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UNIVERSAL BOMB ADAPTOR FOR F-16 AIRCRAFT

Mirosław Adamski[1], Andrzej Żyluk[2]

[1]Polish Air Force Academy, Aviation Faculty
Dywizjonu 303/35 Street, 08-521 Deblin, Poland
tel.: +48 815517423, fax: +48 815517417
e-mail: tetrazen@wp.pl

[2]Air Force Institute of Technology
Ks. Bolesława Street, 6, 01-494 Warszawa, Poland
tel.+48 261 85 13 02, fax: +48 261 85 13 13
andrzej.zyluk@itwl.pl

Abstract

The aim of this study is to present a concept of a bomb adaptor, able to carry and release Russian-made bombs by NATO aircraft, the F-16 fighter jet in particular. The adaptor has been constructed as a response to dealing with a problem of utilizing post-Soviet aerial bombs and thus reducing the costs connected with this undertaking. Owing to such an adaptor, aerial bombs can be suspended to the weapon stations of the F-16 aircraft and used during training or in combat missions. In particular, weapon stations of the F-16 aircraft, construction of a bomb adaptor, cross-section of a bomb adaptor, bomb adaptor suspended on a bomb station of the F-16 aircraft, manner of fixing the samples in the machine for strength testing, safety assessment of the construction, Static tensile test, static strength test, simulated strength testing made by SolidWorks software are presented the article. There were solved problem of stability of an aerial bomb, placed in the adaptor, the applied calculation methods allowed selecting proper construction materials for the project, it does not require high costs of building it. The strength testing confirms full usefulness of the adaptor and ensures safe exploitation both on the ground and in the air. This type of testing was skipped due to lack of technical capabilities to conduct it.

Keywords: *aircraft, bombs, bomb airdrop, bomb adaptor*

1. Introduction

There is ongoing modernization of armed forces, including the Polish Air Force, during which new equipment is introduced and the one in service is upgraded. When the Su-22 and the MiG-29 service life ends, there will appear a problem of using or utilising various Russian-made munitions, including e.g. a large number of unnecessary explosive weapons, stored in Polish bomb depots. All munitions, which are in commission but cannot be exploited, generate excessive stocks and therefore should be properly utilised or defused, according to the Ministry of Defence documents, which regulate management of combat assets.

Therefore, the inspiration to design a bomb adaptor for the F-16 aircraft was an attempt to solve the problem of utilization of post-Soviet aerial bombs, to limit or fully eliminate the costs connected with this task. Aerial bombs fitted with a bomb adaptor can be suspended to weapon stations of the F-16 aircraft and later used in training tasks or combat missions.

Consequently, the adaptor will be able to reduce the costs on three levels: Storing and utilizing bombs of varying weight and size and application; Training pilots in combat missions; Purchasing new ballistic bombs for the F-16 aircraft.

The adaptor is fitted to carry ballistic bombs of different application, weight and size, which are activated by a bomb fuse with a fan [6].

2. Weapon stations of the F-16 aircraft

The F-16 bombs are carried on ejector racks, with single, double and triple hook assemblies. On each hook assembly, it is possible to suspend ordnance of 9-16 inches in diameter (approx.

0.23-0.4 m), 91 inches in length (approx. 2.3 m) and up to 1,000 pounds in weight (approx. 445 kg) [5].

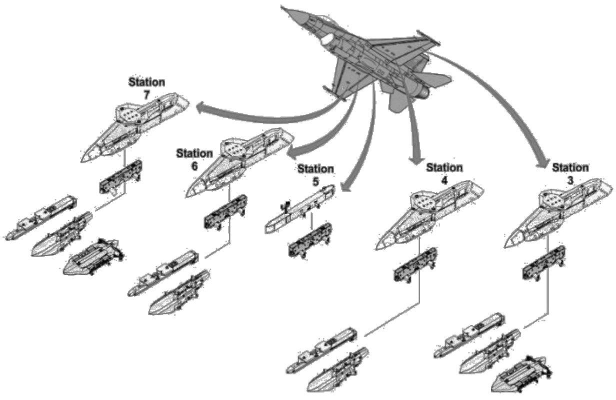


Fig.1.Weapon stations of the F-16 aircraft, used for carrying bombs [5]

