NEW CONCEPTS OF VEHICLES, MODELLING AND SIMULATION USING WMI AND MG20 VEHICLES AS AN EXAMPLE

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Abstract

Paper presents the problems connected with designing new concept vehicles for defence industry as well as modelling and simulation methods issues on the basis of WMI and MG20 vehicles.

Project development process of MG20 vehicle laying kit, separate analysis phases starting from kinematics sketch and development of concept model of the system through strength computation of structure, ending with development of working documentation and vehicle model execution were presented.

The concept of modern Multi-task Engineering Machine provided for engineering troops was presented in this work. Execution of tasks on modern war theatre, during intervention and peace missions as well as during natural disasters effects counteractions requires a specialistic engineering equipment adapted for special military and civil demands. High mobility and versatility are the main parameters that feature this equipment. Within the scope of operational needs review, the need to deploy the Multi-task Engineering Machine to engineering troops, which is to substitute old-fashion and very used single-task machines used up to now. Disused structures of engineering machines used in Polish Military Forces during recent decades had large weight and low versatility. Their structures were based of heavy, deceptive and high operation cost the drive systems. Engines of low efficiency, hard to maintain and servicing the drive transmission systems made difficult common application and execution of engineering works. The greatest disadvantage of engineering vehicles that are used by Polish Military Forces is low mobility. This causes significant difficulties to transport a vehicle to the location where works and tasks are being carried out, frequently of distance several hundred kilometres (for instance, while removing natural disasters effects).

Keywords: *tank bridge, MG20, Daglezja, engineering machine, engineering troops, WMI, PINIA*

1. Introduction

MG20 and WMI vehicles are the result of research-development works, whereas Ośrodek Badawczo-Rozwojowy Urządzeń Mechanicznych OBRUM Gliwice sp. z o.o. was the contractor.

The products are now on the stage of concept model, whereas MG20 product is executed physically as a functional model. Data presented in this paper relate just to such vehicle versions.

The projects of Multi-task Engineering Machine of cryptonym PINIA as well as the bridge on tracklaying chassis MG20 Daglezja were created in accordance with DPZ-MON order in 2008.

In case of WMI, within the scope of work, the concept of modern engineering vehicle was created that would be able to substitute the most of up to now used vehicles in the army. In 2010, the research-development project was started to construct a technology example of base chassis of Multi-task Engineering Machine WMI. Within the scope of project, a functional technology example shall be executed that would contain the most important features of Multi-task Engineering Machine of PINIA vehicle concept. Now, works on support frame, suspension and operation system are in progress. On the basis of the concept 3D models are made as well as mount and configuration simulations of separate components and sub-assemblies of the vehicle.

2. Configuration and basic MG20 vehicle parameters

MG20 Daglezja vehicle is a bridge on tracklaying chassis that makes possible to overcome fast the natural and hand-made terrain obstacles of width up to 20 m to tanks and other heavy vehicles that produce load not higher than MLC70 class – in case of tracklaying vehicle and MLC110 – in case of wheeled vehicles.

The bridge is provided for engineering sub-units equipped with tanks and other heavy tracklaying vehicles.

The bridge includes:

- tracklaying bridge chassis;
- tracklaying bridge span.

Bridge chassis is composed of:

- armoured chassis;
- layer that makes possible handling the span;
- expansion mechanism;
- hydraulic system;
- special and operation equipment.

Tracklaying bridge span may be substituted by MS-20 bridge span and is constructed of two bridge girders that include bridge mobile part, intermediate components, approach ramps as well as special equipment and operation equipment that allow appropriate operation of the bridge.

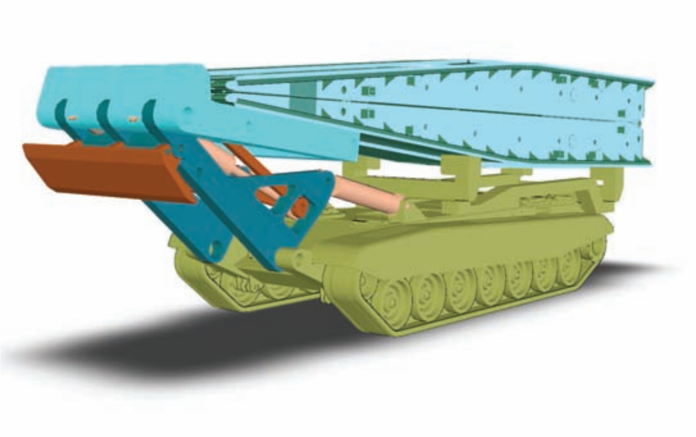

Fig. 1. MG20 vehicle model

Basic technical features of the bridge (PM20):

- carrying capacity of the span 70/110 MLC,
- span length 23.2m,
- span length with approach ramps 25.6m,
- maximum width of an obstacle 20m,
- bridge width 4m.

3. Development of MG20 vehicle concept

The subject of the development was mainly to create a kinematics concept of bi-component layer used to handle the span appropriately that makes possible to lay the span, taking into consideration the extreme terrain conditions. Moreover the layer has to make possible to produce agap in order to change the span width without problem that is settled on expansion mechanism. The basic 6-wheel chassis was assumed including driver's hatch located along vehicle axis.

Dimensions constituted restrictions resulting from tactical and technical assumptions to the project, first of all the height dimension 4 m, as well as indispensable revolution angles of the layer that allow arranging the span on an obstacle, whose opposite bank is located 2 m below the bank from which the bridge is being laid as well as significant parameter 20% of terrain inclination of approach to an obstacle.

Kinematic model of the layer was created based on operation of two layer arms: the main arm mounted to the body as well as grab arm that holds the span.

Arms are moved by means of hydraulic cylinders arranged as pairs. The first pair of cylinders called LS1 moves the grab arm and is fixed to the body. The second pair of cylinders called LS2 moves the grab arm in relation to the main arm. It is mounted between the grab arm and pull rods, by means of which cylinder expansion is changed into grab arm revolution.

A series of analysis was performed that consisted in changing the coordinates of catch points of separate systems components as well as assessment of opportunities to obtain boundary limits including taking into consideration forces and reactions that come from bridge span during laying and that occur in separate positions.

Together with consecutive model analysis, the concept evolved and was subject of changes through 18 consecutive versions. Length and hydraulic cylinder strokes were changed as well as pull rod lengths of LS2 cylinders. Moreover, arrangement of catch points of pull rods were changed in layer arms.

