ECOLOGICAL ELECTRIC CAR USABLE IN THE AGRICULTURAL SECTOR

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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 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.

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 [Agrics 2011, Riedner 2018]. 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 [Riedner 2018, Celjak 2013, Michal 2015].

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 [Agrics 2011, Celjak 2013, Masek 2008, Stehno 2006].

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 [Krenicky 2018]. In addition to the required power [Celjak 2013, Michal 2015], reduced noise and unwanted emissions are required compared to traditional agricultural transport equipment [Janocha 2004, Mitrenga 2011, Pospisek 2013, Trhlik 2010].

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 [Masek 2008, Mousazadeh 2019, Ghobadpour 2019]. The front loader [Celjak 2013, T.E.A. Technik 2015] 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 [Kotlik 2011]. 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] a growing population and the impact of climate change represent clear challenges for the agricultural sector. In [Riedner 2018, Mousazadeh 2019, Ghobadpour 2019] 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 [Celjak 2013] 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 today's fuels-based economies. According to [Stehno 2006] and [Mousazadeh 2019] 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 [Ghobadpour 2019].

Thus, electric vehicles are seen as one means of contributing to sustainable transport policy [Riedner 2018, Hrmo 2014]. From a usability perspective, e-mobility has made significant advances over the past years. According to [Janocha 2004, Mitrenga 2011, Pospisek 2013] 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 [Hrmo 2014 and 2016, Kucerka 2015, Smeringaiova 2022]. 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 METHODS AND RESEARCH

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 [Masek 2008] 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 [Janocha 2004, T. E. A. Technik 2015]. To attach the actuator to the arms, the TIG eyes are welded [Michal 2015] 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 [Mascenik 2020]. According to [Celjak 2013] defines loaders as self-propelled belt 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 [Mitrenga 2011]. 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 [Pospisek 2013, Kucerka 2015]. From this definition, it follows that the loader is primarily designed for handling loads or bulk materials [Agrics 2011, Riedner 2018] we can divide them into small and large front loaders.

According to [CIME 2011] articulated loaders 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 [Stehno 2006].

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 [Ptacek 2002]. In the Fig. 1 [CIME 2011] we shoved standard skid steer loader.

Figure 1. Articulated loader [19]

Figure 2. Skid steer loader [19]

Nowadays, these loaders are no longer used, but have been very popular in agricultural operations. The advantage of skid steer loaders (Fig. 2) [CIME 2011] 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 [Ptacek 2002]. The front loader we can see in the Fig. 3 [Agrics 2011].

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 [Ghobadpour 2019, Kucerka 2015].

Figure 3. Front loader [1]

Different types differ mainly in loader size, lifting force, lift height and equipment [Stehno 2006]. 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 [Ptacek 2002], 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 (2nd 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 (1st 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. 4.

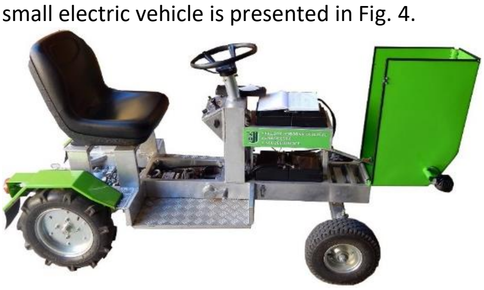

Figure 4. Prototype of ecological small electric vehicle (own research)

In the Fig. 4 are shown the prototype of ecological small electric vehicle usable in agriculture, e.g.in interior glasshouse.
According to [Janocha 2004] writes about the actuator in his publication as a functional element connecting the information and technical process. We can imagine, for example, a device for transforming the control signal into a mechanical motion.
According to [Hrmo 2016], actuators are defined as devices used to convert rotational motion of a low voltage DC motor to linear motion. The actuators can push or pull. In the Fig. 5 we can see schematic illustrated of the electric actuator [Janocha 2004].
Thanks to these actuators, we can simply tilt, lift, push, adjust and pull bulky, heavy or heavily accessible loads with a push of a button. When using actuators, we can rely on safe, quiet and clean scrolling or positioning with accurate motion control. They have almost no maintenance, durability and efficiency. Since the device does not need any pumps or hoses and takes less space than hydraulics, the installation of the electric actuator is much easier.
The front loader gives an expanding use of the prototype electric utility vehicle (prototype), contains four basic parts:
- Loader arms attachment.
- Loader body, consisting of two base arms connected in front of the stiffener in one unit.
- Bucket connected by means of pins with the main boom of the loader.
- Device drive: electric drives.

