Piotr **WOCKA**
Łukasz **BURY**

LEOPARD 2A4 TANK DRIVING SIMULATOR
PART 1. DRIVER'S CAB

Abstract: The article discusses previous solutions used in the process of training Leopard 2A4 tank crews. A concept of the design of a driving simulator (formulated by OBRUM) for training a Leopard 2A4 tank driver is presented. A more in-depth discussion is provided regarding some selected structural units of the simulator cab and applied design technologies, where the required representation and all functionalities of the real object are maintained.

Keywords: tank, driver training, driving course, simulator, Leopard 2A4 tank.

1. INTRODUCTION

Comprehensive and proper training of soldiers/equipment users, that later warrants that combat operations can be carried out in diversified terrain, under various climatic and weather conditions, is an important element of the operation of modern military equipment. For this purpose training tools are used that optimize the relationship between the results achieved and the expense incurred. Such tools include instruction and training tools of the simulator type; these make use of modern technologies in the field of motion simulation (motion platforms), data processing, image projection and specialized imitators of real devices (equipment).

In the Polish Armed Forces, like in any other army, it is extremely important to provide comprehensive and proper training to soldiers/equipment users, that later warrants that combat operations can be carried out in diversified terrain, under various climatic and weather conditions. One of the most costly forms of training is that carried out with the use of real combat equipment. Handling the real equipment cannot be completely eliminated from the training process, and it usually takes place in the final stage of training. This approach significantly reduces costs and virtually eliminates the possibility of damage to the equipment by an untrained crew. How much training is done with real equipment in the whole training cycle, including that for tank crews, is determined by professionals who develop training programmes.

The introduction into service in the Polish army of German Leopard 2A4 tanks in 2002 created the need to expand the existing training base. The trainer devices and simulators, purchased from the German party together with the tanks, are based on technological solutions dating back to the 1980s, it is therefore necessary to upgrade and adapt the functionalities of the equipment to modern training methods.

A device of a relatively narrow training scope is the "STEND" type trainer device for drivers of the Leopard 2A4 tank. It is a stationary device allowing only to learn the layout and arrangement of the tank driver compartment, including the functions of the control elements and equipment. The trainer device does not allow to conduct tank driving lessons, and its structure and applied solutions do not allow to extend its functionality.

Piotr **WOCKA**, Łukasz **BURY** – Ośrodek Badawczo-Rozwojowy Urządzeń Mechanicznych "OBRUM" sp. z o.o., Gliwice

2.   LEOPARD 2A4 TANK TRAINING DEVICES

The training of Leopard 2A4 tank crews in the German army was carried out using devices developed by German companies, i.e.:

- ➢ Leopard 2A4 turret training device "AAT";
- ➢ "CDT" type trainer device for drivers of the Leopard 2A4 tank;
- ➢ "ASPT" firing training simulator for Leopard 2A4 crews;
- ➢ "AGPT" tactical training simulator for Leopard 2A4 tank platoon;
- ➢ AGDUS duel simulator.

With the acquisition of the Leopard 2A4 tanks by the Polish Armed Forces, the following devices were also purchased: simulators and trainer devices. As in the case of the Leopard tank modernization and "polonization" program run by the Polish Armed Forces, a program of modernization, polonization and development of instruction and training devices is run in parallel.

3.   DRIVER STATION INSTRUCTION AND TRAINING DEVICE

The previous driver training, conducted as part of the Leopard 2A4 tank crew training program, was implemented using:

- ➢ "CDT" type stationary trainer device - familiarizing with the structure and equipment of the driver station;
- ➢ "AGPT" container simulator - learning how to coordinate the work of the driver with the tank crew.

Both the "CDT" and the "AGPT" provided training and instruction for Leopard 2A4 tank drivers within a limited scope. The "CDT" enables only familiarizing the driver with the arrangement and systems of the driver station. The purpose of the "AGPT" is to train crew coordination, while the driver's functions and systems are very limited in this simulator. None of the existing devices allowed conducting Leopard tank driving lessons.

Therefore, the decision was made to develop a new device, a simulator, as part of the modernization and development program of instruction and training devices.

4.   LEOPARD 2A4 TANK DRIVING SIMULATOR (SJCL)

The stationary driver station simulator, of modular design (Fig. 1), according to the OBRUM concept, is a completely new instruction and training device, which enables conducting a wide range of Leopard 2A4 driving instruction and training.

