TECHNIKA TRANSPORTU SZYNOWEGO

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THE METHOD FOR HIGH-ENERGY THROWING OF THE OBJECTS IN IMPACT TESTING

Abstract

A 250 mm pneumatic gun for the realization of bird tests that is the topic of this article was designed and built at the Institute for Sustainable Technologies – National Research Institute in Radom, Poland. The cannon built, used as a projectile thrower, allows for the reconstruction of the collision conditions at the speed that can be reached by a majority of contemporary civil and military aircrafts. The solution developed uses the energy of the compressed air stored in the container. The pneumatic installation was adjusted to the maximum working pressure of 40 bars. The acquisition of high velocities is dependent on the speed of energy release for the compressed air stored. Due to long opening and closing times for typical valves with 250 mm bore, that amount to several dozen seconds, a special quick release mechanism was constructed for the pneumatic cannon in question.

INTRODUCTION

Bird tests conducted on a wide scale in the aviation require the application of specialist propellant devices capable of throwing projectiles at the speed similar to the speed the aircrafts reach at the take off, during the flight and at the time of landing [4,5,7]. Real-time tests constitute a method that allows for the most reliable results to be obtained [6]. In practice this is synonymous with a wide scope of results achieved in the range of supersonic speed (military jetfighters), transonic speed (transport aircrafts) and subsonic speed reached at the time of take off and landing [1,3]. In such tests structural elements are bombarded with a number of objects that can even reach the size of largest birds the aircrafts can collide with, hence the very name of the tests – “bird tests.” Apart from the size of the objects, their mass corresponding to the weight of different kinds of birds, is an additional complication. In order for the requirements concerning the scope of energy parameters to be met, pneumatic propellant systems need to be applied.

A 250 mm pneumatic gun for the realization of bird tests that is the topic of this article was designed and built at the Institute for Sustainable Technologies – National Research Institute in Radom, Poland [10]. The cannon built, enables projectiles of different size that are stored in a special sabot to be thrown with the use of the compressed air. The large caliber and high energy projectile thrower allows the objects weighing up to several kilograms to be thrown at the transonic and supersonic speed, which truly reflects the moment the aircraft collides with a bird or any other object. The cannon that plays the role of a pneumatic projectile thrower enables the conditions of such a collision to be reconstructed even at top speed reached by both civil and military aircrafts.

1. STRUCTURE OF THE SYSTEM

The solution developed makes use of the energy of the compressed air stored in the special air container that is connected with the release mechanism, which in turn, by means of a charging port, is connected with the barrel of the gun, at the end of which an muzzle device catching and destroying the sabot is located (Fig. 1).

Fig. 1. 250 mm pneumatic gun

Source: Author's collection

In the solution presented above, a high pressure system cooperating with a compressor of 35 bar working pressure was used. Pressure accumulators are charged either by a compressed air or a nitrogen bottle that are connected with the charging port consisting one of the elements of the pneumatic structure

The pneumatic installation (Fig. 2) of the cannon is an important part of the structure of the entire propellant system. The executive and control elements of the installation were integrated directly at the gun mount in a way that enables their manual and automatic control.

