EXPLOSIVE FORMING – ECONOMICAL TECHNOLOGY FOR AEROSPACE STRUCTURES

Anniversary Session ***"Celebrating 100 year of the first jet aircraft invented by Henri Coanda"****, organized by INCAS, COMOTI and Henri Coanda Association, 14 December 2010, Bucharest, Romania*

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DOI: 10.13111/2066-8201.2010.2.4.15

Abstract: *The explosive forming represents a technological alternative for obtaining small-lot parts, with inexpensive and efficient manufacturing preparation. The explosive forming processing methods present a series of important advantages, being recommended for the wide-scale application in the aerospace industry. The economic benefit varies from case to case, independent from the part type, manufacturing series and user.*

Key Words: explosive forming, economical technology, wide-scale application, aerospace structures.

1. INTRODUCTION

The explosive forming processing methods present a series of important advantages, being recommended for the wide-scale application in the aerospace industry.

By using the high explosive forming, items can be obtained, with different shapes and almost unlimited overall size, made of heavy-duty materials.

Economically, there is the possibility of costs decreasing of the forming operation, below $1/10^{th}$ of those necessary for classic forming technologies, especially in what concerns the prototype and small-scale production.

The economic benefit varies from case to case, independent from the part type, manufacturing series and user.

In our country, although the experience in the field is relevant, its practical application does not meet the possibilities.

This paper supports the idea of learning the explosive forming technology and, therefore, its application, by presenting the applications resulted from own research works or from the existing literature.

2. CURRENT STATUS IN THE FIELD

The main impulse in the field of metals explosive forming appeared in the middle 1950s, together with the demands for metal forming operations in the huge aerospace industry. In 1960s there were at least 80 programs financed by the US Government, simultaneously developing.

The need to form large segments for the domes with a diameter of 10.5 m, to be used on the Saturn V secondary motor (fig. 1), led to a series production of large segments, made of 2014 aluminum alloy, explosively formed, manufactured at the premises of North American Aviation. At Aerojet Corporation domes having a diameter of 1.37 m were formed, domes that were made of AMS 6434 high-grade steel, of 3.175 mm thick.

Fig. 1 Saturn V rocket fuel tank bottom Segment [11]

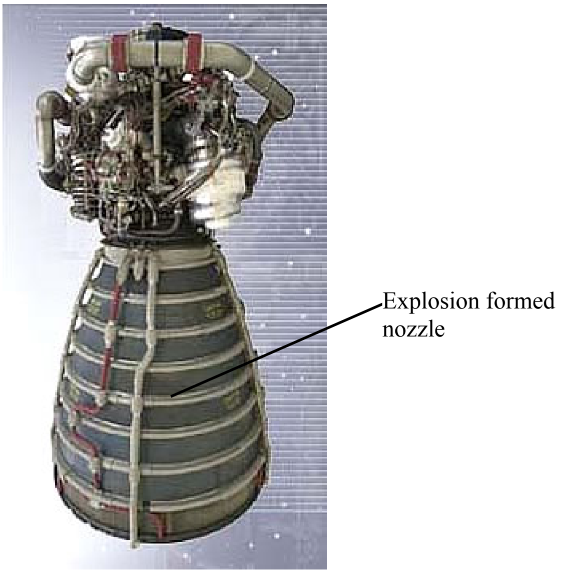

Fig. 2 The main engine of the space shuttle

PA&E Company manufactures the main engine nozzle of the space shuttle, made of stainless steel. Its dimensions are: the length of 2.9 m and the diameter in the discharge area of 2.4 m. In Fig.2 the space shuttle engine is illustrated and Fig.3 represents the nozzle, before and after the explosive forming [12].

Fig. 3 The nozzle of the space shuttle main engine (before and after explosion)

Within the aerospace industry there were also developed the bottom parts of large-sized containers (fig.4) [13] and domes with punched holes, also obtained by explosion (fig.5).[13].

