disadvantage is low productivity, especially in manual welding, so it is not appropriate to use this method in large-scale production of relatively simple weldments

– especially when welding TIG AC is high technical demands on welding equipment.

6 Discussion of experimental results

In our research, we focused on the design and preparation of a prototype of a small ecological adaptable electric loader, usable in the interiors of growing halls and greenhouses. We have used several years of experience with the design and preparation of such multifunctional adaptable devices, especially for use in agriculture, where there is an increased demand for high-performance electric mobile devices with an ecological attribute - reduced noise and minimized emissions.

Based on the design, a prototype of a small electric loader with specific dimensions (compared to traditionally manufactured types of these devices) was built, which is adapted to the conditions of use in interior applications in the agricultural sector.

An integral part of the construction of the front loader is the drive stroke unit, so we also focused on the actuators. In addition to the description of existing types of loaders, we show the solution of one of the possible design solutions of the front loader body with a prototype of a commercial electric vehicle with technical parameters.

At the beginning, we designed the elements and parameters of the loader body and then we designed the loader body as a whole. The next step was to design a loader bucket with attachments to and attachments to the loader body. When designing the front loader drive, we proposed to use two HG200S actuators.

To attach the actuator to the arms, the TIG eyes are welded at the weld location of the first and second parts of the arm, into which the grooves of the actuator will be attached and connected by means of a pin. The actuator will have a maximum stroke of 120 mm, which results in a basic length of the actuator, which will be 280 mm and when fully extended, its length will be up to 400 mm.

The benefit of our research is the design and construction of a prototype, which has qualitatively fortified technical parameters, such as increased bucket lift, improved mobility of individual designed attachments and the required power to achieve smaller dimensions of this equipment.

The positive of our research can be considered the connection of innovative dual technical education for the needs of practice, the involvement of students in the real solution of specific tasks in the field of agriculture, which supported their creativity in the educational process.

The presentation of the results of our research also revealed certain limitations, namely the problem of obtaining funding for the implementation of research outputs and their implementation in practice.

7 Conclusion

1. The most important qualitative contribution of our research is the design of a small ecological electric loader, usable in the agricultural sector in closed greenhouses and growing halls.

2. A measurable indicator of our research is the construction of a functional prototype of a designed small ecological electric loader with atypical dimensions (compared to standardly manufactured equipment), which we specified at the end of the discussion. This prototype enables better mobility, adaptability to confined spaces in the enclosures of agribusinesses with the required performance, reduced noise and almost zero emissions, which can be considered an innovative product in environmentally sustainable agriculture.

3. Another benefit of our research is the real involvement of students of secondary technical schools in the dual mode of education in research and implementation of results into practice, which has supported their creativity in innovative education.

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References

[1] RUDNER, L. et al. 2018. E-mobility in agriculture: differencies in

perception between experienced and non-experienced electric vehicle user. *Clean Technologies and Environment Policy*, 21(1): 55-67. https: doi.org/10.1007/s10098-018-1615-2.

[2] CELJAK, I., 2013. Strojní zařízení potřebná k manipulaci. *Zemědělec.* **21** [cit. 2016-04-05, 10:13]. ISSN 1211-3816. Available from: http://zemedelec.cz/strojni-zarizeni-potrebna-k-manipulaci/

[3] MICHAL, P., VAGASKÁ, A. GOMBÁR, M. et al. 2015. Usage of Neural Network to Predict Aluminium Oxide Layer Thickness. In: The Scientific World Journal. Vol. 2015 (2015). - ISSN 2356-6140.

[4] MAŠEK, J., 2008. Volba mobilního čelního nakladače. Zemědělec. 16 [cit. 2016-04-02]. ISSN 1211-3816. Available from: http://zemedelec.cz/volba-mobilniho-celniho-nakladace/

[5] STEHNO, L., 2006. Manipulační technika v zemědělském podniku. Zemědělec. 14 [cit. 2016-04-3, 14:21]. ISSN 1211-3816. Available from: http://mechanizaceweb.cz/manipulacni-technika-v-zemedelskem-podniku/

[6] JANOCHA. H., 2004. Actuators Basics and Applications. Berlin: Springer Berlin Heidelberg. ISBN 978-366-2055-878. Available from: http://www.springer.com/gp/book/9783540615644