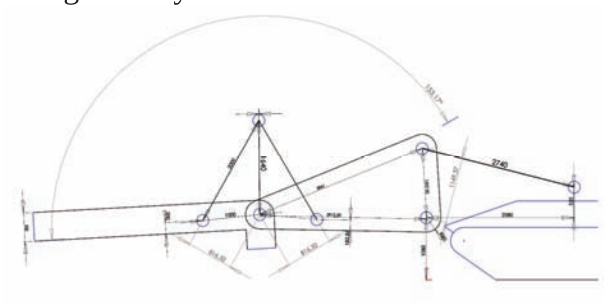

Fig. 2. Output model of layer kinematics

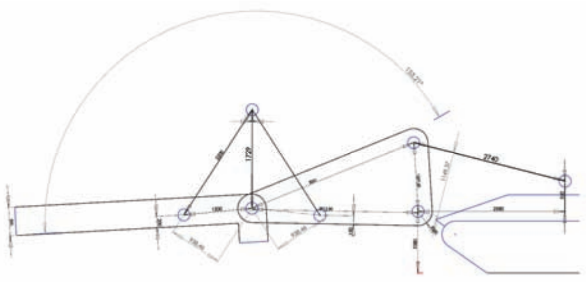

Fig. 3. Changed version of layer kinematics model

Fig. 3 shows the version of the model with LS2 actuators of stroke 1,570 mm and pull rods of length 2,200 mm. Pull rod mounting points were changed. Attention was paid to the value of force arm acting in pull rod in relation to mounting point of LS2 cylinder. Under these circumstances the arm reached the value of 938 mm.

Fig. 4 shows a situation when LS2 cylinder is entirely advanced and arms are folded. The force action arm in pull rod changes in this case up to 587 mm, thus relation of arm value of force action in the pull rod as advanced and folded position equals 0.62. It has been proved using analytical methods that one should aim to the situation in which this ratio shall achieve the value 0.55.

Thus, alterations were made that increased the value of force action arm in the pull rod in folded position in relation to advanced position. Generally, one should aim to achieve the greatest values of arms of force action in the pull rod.

Implementing the LS2 cylinder with pull rods mounting method was a special alteration by sliding out the pull rods, by producing the "T" type mount. This situation is presented in Fig. 5.

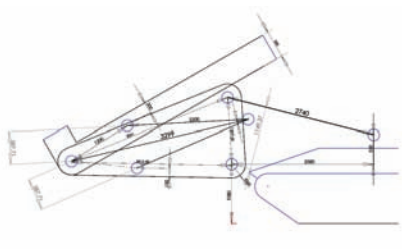

Fig. 4. Changed version of layer kinematics model – LS2 cylinder advanced

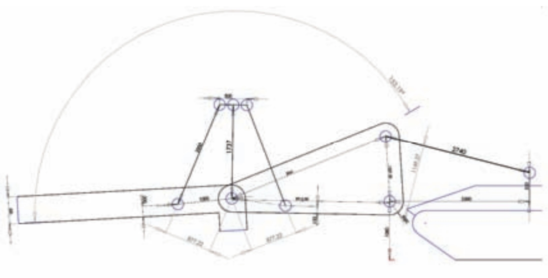

Fig. 5. Changed version of layer kinematics model – T type mount

Finally, after application of changed in length and in cylinders stroke, pull rod lengths of LS2 cylinders, location of pull rods catch points in layer arms as well as "T" type mounting, analyses let to the final version of the model, in which all parameters were equal to the previously assumed level.

Fig. 6 and Fig. 7 show the final model of layer kinematics.

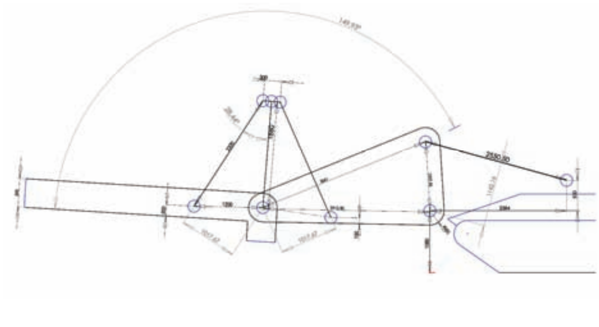

Fig. 6. Final version of layer kinematics – expanded arrangement

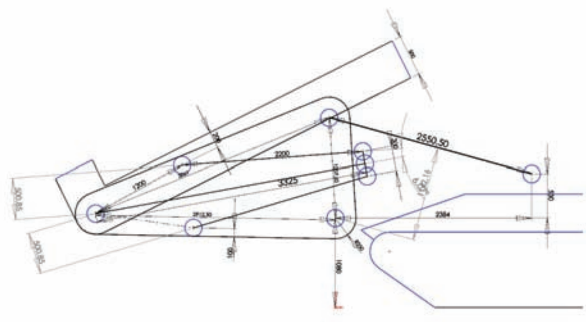

Fig. 7. Final version of layer kinematics – folded arrangement

In the second turn, after two-member layer kinematics concept was created, it was to develop the layer solid model that was then transferred to strength calculations using the finite elements method.

The complete layer model is composed of main arm, grab arm, support footing, pull rods as well as hydraulic cylinders. In order to model the solids properly, it was necessary to develop a 7-wheeled chassis model on the basis of PT-91 tank.

In order to provide an opportunity that cylinders could make specified strokes, cylinders mounting method was assumed to the body using two journals instead of standard eye on the body.

Fig. 8. Hydraulic cylinder mounted conventionally

Fig. 9. LS1 hydraulic cylinder mounted to the body

Additional advantage of such mounting the actuator is an opportunity to use a sensor of linear elongation (seen in Fig. 10), which fact constitutes a great convenience and provides precise control of the layer.

Fig. 10 presents also how mounting the pull rods to the actuator was solved, i.e. "T" type mounting. To this end, a special eye with two holes shall be made.

Layer arms were made as simplified solid models and then an output model of chassis layer together with layer was composed.

These models are presented in Fig. 11, Fig. 12 and Fig. 13. As a support footing of the layer, the bridge layer footing on MS-20 wheeled chassis was used.

