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- Technical and technological background of power and efficiency evolution process of gas turbine engines and its influence to the modernisation of military helicopters -

Author's synopsis and official report on the Ph.D. thesis

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- Technical and technological background of power and efficiency evolution process of gas turbine engines and its influence to the modernisation of military helicopters -

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1. Formulation of the scientific problem

Significant improvement of helicopter engines, which has embodied mainly in power–weight ratio, thermal cycle efficiency, specific fuel consumption, together with reliability and maintainability, of course, has influenced the technical-tactical parameters of helicopters. This fact makes it well worth examining this field. In my dissertation, this evaluation process is analysed through comparative examination of late and present eastern and western types of helicopters, which includes the thermal and structural analyses of turboshaft engines and their main elements.

2. Research objectives

In the dissertation, I have proposed four main objectives to myself.

1. To present the early days of helicopter evolution, the arising technical problems, the difficulties of their introduction in armies, the process of their specialization, the different steps of their appearance on battlefields, through their roles they played in the past conflicts.
2. To provide historical view about the development of helicopter engines from the early internal combustion engines to the powerful special helicopter gas turbines, so called turboshaft engines.
3. To perform the mathematical and structural examination of helicopter engines and their main components and through this comparative analyses present the evolution process of last 60 years.
4. To analyse the present day main ways of turboshaft engine innovations giving full details of technical novelties, and their influence on the helicopter operations on battlefields.

3. Hypothesises

The helicopter turboshaft engines like any other gas turbine engines, between given temperature limits and component efficiencies, have optimums of specific net work and thermal cycle efficiency, which are function of compressor pressure ratio. After determination of these optimum pressure ratios, the relationship among the compressor pressure ratio, maximum turbine entry temperature and component efficiencies, furthermore their influence on the specific parameters of gas turbine engines can be revealed.

Helicopter turboshaft engines, because of the particularity of helicopter operation, have some structural specialities, which provide protection of turboshaft engines (dust protection system), or protection of the whole aircraft (protection against infrared guided missiles), but they influence the engine operation. Examination of these influences can minimize their negative effects on the engine power and thermal efficiency.

Well-known fact, that today an average aircraft is planned to use for 30-40 years or more. It does not mean they are able to perform the higher and higher standards of new ages, without any structural change, or capability enhancement. There are numerous programmes, which provide possibilities for the modernisation of one or more subsystems of the existing (older) helicopter fleets. In these programmes the change of obsolete turboshaft engines to modern, economic and cost efficient engine, has especially important role.

4. RESEARCH METHODS

In my dissertation, I used the next research methods:

- With *historical method,* I provide general view about the early days of helicopters, their introduction in different armies, their role in the wars and conflicts from the WW II to the present days and their specialization driven by their evolution.

- Using the *method of analyses,* I examine the modern helicopter turboshaft engines introducing the technical novelties, the similarities and differences of different types.

- Using the *method of comparison*, I examine and compare the war-operability, maintenance, service, efficiency and economic indicators of the currently used and prospectively introduced military helicopter turboshafts.

- I use *mathematical methods* for the thermodynamic examination of turboshaft engines and their main components, together with the calculation of their thermal efficiency, specific fuel consumption and specific net output work.

5. SUMMARY OF THE CONDUCTED EXAMINATION CHAPTER BY CHAPTER

In the Introduction part of my dissertation I list the motivation facts, which inspired me to write this dissertation. I describe the research actuality, introduce the research methods, and formulate the research objectives.

In **Chapter I,** I present the way the helicopters has gone through from the quasi un-useful, "unable or minimally able to fly" condition to the state, they have become significant part of military and of course the civil aviation. I introduce the evolution of helicopter turboshaft engines, review the specialities of their operation, the most important producers and types. Through statistical analyses I display, what kind of performance parameters the helicopter turboshaft engines had in the past and have present days.

In **Chapter II,** I present the theoretical background of the thermodynamic mathematical model, I created, together with some samples from the results produced by this programme. With this model, I analysed and compared some eastern and western turboshaft engines from different ages. I show how the geometrical dimension of gas turbine engines influences the power and efficiency parameters.

In **Chapter III,** I display the Dust Protection Systems of helicopter turboshaft engines. With the mathematical model, I analyse their effect on the engine specific net output work and thermal efficiency. I present the equipment and methods, which have been employed to reduce the infrared signature intensity of the exhaust from turboshaft engines under the sensitivity threshold of infrared guided missiles, while they minimise the chance of reconnaissance washing away the contrast between the infrared source and background signature.