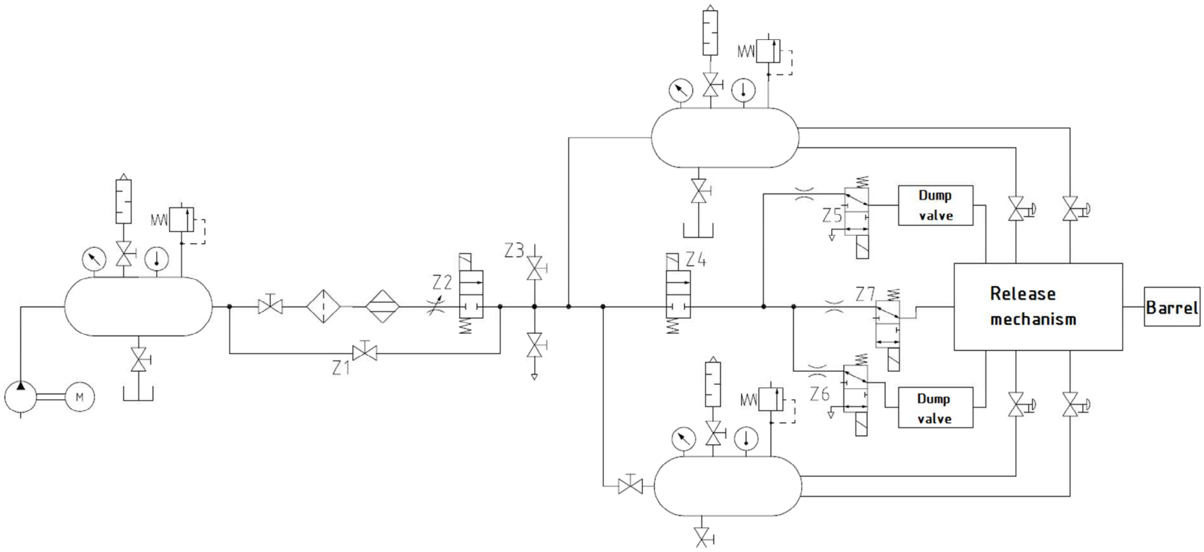

Fig. 2. Diagram of the pneumatic system

Source: Author's elaboration

The pneumatic installation was adjusted to the maximum working pressure of 40 bars. It was assumed, that the time needed for the accumulators to be charged up to the level of 35 bars should not exceed 140 min. Such requirements were met by the ALMIG HL 103523 piston compressor that ensures that 2000 l containers are charged to the assumed pressure level in 120 min. The air flows directly from the compressor to the 300 l buffer container, and then to the drying systems in which the ALMIG DTF90HP dryer with the dew point of 3°C is mounted. In order for the optimum conditions of the drying process to be maintained, the intermittent cycle flow connected with the throttling of the airflow drying the cooling device was used. The intermittent cycle was forced by the electromagnetic shutoff valve (Z2) connected with the throttle valve. The flow of the air from the buffer container is initiated by the dryer when the agent in the buffer reaches the pressure in the range of 25-35 bars.

The Z1 valve allows the opening of the bypass as a result of which the airflow takes place with no interference from the drying system. The Z3 valve opens/ closes the flow of the agent from the additional charging port intended for the installation of the bottle with the alternative working agent. The Z4 valve allows the air to flow to Z5 and Z6 initiation valves. These are the electrically powered pneumatic axial valves 3/2 of NC type whose role is to control the work of the dump valves. The Z7 valve allows the aeration and pneumatic locking of the release mechanism. In order to reduced the number of dynamic influences on the structure of the dump valves and the release mechanism that usually take place at the time of the aeration of the system, flow throttles were installed. As there is no voltage in the coils of Z5, Z6 and Z7 valves, the working chamber, the dump valves, and the release mechanism needs to be supplied. The air that is fed into this mechanism comes from the two accumulators with the capacity of 1 m3 each via four DN150 pipelines. The airflow from the accumulators to the release mechanism is controlled by ball valves that are released by electric actuators or manually.

2. RELEASE MECHANISM

The achievement of great velocities of the projectile depends on the pace the energy of the compressed air is released with. For that purpose, the application of a release mechanism in a pneumatic cannon is crucial, as it enables the quickest flow connection of the barrel with the compressed working agent. Release mechanisms release the air stored in the container in a way that ensures the projectile to be pushed out dynamically from the barrel. The basic condition that determines the usefulness of the solution as a release mechanism is the shortest opening time and the lowest suppression of the flow of the working agent. Release mechanisms of pneumatic propellant devices can have the form of valves typically applied in compressed air installations [8]. In this case solutions in form of standard valves allowing the flow of the working agent with no obstacles are applied. These are mainly constituted by the full flow ball valves for industrial installations and pipelines. Their limitations concern long opening times, particularly in the case of large section valves. This inconvenience is even greater in the case of high pressure installations. High pressure valves, due to the type of sealing used in them, highly restrict the flow, which requires great external forces to be applied onto the executive elements of the valve. Ball valves can have their own electric or pneumatic drive, however in the case of big valves, whose diameter, for instance, exceeds 150 mm, the opening time, depending on the drive used, varies between several seconds (pneumatic drive) and minutes (electric drive).

