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Marek ADAMOWICZ[1], Adam POŚWIATA[2], Mariusz WESOŁOWSKI[1]
[1] *Inspectorate for Armed Forces Support (Inspektorat Wsparcia Sił Zbrojnych)*
[2] *Air Force Institute of Technology (Instytut Techniczny Wojsk Lotniczych)*

OPERATIONS & MAINTENANCE OF THE AIRCRAFT ARRESTING GEAR SYSTEMS IN THE POLISH AIR FORCE. PART 1

Eksploatacja urządzeń awaryjnego hamowania samolotów w lotnictwie Sił Zbrojnych RP. Część 1

Abstract: *In the article, the authors reviewed the arresting gears used in military aviation. The second part of this part describes the operation concept that is used in the Polish Air Force, in relation to the two types of gears, namely the post-Soviet ones that are still in service, and the second one: of U.S. production obtained due to the purchase of F-16 aircraft. The authors emphasize that in the case of an appropriate operation system, it is possible to extend the service life of devices and maintain safety of the air operations.*
Keywords: safety, reliability, operations & maintenance, air transport, aircraft arresting gear systems, airport arresting devices

Streszczenie: *W artykule autorzy dokonali przeglądu urządzeń awaryjnego hamowania użytkowanych w lotnictwie wojskowym. W drugiej części został opisany system eksploatacji tych urządzeń, jaki funkcjonuje w lotnictwie Sił Zbrojnych RP, w odniesieniu do dwóch rodzajów tych urządzeń: eksploatowanych jeszcze poradzieckich oraz produkcji amerykańskiej, pozyskanych w związku z zakupem samolotów F-16. Autorzy zaznaczają, że w przypadku właściwego systemu eksploatacji istnieje możliwość wydłużenia okresu użytkowania urządzeń ponad określony przez producenta bez obniżenia poziomu bezpieczeństwa zabezpieczanych operacji lotniczych.*
Słowa kluczowe: bezpieczeństwo, niezawodność, eksploatacja, transport lotniczy, urządzenia awaryjnego hamowania samolotów, lotniskowe urządzenia hamujące

1. Introduction

Aircraft arresting gear systems are designed to ensure that military aircraft are able to stop while taxiing beyond runway boundaries during aborted take-off operations or extended landing run. In these systems, the kinetic energy of the taxiing aircraft is converted into a different type of energy; usually, it is thermal energy. The mechanical connection of aircraft with the device (arresting gear) is established by arresting components (arresting cable or net barrier) and connecting components (cables, tapes). These gears are situated across the runway, between its thresholds or on the Runway End Safety Area – RESA.

The aircraft arresting gear system started to be applied in the Polish Air Force in the 1980s of the XX century. At that time, Soviet-made ATU-2M arresting nets were introduced into the aircraft regiments. They guaranteed an efficient and emergency braking of all types of aircraft operated by aviation units of the Polish Air Force, including but not limited to the most modern at that time, Su-22 fighter-bomber, and MiG-29 fighter aircraft that was implemented in 1989. In 2005-2006, the US-manufactured Barrier Arresting Kit - 12 began to be used. It was installed on selected airfields in connection with purchasing by Poland the F-16 multi-purpose aircraft. Moreover, in 2007, two devices of the same systems were acquired in the mobile version (Barrier Arresting Kit -12/Portarrest-IV). The organisation of the operations & maintenance protection system of the devices in question required from the institutions responsible for this process to establish a system that guarantees absolute efficiency and operational readiness of these devices, taking into account the current socio-political situation and the existing financial possibilities. This required continuous analyses of the availability of technical materials, technical personnel, purchase of necessary services, etc. These analyses showed the need to organize two separate and different systems for ATU-2M, BAK-12 and BAK-12 / P-IV devices.

2. General information on the aircraft arresting gear systems

Modern military aviation uses many design solutions for the aircraft arresting gear systems. They are characterized by the diversity of the applied arresting components, operation principles of the arresting system, mobility or the braking force's control systems.

The basic operational parameters of the aircraft arresting gear systems include [6]:

- aircraft arrestment speed,
- weight of the arrested aircraft,
- length of the landing run during arrestment,
- generated overloads of the airframe during arrestment,
- time necessary to reconstruct the operational readiness of the system after arrestment.

