https://ntrs.nasa.gov/search.jsp?R=19840008495 2020-03-20T23:32:11+00:00Z

View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by NASA Technical Reports Server

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

NASA TECHNICAL MEMORANDUM NASA TM-77021

FEB 1984 RECEIVED

THE START-UP OF A GAS TURBINE ENGINE USING COMPRESSED AIR TANGENTIALLY FED ONTO THE BLADES OF THE BASIC TURBINE

L. K. Slobodyanyuk and V. I. Dayneko

(NASA-TM-77021) THE START-UP OF A GAS TUBINE ENGINE USING COMPRESSED AIR TANGENTIALLY FED ONTO THE BLADES OF THE BASIC TURBINE (National Aeronautics and Space Administration) 8 p HC A02/MF A01 N84-16563 Unclas G5/37 11412

Translation of "Zapusk GTD szhatym vozdukhom, podvodimym tangentsial'no na lopatki osnovnoy turbiny", Energetika, Vol. 20, September 1977, pp. 135-137.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, DC 20546 FEBRUARY 1983

ORIGINAL PAGE IS
OF POOR QUALITY

STANDARD TITLE PAGE

1. Report No. NASA TM-77021	2. Government Accession No.
3. Recipient's Catalog No.	
4. Title and Subtitle THE START-UP OF A GAS TURBINE ENGINE USING COMPRESSED AIR TANGENTIALLY FED ONTO THE BLADES OF THE BASIC TURBINE	5. Report Date February 1983
	6. Performing Organization Code
7. Author(s) L.K. Slobodyanyuk and V.I. Dayneko	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108	11. Contract or Grant No. NASw- 3542
	13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Zapusk GTD szhatym vozdukhom, podvodimym tangentsial'no na lopatki osnovnoy turbiny", Energetika, Vol. 20, September 1977, pp. 135-137.

(A78-24149)

16. Abstract

To increase the reliability and motor lifetime of a gas turbine engine, the authors suggest using compressed air. The authors carried out experiments, and the results are shown in the form of the variation in circumferential force as a function of the entry angle of the working jet onto the turbine blade. The described start-up method is recommended for use with massive rotors.

17. Key Words (Selected by Author(s))	18. Distribution Statement THIS COPYRIGHTED SOVIET WORK IS REPRODUCED AND SOLD BY NTIS UNDER LICENSE FROM VAAP, THE SOVIET COPYRIGHT AGENCY. NO FURTHER COPYING IS PERMITTED WITHOUT PERMISSION FROM VAAP.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	8	

ORIGINAL PAGE IS
OF POOR QUALITY

The Start-Up of a Gas Turbine Engine Using Compressed Air Tangentially Fed Onto the Blades of the Basic Turbine

L. I. Slobodyanyuk and V. I. Dayneko
Sevastopol' Instrumentation - Making Institute
Sevastopol', Ukrainian SSR

The enhanced reliability and increased motor lifetime of a gas turbine engine place elevated demands on its servicing systems, including the start-up system. /135*

One of the ways of raising the reliability of the starter layout under conditions of lengthy operation is the use of a starting system without starter. Such a system provides for the feeding of compressed air directly onto the turbine blades across special starting nozzles, tangentially arranged about the perimeter of the turbine housing.

Fig. 1 shows a schematic drawing of the mutual arrangement of the peripheral section of the working blade and the starting nozzle.

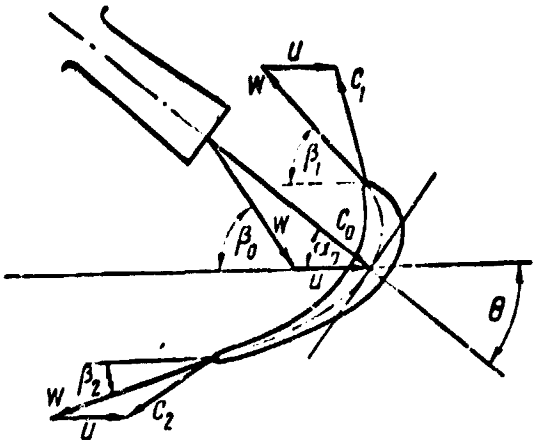

Fig. 1. Diagram of the arrangement of the starting nozzle and working blade.