[7] MITRENGA. A., 2011. Zamyšlení na traktory a čelními nakladači. Agrární obzor. 19, s. 23–24 [cit 2016-04-2, 15:16]. ISSN 1214-1291. Available from: http://www.zetormorava.cz/fotky525/zetor_2011/Zamyleni_nad_traktory_a_elnimi_nakladai.pdf

[8] POSPÍŠEK, V., 2013. Konstrukční řešení pojezdových ústrojí manipulátorů. Brno. Bakalářská práce. Mendelova univerzita v Brně. Ústav zemědělské, potravinářské a environmentální techniky.

[9] TRHLÍK, J., 2010. Využití teleskopického manipulátoru. Brno. Diplomová práce. Mendelova univerzita v Brně. Ústav zemědělské, potravinářské a environmentální techniky.

[10] MOUSAZADEH, H. 2019. A technical review of navigation systems of agricultural autonomous off-road vehicles. Journal of Terra mechanics, 50(3); 2013, p. 211- 232.

[11] GHOBADPOUR, A. et al. 2019. State of the art of autonomous agricultural off-road vehicles driven by renewable energy systém. Energy Procedia, Vol. 162, 2019, p. 4-13. https: doi.org/10.106/egypro.2019.04.002.

[12] T. E. A. TECHNIK, Aktuátory. [s. l.]: T. E. A. Technik, ©2015

[13] KOTLÍK, B. et al., 2011. Matematické, fyzikální a chemické tabulky pro SŠ a nižší ročníky víceletých gymnázií. 2. vyd., Praha: Fragment. ISBN: 978-80-253-1227-8.

[14] HRMO, R., KUČERKA, D., RUSNÁKOVÁ, S.: Strojárstvo. Vysokoškolská učebnica pre majstrov odbornej výchovy. Dubnica: Dubnický technologický inštitút v Dubnici nad Váhom, Vysoká škola technická a ekonomická v Českých Budějovicích, 2014. 236 s. ISBN 978-80-7468-057-1.. ISBN 978-80-89400-90-4.

[15] HRMO, R., KRIŠTOFIAKOVÁ, L. 2016. Quality assurance in higher education with a focus on the quality of university teachers. In *Miština, J., Hrmo, R. (Eds). Key competences and the labour market*. Warsaw : Warsaw Management University Publishing House, Poland, 2016. 298 s. ISBN: 978-83-7520-223-6.

[16] KUČERKA, D. – RUSNÁKOVÁ, S.: Strojírenské technologie I. – 2015. 1. vyd. České Budějovice: Vysoká škola technická a ekonomická v Českých Budějovicích, 2015. 168 s. ISBN 978-80-7468-080-9.

[17] PTÁČEK, L., 2002. *Nauka o materiálu II*. 2. opravené a rozšířené vyd. Brno: CERM. ISBN 80-720-4248-3.

[18] CIME. Galerie kompaktní kloubové nakladače Hoftrac. In: *Oficiální webové stránky Cime* [online]. 2011 [cit. 2016-03-16, 11:43]. Available from: http://www.cime.cz/kloubove-nakladace/kompaktni-kloubove-nakladace-hoftrac/

[19] KOUTNÝ, J., 2006. Hliníkové materiály a možnosti jejich svařování. In: *Portál svařování Svarbazar* [online]. [Cit. 2016-04-05, 18:04]. Available from: http://www.svarbazar.cz/phprs/storage/hlinik.pdf

[20] ELOTECHNIK, Mazací hlavice plochá M1, M4. In: *Oficiální webové stránky Elotechnik* [online]. [Cit. 2016-03-20, 12:15]. Available from: http://www.elotechnik.cz/mazaci-hlavice-plocha-m4-m6.html#zalozka-2

[21] HAJDÍK, J. a M. HEINRICH, 2007. Technologie svařování hliníku a jeho slitin. *Svět svarů*. **5** (1), s. 8–9 [cit 2016-03-26, 18:10]. ISSN 1214-4983. Dostupné také z: http://www.hadyna.cz/svetsvaru/technology/Svar_hlinik1_2007.pdf