The parameter that combines the speed of the arrested aircraft, its weight and landing run will be the capability to convert the kinetic energy of the arrested aircraft into another type of energy.

Due to the type of the applied arresting components, two groups of gears can be distinguished: arresting net barriers and arresting gear cables (figs. 1 and 2).

Fig. 1. Arresting net barriers

Fig. 2. Arresting gear cables

2.1. Arresting net barriers

In the arresting net barriers, the kinetic energy of the moving military aircraft is transferred to the braking system of the device through a net. At the moment of arrestment, this net envelopes the aircraft's airframe as well as is mechanically connected with arrester gears and the system of collocated cables. The modern net barriers consist of multiple components. Separate net components form the so-called webbing of the net barrier. Such a structure ensures a uniform distribution of the loads on the airframe. The number of net components depends on the size of the aircraft. Smaller aircraft requires fewer components (small holes). Arresting nets are manufactured from plastics, especially nylon provided with coatings protecting from the UV radiation. The modern arresting nets are equipped with testing sections of vertical and horizontal tapes mounted on the net. Results from tests performed on the above-mentioned sections (according to the procedures specified by the net's manufacturer) serve as a basis to estimate its technical condition and approval for further use [8].

The net barriers are typically located in the overrun of the runway and are unidirectional. In the Polish Air Force, until now they were situated on the grass pavement (Polish: CzPB) behind the ground braking surface (Polish: GPH). The modern military aircraft have to be arrested on the hardened pavement; thus, arresting nets are located on the hardened pavement CzPB in the allied aviation. The advantage of the net devices is the possibility to arrest the aircraft, although these devices do not depend on arresting hooks on aircraft. Another advantage can be a relatively long-term service life of net barriers which is from 5 to 10 years. The disadvantages of net arresting devices are as follows:

- the possibility to arrest only jet aircraft
- long period of releasing the aircraft from the net and restoring operational readiness of the aircraft,
- the necessity to repair the net after arresting, usually it is replaced with a new one,
- damage to the aircraft's airframe,
- the need to take into account the aircraft's height as an additional parameter when determining the technical data of the device,
- it is not possible to check the efficiency of the device while testing the aircraft's arresting,
- unidirectionality of activity

The example of the net device was shown in fig. 3.

Fig. 3. Su-22 aircraft after being arrested by the ATU-2M arresting net system [Polska Zbrojna]

2.2. Arresting gear cables

Arresting gear cables belong to bidirectional devices located between runway thresholds. The connection of the arresting cable with the device's braking system is established using the synthetic tapes (usually nylon tapes). However, they require the aircraft to be equipped with an element, which will enable a mechanical connection of arresting cable with the aircraft and the subsequent arrestment of this aircraft. Arresting gear hook is such an element, and it is controlled by the aircraft crew (fig. 4).

Fig. 4. Arresting gear hook in the lowered position

Arresting cables have undoubtedly more advantages than arresting nets. Thanks to this, they are frequently applied. The most common advantages include:

- the possibility of arresting an aircraft with jet and airscrew propulsion,
- arrestment without the participation of the crew or engaging systems,
- short period of releasing the aircraft and restoring the operational readiness - several minutes,
- in the vast majority of arrestment operations, arresting cables and tapes do not have to be replaced,
- lack of defects of the airframe due to the arrestment,
- the need to select (configure) the device only with respect to the speed and weight of the arrested aircraft,
- possibility to perform periodic inspections of various devices following aircraft arrestment,
- relatively simple structure,
- the possibility to distribute arresting cables between runway thresholds.
- potential bidirectional action.

Arresting cables are not devoid of flaws. The main flaws of the arresting cables are as follows:

- possibility of emergency braking of only these aircraft that are equipped with the gear hook,
- relatively short service life of arresting cables and tapes (3 to 4 years),
- necessity of the removal of arresting cables:
    - during the airfield preparation for flights (mainly during snow removal),
    - on runway threshold from the direction of approach.