The whole frame is welded from various lengths of aluminium hollow profiles measuring 100x25 mm TIG.
Considering the used material, which is a hollow aluminium profile measuring 100x25 mm, it will be necessary to provide a vertical protrusion frame post by inserting an aluminium insert (Fig. 5) 60 mm in diameter, with M42 x 1.5 mm internal thread and subsequent welding using the TIG method. This thread is used to mount a mounted bronze sleeve, a more durable and easily replaceable material, with an M30x1.5mm internal thread. The housing is used as the frontal friction surface of the silo housing of the main arms of the loader.

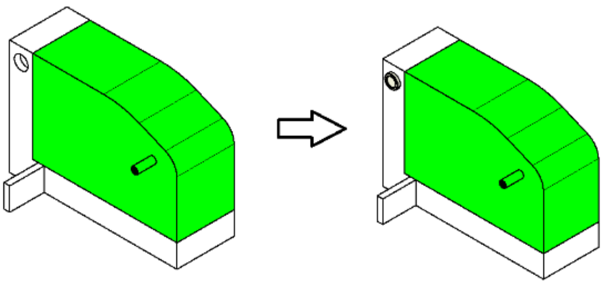

Figure 5. Welding of aluminium insert (own research)

A hexagonal head bolt is firmly anchored into the bore in the M30 x 1.5 mm bush, connecting the front loader arms to the prototype frame. The main body of the loader are two identical mirror-made arms, connected with a strut by a screw connection that is a detachable connection. The main parts of the loader body are in Fig. 6.

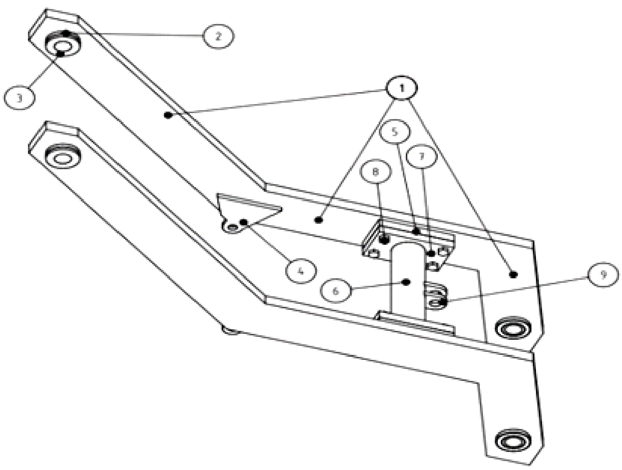

Figure 6. Loader body (own research)
* (Main part: Arms (arm – 1, arm – 2, arm – 3), 2 – aluminium insert, 3 – silon sleeve, 4– actuator attachment lug, 5 –connection plate I, 6 –

pipe, 7 – connection plate II, 8 – hexagonal head screw M10 , 9 – lugs for actuator mounting III)

When choosing the material, I came out from the materials already used and the purpose for which the loader will be used. These are auxiliary work on cleaning, displacement of, for example, bulk material up to approximately 30 kg and movement to allow the unloading and emptying of the bucket. Because the prototype has relatively small dimensions, the dimensions and overall parameters are adapted. For our needs, therefore, the top priority is the weight of the bucket.

On the main arms on which the bucket will be hung, a bare aluminium sheet of 100x25 mm profile is used, so we decided to use a lightweight aluminium sheet with a wall thickness of 5mm to produce the bottom. The whole body will be welded with 5 main parts cut from aluminium sheet into the appropriate shapes and dimensions. The main parts of the loader bucket are graphically shown in Fig. 7.