Fig. 10. LS2 hydraulic cylinder mounted to the body

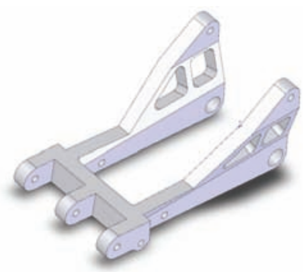

Fig. 11. Output model of main layer arm

Being on the stage of the above model, arrangement of LS2 cylinders inside layer was planned and mounting them in the main arm. However, this solution appeared disadvantageous due to limitation of vehicle driver visibility. Driver visibility in this case is presented in Fig. 14.

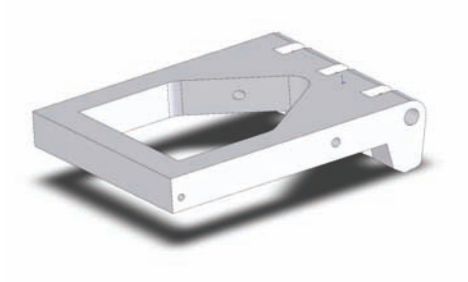

Fig. 12. Output model of grab arm of layer

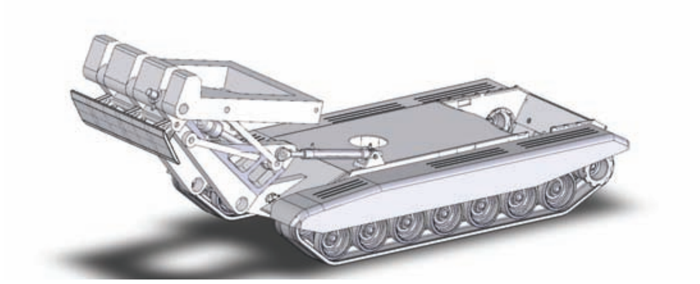

Fig. 13. Output model of the layer on the chassis

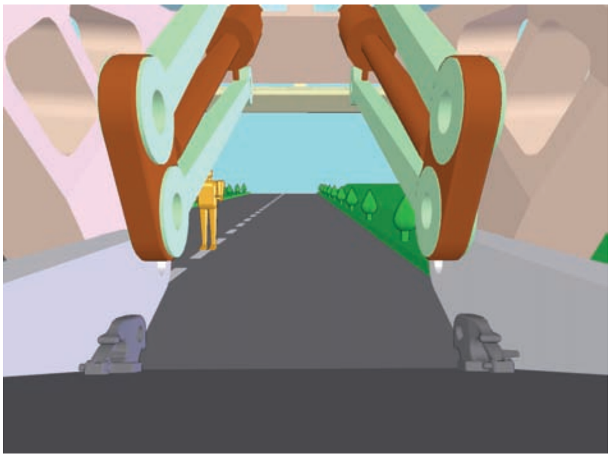

Fig. 14. Driver visibility

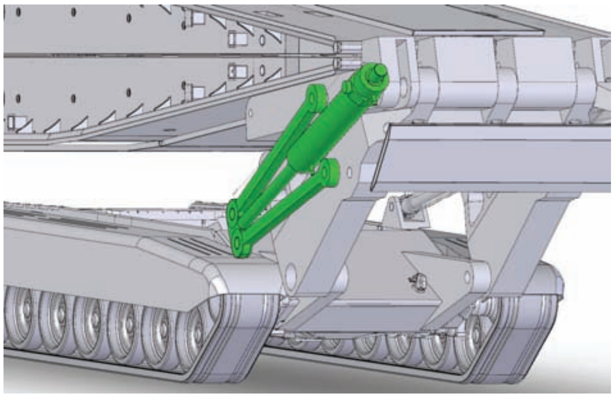

Fig. 15. Arrangement of LS2 cylinders outside the layer

Here, the LS2 cylinders are expanded and inserted outside of layer which fact significantly improved visibility. This situation is presented in Fig. 15 and Fig. 16.

Due to such arrangement of cylinders, the grab arm had to be reconstructed so that appropriate holding the cylinders was provided. This situation is presented in Fig. 17.

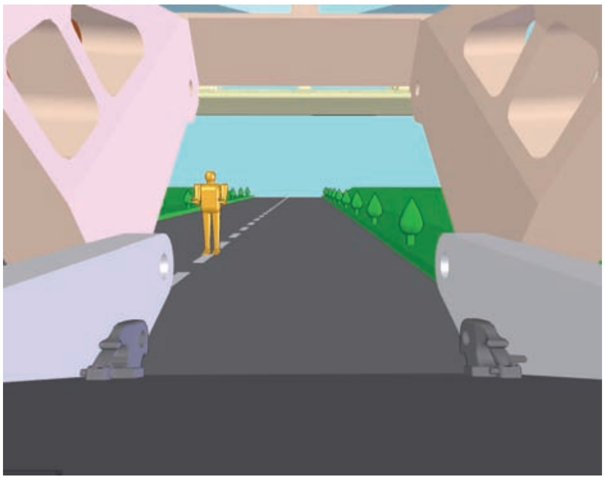

Fig. 16. Driver visibility

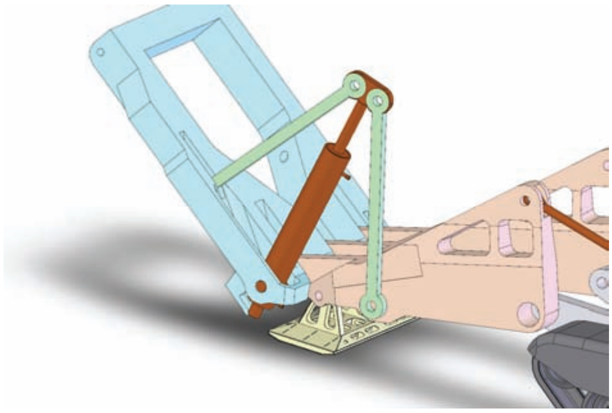

Fig. 17. Arrangement of LS2 cylinders outside the layer

Layer arms were also appropriately cut out so that to avoid collision in extreme positions.

View of main arm as well as grab arm are presented in Fig. 18 and Fig. 19.