The major components of the simulator are:

- ➢ cab module incorporating the driver compartment;
- ➢ driver station systems;
- ➢ vision system module for virtual visual terrain representation;

> ➢ motion platform with 6 degrees of freedom for simulating the movements of the tank chassis while driving;

> ➢ instructor station module for controlling and verifying the progress of training.

Fig. 1. Leopard 2A4 tank driving simulator - SJCL

(photo OBRUM)

The concept and visualization of the simulator was made using 3D modelling in SolidWorks 2017. As technical/design documentation of the Leopard 2A4 tank was not available, the system components of the driver station were modelled using elements of the reverse engineering method, i.e. from the real object to a 3D model. The adopted real object comprised the data from an inventory carried out by design engineers on the real object, i.e. the Leopard 2A4 tank, and on the CDT stationary driver station trainer device made available by the Leopard Training Centre (OSL) in Świętoszów.

4.1. Cab with driver station

The driver station in the simulator should reflect the ergonomics of the real object in the possibly most accurate way and simulate its functionality and operation of the system components present in the real tank. Both the workspace, its configuration, as well as the SJCL simulator components, were developed in accordance with the requirements of users and of the training processes to be implemented.

In the Leopard 2A4 tank, the driver station is on the front right side of the chassis. On the left side, the driver's space is constrained by ammunition store and control panel. On the other sides, i.e. right, front, top and bottom, this space is constrained by tank hull plates. The internal space of the driver station simulator is defined by the main walls, the shape and mutual arrangement of which imitate the driver's space inside the tank. The designed cab framework is shown in Fig 2.
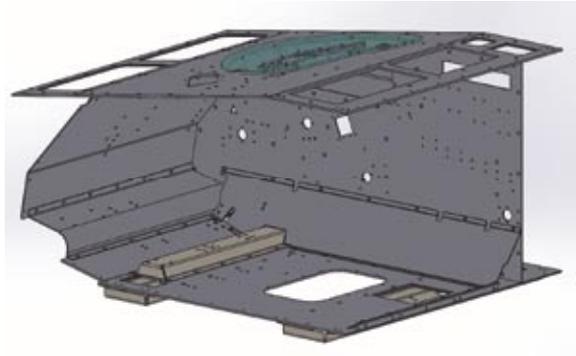
Fig. 2. 3D model of the driver compartment space

The SJCL simulator design included the cab module with the driver station and its system components. The cab module also provides the possibility of installing equipment and accessories necessary for the operation of a complete simulator, but which does not constitute components of the training system and of the driver station system itself. As the cab module needs to be installed on the motion platform which generates accelerations, decelerations, shocks and vibrations, reflecting the movement and operation of the tank, the cab structure must be sufficiently strong and rigid, while maintaining appropriate functionality.

The cab is based on a self-supporting shell structure made of flat sheets, bent elements and standardized structural profiles of structural steel and aluminium. In order to ensure accuracy of fitting and assembly, the individual elements of the cab are connected by screws. There are no welded, adhesive bonded and riveted elements in the SJCL cab. This enabled to provide a completely modular design, allowing easy replacement of components, upgrades, repairs and the possibility of changing the configuration of the simulator. Additionally, due to the lack of welded elements, there are no initial stresses and strains of structural components, and the fabrication of components is easier and more economical.

The 3D models of the driver cab are shown in Fig. 3. The cab consists of an external module (Fig. 3a) providing an aesthetic appearance of the simulator and an internal module inside it defining the driver station space (Fig. 3b). There are common structural components in both modules which reduces the total weight of the cab. Side inspection hatches provide access to the simulator cab systems located in the space between the internal and external modules. In addition to the upper hatch with raised cover and bottom hatch with lowered cover, which are arranged identically as in the Leopard 2A4 tank, in the back wall of the SJCL simulator cab there is the main entrance door and there are inspection hatches in the walls.