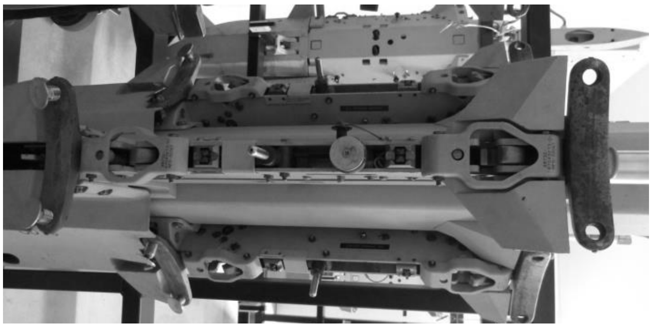


Fig.2. Triple Ejector Rack TER-9/A with MAU-12 hook assembly (own photo)

3. Construction of a bomb adaptor

The main element of the construction is a bomb adaptor. Its main application is to adjust various carriage racks (bomb hook assemblies) of the F-16 aircraft, which are designed to suspend bombs with the store's lugs - 14 inches in span (approximately 355 mm), and to carry bombs of the store's lugs, whose span equals 250 mm [1].

The whole construction comprises:

- a mounting frame;
- a pole supporting store's lugs (which serves as a hook assembly);
- upgraded bolt retainers.

The shape of the bomb adaptor resembles a rectangle. In order to increase endurance of the store's lugs, the decision was taken not to fix it with forward welding. Instead, there is one single element closing the adaptor's bar. In the bottom part of the adaptor, there are three holes, 23 mm in width. The holes are intended to fix the store's lugs, which are stabilized on the pole. The outside holes serve as fitting for bombs with a medium and large weight and size, whereas the middle hole is for bombs with a small weight and size. The adaptor was made from a closed profile, 70x70 mm.

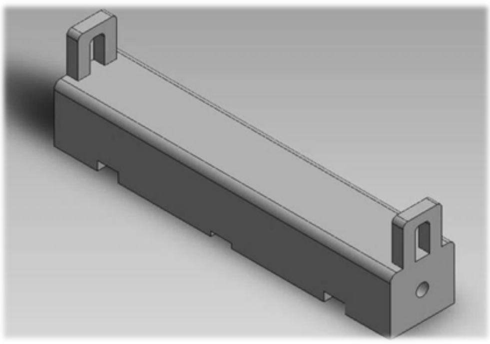


Fig.3. Bomb adaptor (own design)

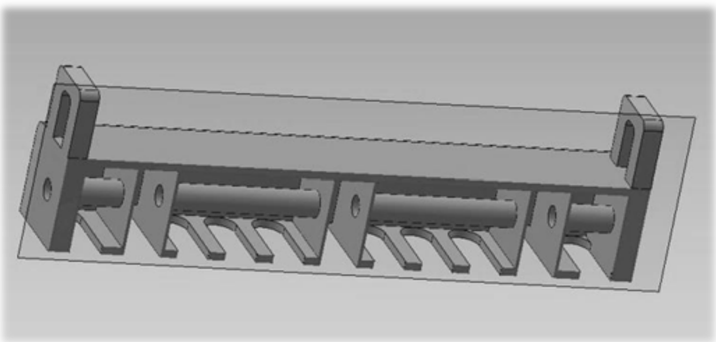


Fig.4. Cross-section of a bomb adaptor in XY plane (own design)

Basic measurements of the bomb adaptor: The span of the lugs equals 14 inches (0.35 m); The length of the adaptor equals 365 mm; The width of the adaptor equals 70 mm; The height, excluding the bomb lugs, equals 50 mm.

In order to lower the mass of the construction, the adaptor was built as a thin-walled 5 mm object. In the bottom part of the adaptor, there are milled holes, which enable to decrease the adaptor's weight (4.3 kg). Cutting the holes does not worsen the endurance of the adaptor (it is possible to further lower the mass by open working the sidewalls).

Inside the adaptor runs a pipe, 11 mm in diameter, whose aim is to improve stability of the pole, strengthen the construction and help insert the pole, which supports the store's lugs.

Parallel to the bomb lug openings, there are 5 mm thick welded plates. They are to stabilize the bomb lugs through minimizing their rocking movement and strengthening the construction.

