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ROTORS CASTING FOR AVIATION TURBOCOMPRESSORS

CHIRA Ion, VERDEŞ Bogdan Alexandru

Politechnica University of Bucharest, ROMANIA

ABSTRACT
Choosing the best casting technology is made considering the quality indices (I.C.) of the casted part, in the status of FINICHED PART. Each phase of the technological process has several possibilities with advantages and disadvantages of techno-technological nature, efficiency, production or the domain in which the part is used.
The projection of the casting technology is realized taking into consideration several imposed parameters – which much be applied and included in the technology which is used and various operations, phases, materials, SDV and technologic equipments, which support optimization processes in order to assure total quality to the casted part.
The current paper intends to present the methodology for choosing the optimum casting technology for a turbo compressor rotor used in the aviation, part which must be assimilated in the national industry.
Key words:
casted turbo compressor rotors used in the aviation industry; precise casting thru special procedures, non-conventional

1. INTRODUCTION

In a flying aircraft is activating four forces which have to be in equilibrium; these forces are weight, traction, resistance and portanta (fig. 1).

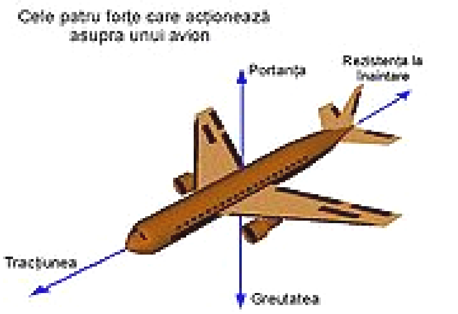


Fig 1 Force systems which operate on an airplane

The traction is assured by the propulsion system; considering the propulsion system the airplanes can be classified in:

- Propeller solutions – equipped with classic engines with pistons (AN-2, Cessna 172, ZLIN Z-142);
- Reaction airplanes – equipped with turbo reaction engines (Boeing 747, A340, MIG-21, F-16, AN-124, Concorde);
- Constructions with propeller and reaction – equipped with turbo propulsion engines (ATR-42, C-130 Hercules).

An engine with reaction produces traction in a similar way as the engine-propeller combination, but while the propeller gives a small acceleration to a high quantity of air, the engine with reaction gives a high acceleration to a small quantity of air.

Currently, there is a large diversification for the aviation engines; if we refere strictly to engines with reaction as aero-reactors, these are developed as:

- Turbo-reactor engine
- Sato-reactor engine: with subsonic burn – ramjet type; with supersonic – scramjet type;
- Pulsoreactor engine;
- Motoreactor engine.

SIMPLE ENGINE REACTOR - MTR is currently equipping the aircrafts flying at high altitudes and speeds over Mach 0.6. Its operating principle is as follows: air entering through the inlet is compressed by the compressor, enters in the combustion chamber where together with fuel injected mixture of combustion gases takes place the actual combustion. The burned gases then pass through the turbine, where the partial retaining thru their rotation, and then pass through the nozzle side and leaving the system with a kinetic energy much higher than the input, thus is providing the traction of the plane. Eventually, at supersonic airplanes we can meet the post-combustion; it is incorporated into the exhaust system and has the role to inject a fuel mixture dose in the combusted gas from the combustion chamber.

We have to remember that the double flow turboreactor engines - called generically turboventilator - are actually turboreactor modified. They are characterized by the existence of two streams flowing parallel: one secondary, trained by a fan mounted on the compressor shaft with a low-pressure turbine, which takes the flow of primary air (inside) made from waste gases. The traction of the dual-stream engine is the thrust of the two resulting streams. Do not forget that the fan has the role of propulsion, operating as a propeller. The double flux turboreactor engine - MTR + DF are the most widespread types of aviation engines, which is equipping most of the civilian aircraft and a good part of military aircraft (see tab. 1).