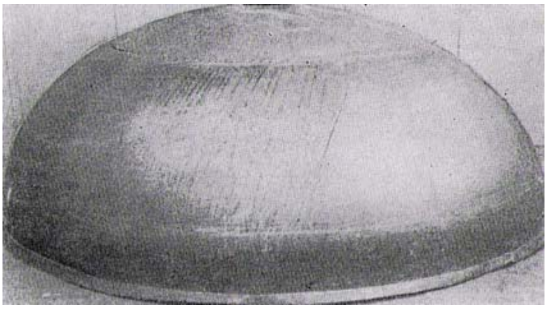

Fig. 4 Container bottom part

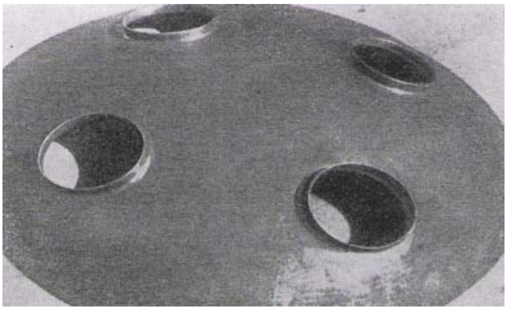

Fig. 5 Dome with explosion obtained punched holes

The asymmetric shapes are explosively formed of metal sheets and plates. The shockwave behaves as a punch, forcing the metal sheet or plate to form in the desired shape of the die. Next there are presented two works of the Dutch company TNO-Wentzel: a panel for Saturn V rocket, made of 2024-O aluminum alloy, with the dimensions 2.7 x 1.5 m [9] (fig. 6) and a corrugated panel for a jet aircraft, manufactured by explosive forming of AA 2024-T3, its dimensions being of 1.8 x 0.8 m (fig. 7).

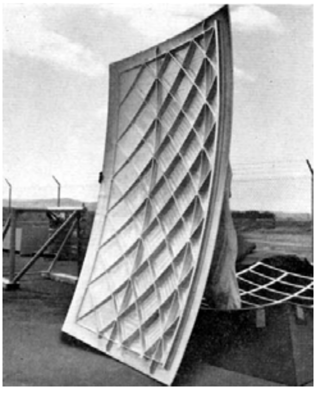

Figure 6 Saturn V rocket panel

Figure 7 Jet aircraft corrugated panel

The aerospace industry needs to find and use efficient materials at the lowest possible processing cost. TNO Company from Holland manufactured titanium alloy parts for helicopters and aircrafts, by using the explosive forming under normal environmental conditions with material attenuation. Fig.8 and 9 illustrate a helicopter nozzle and a door panel for a fighter, both made of titanium alloy.

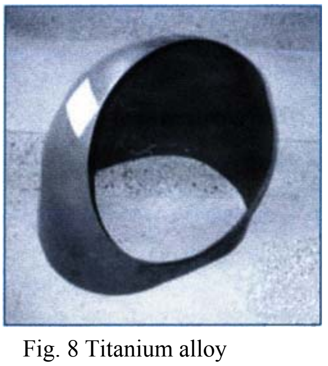

Fig. 8 Titanium alloy helicopter nozzle [9]

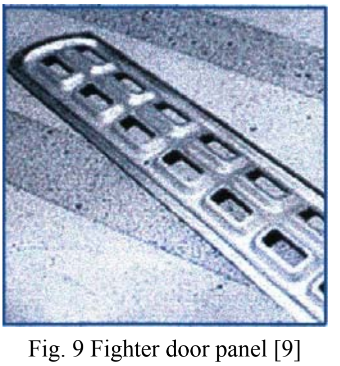

Fig. 9 Fighter door panel [9]

During the last years of the 20th century, DARPA (Defense Advanced Research Projects Agency), in the structure of USA Ministry of Defense, developed 19 research programs/technologies, the explosive forming being the first on this list, along with rare earth magnets, ceramic turbine engines, high-performance IR optics, high-performance ceramic bearings, high-temperature superconductors, etc.