The retraction units of arresting gear cables significantly enhance the operational properties of cable devices cables (fig. 5). These units belong to subsystems of braking devices [7]. The basic requirements, which they should meet, are as follows:

- uninterrupted elevation of the cable off the surface in any meteorological conditions,
- suspending the cable that spans the entire operational width of the runway, in the position ensuring aircraft arrestment,
- arresting an aircraft when the gear hook hits one of the rubber discs (donuts) supporting the cable,
- safe taxiing of the aircraft performed by the donut supporting the arresting gear cable.

Fig. 5. BAK-12 system with the retractable arresting cable - airfield in Łask in Poland

Their correct operation depends much on the careful execution of construction works during its installation. The requirements of the system's manufacturer have to be strictly observed. In cable devices, a very important subunit are the tape guide components mounted at the runway edge. They include guide rollers, which aim to ensure that the tape is moving correctly, and is suspended above the runway surface. They also transfer the loads during arrestment and limit the zone on the runway where the tape is moving- this zone needs to be free of any obstacles. The rollers make it possible to move the energy absorbers away from the runway. They have a different design and can be found both in stationary and mobile devices. Guide rollers increase the permissible distance of the devices from the runway edge [10]. Another characteristic feature of arresting-cable installations are tapes. They ensure a mechanical connection of arresting cable with the braking system of the device. During arrestment, the tape unwinds from the reel assembly and initiates brakes. Thanks to its flexibility, it also limits the transfer of loads on the aircraft's airframe. The tapes are manufactured from plastic; usually, it is nylon. They are one of the most sensitive components of arresting-cable installations; thus, its operations & maintenance is subjected to detailed supervision. They undergo planned preventive maintenance (PPM), and their target operations & maintenance standard is determined in years and calculation arrestment, defined depending on the aircraft speed and its weight at the moment of arrestment [11]. Not to mention the fact that the arresting cable, which ensures a mechanical connection of

the device with the arrested aircraft, also undergoes planned preventive inspection and operations & maintenance standards are specified in years. Following arrestment, the cable is subjected to visual inspection to assess its condition and approve it to further operation [20].

Due to the distribution of devices between runway thresholds when locating them, several aspects have to be considered. One is to ensure a run with the required length for modern tactical aircraft, which is approx. 300–370 m. Moreover, in the vicinity of the arresting cable, the pavement must be in the proper technical condition [24, 25], and it has to satisfy the requirements mentioned above regarding the evenness parameter. It is caused by the potential threat that the hook would break due to the roughness, and thus, the cable will not be caught [11, 13].

2.3. Braking systems

The main unit of aircraft emergency braking devices includes braking systems, where the aircraft kinetic energy is transferred into another type of energy; usually, it is thermal energy. The modern aircraft emergency braking devices are based on different braking systems, ranging from very simple chain brakes (fig. 6), textile brakes (fig. 7), to mechanical or hydraulic brakes (hydrokinetic retarder mechanisms). The chain brake is spread along both runway edges and comprises anchor chain links. In the initial part, in one row, in the further part – in two rows. These brakes cooperate with the arresting cable and net. There are also two-function (hybrid) or combined net-cable versions. Moreover, chain brakes were designed for the needs of US naval aviation. Its main drawback is the rapid increase of the braking force during arresting in its first stage when the arrested aircraft's kinetic energy is the highest and generates the highest load for an airframe.

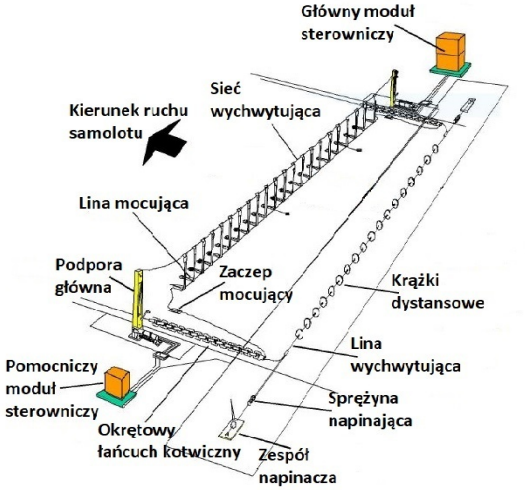

Fig. 6. Diagram of a two-function cable-net arresting system equipped with chain brake [13]

Textile brakes seem to be an interesting solution. However, they are not well known. Contrary to other brakes, they are intended for single use. After arrestment, they must be replaced with the new ones.