In **Chapter IV,** I introduce, how the installation of modern engines with greatly increased power/weight ratios, reduced specific fuel consumption, and digital controls can support the longer operation of fielded and partly obsolete helicopters, while they meet the technical and economical requirements of current age again.

In summary of new scientific results of my dissertation, I summarise the completed scientific work in accordance with my research objectives and compact my new scientific results into theses. At last, I give recommendations for practical applicability of my scientific results.

6. Summary of conclusions

Concluding my dissertatio, it is sure that the helicopters have not only past, but present and future both in military and civil application. The innovations in this field, including their engines have been continuous. The novelties used in other categories of gas turbine engines have appeared in the turboshaft engines, too. For example FADEC, heat protected cooled single crystal turbine blades, active tip clearance control and generally the lighter and better structural materials. These solutions all together contribute to the enhancement of power, thermal efficiency, maintenance and operational properties of helicopters, as well as to their developed flying capabilities.

Despite all these positive improvements, the thermal efficiency and specific net output work of this engine category is more or less equivalent with the related data of an average 30-35 year-old engine with higher (30–50 kg/s) mass flow rate. What is the reason? The direction of innovations, namely smaller geometrical dimensions, even more compact structural arrangement and efforts to protect the engine, annulled the possibility to improve the engine component efficiencies.

- The air intake pressure loss has become worse because of the nowadays generally used Dust Protection Systems.
- Smaller geometrical dimensions have allowed only minimal improvement of compressor and turbine polytrophic efficiency, if not caused some deterioration.
- The combustor pressure loss rather worsened, than got better because of the generally used reverse flow combustors;
- The change of combustor efficiency is not significant.
- The efficiency of free turbine is inherently lower than the efficiency of nozzle because of its more difficult flow pattern.

In accordance with the above mentioned statements it is impossible to produce helicopter turboshafts with the same specific performance data like larger gas turbine engines have in other aircraft categories. The non-debated improvements in this field have been resulted by higher turbine inlet temperature allowed by improved heat resistant single crystal turbine blades and sophisticated turbine cooling system. These results are not negligible considering the doubled specific net output work and 30–40% lower specific fuel consumption comparing to the first generation helicopter turboshafts.

7. New scientific results

I summarise the scientific results of my research – presented in my dissertation – in the following theses:

1. I developed a thermal mathematical model and calculation programme, which is able to produce the general thermal analyses of helicopter turboshaft engines;
2. I produced the parameter sensitivity examination of helicopter gas turbine engines and demonstrated:
    a. considering the specific net output work, the engine responds most sensitively to the change of compression polytrophic efficiency. In order, the next ones are the expansion polytrophic efficiency, mechanical efficiency, and the engine pressure loss, while the combustion efficiency does not have influence on it.
    b. the thermal efficiency is most intensively influenced by the expansion polytrophic efficiency, and less and less effected by the compression polytrophic efficiency, the mechanical efficiency, the combustion efficiency and engine pressure loss.
3. With my programme, I created a diagram, from which directly readable the influence of compressor pressure ratio and compressor polytrophic efficiency on the specific net output work and thermal efficiency.
4. With my thermal mathematical model, I proved that higher specific net output work and thermal cycle efficiency is originated mainly from the higher maximum turbine entry temperature. In the frame of this examination:
    a. I determined the possible compressor pressure ratio range of examined engines and proved that the actual working point, given by the producers, is always part of the determined pressure ratio range, justifying the proper operation of my thermal model.
    b. Analysing the examination results I state, that in middle-power category the RTM 322, LHTEC T800 and

MTR 390 helicopter turboshaft engines and their modifications represent suitable alternative for the helicopter engine modernisation programmes.

8. PRACTICAL APPLICABILITY OF RESEARCH RESULTS AND RECOMMENDATIONS

The whole dissertation as well as particular chapters of dissertation can be used in graduate and postgraduate courses of helicopter maintenance engineers and engine specialists. It can help to form the students' broader professional view both in BSc and MSc courses of the National University of Public Service's Department of Military Aviation.

The thermal mathematical model in my dissertation gives scope for detailed analyses of gas turbine engines and the determination of exact engine component efficiencies and losses.

The chapter, which deals with the Dust Protection Systems, provides better general view for specialists, who deal with these systems and help them to understand their working principle and compare their influence on the performance indicators of helicopters.

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At last, but not least I would like to thank anyone who helped my research work and to achieve the planned objectives with their valuable critical comments, advices and opinions.

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Szolnok, July 15, 2013

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