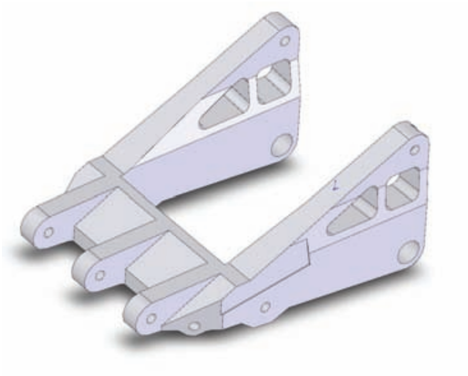

Fig. 18. Main layer arm

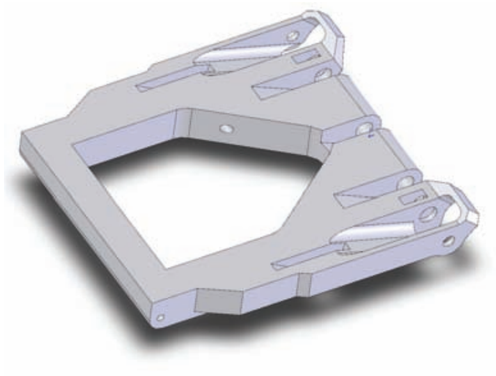

Fig. 19. Layer grab arm

The layer solid model obtained due to analysis was the output material to perform strength calculations using finite elements method (Fig. 21).

On the basis of strength calculations results obtained it was found that it was necessary to reconstruct parts that mounted cylinders.

Changes that resulted from calculations were taken into consideration and, on this stage, the construction model of the layer and the vehicle.

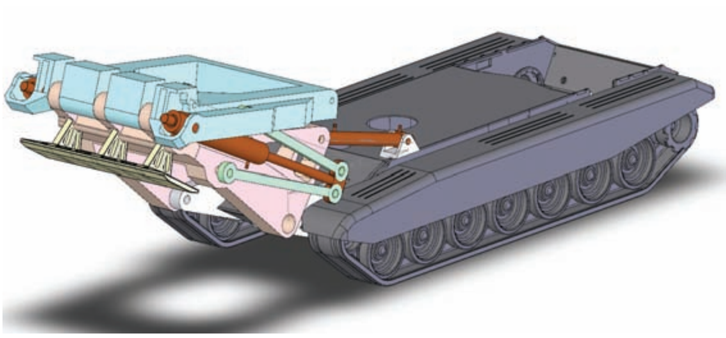

Fig. 20. Layer model mounted on chassis

Fig. 21. Layer model during Finite Elements Method strength calculations

On the basis of construction model, technical working documentation was developed (Fig. 22), which was given to execute the real model of the vehicle.

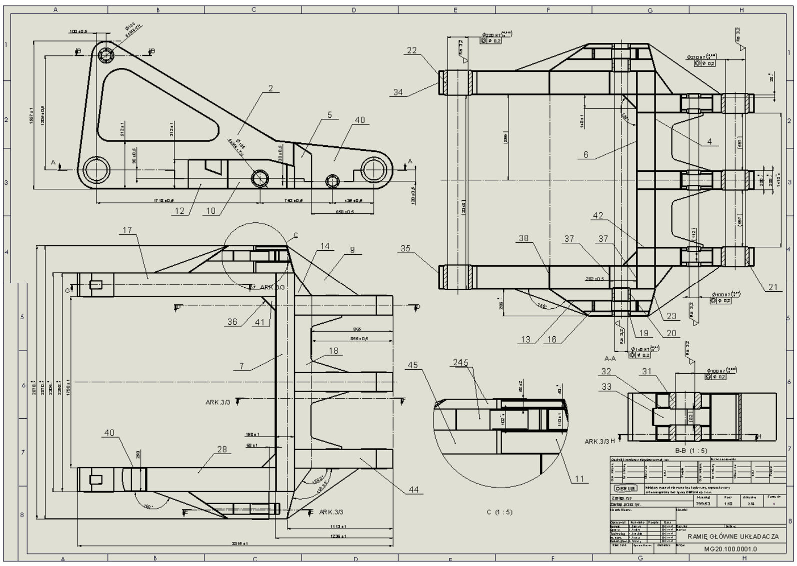

Fig. 22. Sheet of working documentation of layer parts

The vehicle is at present executed and prepared to perform a series of tests and examinations both during driving in terrain and during laying the span on an obstacle.

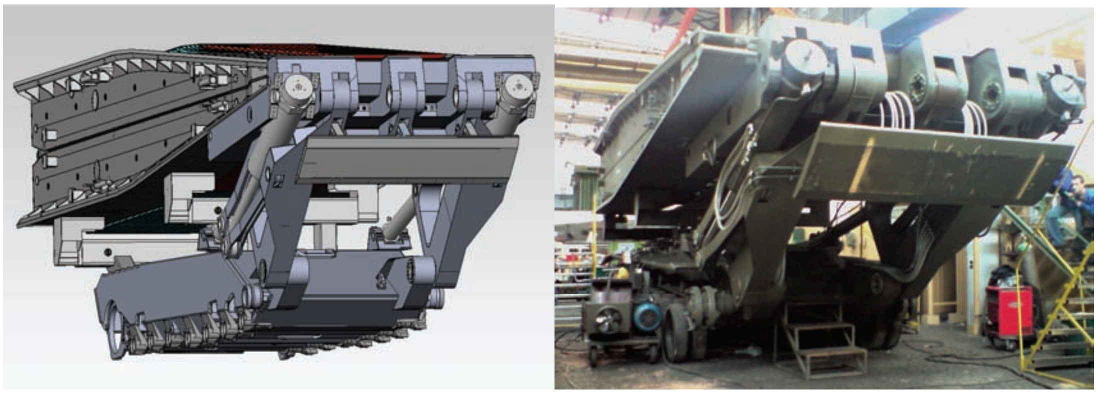

Fig. 23. Vehicle view using computer system and during assembling

4. Construction solutions and basic parameters of base chassis of Multi-task Engineering Machine WMI

a. Engineering tasks shall be accomplished due to usage of front boom located on rotary platform integrated with operator's cab and the said equipment in form of two-part loader bucket of volume 2 cu.m. System allows lifting loads up to 5,000 kg.
b. The base chassis of WMI is based on 2-axles wheeled drive system, including 4x4 drive. Chassis is equipped with controlled suspension including opportunity to lock and adjust the height, both shock absorbing axles with calibration of twist of the machine (alignment), highly effective brakes at high wheels with ABS systems, clearance about 350 mm, wheels with single terrain tyres of high capacity including pressure control system. Vehicle drive is composed of combustion engine of power about 250 kW. Maximum velocity of the vehicle is about 80 km/h. The base chassis WMI is adapted for tow trailers.
c. Operation cab is adapted to be equipped with filter and ventilation equipment that provide protection of the crew during work carried out under contamination conditions and air conditioning, heating and night vision instrument.
d. Base chassis of WMI is equipped with hydraulic hoisting winch of towing power 100kN.
e. WMI vehicle weight including basic equipment of a loader shall equal about 16,500 kg, vehicle width 2.55-3 m, height up to 2.7 m, length up to about 7.5 m.
f. All tasks and vehicle and equipment functions may be accomplished by means of remote control.