The pole functions as a hook assembly in the adaptor, running through the whole length of the adaptor. The pole is secured from sliding out with a welded chuck. On the other side, there is a hole for fixing the pin, which protects the pole from uncontrollable sliding out.

The pole measures 385 mm in length, whereas its diameter equals 10 mm. In order to stabilize the suspended bomb, there are bolt retainers with the thread of 57 mm in diameter. The bolt retainers are made with St3 alloy steel.

Fig.5. Upgraded bomb retainers (own photo)

Fig.6. Bomb adaptor suspended on a bomb station of the F-16 aircraft (own photo)

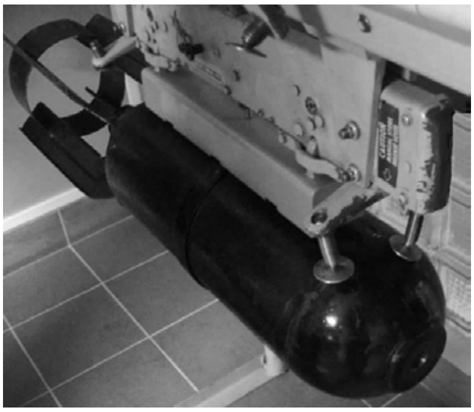


Fig.7. Bomb adaptor with a suspended bomb (own photo)

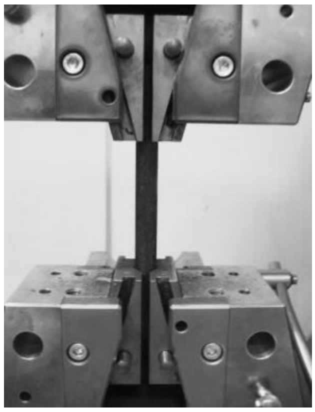


Fig.8. Manner of fixing the samples in the machine for strength testing (own photo)

4. Safety assessment of the construction

One of major elements of the adaptor, particularly vulnerable to overloading is suspension lugs. In order to check the strength of the construction, we conducted strength tests of this element.

In the case under research, the most significant characteristics of stresses are yield strength $Rp_{0.2}$ and ultimate tensile strength Rm. The yield strength $Rp_{0.2}$ is the maximum stress, which causes permanent elongation of the specimen, which equals 0.2% of the initial gauge length.

$$Rp_{0.2} = \frac{F_{0.2}}{S_0} \text{ [MPa]}. \qquad (1)$$

Because of yield strength $Rp_{0.2}$, it is possible to calculate the force $F_{0.2}$. When it is extended, there is irrecoverable change in a geometrical configuration, excluding further use of the material. The strength yield is usually calculated for materials, which do not have clear yield point [2].

Ultimate tensile strength Rm is equal to the maximum value of the force Fm, which causes full fracture of the material, in the researched case it specifies the moment of shearing the rod.

$$Rm = \frac{F_m}{S_0} \text{ [MPa]}. \quad (2)$$

4.1 Static tensile test

The aim of the research is to determine experimentally the following mechanical values: yield point, tensile strength, rupture stress, relative elongation, uniform relative elongation, and necking.

The static tensile test is the basic type of testing metals, which find technological applications, making it possible to determine plastic, and strength properties of a metal. The test involves stretching samples of clearly specified shapes in special machine grips, which allow continuously raise the force from zero level to the value where the specimen breaks.

4.1.1 Test description

The test was conducted on the ZWICK ROELL Z100 machine. In order to assess whether the bomb adaptor complies with the strength requirements, the specimens made with St3 steel underwent stretching.

The table below presents findings of the values obtained after checking the characteristic values as well as $F_{0.2}$ force, calculated based on the average value of yield strength Rp_{02}.

After transforming the formula: $Rp_{0.2} = \frac{F_{0.2}}{S_0}$ it is possible to calculate the value of the force $F_{0.2}$:

$$F_{0.2} = Rp_{0.2} \cdot S_0. \quad (3)$$

The force $F_{0.2}$ deforms the material and excludes its future safe exploitation. However, the force Fm causes total damage of the material.