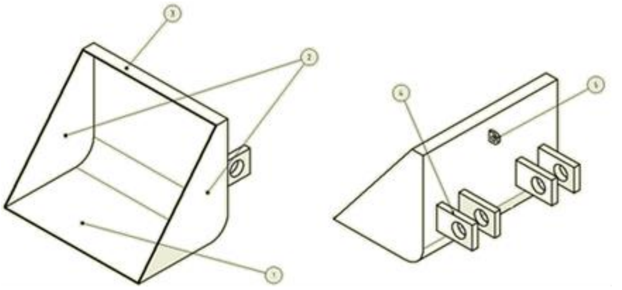

Figure 7. The main parts of the loader bucket (own research): a) 1– Base aluminium sheet, 2 – Sidewalls, 3 – Sheet 590 x 50 mm; b) 4 – Lug for suspension to the main arms of the loader, 5 – Lugs for the attachment of drive units

The foundation is a metal sheet of 660.5x590 mm cross-bended right angle with R80 rounded according to the drawing.

To this part, using the TIG method, the sides of the bucket are welded, also made of a five-millimetre aluminium plate, triangular in size 400x300 mm.

Because the aluminium plate can be difficult to bend at sharper angles, the top of the bucket is constructed by inserting and subsequently welding the 59x50 mm sheet.

For the suspension and movement of the loader bucket, the lugs (Fig. 8) are placed in the rear of the bucket, which are provided with sliding nylon sleeves for smooth and long-lasting operation. The same lugs are located at the ends of the main arms and the sprockets are suspended by means of the pivot pins.

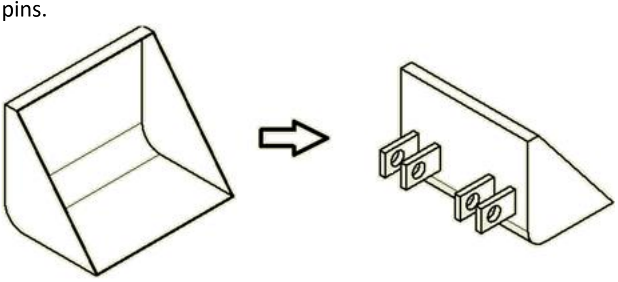

Figure 8. Welding of the lugs (own research)

The aluminium insert with an outside diameter of 60 mm with a wall thickness of 10 mm is inserted and subsequently welded by TIG.

Subsequently, these inserts will be provided with a press-fit of the nylon sleeves (Fig. 9) for sliding the bucket. The housing of this case serves as the main friction surface of the aluminium front liner of the main loader arms.

The bucket movement is provided by an electric drive unit (actuator) suspended in a lug located in the rear upper part of the bucket provided with a pressed bronze lining to strengthen it.

The total volume of the loader bucket is approximately 0.00113 m^3 which means that after multiplying by the density of aluminium (ρ=2700 kg.m^{-3}), the weight of the bucket will be approximately 30.5 kg without welded lugs for connecting the bucket to the main arms and without the lug for attaching the actuator.

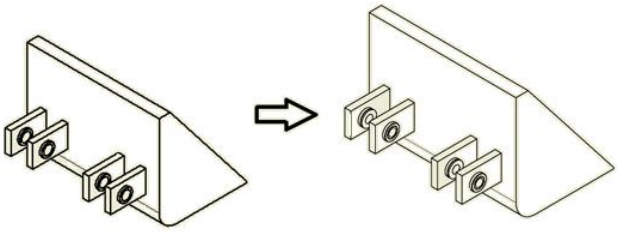

Figure 9. Pushing the nylon sleeves (own research)

When designing the dimensions of the bucket, I assumed that the total volume would be about 30 litres. The maximum volume is 32.3 litres.

The bucket will be connected with the main arms of the front loader by means of pins. The screw is through and, after setting the given axial clearance, is secured by a nut with an M30x1.5 mm internal thread.

This screw is through and, after setting the axial clearance, is secured by a nut (Fig. 36) with an internal thread M30x1.5 mm, parameters: h = 15mm, d = 30mm, s = 46 mm.

The bolt is made of galvanized steel with a lubrication channel of 4 mm diameter. Technical parameters of the oiler thread = M6 x1mm, length L = 14 mm, head diameter = 10 mm and thread length = 4.5 mm.

As a front loader drive, we suggest using the HG200S actuator. Two actuators (one on each side) with a stroke of 200 mm will be needed to optimally lift the front loader arms. In this case, the basic length of the actuator will be 360 mm (160 mm+200 mm lift) and when fully extended (i.e. 200 mm); the total length will be 560 mm. To attach the actuator to the arms, welded by the TIG lugs method at the welding point of the first and second parts of the arm, the actuator grooves are attached and connected with the pin.