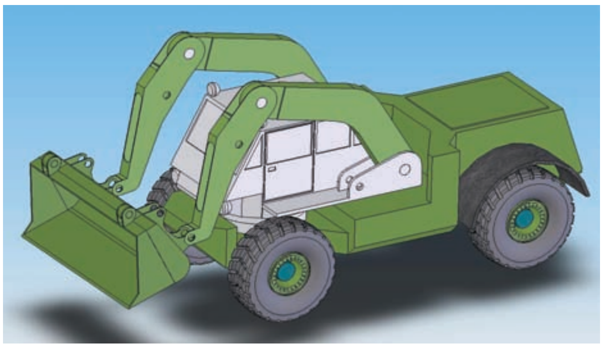

Fig. 24. General concept view of Multi-task Engineering Machine WMI-PINIA with two-part bucket of loader

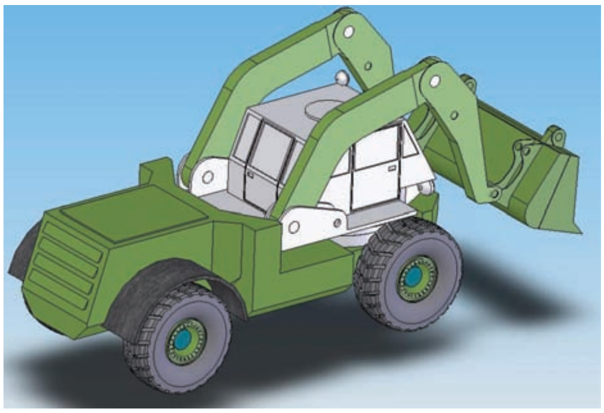

Fig. 25. General view of Multi-task Engineering Machine WMI-PINIA concept with two-part bucket of loader

5. Designing and modelling the base chassis of Multi-task Engineering Machine using 3D software

On the basis of initial concept and design assumptions the 3D concept model of PINIA vehicle was developed that is a solid object of very large scale of simplification that allows only virtual visualization of vehicle concept. During execution of project of base chassis of Multi-task Engineering Machine WMI, the solid model of PINIA vehicle was used just as a base.
In the first phase of designing the basic sub-assemblies and components were separated:
- frame,
- suspension,
- body,
- engine,
- drive axles,
- gear box and distribution box,
- rotary platform – cab,
- boom of operation system,
- loader bucket.

Due to opportunities of virtual modelling and designing of elements, creating new concepts is a quite fast process as well as allows continuous insight to the work progress. Due to this method, collisions of mating elements are significantly limited; spots of large loads in structure are detected including opportunity of entering changes and corrections that lead to develop constructions ready for execution and implementation. Design phases using 3D software shall be presented on the basis of support frame of base chassis of Multi-task Engineering Machine WMI.

The frame as a carrying element of the whole vehicle is one of the most important vehicle elements. It is necessary that its design would provide ability to transfer loads that result from conditions of vehicle motion as well as loads occurring under vehicle operation. Assumption of steel structure made of welded elements was accepted, i.e. composed of two parallel longitudinal members of the frame with crosspieces. The said frame is also used to mount suspension, engine, gear box and base (bearing) of rotary platform.

One of the most important factors that determined appropriate frame design was mutual matching of suspension elements and drive system for the whole vehicle. Due to simulation of mutual arrangement of elements it was possible to specify the design centres, liquidation of collisions as well as matching the structure to the initial concept.

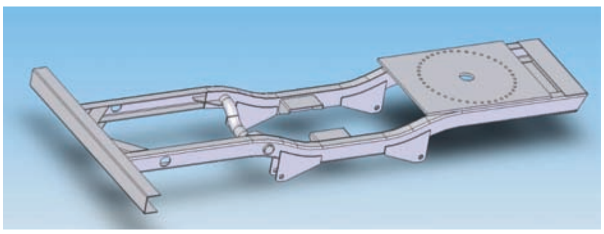

Fig. 26. Preliminary concept of support frame

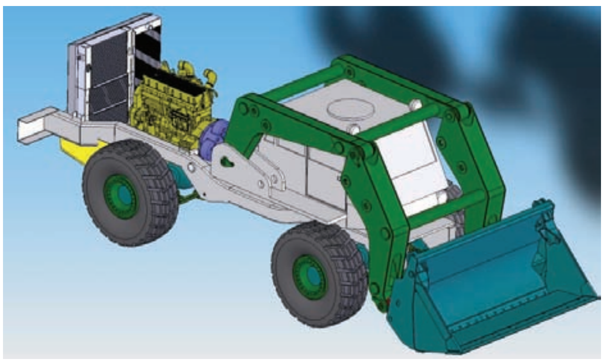

Fig. 27. Frame with basic vehicle sub-units

Due to dimension restrictions, functional and strength requirements, the frame has been significantly changed in relation to the first, simple concept. As works proceeded and remaining sub-units of the vehicle were determined it was possible to develop satisfactorily the frame design that allowed arrangement and mounting the elements, optimisation of structure as well as meeting strength requirements.