a)   b)
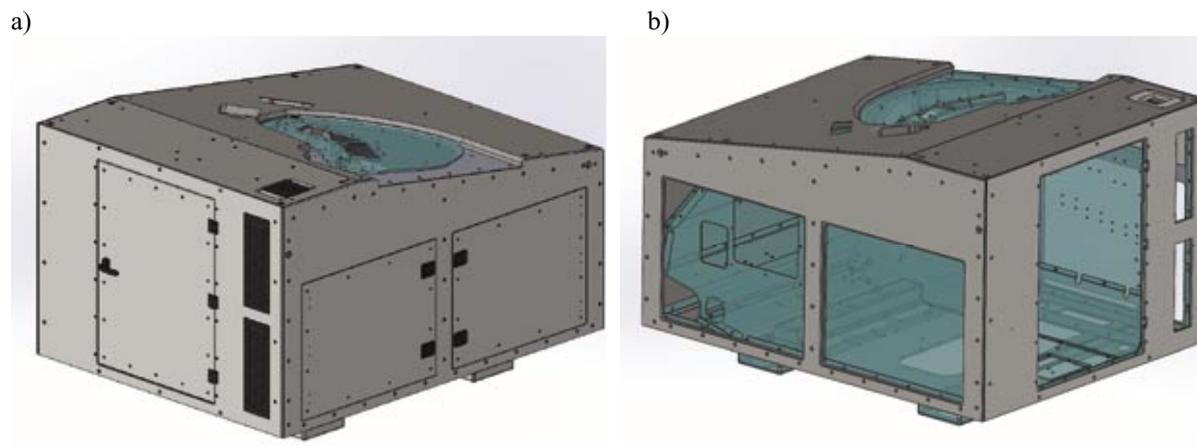
Fig. 3. 3D models of the SJCL simulator cab

a) external module, b) internal module

The Leopard 2A4 tank driving simulator cab can be used as part of a complete SJCL simulator as well as an independent training module which enables familiarizing with the structure and systems of the driver station.

4.2. Driver station systems

The assembly of imitators of the SJCL simulator station systems was designed in the same way as in the Leopard 2A4 tank. Both the arrangement and functions of the individual elements of equipment correspond to the real elements to ensure the most accurate course of the driver training process.

Figure 4 shows the reproduction of the Leopard 2A4 tank driver compartment in the stationary trainer device.

Fig. 4. "CDT" type trainer device for drivers of the Leopard 2A4 tank [8]

The most important electromechanical elements in the driver station designed in the SJCL simulator are described below.

4.2.1. Steering system

The Leopard 2A4 tank is steered by means of a steering wheel that controls the steering mechanism of the transmission in the power-pack. The driver can steer the tank by observing the surroundings directly through an open hatch or with a closed hatch by observing the surroundings through periscopes. Depending on the type of observation, the position of the driver changes, to which the setting of the steering unit must be adapted. The steering unit is mounted to the front plate of the tank chassis and the steering shaft can be rotated between -90° to +90°, moved along its axis and set in one of 3 locked positions and the angle of inclination of the entire steering unit can be set within the range of 18°.

For the purposes of the SJCL simulator, a steering system imitator was developed (Fig. 5) which functionally corresponded to the real system in the Leopard 2A4 tank. For the purposes of driving simulation, the steering unit was fitted with an encoder that reads the rotation of the steering shaft, with a mechanism ensuring automatic return of the steering shaft rotation to its middle position and with a mechanism that locks the automatic return of the steering shaft rotation axis in its middle position. The steering wheel assembly is also equipped with a control handle to simulate the change of lights and direction indicators.
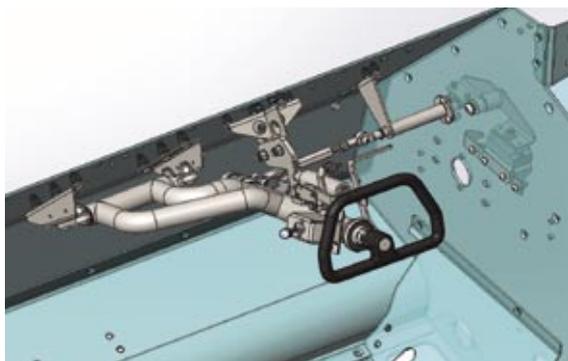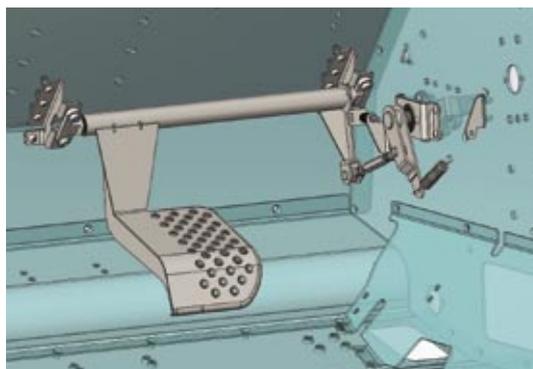

Fig. 5. Steering system imitator   **Fig. 6. Braking system imitator**

4.2.2. Brake pedal

Braking of the Leopard 2A4 tank is effected by means of a foot pedal, which controls the brakes located in the power-pack via intermediate levers and flexible link. The brake pedal is mounted to the front plate of the tank hull by means of brackets. In the SJCL simulator the system of imitators (Fig. 6) has a brake pedal and intermediate levers similar to those of the Leopard 2A4 tank. For the purposes of driving simulation, the braking system has been equipped with an encoder reading the driver's foot pressure on the brake pedal and with a STOP lamp switch.

