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VERSATILITY OF THE ENGINEERING SOLUTIONS APPLIED IN THE BRIDGES OF THE DAGLEZJA GROUP

Abstract. One of the most important areas of research and development carried out at OBRUM during the current decade is that of transportable bridges designed for the engineering troops of the Polish Armed Forces. OBRUM has undertaken design and fabrication works on the bridges of the Daglezja group. The works included three types of bridges: MS-20 Daglezja support bridge on wheeled chassis, MG-20 Daglezja G assault bridge on tracked chassis and MS-40 Daglezja S support bridge. The article discusses the most important elements that are decisive for the high degree of versatility of design and that stand out against the background of design offered by Western manufacturers. Engineering solutions devised at OBRUM and applied in all three bridge types are described. The development history of the control panel of HMI (Human Machine Interface) class is presented. Description is given of a dedicated simulator working in a virtual space for training in the manipulation and operation of a bridge. In the summary, the effects of the projects completed at OBRUM and prospects for their further use in industrial manufacture of products for the domestic market and exports are assessed.

Keywords: mobile bridges, Daglezja group bridges, MS-20 Daglezja, MG-20 Daglezja G, MS-40 Daglezja S, innovative features of mobile bridges.

1. INTRODUCTION

During warfare, one of the most important tasks for the engineering forces is to provide maximum mobility to various types of troops. This applies to both movement in the battlefield, negotiating terrain and water obstacles, as well as to providing transport security after military operations [1]. For the implementation of tasks it is necessary to have specialist equipment, including bridges of various purpose and various operating parameters. Polish engineering forces have always attached great importance to the equipment at hand, as well as to the modernization of the used obstacle crossing equipment. In the past these included DMS-65 folded road bridges [2], BLG-67 bridges on tracked chassis [3], BLP-72 LAUR support bridge [4], or PMC-90 assault bridge on tracked chassis [5], [6], the production of which has not been launched.

In order to improve the design of obstacle crossing means, in the years 2002 and 2003 the Armament Policy Department (now the Armaments Inspectorate) of the Ministry of National Defence launched research and development projects on mobile/transportable bridges code-named Daglezja. The base documents that specified the desired technical and performance parameters were the Tactical and Technical Requirements drawn up and approved for the individual bridge types. These documents enabled the completion of research and development work. The work covered, in succession, the following projects:

- MS-20 Daglezja [7];
- MG-20 Daglezja - G [8];
- MS-40 Daglezja - S [9].

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Complementing these group of bridges is the concept of the Douglas P pontoon bridge, the design work on which has not been launched yet.

All works related to mobile bridge design, including the implementation of research and development work, are carried out at OBRUM. Upon the development of the kinematics of bridge span launching, the mechanical resistance of the spans is optimized using the finite elements method. The calculations are done by a specialized team of scientific staff from the Wrocław University of Technology cooperating with OBRUM. The bridges listed above: MS-20, MG-20 and MS-40 are at different stages of product development. The MS-20 is now at the stage of short-lot production, MG-20 is in test production, whereas MS-40 is undergoing prototype qualification tests.

The high requirements included in the Tactical and Technical Specifications [7], [8], [9] for the individual bridge types given by the Armament Policy Department (now the Armaments Inspectorate) of the Ministry of National Defence and lack of any reference products on the Polish market necessitated a great intellectual effort of OBRUM's research and development and technical personnel and elaboration of multivariant solutions at the subsequent stages of bridge design and construction.

Bridges are classified according to their application and functional features. A systematized classification is given in a defence standard [10].

2. FUNCTIONAL FEATURES OF DAGLEZJA BRIDGES

The final effect of the completed projects are the structures, verified in factory and qualification testing, that stand out against bridges offered by other European and world manufacturers. The features of the various types of bridges are adapted to the intended use of the bridges and to the requirements of the place of use.