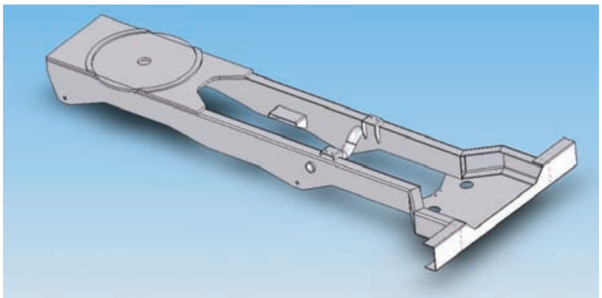

Fig. 28. Frame during further design phase

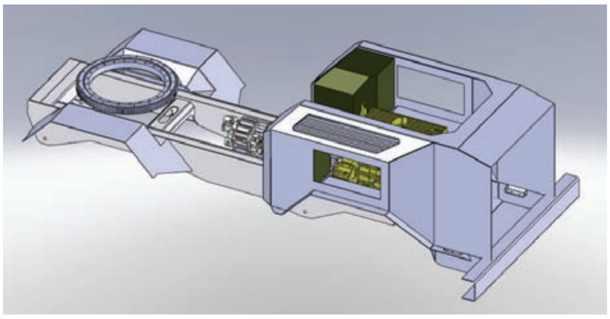

Fig. 29. Frame with body elements

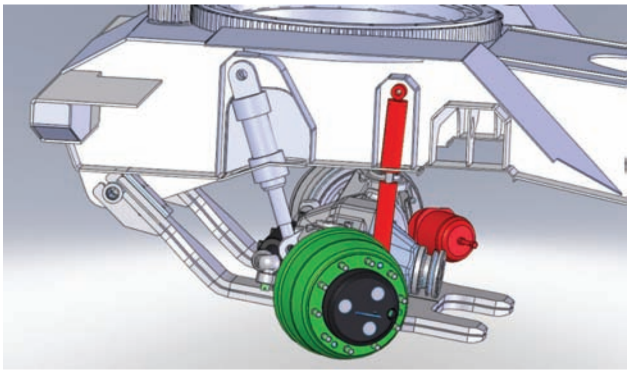

Fig. 30. View of front part of frame including suspension elements and driving axle

While working on frame design, the issue of mounting the driving axles and suspension appeared the most important one. Simulation of suspension operation kinematics allowed selecting and locating its elements.

6. Kinematic analysis of operation system for base chassis of Multi-task Engineering Machine

On the basis of preliminary concept of WMI-PINIA vehicle, to provide achieving the largest opportunities of operation system, two-member boom is provided powered with three pairs of actuators. Boom system with widely spread arms provides its large rigidity and strength, preserving good operator's visibility at the same time. Location of boom mounting to the rear part of the platform significantly improves the value of maximum hoisting capacity as well as provides more advantageous distribution of loads on vehicle axles in relation to commonly used booms mounted in a front part of engineering vehicles.

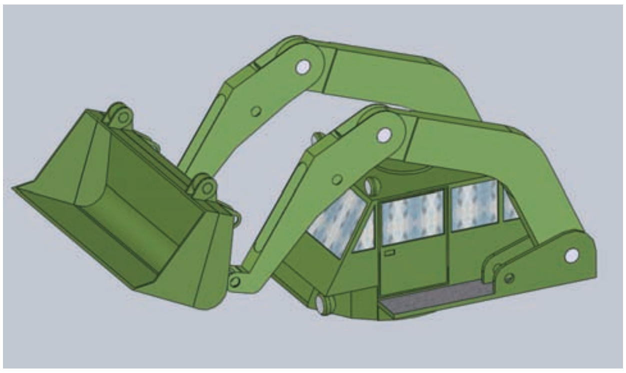

Fig. 31. Boom concept of operation system

Basic parameters that operation system is to meet is an opportunity to work with basic equipment in form of two-part bucket of loader of volume

2 m^3. Maximum bucket load due to vehicle stability is specified as 50 kN. Requirement exists that the vehicle is to be able to load the excavated material to commonly used transportation means as well as to make possible making concealment of military equipment. Due to cooperation with Huta Stalowa Wola (Stalowa Wola Steelworks) the kinematics and structure of operation system boom had been developed that meets all requirements.

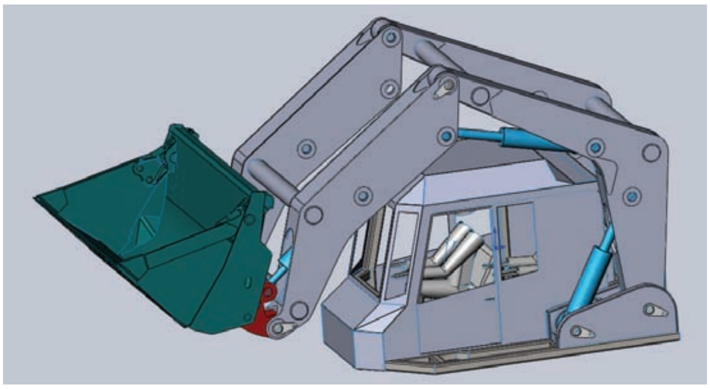

Fig. 32. Boom developed on the basis of preliminary concept

Boom functionality as an operation system is presented by kinematics analysis. Starting from transport position, via opportunities to sink the bucket into ground, to determine the maximum reach of bucket for different works, an analysis of kinematics of system of base chassis of Multi-task Engineering Machine was performed.