4.2.3. Accelerator pedal

Engine speed in the Leopard 2A4 tank is controlled with a foot accelerator pedal, which is connected to the drive engine control system via a flexible link. Due to the need to adjust the driver's position to the hatch being open or closed, as in the case of the steering system, the two-piece accelerator pedal system may be adapted to make it convenient for the driver. The SJCL simulator is equipped with a two-piece accelerator pedal imitator (Fig. 7)

connected to an encoder reading its position. Functionally, the SJCL simulator accelerator pedal system corresponds to the real system of the Leopard 2A4 tank.
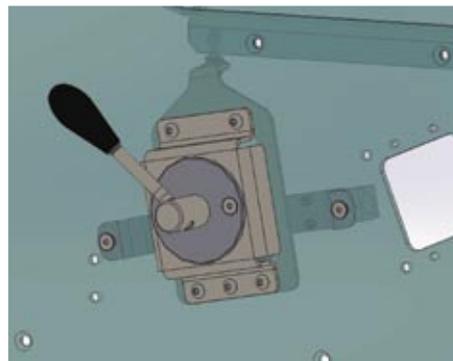
4.2.4. Parking brake lever

The parking brake is activated and released using a lever located on the right-hand wall of the driver station, which via a flexible cable is connected to the control system of the power-pack gearbox.

The SJCL has a control lever imitator (Fig. 8) with a lever position detection mechanism. The imitator simulates an engaged or disengaged parking brake. The functionality is similar to that of the tank.

Fig. 7. Accelerator pedal imitator   **Fig. 8. Parking brake lever imitator**

4.2.5. Gear selector

Leopard 2A4 is fitted with a RENK automatic gearbox. The driver controls the operation of the gearbox by means of a gear selector located on the right-hand wall of the driver station. The gear selector controls the gearbox via electrical signals.

The upper selector lever controls gear shifting in the following way:

➢ A – automatic mode for gears 1 to 4;

➢ 3 – automatic mode for gears 1 to 3;

➢ 2 – automatic mode for gears 1 to 2;

➢ 1 – driving only in first gear.

The rear selector lever controls the driving mode in the following way:

➢ V – forward travel;

➢ N – neutral;

➢ R – backward travel;

➢ W – neutral turn.

Moving the rear lever between travel modes V, N and R is possible only after releasing the lock controlled by an additional "E" button next to the rear lever. The SJCL simulator was provided with a replica/imitator of the gear selector with its functionality identical with that of the real object.
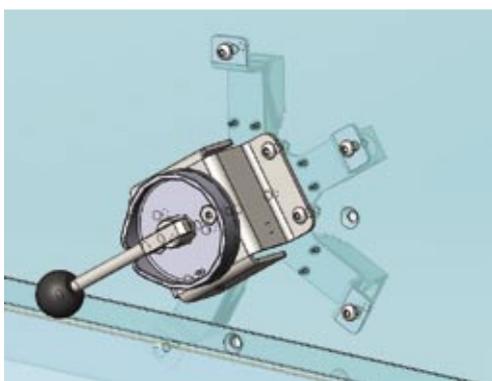
4.2.6. Emergency gear shift lever

If gear selector switch fails, it is possible to mechanically control Leopard 2A4 tank driving mode. On the right-hand wall of the driver station there is an emergency gear shift lever (Fig. 9) connected by means of a flexible link to the gearbox.

Under normal conditions and correct operation of the gear selector, the emergency gear shift lever is locked and sealed in its middle position. After breaking the seal, the lever can be set in one of the three possible positions:

➢ backward travel;
➢ forward travel;
➢ towing mode.

The SJCL simulator was provided with an emergency gear shift lever (Fig. 9) with its functionality identical as in the Leopard 2A4 tank. The lever is moved into the selected position mechanically. The current lever position is detected in the simulator by means of limit switches.