*Numbers in the margin indicate pagination in the foreign text.

ORIGINAL PAGE IS
OF POOR QUALITY

It is known [1] that the sum of the forces acting on the system can be found from the theorem of change in momentum of the flow:

$$P=G_0c_0-G_1c_1-G_2c_2,$$

where G_0, G_1, G_2 is the mass rate of flow of the working substance per unit of time; c_0, c_1, c_2 are the velocities of the working substance in the system at the inlet and outlet. The circumferential force is:

$$P_u=G_0c_{u0}-G_1c_{u1}-G_2c_{u2}.$$

Let us suppose that the current is laminar, the relative velocities of the flow at the inlet and outlet from the blades are identical, and the losses are provided for by a factor ξ, which is experimentally determined.

The amount of working substance spreading over the blade toward the inlet G_1 and outlet G_2 edges will be, respectively:

$$G_1=\frac{G_0}{2}\left[1+\sin\left(\Theta-\operatorname{arctg}\frac{\sin\alpha_0}{\cos\alpha_0-\frac{u}{c_0}}\right)\right];$$

$$G_2=\frac{G_0}{2}\left[1-\sin\left(\Theta-\operatorname{arctg}\frac{\sin\alpha_0}{\cos\alpha_0-\frac{u}{c_0}}\right)\right].$$

In view of the assumptions, the circumferential force is:

$$P_u=\xi\,[G_0\,(c_0\cos\alpha_0-u)+G_1\,(w\cos\beta_1-u)+G_2\,(w\cos\beta_2-u)].$$

After substituting the values for G_1 and G_2 we obtain:

ORIGINAL PAGE IS
OF POOR QUALITY

$$P_u = \xi G_0 \left\{ (c_0 \cos \alpha_0 - u) + \frac{1}{2} \sqrt{c_0^2 + u^2 - 2 c_0 u \cos \alpha_0} \left[\cos \beta_1 + \right.\right.$$
$$\left.\left. + \cos \beta_2 + (\cos \beta_1 - \cos \beta_2) \sin \left(\Theta - \operatorname{arctg} \frac{\sin \alpha_0}{\cos \alpha_0 - \frac{u}{c_0}} \right) \right] \right\}.$$

As shown by research, a change in the angle α_0 within limits of 0 to 30° has little effect on the size of the circumferential force P_u, which is a maximum in this range of angles. /136

In order to determine the loss factor ξ, an experiment was set up at the turbine stage with middle rotor diameter 0.6 m, height 0.1 m, pitch 0.03 m, and blade turn angle Θ = 45°; the exit angles at the edges were β_1 = 90° and β_2 = 25°.

A possibility was provided for changing the angle α_0 in the equatorial plane (U-Z) and the angle γ in the meridional plane (R-Z).

The quantity of working substance and the rate of flow were changed by varying the parameters of the working substance and the geometrical dimensions of the nozzles.

In the experiments the pressure was maintained within limits of 5.88 bar, the angle α_0 varied from 0 to 45°, the angle γ from 25 to 80°. The circumferential force was measured by a dynamometer. The magnitude of the force from the jet of working substance was measured with the blades in various positions with respect to pitch (with a one degree turn), and then averaged by a graph analytical method.

The results of the experiments are shown in Fig. 2 in the form of the variation in circumferential force as a function of the entry angle of the working jet onto the turbine blade α_0

ORIGINAL PAGE IS
OF POOR QUALITY

when the angle γ is equal to 40°. The loss factor ξ, according to the experimental findings, was 0.6-0.62.