Tabel 1. Types of reaction engines and airplanes equipaded with such systems

LICENCE – PRODUCTION	AIRPLANE MODELS
CIVIL AIRPLANES	
SNECMA-GE CFM-56	Boeing 737, Airbus A318, A319, A320, A321
General Electric GE90	Boeing 777
CF6	A300, A310, A330, Boeing 747
Pratt & Whitney JT9D	B747, Boeing 767, A300, A310
W4000	B777, A330
PW6000	A 380
Rolls-Royce Trent 500-900	For almost all types of Boeing and Airbus
MILITARY AIRPLANES	
General Electric F110	F14, F15, F16
F103/CF6	Air Force One, B767 AWACS
F404	F/A-18, F117, A-4 Skyhawk
Rolls-Royce EJ200	Eurofighter Typhoon
Pegasus	Boeing-BAe Harrier
Snecma M53	Mirage 2000
M88	Rafale

A turbine which functions on gas is a thermo one, which uses the fall of the enthalpy of a gas or a mixture of gases to produce through the spinning blades a quantity of mechanical energy available for the turbine; the gas turbine is also known as GAS TURBINE INSTALLATION – ITG.

For the thermodynamics point of view a gas turbine works rather like a car engine. Atmospheric air is admitted in a blades compressor, where is compressed, follows the introduction of a fuel's ignition and its ignition in a combustion chamber. The combustion gases are then discharged into the atmosphere. The process is continuous, and the parts execute only rotation movements, which for a period of time might lead to smaller total mass; as a result, gas turbines were developed especially as reaction engines: turboreactor, turbo propeller, turboventilator and turbines to engage the helicopter propellers (see tab. 2).

The most prevalent type of jet aviation is the turbojet, the main constructive elements: the speaker, compressor, combustion chamber, gas turbine and effuse component.

THE COMPONENTS OF A COMPRESSOR - Compressors are labor consuming machine through which gas pressure is raised. After operation principle, compressors can be classified into two main groups namely:

- Volumetric compressor (pressure at which gas lifting is done by closing it within a certain volume, decrease the volume until the lifting of the gas discharge pressure and gas evacuation). In this group can be piston compressors, which have a cylinder moves linearly and rotary compressors, which also have a cylinder in which we can find a piston with rotary motion. These compressors are used for high and very high pressures (1000 bar), with relatively small gas flows (450 cm3/min);
- Dynamic compressor (to increase pressure is done by transferring kinetic energy to the gas, through a large propeller rotor, followed by its conversion into potential pressure energy, the process taking place continuously; in this group we can include the centrifugal compressors and the axial compressors) .

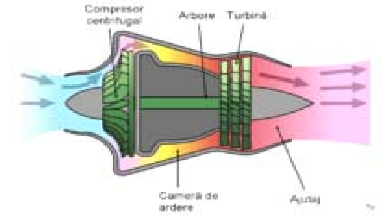
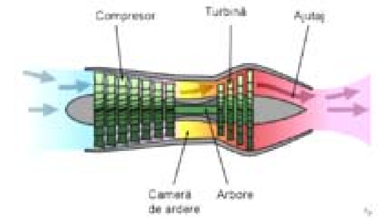
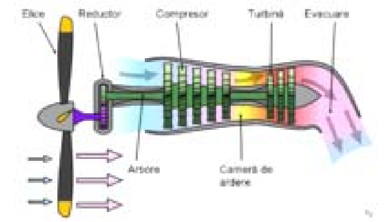
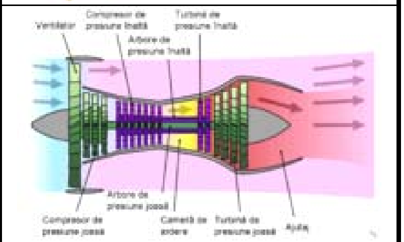
At centrifugal compressors the energy transformation is done through centrifugal force on gas molecules, brought in a circle movement with a propeller rotor. Depending on the ratio of the pressure pr and suction pressure pa, we can identify: - turbo-compressor if pr / pa> 2.5; turbo-ventilator if 1.1 <pr / pa> 2.5; ventilator if pr / pa <1.1.

In axial compressors the transformation of energy is through done through a gas dynamic forces acting on gas molecules, caused by a large rotor. Are used for pressures of 5 - 6 bar and flow rates that can exceed 10,000 m3/min.

2. THE STUDY

High flow centrifugal compressors have a simple rotor or a double sided one, and occasionally is used the two-tier version, simple as building the Rolls-Royce Lance (Dart) engine. Rotor is supported in a housing which also contains a ring of the speaker. If using a rotor with double-entry, the air flow towards the rear is reversed in the opposite direction and requires an intermediary room.