Fig. 9. Emergency gear shift lever
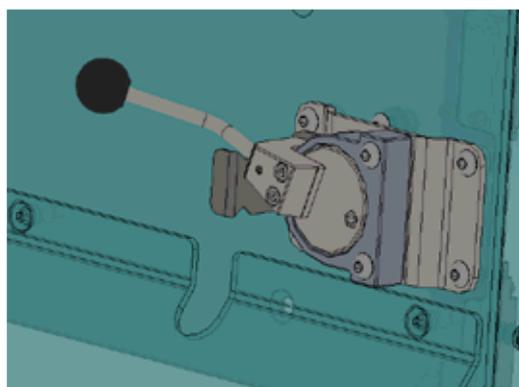
Fig. 10. Hydraulic sealing system lever imitator

4.2.7. Hydraulic sealing system lever and pressure gauge

Leopard 2A4 has a hull sealing system that enables negotiating deep water obstacles. Components of that system are controlled by a central hydraulic system (CUH). The system is activated by means of a lever located on the right-hand wall of the tank, behind the driver station. In order to monitor the operation of the CUH system and to ensure the safety of the crew while negotiating a deep water obstacle, a CUH system pressure gauge is installed in the upper right corner of the driver station.

In the SJCL simulator the CUH activation lever imitator (Fig. 10) is located similarly as in the Leopard 2A4 tank on the right-hand wall of the driver station, but at a shorter distance. The functionality of the real object lever is retained. The CUH pressure gauge imitator has a LED indicator. Its functionality and location is similar to that of the real object.

4.2.8. Upper hatch with raised cover with closed position lock, open position lock and support roller

Leopard 2A4 tanks are fitted with driver hatches with covers raised to the side. The hatch is opened and closed by the driver manually by means of a rotary lever, a set of bevel

gears and articulated shafts. The hatch is set in its open or closed position by means of locks. As the turret rotating range is 360°, the release of the closed hatch lock is possible only when the turret is locked in one of two specified positions. In addition, to ensure driver safety, the revolving handle is equipped with an automatic lock preventing free movement of the hatch cover in case the cover is not locked in the open or closed end position. Due to the large weight of the hatch cover and equipment located on it, a supporting roller is installed to keep the hatch cover in the proper position. To ensure tightness, the hatch cover in the closed position is pressed against the upper surface of the hull plate. When opening the hatch, at first the cover is lifted along the axis of rotation, then it is tilted by rotation. When closing the hatch, the cover is first rotated and in the final stage of the system operation it is lowered and sealed.

The SJCL simulator has a raised hatch system (Fig. 11) with functionality similar to that of the tank with the use of bevel gears and articulated shafts. The overall transmission ratio of the hatch opening mechanism is 1:5, identical with that of the Leopard 2A4 mechanism. As the weight of the components of the hatch and its fittings was lower, it was possible to use lighter, commercial power transmission components. As there is no tightness requirement, the hatch cover movement along the axis of rotation is not effected.
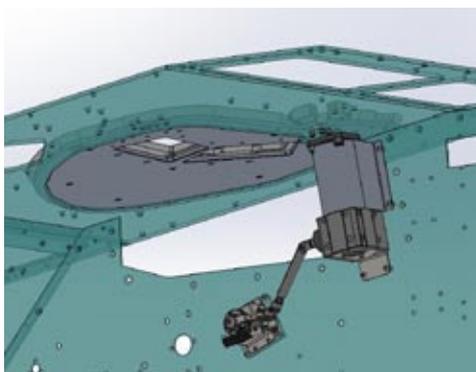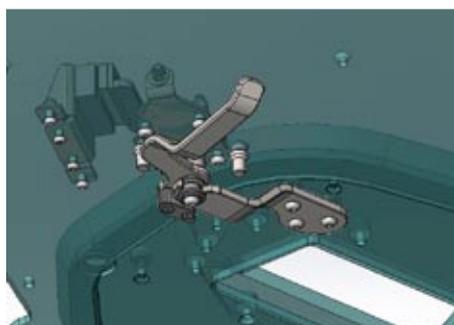


Fig. 11. Driver's hatch with rotation mechanism.
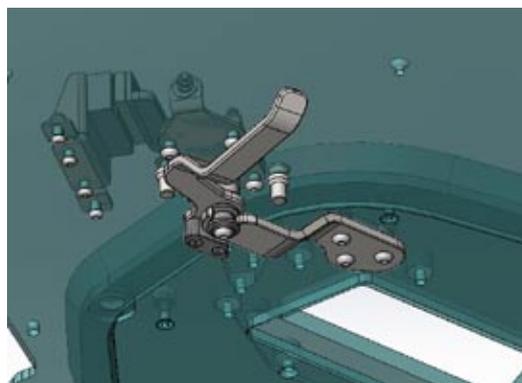
Fig. 12. Driver's hatch closed position lock imitator

The open position lock (Fig. 14), automatic rotation lock and support roller have been designed analogically to real objects. The closed position lock (Fig. 13) is equipped with an electromagnetic lock that simulates the impossibility of locking turret rotation.