3. ORIGINAL WORKS IN ROMANIA

In Romania, the metal explosive forming was the object of some research works and studies, developed at the Military Technical Academy, in collaboration with different beneficiaries. The use of explosives for increasing some processing methods performance was approached: metal sheet deep drawing and cold forming, tube expanding, calibration, surface hardening, punching and plating. Explosion forming methods have been factory used at: *C.M. Reşiţa*- for manufacturing some parts for "*Porţile de Fier II*" *Hydroelectric Power Plant*, at *Romaero*- *Bucureşti*- for manufacturing some annular shape parts, at the *Integrated Steel and Iron works of Galati* (*Combinatul Siderurgic Galaţi*) - for manufacturing some bimetals for co-rolling. Factory platings were also developed at the *Chemical Aggregate works of Fagaras* (*Combinatul Chimic Făgăraş*) and the *Integrated steel and Iron works of Galati* (*Combinatul Siderurgic Galaţi).*

Ribbed Plate

Figure 10 presents a ribbed plate and the metal die used, and Figure 11 illustrates the explosive device that utilizes water contained in a plastic bag as working environment.

Fig. 10 Ribbed die and plate [6]

Fig.11 Explosive device for the ribbed plate manufacturing [6]

“Basket-handle” bottom part

”Basket-handle”-shaped parts (fig.12) were manufactured of three materials presently used for deep-drawn parts [1].

The manufactured parts are characterized by:

- materials: OL 37, 10TiNiCr180 and Al99, 5;
- plate thickness $s_0 = 4$ mm;
- part diameter d = 305 mm;
- deep drawing depth $f_a = 110$ mm;

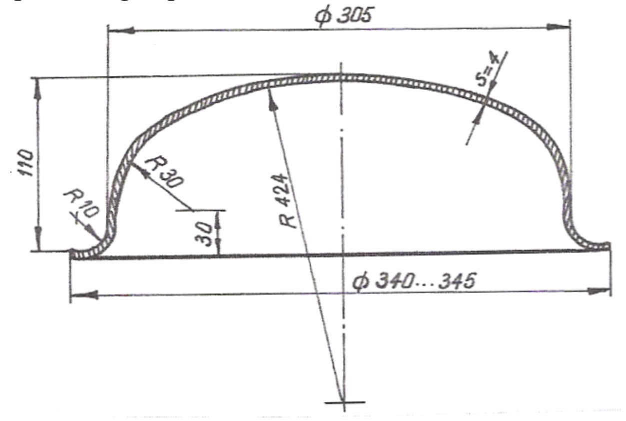

Fig. 12 The shape and dimensions of the deep-drawn part

For the deep drawing operation a closed die, a punching ring (fig. 13) for the air discharge out of the chamber were used, and the die was fitted with 25 holes Φ8 mm [6].

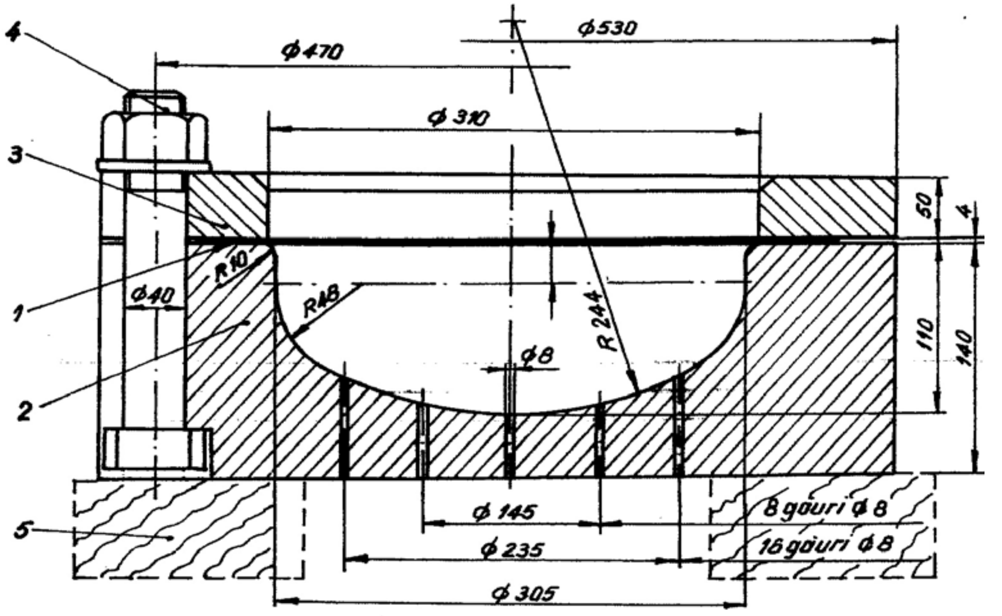

Fig. 13 Experimental device for explosion deep drawing
1 – half-finished product; 2 – die; 3 – punching ring;
4 – pinch bolts; 5 – base plate

Fig. 14 presents deep-drawn parts for the three material features (from the left) OL 37 (the first three); 10TiNiCr180 and Al99, 5 (the last from the right) [6]. The forming was developed by a single explosion or by two successive explosions, with or without intermediate heat treatments.