Tabel 2. Typical construction, principle, for turbine with aviatic gaz and typical solutions for jet engines

Constructive types of turbines	Reactive engines
Turboreactor with centrifugal compressor	
Turboreactor with axial compressor	
Turbopropulsor	
Turboventilator	

Rotor is whirled at high speed by the turbine and the air is controlled permanently by the rotor. Centrifugal force makes the air flow to propagate to the outside, over to cavil (wall profile) so that accelerating mass will cause an increase in air pressure. Inlet pipe of the engine can be imperfect, which can cause an initial turbulence of the air at its entrance into the compressor.

To maximize air flow and increased pressure by the compressor is necessary that the rotor is rotated at high speeds; thus rotors are designed to work on the peripheral speeds of about 500 m / s.

Aviation turbo compressor rotors are made with different construction solutions, with advantages and disadvantages - aerodynamic efficiency, endurance and reliability, economic efficiency and maintenance:

1. Disk blades, mono-block (similar rotor Platan from dense liquid pumps), active on one part or both sides (see fig. 2);
2. Blocks, embedded in pallets (combined with a type of swallow tail), which on the outside may or may not be additional reinforced with a circular fitting (as classic steam turbines);
3. Sandwich, with two lateral discs, which are disposed profiled palettes (like the suction fan).

The designer and the company which obtains the manufacturing license is the owner of technical solutions found, they provide and require a number of features and performance of these rotors, which must be accomplished by the casted part, realized by the technologist: shape, configuration and stability during operation; nominal dimensions and admissible tolerances; speed, peripheral speed, temperature and duration of continuous operation to achieve necessary thermodynamic efficiency; flatness of the surfaces, cost limits for part assimilation and production etc.

3. ANALISES, DISCUSIONS, APPROACHES, INTERPRETATIONS

Fig. 2 Specific constructions of rotors of centrifugal compressors in aviation

The design technical work linked with computer applications is defined as COMPUTER AIDED DESIGN - CAD.

CAD applications, with systems for designing assistance are the most known and consist of the following:

1. a field of communication organizes data entry and exit to and from the design department;
2. a range of methods includes modules for modeling work, information and calculations;
3. a field of administration and management of data and a system of integrated data bank organizes all storage and transfer of data between algorithms and methods of communication on the one hand, and networks of data banks or specialized individual files or standardized on the other; database of design contains all the geometric data and stored non -geometric that both methods are needed to design and communication between the operator and the CAD designer.

A fundamental feature of CAD systems is constituted by the concept RID = internal representation of geometric objects. This system is based on the real object; abstraction is achieved by a virtual mental model, in which the formalization and multiple filtering in specific languages leads to the INFORMATION MODEL. Through a series of transformations and transpositions based on the binary code, it is formed an internal model in the computer memory - RIM type configuration.

Chaining programs with systems engineering data processing, in the engineering sciences field, is abbreviated CAE = COMPUTER AIDEDE ENGINEERING.

The integration of a firm in a complex and comprehensive system of monitoring, processing and managing data is known as COMPUTER INTEGRATED MANUFACTURING - CIM.

In the specific area of design technology of casting systems are used systems as COMPUTER ASSISTED CONCEPTION AND MANUFACTURING - CFAO, and sub-programs: COMPUTER ASSISTED DESIGN - DAO, COMPUTER ASSISTED MANUFACTURING - FAO, COMPUTER ASSISTED CONCEPTION - CAO.

Using computer graphics reduce the period of conception and design; starting from the establishment, development and multiplication of simple design drawing by 3D techniques there have been realized programs that allow complex projections for simple parts or complex parts, rapid completion of drawings by the importation of printed standardized elements (screws, axles, rolling bearings, gears, etc..), the production of prototypes to test the functionality of products for approval and launch phases in the series of casting technologies assimilated.

It has the following special procedures for casting accuracy:

- Static casting in metal shape - shell;
- Casting under high pressure (ICTY) - in the mold;
- Casting at low pressure (TJP) - in the form of mixture or matrix;
- Casting static forms with binder strip thermo-reactive (bakelite; Croning process or Shell);
- Static casting oven by tilting forms multi-layer type crust or rind ceramic form casting, packaged or not: MUF model type, the request - made by injecting mold; MGP model type made by injection or expand in the mold -- REPLICAST process, models of resin made by SLA (see Fig. 3 and 4);
- Casting forms ceramic monolith, Shaw type: metallic, processed on modeling (tool-room) the model consumable - MUF, MGP = injection / expand; of resin, paper.