The actuator will have a maximum lift of 120 mm, which means that the basic length of the actuator will be 280 mm (160+120 mm) and will be 400 mm long when fully extended.

The actuator will be slid into the lug welded on the back of the bucket and connected with a pin of 10 mm diameter. At the other end, the actuator will be inserted between the two lugs welded on the strut and connected again with a 10 mm diameter pin.

To fasten the other end of the actuator, two lugs are welded to the frame structure (Fig. 10). The actuator is attached to the lug using a 10 mm diameter pin.

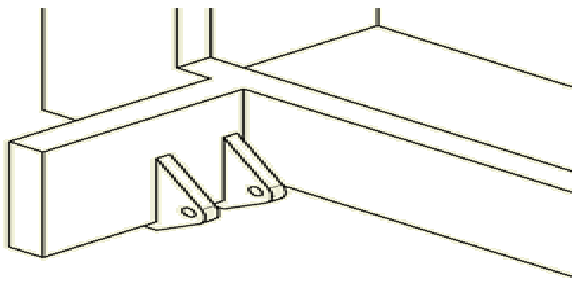

Figure 10. Actuator attachment (own research)

In our design of a small ecological loader, we chose the application of the HG200S actuator, which meets all the required technical parameters in our prototype.

When designing a front loader construction, we tried to build on an existing prototype. It was very preferable to maintain the position of the prototype lights, which is why the main arms are designed this way.

Fig. 11 shows the basic position of the arms, the shortest possible length of actuator – A. Distances: A – maximum possible pull-out of actuator, B – minimal pull-out of actuator, C – maximum loader bucket distance.

At this position of the front loader arms the following distances are: (A = 360 mm, B = 303 mm).

Three other situations will capture the actuator stroke – A to a position that allows the current prototype construction, i.e. maintaining the position of the lights (Fig. 12). In this case, the distance values are: (A = 541.52 mm, B = 362.98m, C = 448.39 mm).

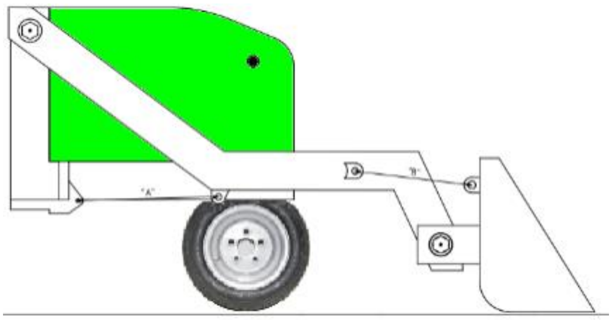

Figure 11. Basic shoulder position (own research)

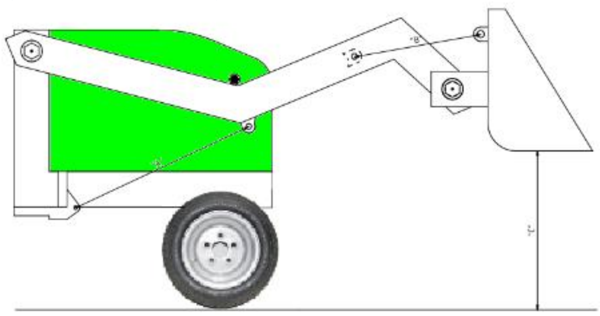

Figure 12. Extended arm position (own research)

The same position of the actuator – A will be depicted in Fig. 13, but the second actuator – B in this case is pulled to the smallest length). For this case, the distance values are as follows: A = 541.52 mm, B = 280 mm, C = 552 mm.

Fig. 14 shows the case with the raised actuator to maintain the prototype lights, it will represent the tilting position of the bucket contents, hence the maximum possible distance of the actuator ejection. In this application, the distance values are:
(A = 541.52 mm, B = 400 mm, C = 345.78 mm).

