SAFETY PROCEDURES WHILE STARTING ENGINE OF F-16 AIRCRAFT

This article is dedicated to the description of security systems of the Pratt & Whitney F100-PW-229 engine used in F-16 Block 52+ serving in the Polish Air Force. It presents general engine characteristics and general safety conditions in force when starting the engine, concerning pilots and technical personnel. Eight basic break-downs with their short characterization as well as preventive procedures are described in this article.

Keywords: turbine engine start, safety procedures

1. INTRODUCTION

First design works on turbojet engine started in 1930s in the United Kingdom. They were carried by teams of Frank Whittle and Dr. Hans von Ohain. The first jet fighter was Heinkel He 178, and Messerschmitt Me 262 was the first operational jet-powered fighter aircraft. Years of experience and searching for new solutions have resulted in designing modern and efficient engines. The multirole F-16 Block 52+ aircraft, used by the Armed Forces of the Republic of Poland, is equipped with a single Pratt Whitney F100-PW-229 jet engine with maximum thrust of 129,6 kN.

Fast and unfailing start of the jet engine is the primary condition to obtain the operational efficiency by an aircraft. Starting the engine consists of a few stages [6] from the rotor’s standstill to the idle speed. Independent work of the turbine engine,
without the support from the starter, is possible when the turbine reaches the power equal to the sum of powers consumed by the compressor and generators and lost in the friction [7]. The engine under consideration belongs to the class of bypass engines [5]. Figure 1 presents F100-PW-229 engine, one of the afterburning bypass turbojets with modular structure.

Fig. 1. Hush house of 31st Tactical Air Base in Krzesiny

The basic technical parameters are as follow: the engine’s maximum thrust is 79.1 kN (the thrust with the afterburner is 129.6 kN); the engine thrust-to-weight ratio equals to 8:1. F100-PW-229 engine is the engine with low bypass ratio equal to 0.36:1 and high overall pressure ratio equal to 32:1. The low-pressure compressor has three stages, and the high-pressure one− 10. Both the compressors are equipped with air flow control systems. The engine is equipped with the annular combustor. The turbine consists of two low-pressure and two high-pressure stages. The exhaust nozzle is a convergent-divergent one with the adjustable cross-section. The turbine is based on five bearings. The engine work parameters are operated and controlled by the Digital Electronic Engine Control (DEEC). The fuel is delivered to the engine through the main fuel pump (Main Fuel Control, MFC) and the afterburner fuel pump (Augmentor Fuel Control, AFC). F100-PW-229 engine is based on the modular structure concept which allows disassembling physically and functionally connected modules. Modules are treated as separate subassemblies of the engine. This concept facilitates and speeds up the process of recondition the engine in case of its serious failure. It is possible to install quickly another module in good working order instead of waiting for repair of the non-operational one, dismounted from the engine.
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Such a modular configuration also enables the replacement of subassemblies and elements of the engine, which is considered to be the most effective method of improving the engine functioning.

Despite the possibilities of repairing the non-operational elements of the engine coming from the engine operation, it is very important to minimize the chance of the engine failure by application of appropriate safety procedures during the engine startup. Of great significance for the aircraft’s safe operating is the safety procedure concerning the engine start-up on the ground; it includes all safety conditions from starting to shut down the F100-PW-229 turbofan engine of the F-16 aircraft. Operations carried out by the personnel while starting up the engine are described in detail in the instruction in force [2]. Colonel G. Ślusarz is responsible in air base for training pilots. One of his duties is the oversight of the correctness of the F-16 aircraft engine starting procedures. The article gives the procedures developed by the manufacturer and its guidelines for pilots and ground staff.

2. GENERAL SAFETY CONDITIONS

When operating the aircraft any person should remember about the used dangerous materials. The personnel working in the aircraft have to know the used dangerous substances, be familiar with and observe safety instructions delivered by the producer of those substances. Failure to comply with the safety instructions when handling with dangerous products can bring the threat not only of aircraft damage, but also of an explosion, eyes, lungs, skin, nose and throat damage, and even of a death. If there is a necessity to evacuate pilot or the technician from the aircraft during the procedure of the engine start-up, the most important thing is to abandon the aircraft and its closest vicinity. Abandoning the cockpit should be done into the direction of the aircraft’s front “over its nose” or of either of its sides. Manual opening the cockpit canopy using the crank is very difficult and time-consuming. If there is a need to abandon the cockpit immediately, one should use the system of the canopy emergency removal. To complete any task safely every person should strictly observe the procedures and bans, including the ban of [1, 2]:

− staying in the vicinity of the hot gases exhaust, such as the jet fuel starter (JFS) nozzle, the convergent exhaust nozzle control (CENC) or the ECS nozzle,
− staying in the vicinity of the engine inlet when the engine is started up or is running due to the risk of being sucked into the intake tunnel,
− taking any actions in the vicinity of the PTO shaft when the engine is running,
− staying in the plane of rotation of the JFS turbine and engine’s turbines set when the engine is started,
− staying in the vicinity of movable planes of the aircraft when the engine or the turbo starter JFS is started, is working or is shut down.
Failure to comply with the above instructions may cause death or serious injury. Moreover, staying in the vicinity of the gas exhaust from the Standby Generator is forbidden. Wheel chocks designed for F-16 should be used while servicing the aircraft. If the Digital Flight Control Computer (DFLCC) is disassembled, the wheels’ breaks are not working; in this case the engine must not be started. Technical personnel servicing the F-16 aircraft should remember of many essential details; the most important, among other things, are [1, 2]:

