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MODERN SOLUTIONS FOR THE REPLACEMENT OF GAS TURBINES USED ON WARSHIPS

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Abstract

The gas turbine propulsion systems have experienced a development in recent decades, being used in both civilian and military fields. At international level, most countries have equipped their naval forces warships or intervention ships with gas turbine. By developing a high propulsion power with less weight and a lower footprint compared to other propulsion systems, gas turbines now equip a multitude of warships (frigates, destroyers etc.) from the United States navy fleet of America, Great Britain, France, Russia etc.

Romanian Naval Forces has been running the T22 frigate modernization program since 2017, a program that in 2018 and 2019 is among the major investment priorities. In this paper are presented some aspects related to a project under implementation, project that consider replacement of gas turbines that equip the frigates.

1. Introduction

Romania, a NATO member country, has a number of military ships equipped with gas turbines, but these are designed and built 30-40 years ago, which leads to reduced performance and high maintenance costs because engine and equipment suppliers have ceased their manufacture. Internationally, literature foresee for the next 50 years a significant increase in the use of gas turbines in non-aviation sectors, with a doubling by 2030 of the number of gas turbines used to equip military naval fleets.

Considering this, it is necessary to replace the morally-used gas turbines which equip Romanian Naval Forces with some of the last generation, more economical, reliable and efficient. TyneRM1C turbo engines, manufactured by Rolls-Royce, which currently equip T22 frigates as marching engines, have gone out of production. Rolls-Royce has announced that it will no longer carry out the repair of these turbines, and the staff in charge of their repair will be re-qualified. The situation has generated the need to replace them with similar ones which are still in the manufacturing and operating processes.

2. Framework for the development of gas propulsion solutions for T22 frigates

The Mircea cel Batran Naval Academy of Constanta is making its contribution to the field of technology transfer by treating Tyne turbine replacement in the context of the project Development and implementation of modern solutions for gas turbine propulsion systems and their related systems (TURBONAV), a project developed within the National Plan of Research and Development and Innovation for the period 2015-2020, Program 2: Increasing the competitiveness of the Romanian economy through research, development and innovation. The TURBONAV project is coordinated by the National Institute for Research and Development of Turbomotors - Comoti, and the implementation consortium includes the following partners: Mircea cel Batran Naval Academy, ROMAERO SA, National Institute of Research and Development for Electrical Engineering and Military Technical Academy of Bucharest.

The aim of the project is to strengthen national defense and to raise the level of national security through innovative solutions to the technical and technological problems identified at the level of the Romanian Naval Forces. In order to achieve the goal, the following general objectives were identified [1]:

1. Modernization of gas turbine propulsion systems used on Romanian Naval Forces ships by adapting systems on board to state-of-the-art technologies;
2. Developing emerging technologies for propulsion systems, with marine applications;
3. Increasing the level of environmental protection by minimizing the impact on marine flora and fauna.

Also, the specific objectives that support the good implementation of the project have been set. These are:

1. Identify and implement a Tyne RM1C turbine replacement solution from the T22 frigates with the ST40M naval turbine engine manufactured by Pratt & Whitney Canada;
2. Improve performance, and in particular the efficiency of the turbine engine that equips these frigates.

Experience in industrial research and experimental development of the human resource involved is a key element in the success of the project. Consequently, specialists who participated in large-scale projects have been co-opted for the achievement of the general and specific objectives, and some of them are: "Prototype 4000 hp turbonaval group", which aimed to achieve a prototype 4000 hp turbonaval group by developing the aviation Viper 632; "Examination and revision of propulsion systems on military fleet vessels to extend service life", which aimed to achieve technical documentation and regulatory work, functional tests for the initial state, metrology and the realization of adjustments and final samples; "Technical inspection of the F22 propulsion system", which aimed at boroscopy operations, checking and metrology of the turboengine measuring etc.

The innovative character of the project results from the application of a new motorisation solution, not yet applied to the Romanian Naval Forces, using a modern, more reliable and more powerful turbine engine than the Tyne RM1C, namely the ST40M. The results of the research carried out within the project will allow to overcome the performance of existing engines, allowing for a more than 15% higher thermal efficiency and a lower fuel consumption, which results in a reduction in operating costs and, implicitly, a lower impact on the environment. It is also important to note that maintenance will be provided in Romania throughout the life cycle of the product.

The project is developed for a period of 3 years, with completion in April 2020. The main stages of the project are: finalizing the constructive configuration (which includes the acquisition of a technological demonstration turbine and the testing stand), the research-development of technological demonstrator on the stand (the final result being the testing, evaluation and approval of the technological demonstrator on the stand), the installation and testing of the technological demonstrator on board a T22 type frigate (by approving the RM1C marine turbine replacement solutions with the ST40M technological demonstrator) and documentation and staff training.

2. Description of the solution for replacement turbines

Starting from the requirements of the project's terms of reference, an installation architecture was built that best corresponds to all the specific technical and operational requirements and ensures the successful achievement of the project objectives. From the synthesis of all the available information, the constructive principles, performance, functional limitations and positioning of the ST40M turbo engine on the ship were determined.

The determination, design, implementation and testing of the optimal solution will be based on the experience and expertise of the technical and scientific teams of the consortium and using high-performance and reliable techniques and technologies. Thus, Computed Fluid

Dynamics numerical simulations of flow through newly engineered drains of the engine, as well as heat transfer and material strength calculations using Finite Element Method will be performed.