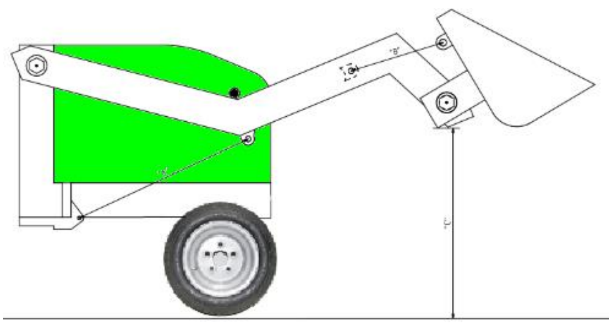

Figure 13. Extending actuators, maximum height when keeping lights (own research)

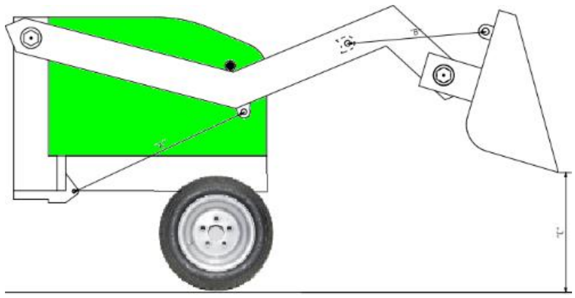

Figure 14. Extending actuators, emptying the bucket (own research)

The following three cases will represent the front loader arms at the maximum lift, i.e. the maximum displacement of the actuator – A. The images will differ only at B distances, i. e. the length of the actuator ejection and the bucket distance from the ground (Fig. 15).

In this case, the distance values will be as follows: (A = 560.00 mm, B = 280.mm, C = 602.00 mm). In the Fig. 16 we can see maximum actuator pull-out A bucket horizontally. In the Fig. 17 the loader bucket is positioned horizontally. Distance values: (A = 560.00 mm, B = 361.96 mm, C = 502.00 mm).

In the last case, Fig. 17 shows the maximum possible pull-out of the actuator – A and the minimal possible pull-out of the actuator – B, i.e. spilling the bucket contents from the maximum possible height of the arms: (A = 560 mm; B = 400 mm, C = 400 mm).

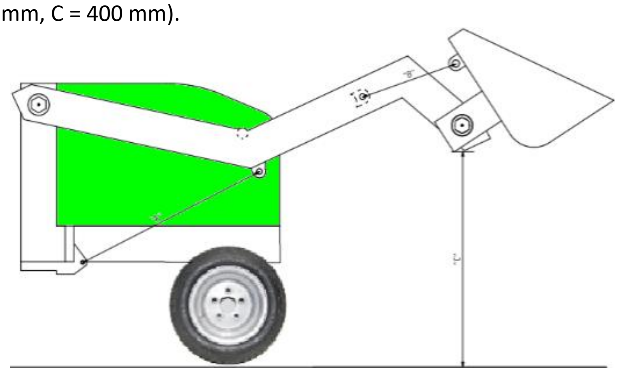

Figure 15. Maximum actuator pull-out – A and minimal pull-out of actuator – B (own research)

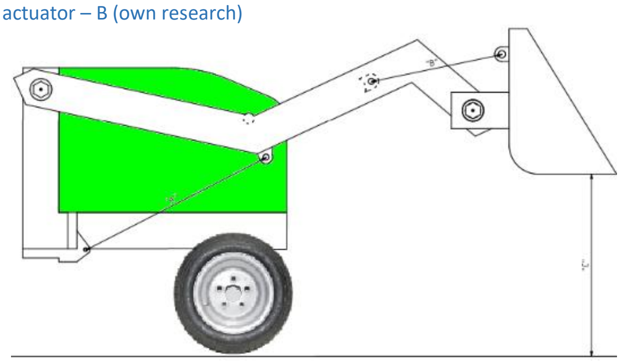

Figure 16. Maximum actuator pull-out A bucket horizontally (own research)

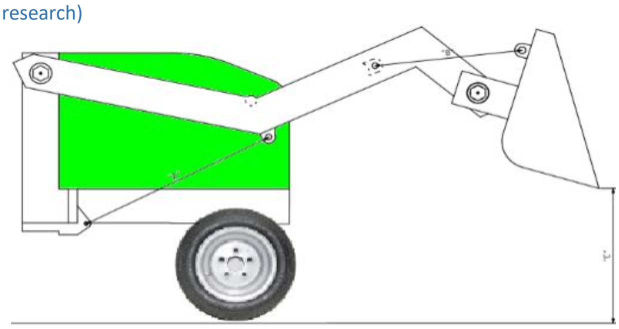

Figure 17. Maximum ejection of both actuators (own research)

5 DISCUSSION

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.

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 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.

6 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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