− aircraft parking brake is released automatically after the throttle is shifted of a range greater than 1 inch,
− when the engine works with rpm above the IDLE revolutions, toe brakes should be used,
− if there is a need to carry out a long test of engine with rpm above the IDLE revolutions but below 85% of rpm, the aircraft should be fixed at the test cell. The level of 85% of engine rpm should not be exceeded; in other case the aircraft could jump over the wheel chocks,
− having shut down the engine one should wait until all heated parts of the air-frame and engine are cooled,
− within 10 minutes after the engine shut down, fuel auto-ignition may occur in the exhaust nozzle of the engine; it is manifested by a small explosion coming from the engine’s nozzle,
− burning fuel may be accompanied by smoke, exhaust gases or small fire within the engine’s nozzle,
− no one should come to or into the engine’s nozzle within ten minutes after the engine is shut down, auto-ignition and concomitant effects do not pose a threat to the engine and the aircraft’s construction. If such a phenomenon occurs, fire could be extinguished by one-minute dry motoring,
− to prevent suction the area in the vicinity of the engine air inlet should be kept clean, without debris, tools, equipment or personal belongings,
− before the engine starts the rear seat should be placed at the position between the mid-height to the half-inch height above the lowest position. If the seat is positioned too highly, there is a danger that the throttle would touch the Aft Ejection Seat Control Handle Safety Pin, which can cause damage to the aircraft equipment,
− if, during the engine start-up, after the throttle lever has been advanced from the cut-off position to the position of IDLE thrust or above it, the Fuel Master Switch is in the Off position, the engine start-up must be stopped immediately.

Failure to comply with the above instructions may result in the engine damage. Particular caution should be exercised when the engine is starting up and running with the illuminated Fuel Low Caution Light; in other case the fuel pump might be destroyed and the engine would be shut down automatically. Air Source Switch should be kept in the Off position for no longer than 30 minutes. Exceeding this time might result in damage to the on-board equipment. Time of engine work parameters stabilization should be observed; in other case it might lead to a serious change of
engine work characteristics and its damage. This time may be elongated but never shortened. Small vibrations of the aircraft might occur in flight or during the engine on-ground work, and when the throttle is positioned closed to IDLE or in other ranges. Those vibrations are not directly hazardous to the engine and the aircraft’s construction, and they should disappear when rpm increase or decrease by approximately 5%.

If there is a risk of the aircraft icing, the engine should not be started. Possible icing conditions are as follow:

– ambient temperature (TAMB) between −7°C and 7°C and precipitations or fog,
– dew-point within the limits of 5°C from the ambient temperature between −4°C and 7°C,
– ambient temperature below 7°C and standing water or the mix of water and ice or snow in the close vicinity of the air inlet to the engine.

Ice accumulation on the inlet or the engine may lead to its damage. In the event of starting the engine and its run in possible icing conditions, the engine inlet has to be monitored constantly. If the ice cap exceeds the height of 0.25 inch on the inlet edge, the inlet inside walls or the inlet strut, to prevent damaging the engine, it should be stopped immediately and icing should be removed. Air condensation in the engine inlet may make it significantly hard to detect icing. If atmospheric conditions indicate that icing is possible, reduce rpm to IDLE which enables observing the inlet area. If the engine was shut down with the iced inlet, icing should be removed completely before another starting [2].

3. STATES OF EMERGENCY

3.1. Engine Fire

Safety procedures apply also to actions taken by the personnel staying in the cockpit. Below we present some hazardous situations which can occur when the engine is in operation and the recommended measures in such situations.

Engine or JFS fire can be indicated either by illuminating Eng Fire light when the Main Power is on, by finding the fire, smoke or explosion, or after receiving a signal from the ground personnel. When the fire occurs and, additionally, the internal leakage of oil in the engine is suspected, do not use the JFS to turn the turbine. Rotating the rotors may cause spread of fire due to additional quantity of oil being pumped into the engine. If, after the engine shut down, the fire is limited to the interior of the engine or the air inlet, the air inlet to the engine should be sheltered (only if Anti Personnel Screen is not installed) and the extinguishing agent should be pumped into the engine nozzle. If the fire occurs within the space of the fuselage, turning the turbine using the JFS is forbidden. Driving the engine may result in adding fuel to the
fire. If the fire is limited to the engine nozzle, use dry motoring in order to blow the fire out. If, as a result of the engine start-up, both hydraulic accumulators are discharged and the engine has been ignited with a delay, it may mean that the after-burning of fuel has occurred in the JFS. In this case the covers of gas inlet to and exhaust from the JFS may stay opened. The flame should go out spontaneously after a lapse of a minute. This situation should be carefully observed because the fire may spread over other parts of the airframe. If the fire is limited to the interior of the JFS, no extinguishing agent should be pumped into it, except when the fire lasts for a longer period of time or spreads over the airframe.