Bridge classification depends on its use in the battlefield. Depending on the qualification of the bridge and the place of its use, diverse requirements are set on the design. The Daglezja bridges are characterized by a set of common features, but the varied requirements determine the detailed applied design and kinematic solutions. For this reason certain functionalities are available only in specific bridge types.

Assault bridges are the most vulnerable to battlefield impact, and therefore the most stringent requirements are placed on them. Although support bridges are not required to have all the obligatory features of assault bridges, nevertheless many of those characteristics are also desirable in support bridges.

2.1. MS-20 DAGLEZJA support bridge [7], [13], [14], [15], [24]

Distinctive features of the MS-20 bridge (Fig. 1):

- Ability to travel on public roads.
  The geometric dimensions of the bridge assembly, including the reduction of the span width in the transport position and the axle load, meet the requirements set out in traffic regulations [11], which allows the MS-20 bridge to travel on public roads with no need to obtain additional approvals.

- Movement of the bridge assembly in open rough terrain.
  The semitrailer of the bridge laying vehicle has been equipped with an additional hydraulic drive on three axles, which supports driving - moving in unpaved terrain while travelling to an obstacle.
- Bridge span with extended deck between treadways.
  The structure of the roadway of the bridge span (PM) has a deck between treadways which enables foot and vehicle traffic. The deck is extended automatically during bridge span expansion from the transport position to launched position.
- The bridge span width is changed from the transport mode to launched mode automatically.
  Upon arriving at the launch site, the bridge span (installed on a truck) is, in the first cycle, extended from the transport position (width 3 m) to the launched position (width 4 m). When the bridge assembly assumes the position for span launching, the span width change cycle proceeds automatically;
- Uniform surface of bridge span roadway.
  The span includes deck extensions which provide a continuous surface of the roadway and facilitate passage of vehicles of diverse design and of infantry.
- Interchangeability of the bridge span.
  The final design of the bridge span enables its use in both MS-20, as well as MG-20. Depending on the tasks performed, the bridge span launched over an obstacle by an MG-20 bridge (during combat operations) can be retrieved by an MS-20 bridge (after cessation of operations).
- Interchangeability of transport means (trucks).
  The truck of the MS-20 bridge is identical with that of the MS-40 bridge. Therefore the repair tasks are uniform and it is possible to replace the truck during combat operations (when the transport vehicle is damaged).
- Enabled passage of low bed semitrailer.
  Approach ramps, designed as additional equipment, enable passage of vehicles with low bed semitrailers over an MS-20 bridge.
- High performance characteristics.
  The MS-20 bridge has a carrying capacity for tracked vehicles corresponding to MLC 70 class, and to MLC 110 for wheeled vehicles [12].
- Safe use of the bridge.
  All bridge span launching and retrieval processes are controlled from outside of the bridge vehicle by a trained operator using a portable control panel.
- Increased safety of bridge usage.
  In order to improve the safe use of the bridge during military operations, the bridge assembly is equipped with a smoke screening system that hinders detection of its location that could result in destruction attempts.

Fig. 1. MS-20 support bridge on wheeled chassis

Characteristic phases of launching an MS-20 bridge over an obstacle are shown in Fig. 2.