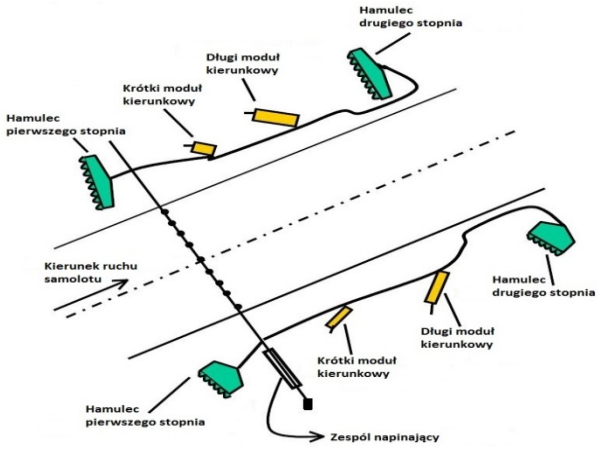

Fig. 7. Diagram of the MB60.9.9.C arresting system with textile brake [13]

This brake is composed of multiple modules arranged in equal numbers on both sides of the overrun that contain specially woven textile tearing strap. This strap is connected to the tensioned cable on one end of each module. On the other end, it is anchored to the ground (figs. 8 and 9). Due to the movement of aircraft and arresting element (cable or net), the brake tape is delaminated, and the energy is absorbed. These brakes are distinguished by the relatively low efficiency of the absorbed energy. Thus, two-stage solutions are applied, e.g. as in MB60.9.9.C (fig. 7) systems used by the USAF. This system mitigated this drawback of low efficiency to some extent. Due to their single usage, systems with textile brakes are installed in runway zones, where arrestment operations are unlikely to occur. Moreover, the main advantage of this system is its maintenance-free, low height (low profile) and the possibility to use it in bidirectional devices.

Fig. 8. Arresting cables with textile brake

Fig. 9. Braking module of the textile brake after aircraft arrestment

The textile brake's most significant disadvantage is the necessity to replace it with a new one after every single arrestment. It generates costs and severe operational restrictions due to the relatively long replacement time, which is approximately 8 hours (removal of worn tapes lasts 4 hours and another 4 hours should be dedicated to installing the new tapes).

The most commonly used brakes in aircraft emergency braking systems are mechanical brakes – friction brakes (fig. 10). In aircraft emergency braking devices, multi-disc brakes are applied. In comparison to the brakes described above, they have a fundamental advantage – it is the possibility to control the value of the braking force generated by brake from the start of arrestment to its finish. They can also be quickly developed by adding new disc and piston units. The modern designs are also very durable (their target service life is approx. 30 years), and they do not require to perform many maintenance treatments.

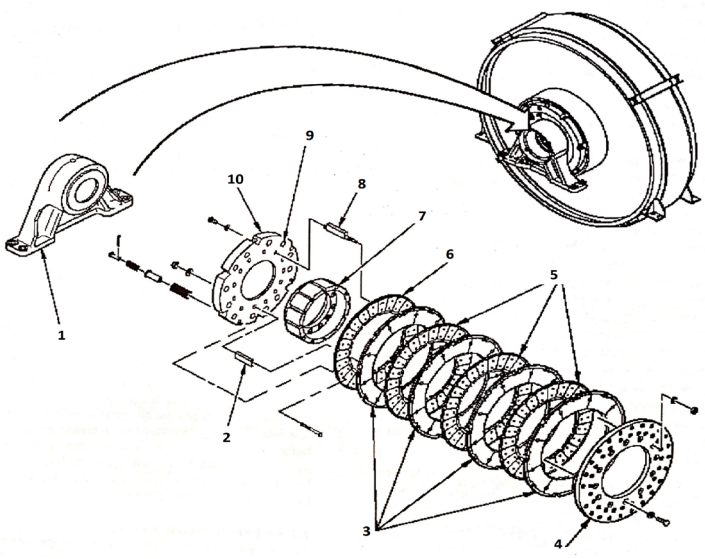

Fig. 10. Multi-disc brake of the BAK-12 arresting system applied in the devices used by the Polish Armed Forces [21]: 1 – brake block; 2 – wedges, 8 pcs.; 3 – brake discs; 4 – thrust disc; 5 – shrink discs; 6 – thrust disc; 7 – mounting sleeve; 8 – water wedges, 4 pcs. 9 – brake pistons, 12 pcs; 10 – brake plate