Fig. 13. Driver's hatch closed position locks
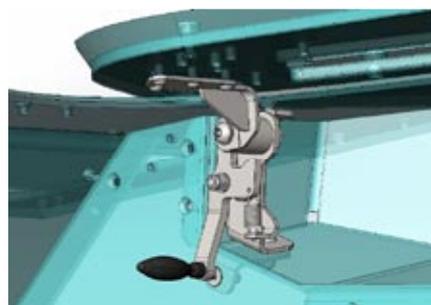
Fig. 14. Hatch open position locks

4.2.9. Seat and foldable headrest

The design of the seat in the Leopard 2A4 tank provides the ability to set its position depending on how the driver observes the surroundings, which can be done by periscopes or directly through an open hatch. In addition, the position of the seat and backrest can be adjusted, and the backrest can be quickly dismantled to facilitate the moving of crew members between the stations. The driver station is also equipped with a foldable headrest attached to the upper hull plate in the driver compartment. The SJCL simulator is equipped with a complete, original seat from the Leopard 2A4 tank. The design of the folding headrest in the SJCL simulator corresponds functionally to that applied in Leopard 2A4.

4.2.10. Footrest with wiper and periscope washer switch

In addition to the accelerator and brake pedal system, the driver station of the Leopard 2A4 is equipped with an additional footrest for the driver's left foot. In the upper part of the footrest there is an integrated foot switch for controlling the wipers and driver periscope washers.

The design of the footrest in the SJCL simulator corresponds functionally to that applied in Leopard 2A4. The wiper and washer switch is a functional replica of the original switch.

4.2.11. Rescue hatch in the bottom

A rescue hatch is located in the bottom of the tank hull, directly in the driver compartment, under the seat. If the driver's life is threatened, or when other escape routes are blocked, the hatch is opened and its cover is lowered below the bottom of the tank hull. The mechanism that locks the rescue hatch in the bottom of the Leopard 2A4 tank consists of a lever connected to the closing bolts by means of pins and a latch pressed against the lever by a spring, preventing the rescue hatch from being unintentionally unlocked while the tank is moving. To ensure proper sealing, the hatch is equipped with a turnbuckle for adjusting the pressing force of the lock bolts. The design of the rescue hatch in the SJCL simulator corresponds functionally to that applied in Leopard 2A4. For the purpose of training future drivers, simulation of the opening of the hatch was limited only to the release of the lever lock, unlocking of the hatch by the lever, and slight lowering of the hatch cover (under the bottom of the cab there are brackets supporting the released hatch cover). The opening of the hatch is indicated at the instructor's station by an appropriate signal from the limit switch located under the bottom plate at the hatch.
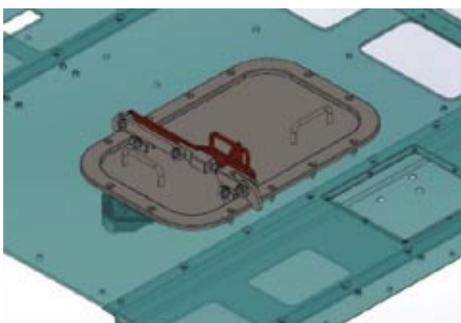
Fig. 15. Rescue hatch in the simulator bottom
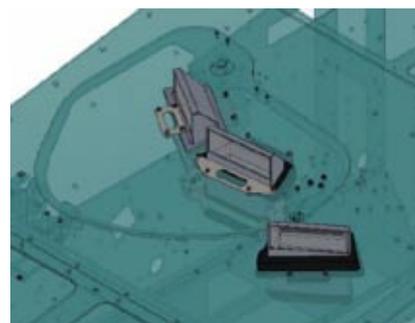
Fig. 16. Periscopes of the driver compartment in the SJCL simulator

4.2.12. Driver's periscopes and night vision device with accessories

The driver compartment in the Leopard 2A4 tank has three periscopes (Fig. 16), through which observation is carried out while driving with the driver's hatch closed. Two periscopes are mounted on the driver's hatch; when the hatch is open the periscopes are concealed in a hull cavity

on the right-hand side. The periscope on the left side of the driver station is attached to the top armour plate of the tank hull. Each periscope can, if necessary, be detached from its quick-mounting brackets by the driver and replaced (or exchanged).