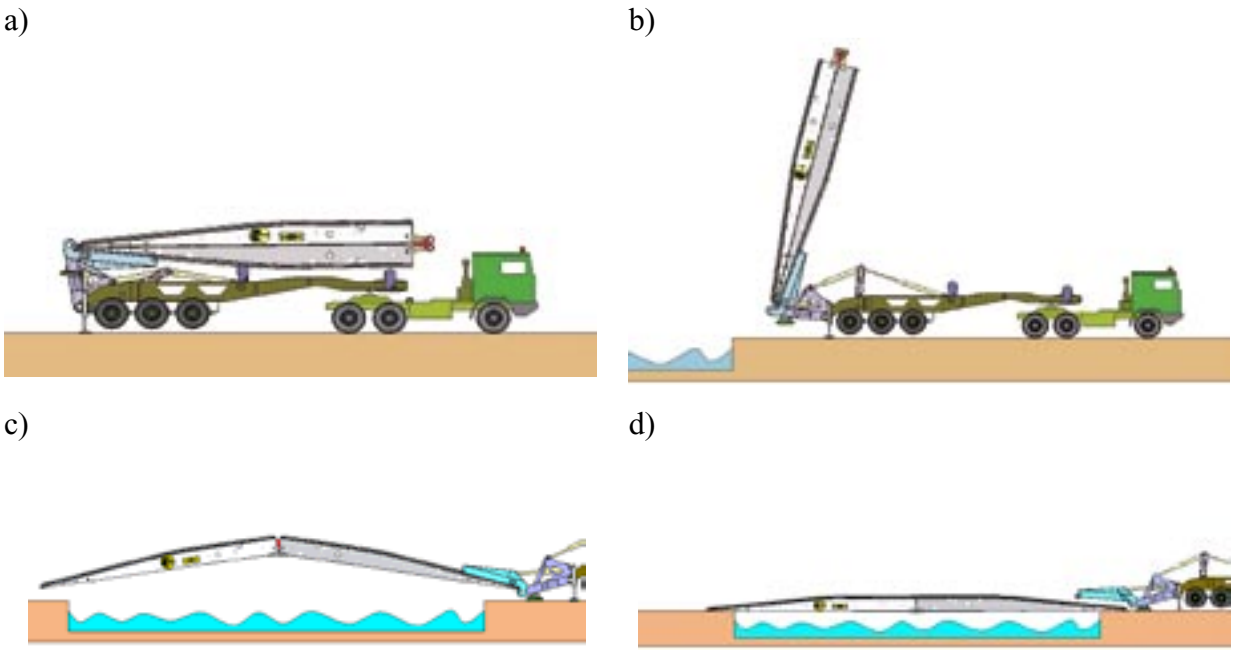

Fig. 2. Phases of launching the MS-20 bridge

a) transport position – preparation of the assembly for launching the bridge span; b) start of bridge launching over an obstacle; c) launching the bridge span over the obstacle; b) completion of bridge launching over the obstacle

2.2. MG-20 assault bridge [8], [16], [17], [18], [25]

Another bridge of the Daglezja group is a bridge on tracked chassis MG-20 (Fig. 3).; The intended use of that bridge under combat operation conditions requires of the MS-20 bridge additional features:

- Controlling bridge span launching over an obstacle from inside of the vehicle.
  The design of the bridge enables controlling the bridge span launching from inside of the vehicle (without the need for the crew to disembark from the vehicle).
- Automated control of bridge span disengagement.
  Upon positioning the bridge span over an obstacle, the tracked vehicle can pull out after automatic disengagement of the span (including the disconnection of hydraulic and electric systems). This is a very important feature, especially under the conditions of military operations.
- Negotiation of water obstacles.
  The bridge is adapted to negotiate a water obstacle as a complete assembly. The bridge carrier is a tank chassis that meets all performance requirements of tracked vehicles.
- Features common with those of the MS-20 bridge: bridge span with deck extended between treadways, interchangeability of the bridge span, passage of low bed semitrailer possible, high performance characteristics; increased safety of bridge usage.
- Bridge span launching in terrain of longitudinal slope up to 14% and transverse slope up to 5%.

The MG-20 bridge on tracked chassis is also fitted with systems required in the battlefield, including:

- radiation detection system;
- chemical contamination detection system;
- bridge span smoke screening system;
- OBRA self concealment system.

Fig. 3. MG-20 tracked assault bridge

2.3. MS-40 DAGLEZJA S support bridge [9], [14]

The MS-40 (Fig. 4), designed for negotiating obstacles up to 40 m wide, is one of the few bridges which, apart from OBRUM, are offered by three manufacturers in the world. Unlike in the previously discussed structures, the bridge assembly consists of four transport

vehicles and one laying vehicle. The transport vehicles are designed for transporting the sections of the auxiliary and main spans along with the necessary equipment. Figure 4 demonstrates the vehicle arrangement of the complete bridge.