Another brake solutions applied in the aircraft emergency braking systems are hydraulic-hydrokinetic retarders[1] (fig. 11). They work in the same way as hydrokinetic clutches with this difference that in the brakes, the turbine rotor is permanently connected with the stator, and pump rotor is connected with the rotating shaft. The design of these brakes enables to construct low-profile devices.

[1] In the nomenclature of manufacturers of the aircraft emergency braking devices, the term water brakes or twister brakes is used.

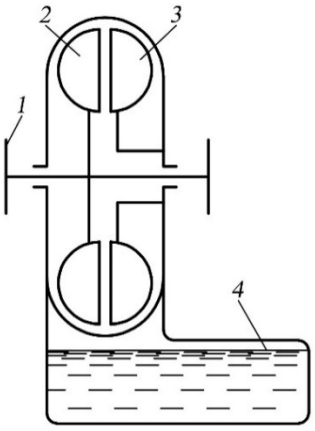

Fig. 11. Diagram of hydrokinetic retarder: 1 – shaft, 2 – rotor, 3 – stator, 4 – oil tank

Runway arrestor gear systems can be divided according to their method of connection with the surface (ground or hardened pavement) into stationary and mobile. Stationary arresting systems are installed on reinforced concrete foundations and fixed to them in a way that enables their further use (fig. 12). The 'house' with a light metal structure mounted on straight rails protect against unfavourable weather conditions. The rails ensure that the house can be moved away. In this way, access to the devices is provided when the house has to be removed from its place of foundation. Stationary devices can be removed from foundations during overhaul, and they can also be moved to the small underground cellars.

Fig. 12. Stationary devices of the BAK-12 arresting kit: view of the arresting cable, energy absorber and external 'house'

2.4. Mobile devices

In the mobile devices, brakes with the necessary equipment, i.e. anchoring elements, arresting cable, tape and any tools indispensable for anchoring are mounted on specially

developed trailers (fig. 13). The trailer is a base of the device during its operation and is used for its anchoring.

Fig. 13. Mobile devices of the BAK-12 arresting system in the transport position and anchored into the natural pavement (in the ground)

To be able to say that a given device is a mobile device, it must be structurally adapted to transport, at least by road and on its own wheels, as well as have autonomy during deployment and operation of equipment necessary for its deployment for the operational position and autonomy in the number of direct staff.

Mobile devices are mainly applied to secure air operations in the following circumstances and conditions [9]:

- runway destroyed as a result of the opponent's deliberate actions,
- no arresting gear devices on the airfield,
- during a malfunction of stationary devices or their repairs,
- performing air operations on airstrips or highway strips,
- securing air shows.

3. Aircraft arresting gear systems in the Polish Armed Forces

Currently, the Polish Armed Forces are equipped with the following three types of aircraft arresting gear systems:

1) stationary:
    a) ATU-2M arresting nets manufactured by the USSR,
    b) BAK-12 arresting cable system manufactured by the USA,
2) mobile BAK-12 arresting systems.

3.1. Stationary ATU-2M net arresting devices

ATU-2M devices (fig. 14) were introduced into the Polish Air Force in the 1980s of the last century. Their technical parameters enabled to efficiently slow down the aircraft with the permissible take-off weight up to 20 000 kg and the maximum speed of entry into the arresting net of 180 km/h, take-off mass of 6 000 – 12 000 kg or with the maximum speed of arrestment of 220 km/h and the overrun (for both operational modes) of 250 m. The detailed parameters of a device were shown in the tab. 1. ATU-2M devices work on the principle of the electrohydraulic mechanical operation of arresting elements. The signal is transmitted from the automatic system or the manual control panels [14].