Experimental testing will asset the overall performance of the engine in the new configuration and the collection of experimental data relevant for optimization, such as instantaneous speeds and temperatures, determined by LASER spectroscopy and spectroscopy techniques (PIV and Rayleigh) as well as high frequency critical temperatures and pressures to characterize and optimize the performance of the turbo engine. Determination of the optimal solution will form the basis for the further development of the propulsion and propulsion of the ST40M turbomodulator's computing and design operations.

The ST40M turbine engine has a clockwise rotation and is installed in a working position same as the Tyne RM1C engine with the cold zone to the main gearbox flange. The main technical-tactical features of the ST40M turbomachine are shown in Table 1. The ST40M is developed from the PW150 aviation engine used on commercial lines. As a result, it is stable for a wide range of working environment temperatures and high longitudinal and transverse tilt values. Also, the mechanical vibration and electromagnetic radiation values produced by ST40 are inferior to those produced by TYNE R1MC, which represent an advantage especially for warships.

The length of the ST40M is about 900 mm less than that of the Tyne RM1C, and this allows axial positioning of the engine in the existing propulsion cell so that air suction and exhaust springs can be installed without changing the configuration of the machine compartment (figure 1). This solution also allows to return to the configuration used for Tyne RM1C at any time.

Table 1 Main characteristics of the ST40M turbine [2]

Parameter	**Value**	**Unit**
Length	1690	mm
Width	660	mm
Height	965	mm
Mass	525	kg
Shaft power	4039-4100	KW
Shaft speed	14000-14875	rpm
Rotation direction	Right	
Thermal efficiency	33,4	%
Hourly consumption (at full power)	1,25	t/h
Fuel type	F-76	
Specific fuel consumption	350	g/KWh
Average annual performance	over 2500	hours

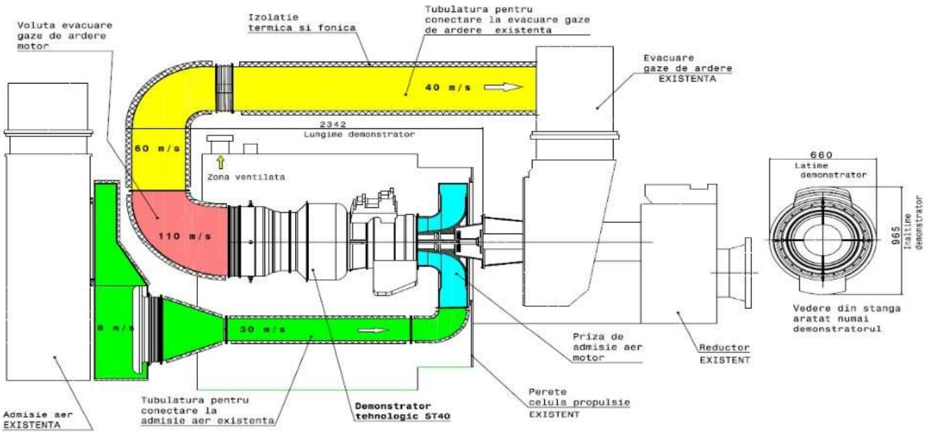

Figure 1 ST40M turbine propulsion cell design [1]

Power is transmitted from the ST40M to a ship similar to TYNE RM1C. The power shaft of the ST40M is provided with a membrane-type elastic coupling which is fixed to the primary reducer of the ship by a specially adapted coupling piece. Demonstration of the functionality of the new solution will be achieved by running and performance tests followed by 2-stage homologation programs and tests: on the pilot's test bench and on a T22 type frigate.

Fuel supply, lubrication and cooling oil, air and other auxiliaries will be made using existing on-board facilities, requiring only adjustments between power outlets and the engine, which is an asset in terms of allocated resources and maintenance time in state of non-operability of the ship. The command and control system of the ST40M will be totally new, designed and made from state-of-the-art equipment using military process computers.

4. Conclusions

Replacing the Tyne turbines that currently equip the T22 frigates of the Romanian Navy is a priority and a necessity in the medium term. In this context, the ongoing project offers the solution for the adaptation and implementation of the ST40M turbines on board the T22 frigates, and the results and benefits of this project can be remembered: transformation of R & D results into results with applications in the economy, acquisition of experience for consortium members and Naval Forces, creating jobs and providing the expertise needed to implement this removal solution to other types of seagoing ships with minimum adaptations.

The complexity of the project also provides the ability to further develop the proposed solution. The current solution incorporates a state-of-the-art turbine engine with outstanding performance (low fuel consumption, high thermal efficiency). The solution configuration can be developed to achieve better performance by at least two methods: the injection of water into the combustion chamber (which restores power on very hot days and requires a water treatment plant to prevent the integrity of the room combustion and turbine) and the implementation of the heat recovery thermodynamic cycle (which can increase the global rate by about 12 percent and reduce fuel consumption by about 30 percent).

The project also produces technical, economic and social impact. The technical impact is ensured by improving the performance of the ship's propulsion system by using the new turbine engine, by increasing the capacity of the Romanian military fleet to respond with new and more reliable engines, and by providing technical assistance and maintenance throughout life cycle of the turbo engine. The economic impact is generated by the economy of around eight million Euro, which is made from the beginning by equipping frigates with ST40M instead of the TyneRM1C turbo engines. To this economy will add fuel economy (diesel) generated by the ST40M consuming 13.79% less fuel than Tyne RM1C, with a positive impact on environmental protection. From a social point of view, this project will help to develop the activity of Romanian military research, partners being institutions and enterprises working in the field of national defense.

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