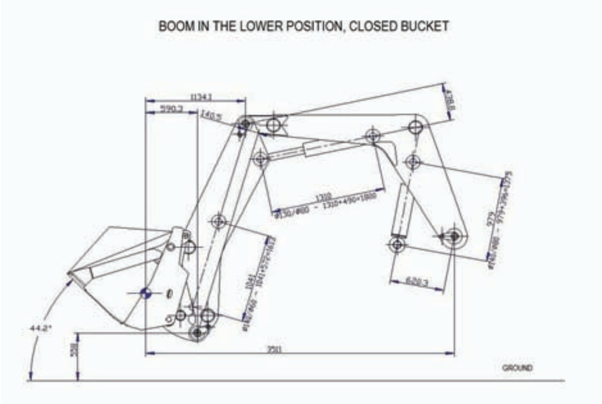

Fig. 33. Location of boom and bucket during driving with excavated material

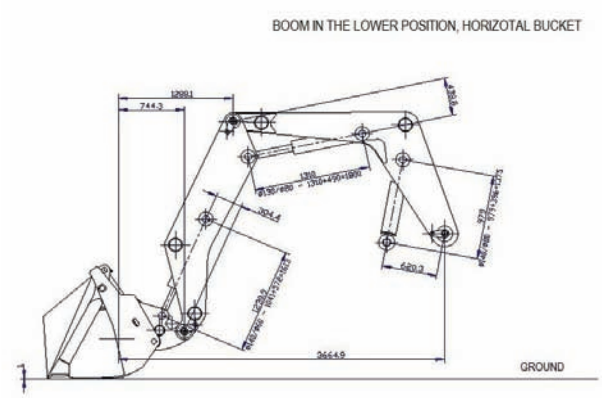

Fig. 34. Location of boom and bucket during ground grading

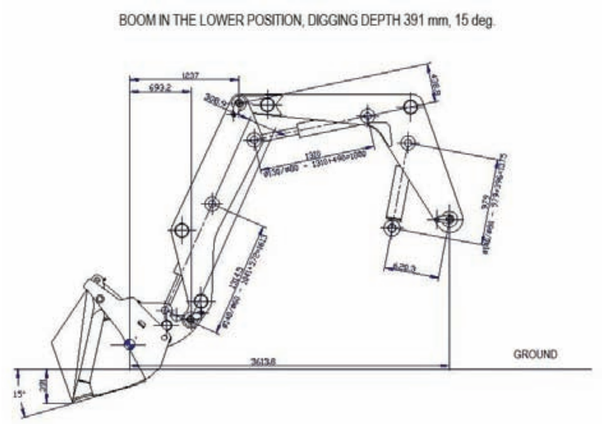

Fig. 35. Location of boom and bucket at maximum sinking in ground

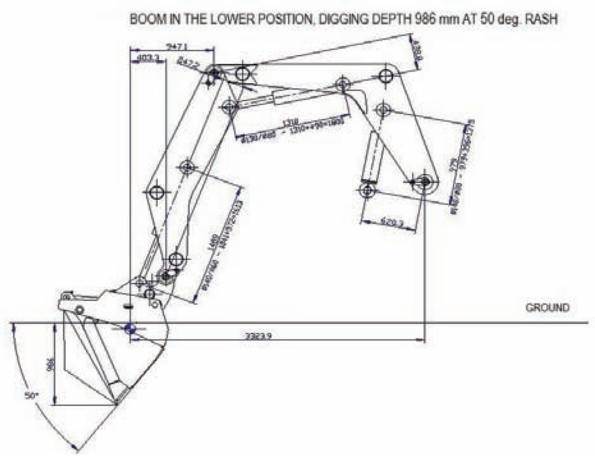

Fig. 36. Location of boom and bucket while dumping below ground level

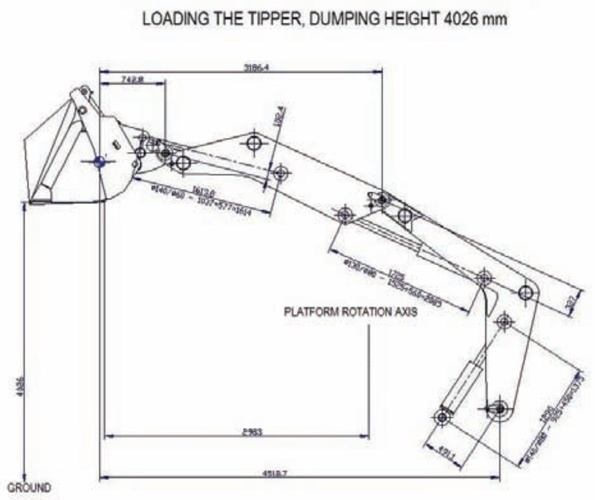

Fig. 37. Loading the excavated material to transport means

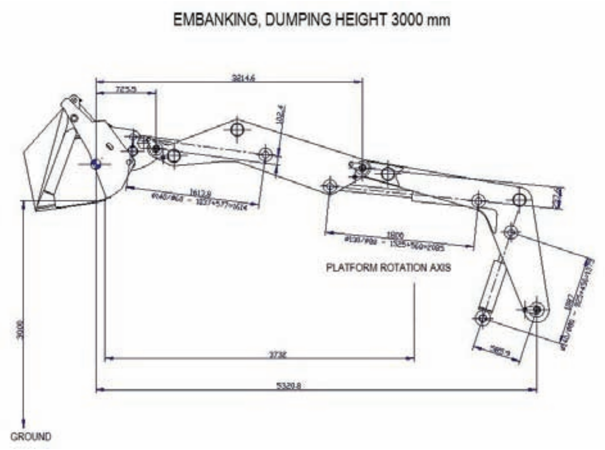

Fig. 38. Embanking the excavated material while making concealments in ground

7. Strength analyses of platform-cabin for base chassis of Multi-task Engineering Machine

Vehicle is to be equipped with rotary platform integrated with operator's cabin. In order to provide appropriate kinematics of operation system boom and general functionality of the vehicle, the platform-cab has opportunity to rotate by 90° towards both directions in relation to middle position. On the basis of stress and strain analyses using finite elements method, the effect of selection of structure elements on rigidity and strength was presented.

Initial platform-cab concept based on pipes 80x80x6,3 proved significant stresses and strains. Weight of structure is 989.92 kg. Stresses > 285MPa cover 8.89% of volume. Maximum stresses 2667MPa. Maximum deflection is 58.89mm.

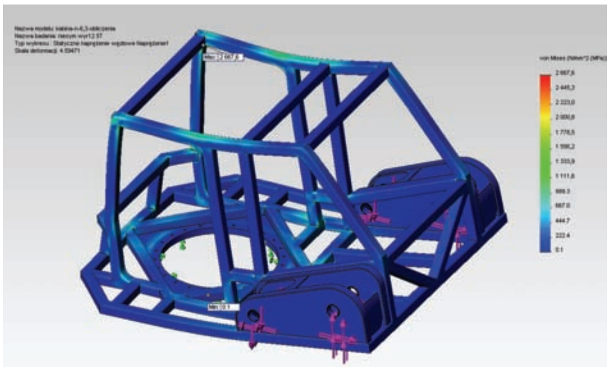

Fig. 39. Cab made of pipes 80x80x6,3 (unsymmetrical load). Distribution of stresses

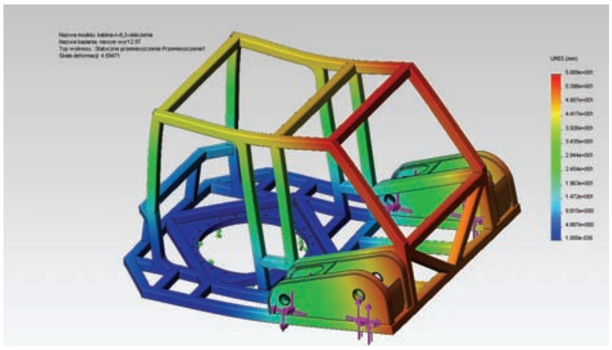

Fig. 40. Cab made of pipes 80x80x6,3 (unsymmetrical load). Strains

After application of reinforcing sheets and changing the design i lower part of platform cabin, significant reduction of stresses and strains occurred but structure weight increased.
Weight of structure is 1,396kg. Stresses > 285MPa cover 2.92% of volume. Maximum stresses 2328MPa. Maximum deflection is 18.07mm.