The discharge of the air under the half-finished product during the explosion was made through some holes fitted in the die body and connected to a down tank. This construction of the die also allows the air suction if explosions in water tanks are used.

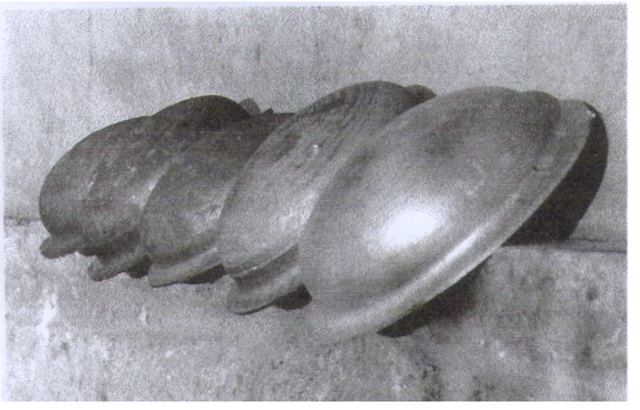

Fig. 14 Explosion deep-drawn parts

Spherical Cap

Fig. 15 presents a part resulted from an aluminum alloy plate deep drawing, and Fig. 16 [6] illustrates the metal die used in the process.

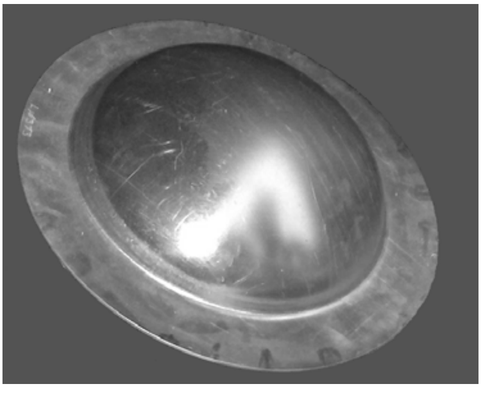

Fig. 15 Explosion manufactured spherical cap

Fig. 16 Die fitted for the spherical cap

The main characteristics of the deep-drawn parts:

- Material quality: L164T4 and L82T_0;
- Dome diameter: d = 230 mm;
- Metal sheel thickness: s = 0.9; 1.2 and 2 mm;
- Deep drawing depth: f_a = 45 mm.

Corrugated Tapered Joint

A part obtained from a tapered half-finished product, made of welded sheet metal, as well as the explosion device, are presented in Figure 17 [6].

The die, longitudinally divided, profiled, is formed of:

- the body made of Al 6061, dimensions 360 x360 x450 mm;
- the clamping plate, made of OL 37;

Fig. 17 Corrugated joint: half-finished product, manufactured part, explosion device.

Torus Part

For manufacturing the torus part in Figure 18, the half-finished product was sized in the same way as for the classic deep drawing, for the case of drawing without attenuation of the part walls [5].

For the deep drawing a cord of HITEX plastic explosive was used, NH8 type, having: the linear weight q=0,61kg/m; TNT equivalent coefficient 1.3 and the velocity of detonation V_D=7400…7600 m/s, delivered by *U.P.S. Dragomireşti*.