MS-40 has the following features:

- MS-40 transport vehicles can move on public roads.
  The design of the transport means meet the requirements set out in traffic regulations [11] and these are allowed to move without the need to obtain additional permits and the presence of an escort vehicle.
- Compatibility and interchangeability of MS-40 and MS-20 transport means.
  During the design work the bridge transport vehicle (MPT) of the MS-20 bridge was adapted to the new functions of the MS-40 bridge. The built-in additional hydraulic drive of the semitrailer improves the traction properties on unpaved terrain.
- The obstacle maximum width of 40 m.
  The maximum length of the bridge is 46 m, and it allows to negotiate obstacles up to 40 m wide. The bridge is laid using an auxiliary span using individual sections of the main span in semi-automatic mode.
- Adapting the bridge length to the obstacle dimensions.
  The span components enable setting up two separate shorter bridges.
- Ability of laying combined bridges.
  Depending on field conditions, the bridge can be laid in combination with a pontoon bridge (e.g. PP 64).
- Laying bridge spans on banks of different height.
  A full length span can be laid over an obstacle the bank heights difference of which is up to 2.8 m.
- Safe use of the bridge.
  All bridge span launching and retrieval processes are controlled from outside of the bridge assembly by a trained operator using a portable control panel and a trained crew. The bridge is equipped with special mechanism for controlling the movements of the sections of the auxiliary and main spans.
- Specialized design components that improve operating safety during crossing preparation.
  A number of solutions have been applied in the design of the bridge to increase the operating safety during bridge launching and retrieval: set of locks and protection of main span sections, set of adjustable platforms, lattice structure of the span (reduces the impact of wind when launching over an obstacle in comparison to a box girder structure) or additional safeguards in the hydraulic system in the form of valves and locks. There is also a device for indicating excessive ground slope which prevents against launching the bridge under improper conditions.
- Passage of trucks with low bed trailer over the bridge.
  Additional equipment of the bridge enables passage over the bridge of vehicles with low bed trailers which extends the applicability of the bridge (transport of various types of damaged combat vehicles).

- Passage of people and civilian equipment.
  The extended deck surface of the main span sections enables the transport and passage of people, single track vehicles, automotive vehicles of various weight and use.

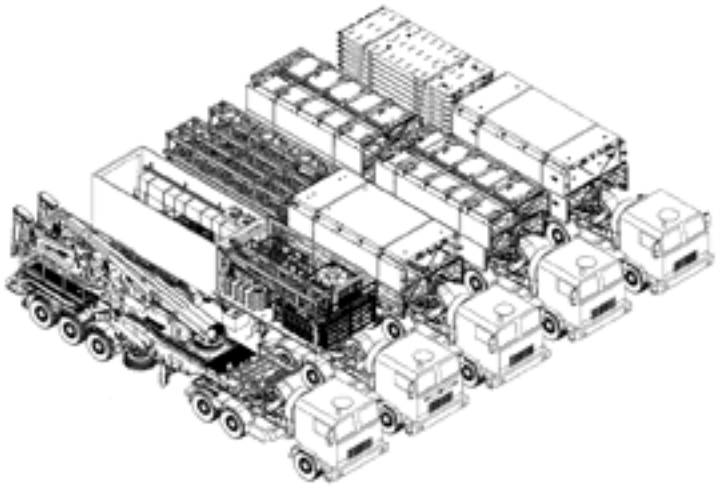

Fig. 4. MS-40 support bridge on wheeled chassis

3. HUMAN – MACHINE INTERFACE

The solution used in bridges for the control of bridge laying and retrieval processes is an advanced human-machine interface (HMI) designed in the form of a portable control panel consisting of technically advanced electronic systems of large scale of integration. The control panel, which is connected by means of a dedicated cable, allows the operator to control and supervise at a safe distance the launching and retrieval of the span, to monitor selected parameters of the hydraulic system, monitor the course of a selected cycle, halt the movement of the span and/or the bridge layer. One of the most important elements installed on the front plate of the control panel is a special emergency switch, which allows immediate stopping of the span movement in an emergency situation.