The devices were founded on CzPB behind the ground braking surface. Originally, the arresting element was one-element US-3M net [14]. Since the 1990s, the SL-24 nets started to be implemented. They were manufactured by a Swedish company Scama s.c., and their service life is 10 years.

Fig. 14. ATU-2M aircraft emergency arresting system with SL-24 net ready for an arrestment – airfield in Mirosławiec in Poland

The social and political changes at the breakthrough of the 1980s and 1990s of the last century resulted in a gradual limitation of operations & maintenance support from ATU-2M net manufacturers. As mentioned above, the situation deteriorated over time, until the technical and commercial cooperation was terminated. In the years 2008-2010, it became impossible to obtain any original technical means in materials (tapes) Taking into account that the target service life of devices was coming to an end and bearing in mind the constant problems with obtaining tapes, the aerodromes were equipped with BAK-12 retractable cable arresting system in connection with the implementation of F-16 multi-purpose fighter. Furthermore, due to the lack of the possibility to obtain new devices for financial limitations, the number of ATU-2M arresting nets was reduced from two to one, which secured the major direction of take-offs and landings (Polish: GKSiL). The removed devices were allocated to an economic fund (source of specialist tapes), which secured the operations & maintenance of the remaining operated devices.

The economic changes at the turn of 1980s and 1990s also affected the Polish Armed Forces and mainly related to their logistics system, where the system of purchasing services (outsourcing) started to dominate at the expense of performing them in specialist overhaul companies of the Polish Armed Forces, which were largely excluded from the structure of the Armed Forces and gained economic independence. Such a situation resulted in the necessity to conclude a contract with the entity according to the Public Procurement Law to remove a specific malfunction. It prolonged the repair time (due to the procedure of selecting a contractor) even up to a month, which the device's user did not accept. Taking into consideration the existing economic conditions and wanting to shorten the time of improving the device to the necessary minimum resulting only from organisational (failure notification, access) and technical reasons, the Central Logistics Authority[2] (Polish: COL) decided to periodically purchase the provision of services in the following fields: current repairs and inspections after arrestment.

In May 2011, following the contractor selection procedure, the 3rd Regional Logistics Base in Cracow (3 RBLog) concluded a contract with military aviation works (WZL) no. 3 in Dęblin. This agreement was valid up to 31 December 2011 r. It was a pilot one, and one of its tasks was to provide experiences for COL from the functioning of such an organised system. Since the opinions of users and the COL itself were positive, it was decided to sign long-term contracts.

Financial conditions in the 1990s of the last century and the first decade of the XXI century forced the device's operator, apart from securing the existing operations & maintenance described above, to ensure the prolongation of the service life of ATM-2M arresting nets. To this end, cooperation with military aviation works (WZL) no. 3 in Dęblin was established. With the use of operational bulletins, planned preventive maintenance (PPM) was replaced with condition-based maintenance (CBM), and then the service life was extended up to 28 years. The next operational bulletin allowed for a single prolongation (following inspection of technical condition) of service life up to maximum 5 years, so up to 33 years [2–5]. Currently, ATU-2M arresting nets are gradually withdrawn. There are still 3 pcs.[3] The basic operational-technical data of ATU-2M arresting net system were illustrated in tab. 1.

In 2021, it is also planned to select a specialist entity to secure operations & maintenance of the remaining ATU-2M arresting net systems. The contracting authority will be the 3rd Regional Logistics Base in Cracow (3 RBLog) as it was in the previous years.

Operations & maintenance of ATU-2M arresting net systems in the Polish Armed Forces will terminate in 2023. The last arresting net system to be withdrawn will be the system operated now in the 21 Air Force Base in Świdwin in Poland.

[2] Infrastructure Authority of the Inspectorate for Armed Forces Support

[3] State as of 31 December 2020

Table 1

The main operational and technical data of ATU-2M arresting net systems

No.	Parameter	Unit of measurement	Value
1.	Maximum mass of arrested aircraft	kg	20 000
2.	Maximum speed of arrested aircraft: - when the aircraft weight is 6 000 – 12 000 kg - when the aircraft weight is 12 000 – 20 000 kg	km/h.	220 180
3.	Minimum aircraft speed ensuring device activation	km/h.	60
4.	Maximum length of braking distance (overrun)	m	250
5.	Time of suspending the supports (nets)	s	$3^{+0,5}$
6.	Controlling the device	Control panel near the device Dispatcher panel on the airport traffic control tower System of automatic suspension of supports	
7.	Motor for net winding mechanism	hydraulic	
8.	Motor for raising and lowering the supports	hydraulic	
9.	Permissible air humidity	%	98
10.	Maximum operation altitude above sea level	m	3 000
11.	Range of operation temperatures	°C	-50 to +60
12.	Peak point in the middle of the SL-24 net	m	$4,0^{+/-0,10}$