There also are such solutions of release mechanisms that are dedicated particularly for propellant systems in which the rule of the intermediate chamber is applied [2, 4]. The intermediate chambers are located between the walls of the set of fragile membranes placed between the barrel and the air accumulator. The pressure in the chambers is regulated by reduction valves – one per chamber. Reduction valves gradually lower the pressure in each of the chambers in relation to the pressure in the accumulator. The pressures are set in such a way that the membranes, thanks to the two sided application of hydrostatic forces, remain in the state of static balance. The membranes can be destroyed pyrotechnically or mechanically with the use of a movable pin.

The application of membranes in release mechanisms is an expensive, time and labour consuming solution that requires the barrel or the slide to be dismantled whenever a new set of membranes is to be installed and the projectile to be loaded into the barrel.

Due to the long opening and closing times of typical valves with a 250 mm bore, which can reach up to several dozen seconds, a special release mechanism for this particular type of the cannon was constructed. The release mechanism developed enables the cannon to be loaded with the sabot into the "pouch" located in the axis of the barrel. The release mechanism is controlled in a way that facilitates remote system control once the sabot has been placed in the pouch.

3. DUMP VALVE

The release mechanism applies the rule of a movable cylinder lock controlled pneumatically. Depending on its position, the lock either opens or covers the passage between the barrel and the source of the working agent. In order to enable the airflow to the barrel, the shift of the lock into a proper position is required. This process is realized by a dynamic deaeration of the lock chamber by dump valves additionally supported by electromagnetic valves. The solution applied allows remote initiation of the release mechanism by means of switching the supply for the coils of initiation valves on.

The release mechanism is thus a type of a cascade solution in which the setting of the initiating electromagnetic valve triggers the dump valve deaerating the lock chamber.

The dump valve developed (fig. 3) is composed of a cylinder body with the outer chamber with which the connection port for the valve of the lock chamber that has a form of the flange is connected.

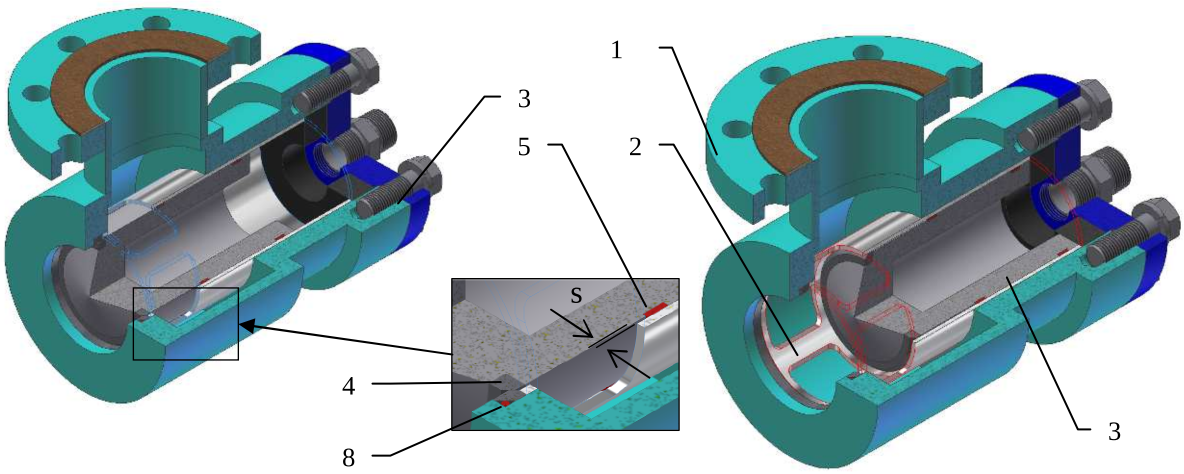

Fig. 3. Dump valve model: a) closed, b) open; 1 – body, 2 – sleeve, 3 – slide, 4 – closing rings, 5 – guide ring, 6 – shock absorbing ring, 7 – lid, 8 – sealing ring