3.2. Uncommanded/Auto Acceleration

Uncommanded or auto acceleration may occur when the engine is starting before the throttle was advanced from the STOP position to the IDLE position. It is manifested by increasing the engine rpm beyond 30%. This may also happen after the engine start-up cycle is finished. If the engine rpm increase beyond 30% while starting it or the FTIT (Fan Turbine Inlet Temperature) begins to grow before the throttle is advanced to the IDLE position, immediately turn the Fuel Master switch to the Off position, which will result in cutting the power off and gradual rpm decreasing [4].

3.3. Engine Hot Start or Hung Start

Engine hot start is characterized by an increase of the temperature of exhaust gases FTIT over 8000°C. Engine hot start may occur if – during the start up – the FTIT grows over 5000°C while engine rpm is below 40% or the FTIT grows in uncontrolled way (too fast) over 7500°C. Hung start is characterized by stoppage of the engine rpm growth below the IDLE value and stabilization of the FTIT below 8000°C. When such a defect is found, immediately retard the throttle to the STOP position.

3.4. Improper Indication of Oil Pressure

If an improper engine oil indication is found, the engine start-up should be stopped. The same refers to the cases when the indication of oil pressure does not appear within 1 minute from igniting the engine, the oil pressure exceeds maximum values (such exceeding lasting for 1 minute is acceptable while starting the cold engine), or when the oil pressure decreases below 1034 hPa (15 psi).
3.5. Engine Stall or Stagnation

Engine stall may occur when the engine rpm is stabilizing within any range or when the throttle is being advanced to the Intermediate Power position or the Full Augmentation position. Stall may be accompanied by noise coming from the engine. It usually disappears automatically. If stall lasts we deal with the stagnation, which is characterized by the growth of the FTIT and the decrease of rpm, or by the growth of the FTIT while rpm is below 60%. In both cases the engine does not respond to the throttle’s movements; however sound effects do not have to occur. When this defect is found, the throttle should be advanced to the Intermediate Power position, and when the stall disappears, the engine should be shut down.

3.6. FTIT Overtemperature

Failure to react to the FTIT overtemperature leads to decrease of the engine rpm and further growth of the FTIT, which will result in the engine damage. If this occurs within the range of afterburning, advance the throttle to the Intermediate Power position; if the temperature does not decrease, immediately retard the throttle to the IDLE position, and if it does not help and the FTIT is still beyond the permissible values, retard the throttle to the STOP position. Observe the FTIT. If it remains above 5000°C, turn the turbine using the JFS until the FTIT decreases below 2000°C. If this occurs within the range below afterburning, retard the throttle to the IDLE position. If the FTIT is still beyond the permissible values, retard the throttle to the STOP position. Observe the FTIT. If it remains above 5000°C, turn the turbine using the JFS until the FTIT decreases below 2000°C.

3.7. Hydrazine Leakage

When hydrazine leakage is noticed the personnel should make sure that in the vicinity of the aircraft there are no casual persons. The engine should be shut down. Personnel should abandon the aircraft and its vicinity.

3.8. Chock Jumping

Due to a considerable thrust of the engine and relatively little weight of the aircraft the personnel should take a special care that the aircraft does not jump over chocks. If so happen, retard the throttle to the IDLE position. Press maximally the toe brake. If it does not react, turn the brakes switch to the Channel 2 position, and once more press the toe brake [1].
4. SUMMARY

This article presents safety procedures in force while starting the F-16 aircraft. Operating the aircraft, and in particular the engine, requires from the ground and flying personnel assimilating a huge amount of information concerning the structure of the aircraft and safety procedures. This knowledge is supplemented by skills gaining in numerous training courses. The efficiency of the aircraft as well as life and health of the personnel, both – that servicing the aircraft on the ground, and that using the aircraft functional capabilities in flight, depend on appropriate behaviour in particular situations. Pilot being at the controls of the aircraft and fulfilling his tasks in the air entrusts the technical personnel with his health and life, but he cannot believe blindly their work. He has to possess skills enabling him to verify particular activities they have done. Safety procedures while starting the engine of the F-16 aircraft are known to each and every pilot. They belong to this range of knowledge which is always used when the pilot fulfills his everyday tasks.

REFERENCES


PROCEDURY BEZPIECZEŃSTWA W TRAKCIE URUCHAMIANIA SILNIKA SAMOLOTU F-16

Summary

W artykule opisano systemy zabezpieczeń silnika Whitney F100-PW-229, stosowanego z samolotach F-16 Block 52+, będących na wyposażeniu polskich sił zbrojnych. Oprócz ogólnej charakterystyki silnika przedstawiono podstawowe zasady bezpiecznego uruchamiania silnika, których muszą przestrzegać piloci i naizemny personel techniczny. W artykule opisano osiem podstawowych przypadków awarii, podano ich krótką charakterystykę oraz postępowanie zapobiegawcze.