3.2. Stationary and mobile BAK-12 cable arresting systems

10 cable devices were introduced into the Polish Air Force in the years 2004–2006 in order to secure air operations of the newly purchased F-16 aircraft. The systems were delivered under the NSIP program. They were installed on both take-off and landing directions of five selected airports: at the 12 Mirosławiec UAV Base (12 BBSP), 21 Świdwin Tactical Air Base (21 BLT), 22 Malbork Tactical Air Base (22 BLT), 31 Tactical Air Base Poznań – Krzesiny (31 BLT) and 32 Tactical Air Base Łask (32 BLT).

The specification of the devices purchased for the Air Force meets the requirements for the US Air Force (USAF) basic cable arresting system, i.e. the BAK-12 arresting system. ESCO devices were equipped with two control systems: electric servomechanism (main system) and mechanical system (reserve). The main parameters of the technical specification of the BAK-12 cable arresting system are presented in tab. 2.

Table 2

The main operational data of technical specification of the BAK-12 aircraft emergency cable arresting systems

No.	Parameter	Unit of measurement	Value
1.	Take-off weight of an aircraft	pound (kg)	50 000 (22 680)
2.	Energy absorbing capacity	foot x pound	$85x10^6$
3.	Nominal overrun	foot (m)	1 200 (366)
4.	Durability of the connecting tape	pound (kg)	105 000 (47 627)
5.	Durability of the arresting cable	pound (kg)	130 000 (58 967)
6.	Maximum arresting speed	knot (km/h.)	180 (333)
* data for the device with connecting tape reel with the diameter of 66 cals (167,64 cm).			

In order to ensure their appropriate operations and maintenance, the devices were backed by a 5-year guarantee. In the scope of the guarantee period, the maintenance and repairs of devices were done by a Polish company that makes installations of devices on airfields. The company's specialists have been trained by the manufacturer and obtained the required authorizations. When the guarantee protection terminated, the same economic entity (lack of other entities on the market with the necessary authorizations) still provided operations & maintenance for these devices.

While using this system, its basic disadvantage was revealed: very long periods of device improvement up to several months. The above state was due to the availability of specialist tapes, which were imported from the USA. The entity that was in charge of the maintenance of devices refused to produce a warehouse with the necessary tapes, which could be available immediately in the event of a breakdown, and not ordered from a manufacturer after reporting a failure, who also had to order them form its subcontractors. This situation was particularly painful during the warranty period, when all tapes had to be obtained from the manufacturer of the devices. The Moog Inc. Servo system turned out to be particularly failing. This system ensures the optimization of the braking force as a function of the aircraft weight and speed at the time of arrestment, and also corrects the taxiing direction in case of non-axial arrestment. Its failure did not result in the device shutdown - the device operated in a mechanical system, but it reduced the protection of the aircraft and its crew during the arrestment. The mechanical system does not introduce the taxiing direction of the aircraft after its arrestment, so it is possible to taxi the aircraft outside the hardened surface, which results in its loss.

The lack of any activities from the entity in charge of the operation and maintenance aiming to improve failure removal system resulted that in 2014 the Central Logistics Authority (COL) of the Inspectorate for Armed Forces Support (IWsp SZ) decided to create an overhaul facility in the unit subordinate to the Head of the Inspectorate for Armed Forces Support. This overhaul facility would be able to provide the operations & maintenance of stationary and mobile BAK-12 arresting systems. The repair facility with such capabilities was created in the Aviation Technology Workshops (WTL) in Toruń in Poland, where previously the Airport Infrastructure Repair Workshop was located. The scope of training was established with the device's manufacturer (through the representative in Poland). Three theoretical-practical training courses were conducted at the manufacturer's facility in the years 2012-2016.