Source: Author's elaboration

In the cylindrical part of the body a sleeve with evenly placed openings is located. One of its ends is responsible for inactivating the conical socket of the valve, whereas the other one by means of a flexible shock absorbing ring is supported by a lid that is adjusted to the body of the valve. Inside the sleeve, a two-stage cylindrical slide made of light alloy and equipped with guide rings can be found. In the conical part of the slide, found at the end of smaller dimension, a closing ring is located. Its external shape corresponds with the geometry of the socket of the valve. The closing of the valve consists in the supply of the air whose pressure equals the pressure found inside the lock chamber. The compressed air makes the slide move inside the body, which shuts off the area between the lock chamber and the outflow of the chamber. The tightness of the valve is ensured by elastomeric rings placed between the body and the ring as well as the body and the lid. The compressed air in the lock chamber, via the openings in the sleeve and through the cracks in the rings, flows out to the area between the slide and the elastic stop ring. The size of the cracks in the slide rings is selected in a way that the sum of their cross-section area is significantly lower than the diameter of the connection port in the lid. As a result of the differences in the diameters of the slide in its conical part and the part with guide rings, the slide is pressed to the ring in the body which then closes the valve. The opening of the valve consists in the removal of the atmosphere from the area between the slide and the stop ring. This is realized by the opening of the external valve 3/2 connected to the port in the lid. The resulting pressure and diameter differences of 2s make the valve move towards the shock-absorbing ring. As a result, a gap between the closing rings is created and the air flows through it out of the outer chamber, which accelerates the movement of the slide at a simultaneous outflow of the air to the atmosphere through the outlet collector that deaerates the lock chamber.

The developed structure of the dump valve, similarly to the structure of the release mechanism, applies the rule of the moveable cylindrical slide with the closing frontal area. The prototype of the valve (fig. 4) was connected to the release mechanism and subject to maintenance tests.

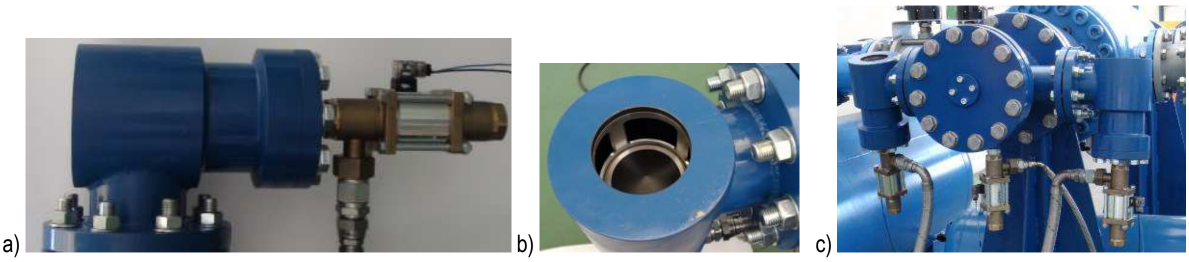

Fig. 4. Dump valve: a) dump valve initiated by valve 3/2, b) outlet collector, c) valves installed in the release mechanism

Source: Author's collection

With the use of a high speed camera, the image of the moving slide was recorded. The data recorded allowed for the characteristics of the stroke (Fig. 5), the speed (Fig. 6) and the acceleration (Fig. 7) of the slide to be determined, which was conducted with the use of commercial TEMA Motion software by Image Systems.