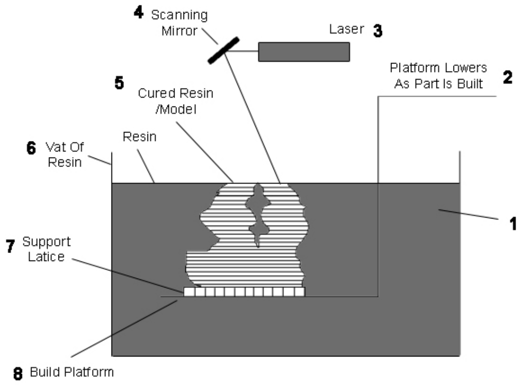


Fig. 3 Stereo lithography SLA: 1- liquid resin; 2 - model support; 3 - laser scanning system; 4 - mirror; 5 – solid model realized by polymerizing the resin; 6- compartment with liquid resin; 7– support for this model; 8 – system with vertical movement.

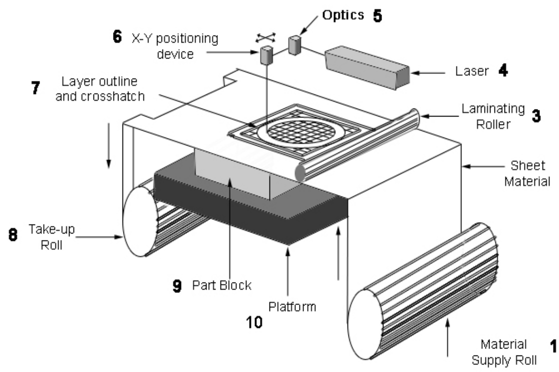


Fig. 4 Scheme to achieve prototypes through LOM technology : 1- material supply role; 2 – sheet material; 3 – laminating roller; 4 –laser scanning system; 5 - optics; 6 – positioning device; 7 – layer outline and crosshatch; 8 – take-up roll; 9 – part block; 10 – platform and system with vertical movement.

The stereo-lithography technique (variants RAPID PROTOTYPING, SLA, LOM) permits to fabricate photo-sensible resin prototypes (MODELS) by selective and controlled strengthening with laser beams and computer assisted control panel; is a current CAD application.

In Table 2 are listed the main indices of quality of casted parts by special casting processes, technologies by which are casted the rotors for turbo-compressors for aviation.

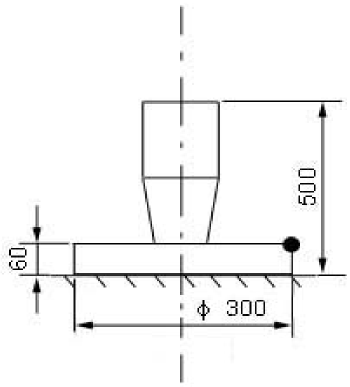
4. CONCLUSIONS

As it is known, the mixture forms – ceramics, used exclusively preheating, ensure moderate rates of cooling; on the one hand it fosters a directed and successive solidification, but the gross cast part has a rough appearance, with impurities, which complicates the thermo treatment.

Possibly to increase the wall capacity and its fluidity, either will be used the tipping of the oven when crust shape or form will spin Shaw (see fig. 5, where a rotor with Ø 300 mm and H 60 mm - the horizontal position, with the blade down and blocking the top; for calculation is considered the highest point at the top of the blade).