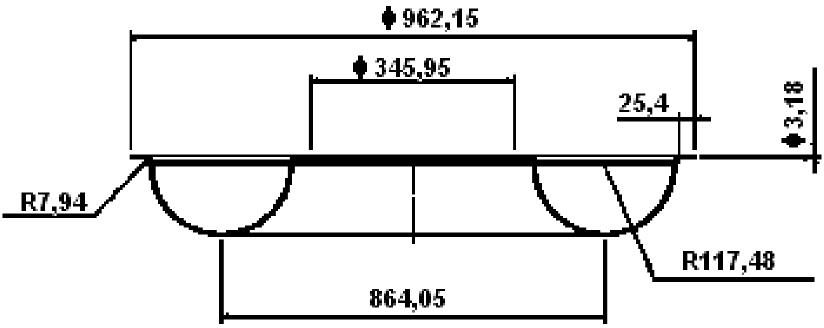

Fig. 18 The half torus shape and dimensions

The material was stainless steel, 347 type, ASTM A240.

Fig. 19 Annular part after the deep drawing and calibration

Filling table tray

The part"Tray for rotary filling table" in fig. 20, used in the alimentary industry, had the following main characteristics [7]:

- material 10TiNiCr180;
- outer diameter of the finished part $d = 1525$ mm;
- sheet metal thickness $s_0 = 1.5$ mm;
- maximum depth of the profile $f = 75$ mm;

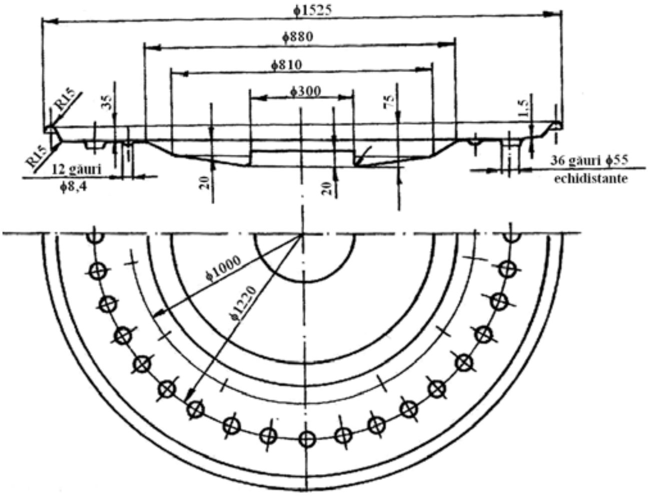

Fig. 20 The finished part shape: tray for rotary filling table

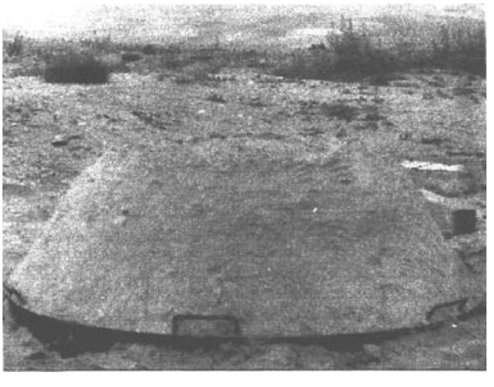

Fig. 21 Working device view:
a – ready for the deep drawing before the explosion; b – the explosion

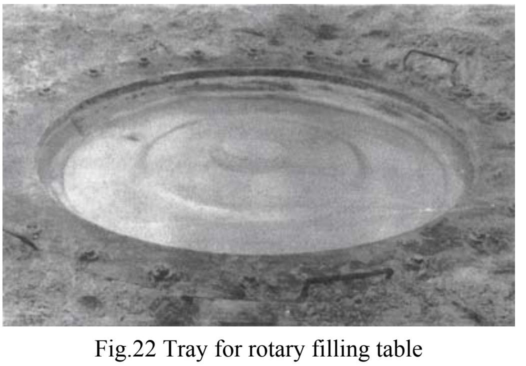

Fig.22 Tray for rotary filling table

4. INSTALLATIONS FOR WORKING WITH EXPLOSIVES

Fig. 23 presents a service installation for a large tank, for which specific equipment for the dies and half-finished products automated operation are required [13].