The designed version of the control panel [19] is an advanced extension of devices developed at OBRUM in recent years for radar stations (control of station levelling processes), engineering and road vehicles (control of jib and attachments) [20] and of earlier versions of the control panel designed at the model/prototype stages of the MS-20 bridge development. The functionality of the HMI of MS-20 is level with Western designs used in the PMC-LEGUAN bridge [21], [22] for which the control system was developed by MAN Technologie AG.

The initial design versions of the control panel were based on analog elements with information indication effected by means of signal lamps or LEDs. An example of the control panel / HMI developed at OBRUM is shown in Fig. 5.

Fig. 5. Control panel for radar station levelling system

Subsequent versions of the control panels used graphic terminals and programmable controllers. The HMI supplied with the MS-20 bridge [19] is a highly advanced microprocessor-based graphic controller with a keypad on the front plate (Fig. 6) that enables, among other things, the following:

- display of the span movement phases;
- display of hydraulic system parameters: pressures in actuator cylinders;
- graphical presentation of the status of the machine;
- modifications related to both the functionalities, as well as to user comfort, depending on the application;
- use for controlling other machines (needs dedicated software) the operation of which is based on data transfer via CANbus.

Fig. 6. HMI – front plate of portable control panel for MS-20

4. S-MS-20 SIMULATOR FOR TRAINING IN OPERATING THE BRIDGE

In order to improve the level of training of future users and to increase the safety of use of the MS-20 bridge, OBRUM developed a dedicated IT tool in the form of an S-MS-20 simulator for training in the operation of the bridge [23].

For this purpose, specialized software was developed based on the use of virtual space with an implemented model of the MS-20 bridge. The operator can carry out all control operations of the launching and retrieval of the span using the actual interface - control panel, observing the effects of actions (bridge operation phases) – images displayed on the screen of a computer projector. The method of interaction of the simulator components is shown in Fig. 7.

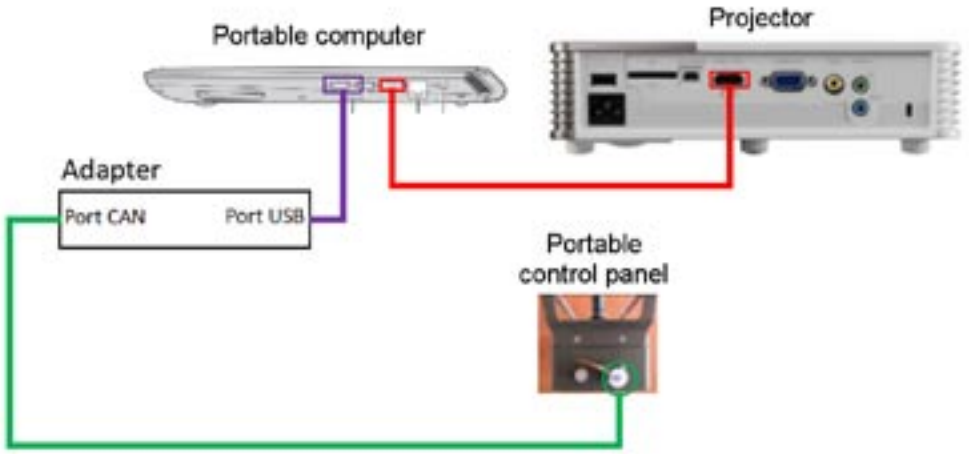

Fig. 7. Interaction between the S-MS-20 simulator and the portable control panel

The simulator can also be used for training without the portable control panel. In this case the operation of the simulator is illustrated in Fig. 8.