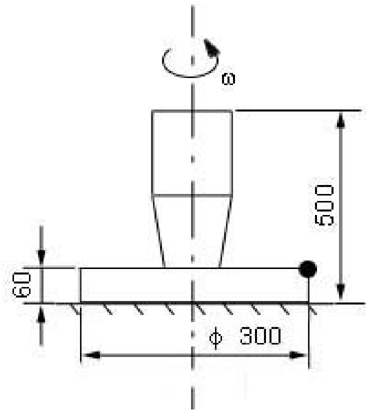
Tabel 2. The main quality indices of casted parts, casted by special procedures

QUALITY INDICES	SPECIAL CASTING PROCEDURES						
	CRONING or SHELL	Shaw	MUF ceramic shell	MGP ceramic shell Replicast	Static metallic forms	Casting at high pressure	Casting in liquid form
1	2	3	4	5	6	7	8
Material often cast	cast iron, steel, ferrous super alloy	steel, cast iron, super alloy, nonferrous	special steel, iron, super alloy	special steel, iron, super alloy	non-ferrous, steel, iron, super alloy	non-ferrous (Al, Mg, Zn, Sn, Sb, Pb-Alloy, brasses, bronzes)	special steel, non-ferrous (silumins, brasses, bronzes)
Complexity of cast part	large, with cores, straight separation	large, with cores, without separation	Large, with cores, without separation	large, with cores, without separation	big, metallic and un-metallic cores, straight separation	large, with metallic cores, straight separation	small and medium, without cores
Parts size min., kg/pc. Min. sizes, mm	0.02 3.0	0.03 1.5	0.01 0.3	0.01 3.0	0.03 1.5	0.01 0.2	0.04 5.0
Parts size max./usual, kg Max. sizes, mm	150 / 5.0 800	250 / 25 1200	40 / 0.8 600	80 / 15,0 700	130 / 10 800	50 / 5.0 700	60 / 10 300
Dimensional precision, % Dimensional tolerances, ± mm / la 100 mm	10.5 ± 1.5	3.5 ± 0.4	2.0 ± 0.3	3.0 ± 0.4	11.5 ± 0.8	1.5 ± 0.2	12.0 ± 2.0
Usual rugosities, µm	12.5 - 25	1.6; 3.2; 6.3; 12.5	1.6; 3.2; 6.3; 12.5	3.2; 6.3; 12.5; 25	3.2; 6.3; 12.5; 25	1.6; 3.2; 6.3; 12.5	25 - 50 steel; 3.2 – 6.3 nonferrous
Special properties registered for casted parts	for permanent magnets, refractory and anticorrosive steels, big productivity for iron	for steel-mold for forge and rubber and plastic industry	finless parts, threads from M5 casting parts without pulp, high productivity	Steel parts, big dimmensions like by MUF	armed with inserts parts, parts of cast iron with hard crust, nonferrous with fine structure	finless parts, threads from M2 casting, with micro-porosity, volumetric solidification, armed pieces	structure-oriented material, fibrous, compacted, special steel and nonferrous
SDV durability, max. no. pc. casting parts	100000	25000	100000	1000000	10000	50000	5000
Efficient lots/ production series, min. pc.	10000 / 1000000	1000 / 15000	1000 / 100000	1000 / 100000	500 / 10000	20000 / 1000000	1000 / 10000



$$P = \gamma \cdot H$$
$$H = 440\,\text{mm}$$
$$\gamma = 7.8\,\text{daN/dm}^3$$
$$\Rightarrow P = 7.8\,\text{daN/dm}^3 \cdot 4.4\,\text{dm} =$$
$$P = 34.32\,\text{daN/dm}^2$$

a



b

$$P = \rho \cdot \left(\frac{\omega^2 \cdot r^2}{2} - g \cdot z \right) + C \Leftrightarrow$$

$$P = \gamma \cdot \left(\frac{\omega^2 \cdot r^2}{2g} + z_0 - z \right)$$

$$H = 440 \text{ mm}$$

$$\gamma = 7.8 \text{ daN/dm}^3$$

$$n = 600 \text{ rot /min}$$

$$\omega = \pi \cdot n / 30 = 3.14 \cdot 600 / 30 = 62.80 \text{ rad/s}$$

$$\Rightarrow P = 7.8 \cdot \left(\frac{62.8^2 \cdot 15^2}{2 \cdot 980} + 44 \right) =$$

$$= 7.8 \text{ daN/dm}^3 (452.74 \text{ cm} + 44 \text{ cm}) =$$

$$= 7.8 \cdot 496.74 \cdot 10^{-1} \text{ daN/dm}^2 =$$

$$P = 387.45 \text{ daN/dm}^2$$

Fig. 5 Calculation scheme for the metal-static pressure: a – for static casting; b – for centrifugal casting, with vertical ax.

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