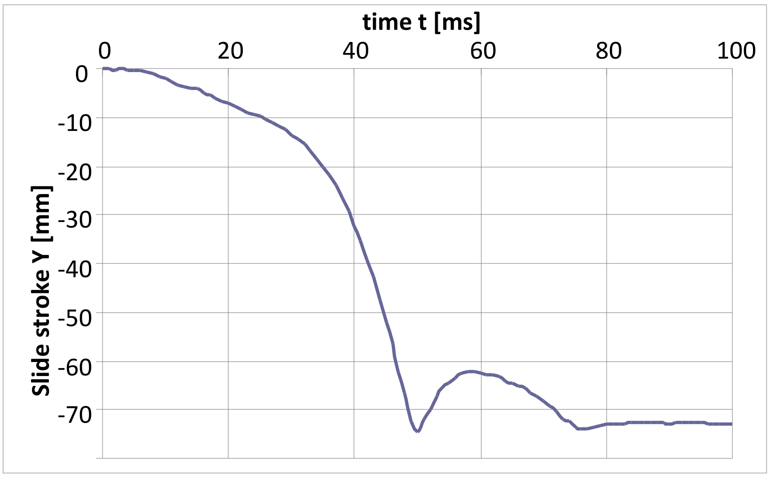

Fig. 5. Characteristics of the slide stroke

Source: Author's elaboration

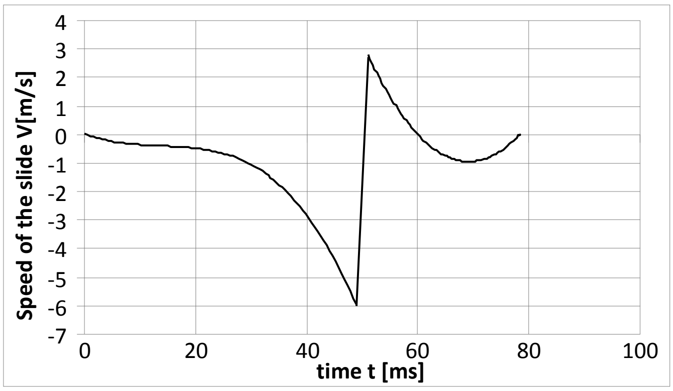

Fig. 6. Slide speed characteristics

Source: Author's elaboration

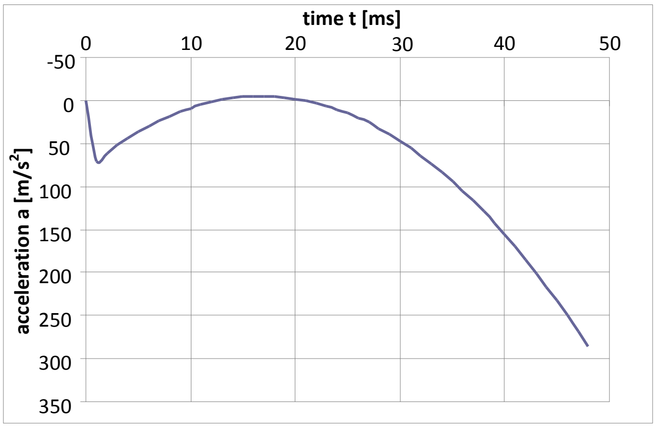

Fig. 7. Slide acceleration characteristics

Source: Author's elaboration

The characteristics obtained indicate a uniformly accelerated character of the motion of the slide. The pressure difference on both sides of the slide and additional influence of constantly growing stream of released air result in constant increase in the speed of the slide up to the moment it stops at the elastomeric fender. As a result of the impact, a slight retraction of the slide can be noticed, which is then eliminated by the pressure of the compressed air that still flows out of the body of the release mechanism of the cannon. The values of the speed reached by the slide correspond with the values for the impact cylinder pistons [11].

The advantage of the solution presented consists in the ability to obtain maximum flow coefficient at a relatively short time allowing for cyclic evacuation of a high pressure and great volume air container in technological processes or in state of emergencies.