Fig. 8. S-MS-20 simulator configuration without the portable control panel

The use of the actual operator panel in the training process allows the trainee to get accustomed to the use of future equipment. All the phases and actions required during real operations are carried out on the simulator without the stress that is usually present during the initial stage of training. The simulator enables multiple repetition of the span movements performed incorrectly until the full ability to properly carry out all the steps required under real-world conditions is attained. This training mode allows for significant savings resulting from the elimination of the use of a real MS-20 bridge at this stage. An example of simulator screen, view of the bridge in front of an obstacle, is shown in Fig. 9.

Fig. 9. An example of simulator screen, view of the bridge in front of an obstacle – span launching

The simulator operates in several modes. The user can observe the procedures for laying and retrieving the bridge spans (presentation mode). He/she can use the simulator on his/her own or learn how to operate the MS-20 bridge under the supervision of a trainer (training mode). The simulator can also work in a mode that allows to carry out an examination to verify the skills of operating the MS-20 bridge under various operating conditions (examination mode).

The S-MS-20 simulator is supplied as a complete set with the MS-20 bridge.

5. THE USE OF MS-20 AND MS-40 BRIDGES IN CIVILIAN RESCUE OPERATIONS

The main application of the mobile bridges described here is during military operations. Due to the engineering solutions used and built-in systems that improve the safety of use and operation, there are indications for alternative applications of the bridges, e.g. in civilian rescue operations. If basic safety rules are maintained and occupational health and safety regulations are observed, the use and operation of the bridges by civilian personnel is made possible.

The distinctive design features of the bridges that allow for their non-military use include:

- existing extended deck between treadways;
- barriers and curbs on the main span;
- main span lighting and marking;
- mats – non-slip surfaces;
- transport – movement of bridge assemblies on public roads without escort.

Use of additional equipment (approach ramps of special design) supplied with the MS-40 bridge enables:

- passage of low bed semitrailer;
- passage of people;
- passage of civilian vehicles.

Bridges of the Daglezja group can be used in civilian rescue operations for making temporary crossings, as well as during the construction or renovation of bridges.

6 . SUMMARY

The bridges of the Daglezja group have been designed and developed with the utmost care and diligence. It was particularly important to meet the requirements specified in tactical and technical objectives. The completed development projects also focused on providing the widest possible group of functional features in every bridge of the group. At the same time, efforts were made to obtain the greatest degree of compatibility of the applied engineering solutions and components used. The main areas of compatibility include the interchangeability of trucks, additional drives (trailer drives), used drive and hydraulic systems and control systems.

Compatibility, in its broad sense, at the stage of design/development, production and operation is highly desirable, because it enables interchangeability of systems, units and subassemblies within the entire product group. It also helps simplify the design and reduce costs at the stage of development and manufacture and during use (equipment maintenance).

Sometimes compatibility is difficult or impossible to attain, because the purpose, specific design and dimensions of particular products included in the group of products often require the use of different engineering solutions and the use of dedicated components, designed and selected individually for each product.

Finding a compromise between product compatibility and ensuring the widest possible range of functional features is one of the greatest challenges in the design and R&D process throughout the entire product life cycle. Therefore, the developed and applied systems are based mainly on components, parts, interfaces and actuating systems available on the market. This approach ensures high efficiency and effectiveness, while maintaining compatibility, which also provides ease of access to subassemblies, consumables and spare parts. This shows the great versatility of the engineering solutions applied in bridges of the Daglezja group.

The engineering solutions applied in the MS-20, MG-20 and MS-40 bridges help them meet the requirements of modern military equipment, and especially those of the bridges of contemporary battlefield. The designs of the bridges of the Daglezja group presented in this paper can successfully compete with other world-renown designs.

The first production lot of ten MS-20 bridges, fabricated by a consortium comprising OBRUM and ZM Bumar-Łabędy S.A. for the Ministry of National Defence and consigned in 2017 to engineering troops, is a good recommendation for the bridges of the Daglezja group developed at OBRUM.

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