Tab. 1. Findings of strength tests (own research)

Sample no	**$Rp_{0.2}$ MPa**	**$Rp_{0.2}$/Rm%**	**Rm MPa**	**Fm kN**	**$F_{0.2}$ kN**
1	308	73.68	418	60.21	42.36
2	292	70.87	412	59.36	
3	281	69.21	406	58.51	
4	294	71.35	412	59.36	

Fig.9. Samples after testing (own research)

If we multiply the bomb mass by the value of gravitational acceleration, we obtain the weight of the bomb, measured in Newtons.

$$F = m \cdot g, \quad (4)$$

$$F = 500\text{kg} \cdot 9.81\frac{m}{s^2};\ F = 4.9 \text{ kN}.$$

One should remember that this force is distributed on two suspension lugs. Therefore, the final value of the force, which while at rest, is exerted by the bomb of weight and size equalling 500 kg is $\frac{1}{2}$ F that is 2.45 kN.

According to the safety requirements, the maximum exploitation load Pe should be lower than the maximum acceptable one Pacc, equal to a breaking load Pn, divided by a safety factor n. We took the value of a safety factor as n=1.5 for further deliberations.

$$Pe \le Pacc = \frac{P_n}{n}. \tag{5}$$

For the sake of calculations, we accepted the yield strength $Rp_{0.2}$, since as it was already mentioned, this is the point, which when exceeded, excludes further proper exploitation of the device.

This condition may be as follows:

$$Fe \le F_{acc} = \frac{F_{0.2}}{n}, \tag{6}$$

$$Facc = \frac{F_{0.2}}{n}, \tag{7}$$

$$Facc = \frac{42.33kN}{1.5},$$

$$Facc = 28.22 \text{ kN}.$$

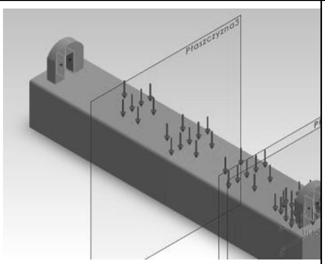
If we divide the value of maximum acceptable force by the value of the force, which is exerted by the bomb, weighing 500 kg, on the adaptor, we obtain the value of maximum acceptable overload a_{max}, which can be achieved by an aircraft, being certain that the lugs of the bomb adaptor will not be destroyed.

$$a_{max} = \frac{Fdop}{\frac{1}{2}F}, \tag{8}$$

$$a_{max} = \frac{28.22N}{2.45kN},$$

$$a_{max} = 11.5.$$

In order to check the strength calculations, we additionally used "SolidWorks" software, where the model of the adaptor was subjected to the load, which equalled 5000 N [8].

Fitting	Data imaging	Fitting details
Fixed-1		Elements: 4 walls Type: Static geometry
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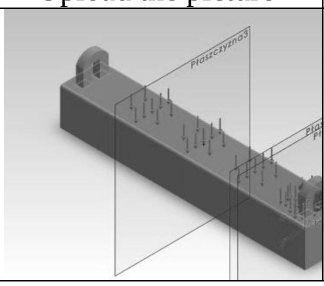
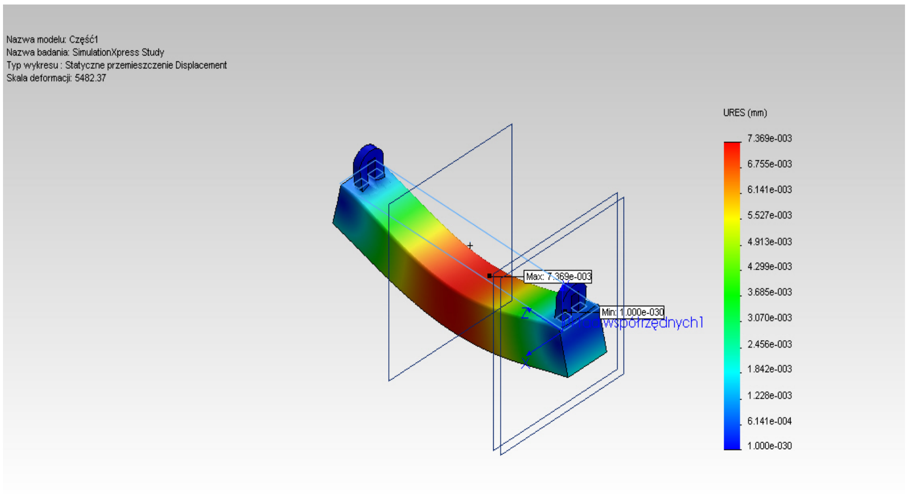
Force-1		Elements: 1 wall Type: Apply normal force Value: 5000 N