The trained specialists from WTL obtained final qualifications to:

1) conduct periodic inspections;
2) diagnose malfunctions and conduct ad hoc repairs;
3) make major repairs including the planned repairs arising out of the device technical documentation;
4) direct (full-time) training of the staff responsible for devices and logistics personnel of military units.

In the Aviation Technology Workshop (WTL), the workshop was built, which was equipped with specialist tools and equipment indispensable to perform repair works (fig. 15) as well as workshop truck providing repair services at the user's site (fig. 16).

Fig. 15. Workshop hall of aircraft arresting gear systems in WTL in Toruń (Poland)

Aviation Technology Workshop in Toruń also contained tape and equipment warehouse. Spare parts (except for arresting cables and connecting tapes), which were previously situated in the Large-Scale Multi-Sector Materials Warehouse in Kutno, were moved to this warehouse.

Fig. 16. Workshop truck of BAK-12 aircraft emergency arresting systems

At the same time, in the scope of the ongoing process of creating the system protecting the operations & maintenance of the above-mentioned devices in the Polish Armed Forces fully accepted by the device manufacturer, its representative in Poland developed the principles for verifying the technical condition following the main repair [22]. This document also specifies the principles of extending the mean time between failures. Due to the limited execution possibilities of the Aviation Technology Workshop (WTL) in Toruń (no possibility to perform planned repairs according to the terminating mean time between failures) it was necessary to prolong it. The BAK-12 aircraft emergency arresting systems currently operated by the Polish Armed Forces served half of their target operation life.

4. Conclusions

Aircraft emergency arresting systems belong to one of the elements of flight safety system and ground flight safety devices. Their special feature is a constant operation and functioning in the crisis situation. Due to this, they require a special approach to the issue of taking care after their technical condition, which directly contributes to their technical condition and operational readiness. This paper starts the cycle of publications which aim to determine solutions, which could improve the current operations & maintenance of the aircraft emergency arresting systems, produce measurable financial results while maintaining the efficiency of devices at the same level.

The authors made a review of the aircraft emergency arresting systems currently used in the Polish Armed Forces, focusing on the applied design concepts of the devices themselves by delineating their pros and cons. Moreover, they described the currently used design solutions of their brakes, which are responsible for the efficient arresting of the military aircraft.

The second part is dedicated to describing devices operated by the Polish Armed Forces and the currently implemented protection systems of their operations & maintenance. There are two separate systems: for ATU-2M arresting nets based on the external economic entity and for BAK-12 arresting system, which uses the overhaul potential of the Inspectorate for Armed Forces Support (IWsp SZ) and the role of the external economic entity is reduced to the minimum – providing tape supplies.

Both systems turned out to be effective in specific external conditions. In the case of ATU-2M devices, an external, domestic economic entity was able to ensure the appropriate level of contracted activities, due to the intellectual potential in this area. The second factor was availability, which was quite limited, but sufficient for specialist tapes. These two elements made it possible to use an outsourcing solution in the case of ATU-2M tapes, but the expected effect was achieved only after periodic contracts.

The outsourcing system did not work completely for BAK-12 system devices. The reasons for this should be seen in the attitude of the company's management, who was not willing to set up an appropriate warehouse of spare parts and explained that it is due to freezing serious amounts. Therefore, it can be concluded that there is no universal solution that can be applied even to the same group of devices. The operations & maintenance system implemented in the Armed Forces should take into account the availability of tapes, the level of professionalism of economic entities available on the market, the level of support from the producer, and other factors occurring in a specific situation.

Moreover, considering the experience gained from the operations & maintenance of the devices, the authors claim that they have large operational reserves. A striking example can be the ATU-2M devices used for almost twice as long as predicted by the manufacturer thanks to the proper and careful operation. In the opinion of the authors, based on the current technical condition of BAK-12 arresting systems, there is a high probability that they will be operated for a much longer period. They claim that it is possible to prolong the service life of arresting ropes of these devices, which is 3 years [21] and then they are replaced. In the following articles, the authors will present their proposals on these two issues, i.e. the possibility of extending the life of the arresting ropes and the devices themselves.

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