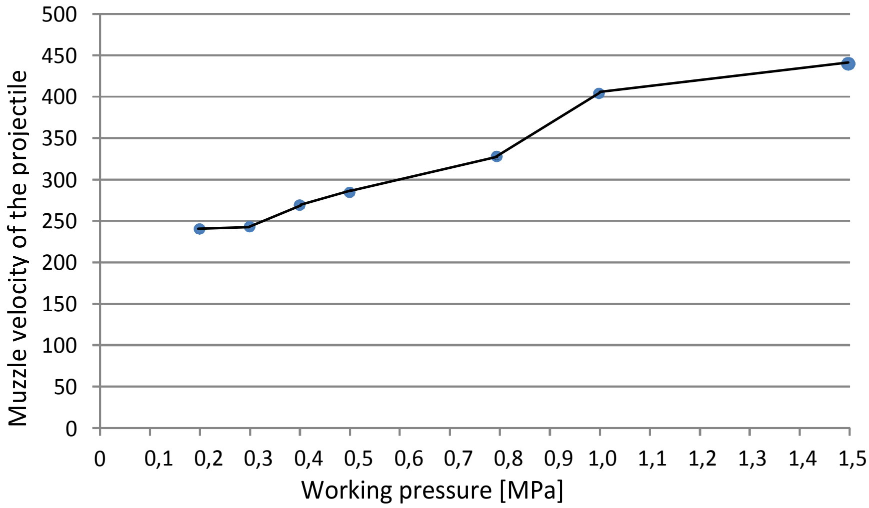

Fig. 8. Muzzle velocity of the projectile weight 2.5 kg in feed pressure function.

Source: Author's elaboration

The solutions applied in the gun allow, for the thrown objects, to achieve supersonic velocities. The possibilities of high energy shooting with the system allow proper throwing of the objects with weight and dimensions of even the heaviest birds. The achieved parameters allow classification of the solutions into the narrow group of world leading solutions in the considered area.

CONCLUSIONS

The developed pneumatic system applied in the cannon supplied with compressed air enabled the construction of a propellant system intended for the realization of bird tests for aviation. The key element of the aforementioned pneumatic system is the release mechanism allowing the energy of the compressed air stored in pressure accumulators to be quickly released. The dynamics of the release mechanism enable objects of several kilograms to be thrown at supersonic speed. The efficiency of the release mechanism depends on the pace at which the lock chamber is deaerated. A special dump valve developed intended for the deaeration of the lock chamber is characterized by a very short time of full overdrive amounting to 0.05 s. The structure of the valve additionally allows for the application of the product in industry, where there is a need for a fast, dump deaeration of pressure containers with a gaseous working medium.

METODA WYSOKOENERGETYCZNEGO MIOTANIA OBIEKTÓW W TESTACH ZDERZENIOWYCH

Streszczenie

Pneumatyczne działo kalibru 250mm służące do realizacji testów zderzeniowych tzw. testów ptaka (z ang. bird test) będące tematem artykułu zostało zaprojektowane i wykonane w Instytucie Technologii Eksploatacji - PIB w Radomiu. Armata spełniająca funkcję pneumatycznego miotacza ładunków umożliwia odtwarzanie warunków kolizji przy maksymalnych prędkościach lotu rozwijanych przez większość samolotów cywilnych i wojskowych. Zaprezentowane rozwiązanie wykorzystuje energię sprężonego powietrza zmagazynowaną w zbiornikach. Instalacja pneumatyczna działa została przystosowana do maksymalnego ciśnienia roboczego 40 bar. Uzyskiwanie dużych prędkości wylotowych pocisku jest uzależnione od szybkości wyzwalania energii sprężonego powietrza zmagazynowanego w akumulatorach ciśnienia. Ze względu na długie czasy otwierania i zamykania typowych zaworów o przelocie 250 mm, sięgające kilkudziesięciu sekund, skonstruowano specjalny, szybki mechanizm spustowy dedykowany dla działa pneumatycznego.

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