In aircraft, a typical solution is to mount bombs on hook assemblies, which are placed on frames. In the designed adaptor, the role of the assembly hook is taken by a pole. This is quite a novel solution, therefore the component is considered to exert a vital role for the whole construction, which in turn resulted in conducting appropriate strength tests.

Tab. 2 Protocol of simulated strength testing made by SolidWorks software

Name	Type	Min	Max
Displacement	URES: Resultant displacement	0 mm Knot: 896	0.00736909 mm Knot: 9862
			

4.2. Static strength test

The aim of the test is to conduct an attempt of shearing the rod. This attempt makes it possible to observe the behaviour of the specimens under increasing load, to determine the biggest tension, which can be applied to a given specimen in order to exceed the yield point and cause its fracture.

In the case at stake, the aim was not to compare various materials but to make an attempt at creating the most realistic reflection of stresses, which are present in the rod. Therefore, we constructed a new testing machine to fix the sample [4]. The new device is a "compromise" between the real conditions and the conditions which take place during the testing, according to the norm PN-86/H-0432.

4.2.1 Description of test

The tested specimens were made of brass, aluminium and various types of steel. All the specimens were d_0=10 mm in diameter, which denotes that the cross-sectional area of the sheared surface equalled S_0=78.54 mm^2.

The following graph depicts the dependence of the maximum bomb mass, possible to carry by poles made of materials which underwent strength testing, firstly for bombs suspended only on one lug and secondly on two suspension lugs [6].

Fig.10. Phases of shearing steel (own photo)

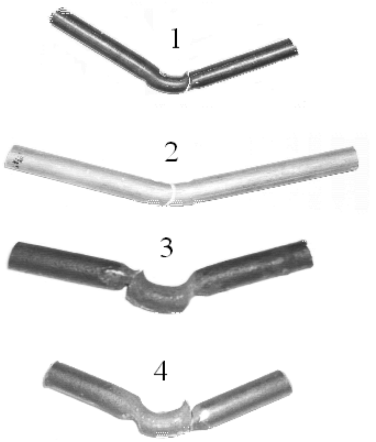
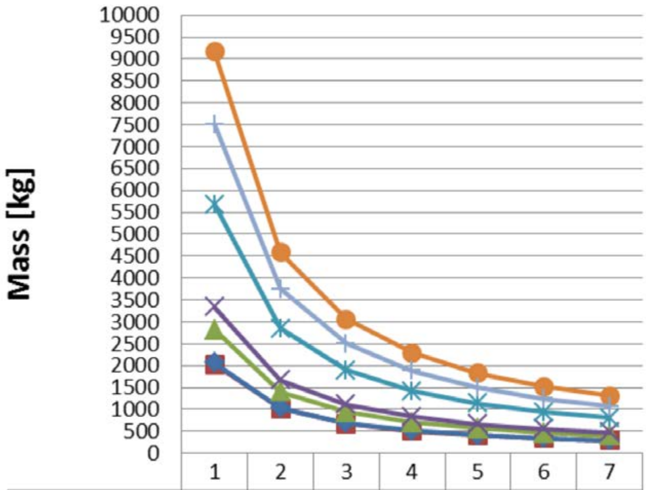


Fig. 11. Specimens after research (1-brass, 2-aluminium 3-steel, 4-hardened steel) (own photo)



	1	2	3	4	5	6	7
Aluminum	2030	1015	677	507	406	338	290
Copper	2068	1034	689	517	414	345	295
Brass	2819	1409	940	705	564	470	403
St3 Steel	3330	1665	1110	833	666	555	476
45 Steel	5681	2840	1894	1420	1136	947	812
H18N9 Steel	9158	4579	3053	2290	1832	1526	1308
40HM Steel	7507	3753	2502	1877	1501	1251	1072