Analyses of welded structure made of sheets in form of body were also made. Stresses and strains were reduced with increase of weight at the same time.
Weight of structure is 1,644kg. Stresses > 285MPa cover 0.57% of volume. Maximum stresses 1086MPa. Maximum deflection is 12.4mm.

Due to application of virtual modelling 3D as well as stress and strains analysis by means of finite elements method, we can see an effect of selection of appropriate structural materials as well as the structure type itself on its properties and opportunities to meet assumed requirements.

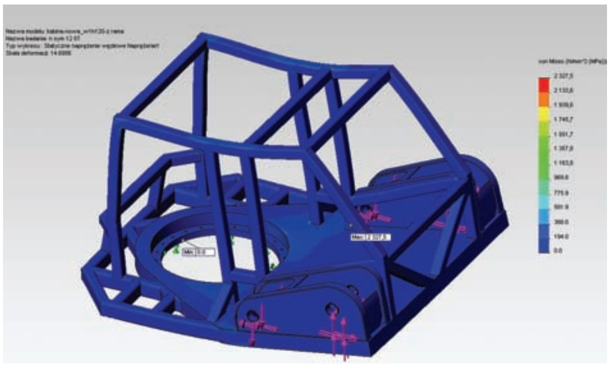

Fig. 41. Cabin with base made of sheets h=120 g=10 and upper part made of pipes 80x80x63 (unsymmetrical load). Distribution of stresses

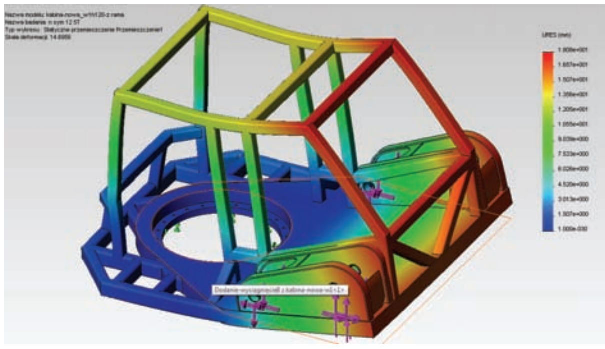

Fig. 42. Cabin with base made of sheets h=120 g=10 and upper part made of pipes 80x80x63 (unsymmetrical load)

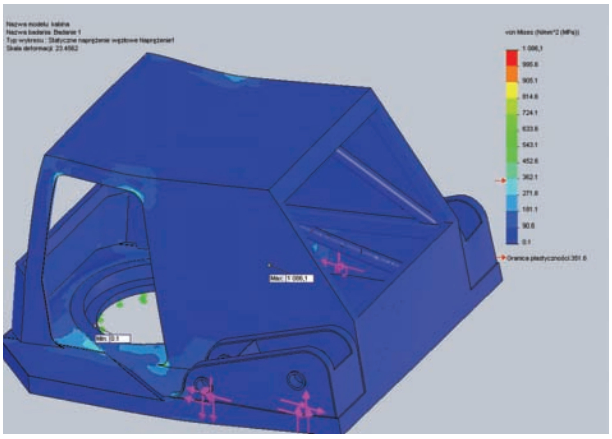

Fig. 43. Cabin with base made of sheets h=150 g=10 and upper part made of sheet and reinforcements (unsymmetrical loads). Distribution of stresses

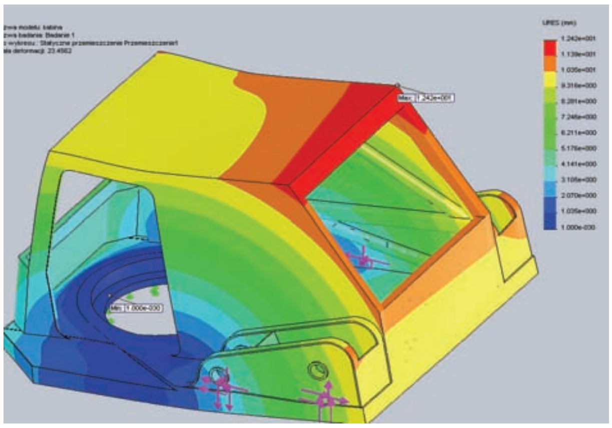

Fig. 44. Cabin with base made of sheets h=150 g=10 and upper part made of sheet and reinforcements (unsymmetrical loads). Strains

8. Summary

The arising concept of new engineering vehicle under development that allows fast implementing for usage seems to be very interesting item for Polish Military Forces in stage of modernization. New vehicles, for which high requirements are put, become indispensable both during military actions, for instance, during foreign missions and as a background while counteracting and removing natural disasters effects, calamities or rescue actions where usage of engineering equipment is necessary. In many cases, the shortest possible time when vehicle may undertake action as well as versatility that allows performing a broad scope of operations is a key issue.

Due to opportunities of constructing and 3D modelling it is possible to develop relatively fast the vehicle design that may meet requirements put at present to military vehicles. At present, works are in progress over next stages of design of base chassis of Multi-task Engineering Machine WMI, which shall be made in form of technology example and shall be subject to tests.

Positive examination results of MG-20 and WMI vehicles including all remarks after tests shall be used to develop a vehicle prototype that lead to develop a pre-production batch. Pre-production batch shall be subject in turn to series of examinations necessary to approve the product to be implemented and used in army and to start a series production that constitutes the finial of design process of new vehicle, i.e the greatest success of designer as well as the whole Ośrodek Badawczo-Rozwojowego Urządzeń Mechanicznych OBRUM Gliwice Sp. z o.o.