Leopard 2A4 is equipped with an infrared observation camera (night vision device). When necessary, the night vision device is attached in the middle periscope position. Due to the design of the night vision device (smaller overall size as compared to the periscope), a special adapter is required for mounting. Mounting to the driver's hatch of the adapter with a night vision device fastened to it is carried out using a quick-mounting bracket.

The periscope and night vision design developed for the SJCL simulator functionally corresponds to a certain extent (requirements set by the ordering party) to periscopes and night vision devices included in the Leopard tank equipment. Observation of the surroundings by the driver is enabled by every periscope and the night vision device. In SJCL the middle periscope can be detached and a night vision device can be attached in its place. The middle periscope is provided with a quick-mounting bracket. The right-hand periscope in the hatch and the left-hand periscope on the upper plate are fixed permanently. The SJCL simulator also reproduces the storage location of the night vision device (box under the driver's panel) and of the night vision adapter (periscope case in front of the night vision box). In addition, the periscopes are fitted with rubber covers to protect the driver while driving against hitting the periscopes, and the night vision device has a rubber eyepiece.

4.2.13. Fire suppression cylinders

The Leopard 2A4 tank is equipped with a fire suppression system. Four cylinders (Fig. 17) with extinguishing charges are hung on the right side of the tank in the driver compartment. When a fire occurs, depending on the tank compartment where it was detected, the fire suppression system is activated. After the cylinder is emptied, a pin indicating the absence of extinguishing agent juts out of the cylinder bottom. Before starting the tank, the driver must check if the cylinder is filled with the extinguishing agent. The check consists in touching the bottom of the cylinder with a finger and checking the position of the signalling pin. The pin can take one of two positions. The cylinder is replaced if it is found to contain no extinguishing agent.

The design of the fire suppression system in the SJCL simulator corresponds functionally to that installed in Leopard 2A4. Inside each cylinder there is a safety device with a knock-out pin, controlled from the instructor station. In this way, the activation of the fire suppression system and emptying of the cylinder is simulated. Maintenance operations involving the replacement of cylinders were not implemented as this was not required.
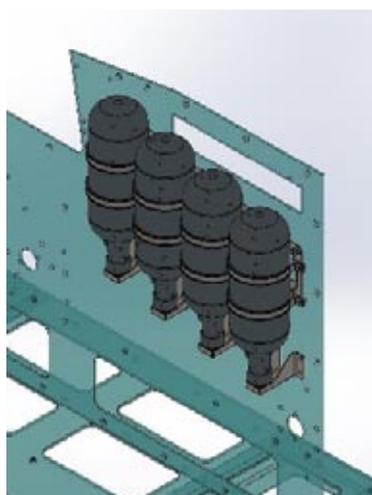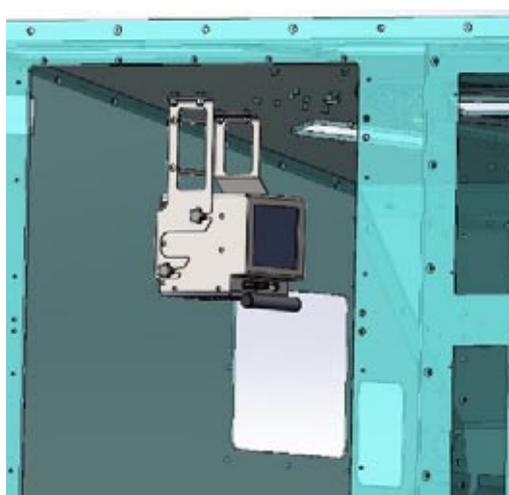

Fig. 17. Fire suppression cylinders

Fig. 18. Rear view camera display

4.2.14. Rear view camera display

Leopard 2A4 is not equipped with a rear view camera display and a rear-view camera. The rear view camera and display are installed in newer versions of the Leopard tank. The camera allows the driver to easily manoeuvre the vehicle when driving in reverse, because the image is displayed directly on the display located near the driver's seat. The Leopard tanks in the Polish Army were retrofitted with rear view cameras and displays.

In the SJCL simulator, the design of the rear view camera display (Fig. 18) corresponds to the requirements set by the client. The image on the display shows the surroundings/space behind the tank. The image is generated by graphic software, which is an integral part of the simulator, responsible for the image displayed during driver training.