Fig. 12. Influence of the bomb mass on the load factor for bombs suspended on one suspension lug (own research)

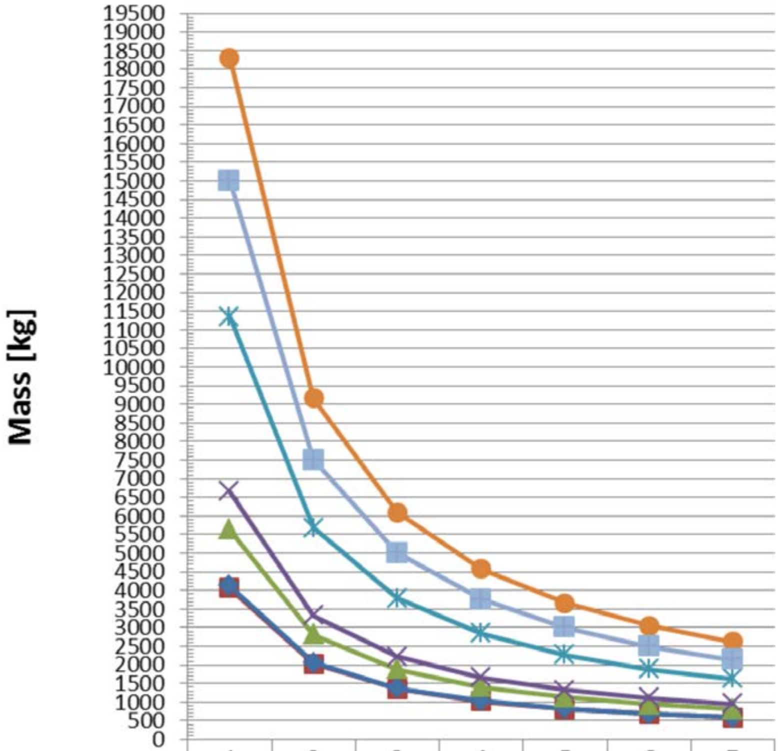
In order to build the pole in the adaptor, we used 40HM steel, which is quality, chrome-molybdenum, alloyed steel. It is used for element components, which require very high strength, malleability, and parts, which are exposed to variable loadings [2].

In conclusion to the test findings, the designer bomb adaptor will prove its usefulness, since the adopted construction solution is capable of carrying a bomb with the mass equalling 500 kg and load factor of=11, with no risk of damaging the suspension lug. The pole itself is capable of carrying the bomb whose mass equals 2.144 kg during its flight path, with the load factor which does not exceed n=7.

5. Conclusions

The suggested bomb adaptor, designed for the multi-role F-16 aircraft is an attempt to take advantage of exploiting post-Soviet bombs. Constructing the adaptor allowed to formulate a number of conclusions:

- firstly, we proved that there are construction possibilities to use post-Soviet bombs of various weight and size, and various span between the suspension lugs.
- we solved the problem of stability of an aerial bomb, placed in the adaptor. A great deal of research as regards strength of materials and the applied calculation methods allowed selecting proper construction materials for the project.
- the adaptor has uncomplicated construction and it does not require high costs of building it (this solution was essential due to the fact that the bomb adaptor will be separated from the aircraft, during launching, together with the bomb.)
- The conducted strength testing confirms full usefulness of the adaptor and ensures safe exploitation both on the ground and in the air. For the sake of full view of the behaviour of the adaptor during a flight, it is advisable to conduct testing in an aerodynamic tunnel [7]. This type of testing was skipped due to lack of technical capabilities to conduct it.



	1	2	3	4	5	6	7
Aluminum	4059	2030	1353	1015	812	677	580
Copper	4137	2068	1379	1034	827	689	591
Brass	5637	2819	1879	1409	1127	940	805
St3 Steel	6661	3330	2220	1665	1332	1110	952
45 Steel	11362	5681	3787	2840	2272	1894	1623
H18N9 Steel	18316	9158	6105	4579	3663	3053	2617
40HM Steel	15013	7507	5004	3753	3003	2502	2145

Fig.13. Dependence of the bomb mass on the load factor for bombs suspended on two suspension lugs (own research)

The main problem of the implementation of the project is the viewpoint of the American side, which may not agree to this type of modifications.

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