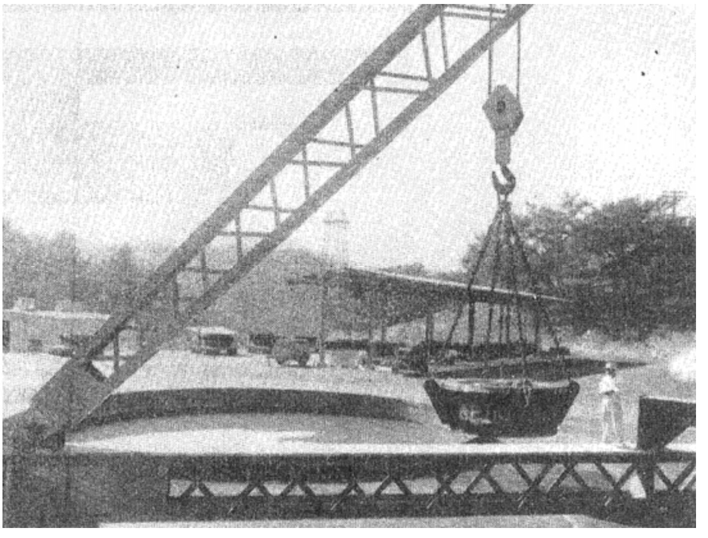

Fig. 23 Servicing a tank for underwater explosion forming

The extra-large parts are made of previously welded half-finished products, to obtain a shape similar to that of the finished part, an example being the rocket engine nozzles, obtained by this process technology (Fig. 24) [13].

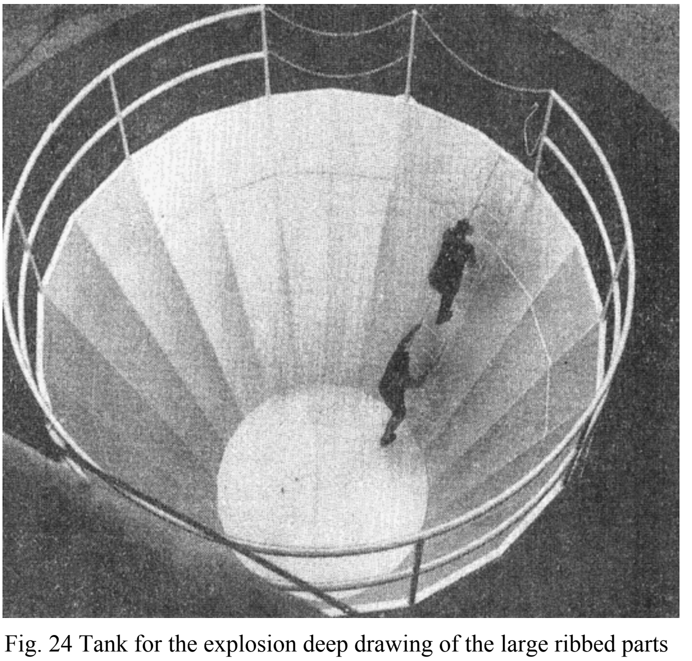

Fig. 24 Tank for the explosion deep drawing of the large ribbed parts

Fig. 25 presents the armored chamber built by TNO Company (Holland), having the possibility of interior air suction, or within which tanks for the underwater plastic explosion forming may be enclosed. Another company, this time from the Eastern Europe, developed, in collaboration with the Ukrainian experts, several armored chambers, similar to that in Figure 26. This company is OZM Research from the Czech Republic.

Fig. 25 Vacuum armored chamber TNO – Holland [9]

Fig. 26 Close systems for explosive forming [8]

5. CONCLUSIONS

1. The explosive forming represents a technological alternative for obtaining small-lot parts, with inexpensive and efficient manufacturing preparation.
2. The technology has a wide application and distribution range, being successfully used in well-established countries in the field of aerospace research.
3. The difficulties in what concerns the providing the work area location and security conditions are compensated by the quality and the high rate manufacturing of the large-scale parts, and especially by the low costs.
4. We can classify the parts manufactured by explosion forming, into the following categories:
   a. parts deep-drawn from flat half-finished products: caps, domes, tank bottom parts, parabolic segments, etc;
   b. shaped flat parts: panels, ribbed plates;
   c. tapered parts: ogives, curved cones, bellmouths, etc;
   d. corrugated or flaring tubular parts: furnace bottoms, expansion bends, joints, etc.
   e. different shaped parts, simple or complex;
   f. explosion punched parts, with or without bulges.

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