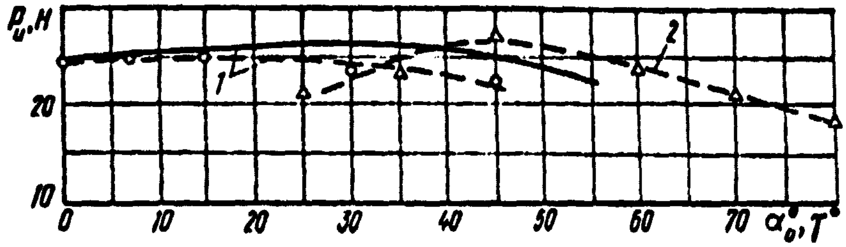

Fig. 2. The circumferential force as a function of the nozzle angles of position: 1 - as a function of angle α_0; 2 - as a function of angle γ; solid line - calculated curve; broken line - experimental.

The influence of the angle γ is extreme and, as shown by the experiments, we may consider γ = 40-45° as most rational; the given values of ξ also correspond to this value.

After computing P_0, we can determine the torque $M_t = P_u r$, where r is the outer radius of the rotor, and then we can also determine the power of the starting layout:

$$N = M_t \omega.$$

For the investigated case, the specific rate of flow of compressed air when the pressure of the air in front of the nozzle is P_p = 9.8 bar and the circumferential velocity varies between 0 and 70 m/s is:

$$\bar{G}_p = \frac{G_n}{P_u} = 0{,}00285 \div 0{,}0033 \quad \text{kg/N·s}.$$

The specific rate of flow of compressed air, adjusted per unit of power, under the same air parameters in front of the nozzle and when u = 70 m/s, is: /137

$$\bar{G}_N = \frac{G_n}{N} = 0{,}0493 \quad \text{kg/s·kW}.$$

When a small-scale turbine is used as a starter motor, the rate of flow of working substance will be less, but a rigid mechanical linkage is required with the rotor of the turbo-compressor being started, the reducer, and the uncoupling clutch.

As shown by investigations, for purposes of economizing on working substance when starting up the gas turbine engine of a small-scale turbine, the start must be done quickly, for despite the increasing rate of flow per second the overall amount of air for the start-up is diminished [2]. For example, for an GTM having a rotor moment of inertia $J = 50$ kgm^2, when the rate of flow of air per second is $G_0 = 0.5$ kg/s the start-up is done in 122 seconds, while the overall rate of flow of air is equal to 62 kg; when the rate of flow per second is increased to 5 kg/s, the rotor attains its starting revolutions ($u = 70$ m/s) in 10 seconds, and the overall rate of flow of air is reduced to 50 kg.

An analysis of the start-up without starter reveals that the consumption of air does not depend on the starting time (for a rotor similar to that in the preceding example, the necessary air consumption is 88 kg for any given start-up time).

This peculiarity of the described start-up method recommends it for use with massive rotors, requiring a lengthy time of acceleration for warm-up, and in this case it is fully competitive with a small-scale turbine.

A non-rigid gas dynamic transmission with start-up rotor minimizes the possibility of fracture resulting from incorrect action on the components of the starting system.

Moreover, large rates of flow of compressed air per start allow us to recommend the described start-up as the main operation only when a capacious source of compressed air is present (a powerful multipurpose compressed air system, tapping of air from the compressor of a neighboring gas turbine engine in operation, etc.).

When it is necessary to create a back-up starting system for the GTE from an energy source other than the main, e.g. an electric source, we may recommend a similar start-up from cylinders of compressed air or a compressor of sufficient power.

References

1. Moiseyev, A. A., Sudovyye parovyye turbiny [Ship Steam Turbines], Morskoy transport, Moscow, 1958.

2. Yemin, O. N., Vybor parametrov i raschet osevykh aktinvnykh turbin dlya privoda turboagregatov [The Selection of the Parameters and the Design of Axial Active Turbines for the Drive of Turboassemblies], Oborongiz, Moscow, 1962.

Submitted by the Department for Ship Power Plants

[July 14, 1976]