4.2.15. Internal guards and handles

The driver station in Leopard 2A4 is fitted with three handles located on the upper and the front hull plate. The handles allow the driver to settle in the station, and also help in setting the seat in position for driving with the hatch open and direct observation of the surroundings, and for driving with the hatch closed and observing the surroundings through periscopes. The driver's seat in Leopard 2A4 is placed directly above the torsion bars of the second axle, the latter covered by a guard that is part of the driver station.

The SJCL simulator has three handles, arranged in the same way as in the Leopard 2A4 tank, attached to the front and top walls of the cab. There is also an additional handle that facilitates entering and exiting the simulator cab.

In order to mirror the appearance and functions of the driver station, the SJCL simulator design also includes the imitation of the guard over the torsion bars located under the driver's seat.

In addition the SJCL simulator also includes:

4.2.16. Driver's dashboard
4.2.17. Turret position indicator
4.2.18. Driver station lighting
4.2.19. Fire suppression system control panel
4.2.20. Intercom
4.2.21. Ventilation system

5.   SUMMARY

The developed, fabricated and implemented for use SJCL simulator (Fig. 1) is a modern device allowing to conduct the training process, including Leopard tank driving training. The main and most important feature of this simulator is the integration and cooperation of the driver station (and its systems) with the terrain projection and imaging systems, the motion platform and the instructor station. The driver being trained can both learn how to use the systems and grasp the tank's traction performance. He/she also has the opportunity to drive under the conditions found on the training grounds, including varied terrain and infrastructure allocation. The SJCL allows mastering the techniques of driving a tank and how to negotiate obstacles. The simulator, as a whole, is a complex device, and its design required the participation of specialists of diverse scientific disciplines - mechanics, automation, electronics, computer science and computer graphics.

The article focuses mainly on the issues of 3D design of mechatronic elements of a simulator intended for the training of drivers of the Leopard 2A4 tank. The issues of design and development of other components and systems of the SJCL simulator will be presented in future articles.

Simulators and simulation training techniques for various areas of instruction on the use of military and other equipment, are a requirement of today. OSL Commander, Maj Krzysztof Kacperek says: *Extensive use of simulators at the Training Centre in Świętoszów is the foundation for achieving good results during exercises and tests. Simulators provide both the ability to teach and improve previously acquired skills. By reducing the use of combat equipment and reducing the consumption of ammunition, training costs are reduced. However, the most important advantage of the wide use of simulators is the ability to track the current progress in training and to rectify errors emerging during the training.*

6. REFERENCES

[1] Jackson R.: 101 słynnych czołgów. Oficyna Wydawnicza Alma-Press. Warszawa 2017.

[2] Ogorkiewicz R .M.: Technology of Tanks. Jane's Information Group. https://archive.org/details/Janes_Technology_of_Tanks_01 [Retrieved: 25.01.2019].

[3] Merhof W., Hackbarth E.M.: Fahrmechanik der Kettenfahrzeuge. 2015. ISBN: 978-3-943207-13-2. https://athene-forschung.unibw.de/doc/111331/111331.pdf [Retrieved: 25.01.2019].

[4] Grabania M. Ł.: Symulacyjne metody szkolenia załóg czołgów. Szybkobieżne Pojazdy Gąsienicowe (3) No. 1/1993 (pp. 5-20). ISSN: 0860-8369.OBRUM sp. z o.o. Gliwice, November 2013.

[5] Dąbrowski M.: Kierunki rozwoju symulacji i treningu wojsk. Szybkobieżne Pojazdy Gąsienicowe (33) No. 2/2013 (pp. 43-50) ISSN: 0860-8369.OBRUM sp. z o.o. Gliwice, September 2013.

[6] Grabania M. Ł., Synowiec M.: Trenażer nauki jazdy KTO ROSOMAK. Szybkobieżne Pojazdy Gąsienicowe (30) No. 2/2012 (pp.127-132). OBRUM sp. z o.o. Gliwice, September 2012.

[7] Kapruziak M., Parczewski S., Nikisz T.: Nowoczesne symulatory KTO_ROSOMAK. Szybkobieżne Pojazdy Gąsienicowe (37) No. 2/2015 (pp.19-26). OBRUM sp. z o.o. Gliwice, June 2015.

[8] Ośrodek Szkolenia LEOPARD (OSL). http://10bkpanc.wp.mil.pl/pl/179.html [Retrieved: 25.01.2019].