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ANALYSIS OF THE OPERATING LOAD OF THE TURBINE ENGINE DURING DECELERATION TO DASH MANEUVER

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ABSTRACT

The article presents the analysis of the loads on the gas generator of turbine engine power of unmanned helicopter. The analysis was performed for deceleration to dash maneuver. Particular attention was paid to loads of bearing assembly in gas generator of turbine engine. The analysis was based on the timelines of changes in velocity of manned helicopter PZL W3-Falcon. The dependence of velocity changes during the flight was made as approximation by the least squares method and then determined for its change in acceleration. On this basis, the forces acting on the bearing gas generator assembly in static and dynamic conditions were determined. These values were compared with values obtained during maneuvers such as "jump up and jump down" and "acceleration and deceleration maneuver".

KEYWORDS: helicopter, turbine engine, gas bearings, foil-air bearings

ANALIZA OBCIĄŻEŃ SILNIKA TURBINOWEGO PODCZAS WYKONYWANIA MANEWRU HAMOWANIA PRZED ATAKIEM

STRESZCZENIE

W artykule przeprowadzono analizę stanów obciążeń działających na zespół wytwornicowy silnika turbinowego z odbiorem mocy na wale do napędu bezałogowego śmigłowca. Analizę wykonano dla manewru hamowanie przed atakiem. Szczególną uwagę poświęcono obciążeniom węzłów łożyskowych zespołu wytwornicowego silnika turbinowego. Analizę dokonano na podstawie przebiegów czasowych zmian prędkości lotu załogowego śmigłowca PZL W3-Sokół. Zależność zmiany prędkości lotu w czasie aproksymowano metodą najmniejszych kwadratów, a następnie wyznaczono dla niej zmiany przyspieszeń. Na tej podstawie wyznaczono wartości sił działających na łożyska zespołu wytwornicowego w warunkach statycznych i dynamicznych. Wartości te porównano z wartościami uzyskanymi podczas manewrów takich jak „skok w górę i skok w dół” oraz „przyspieszenie i hamowanie”.

SŁOWA KLUCZOWE: śmigłowce, silniki turbinowe, łożyska gazowe, gazowe łożyska foliowe

1. Introduction

A helicopter very often does a task in such flight conditions, in which it is exposed to significant loads on the rotor, tail rotor, structure of the fuselage and drive components including drive motors, thus bearing nodes of the engine rotational units. These states are the consequences of extreme flight maneuvers resulting from the tasks of flight or variable flight conditions. In addition, rapidly changing flight parameters, such maneuvers cause suitably intense changes of the engines parameters and achieve the limit state [1]. This paper presents an analysis of acceleration, subjected to the gas generator of turbine engine, which was carried out and based on the experimental studies

of the behavior of the helicopter PZL W-3 "Falcon" in flight NOE [2]. The helicopter including unmanned constructions must perform specific tasks combat, such as observation of the enemy, discharging of an explosive device, fire a shot at its sufficient maneuverability avoiding the possibility of shoot down. It is assumed that the helicopter does not take air combat. The presented method of the analysis results from the lack of experimental data relating to the behavior of extreme flight of unmanned helicopters.

2. Description of the research problem

The study analyzes the foil-air bearings load of gas generator in turbine engine with a power of 18 kW. The object of the research is a turboshaft engine. The rotational speed of gas generator turbine, as well as the whole assembling is 96,000 rev/min, while the drive unit is 60,000 rev/min (Fig. 1). This engine and its gas generator assembling has been thoroughly described in [3, 4].

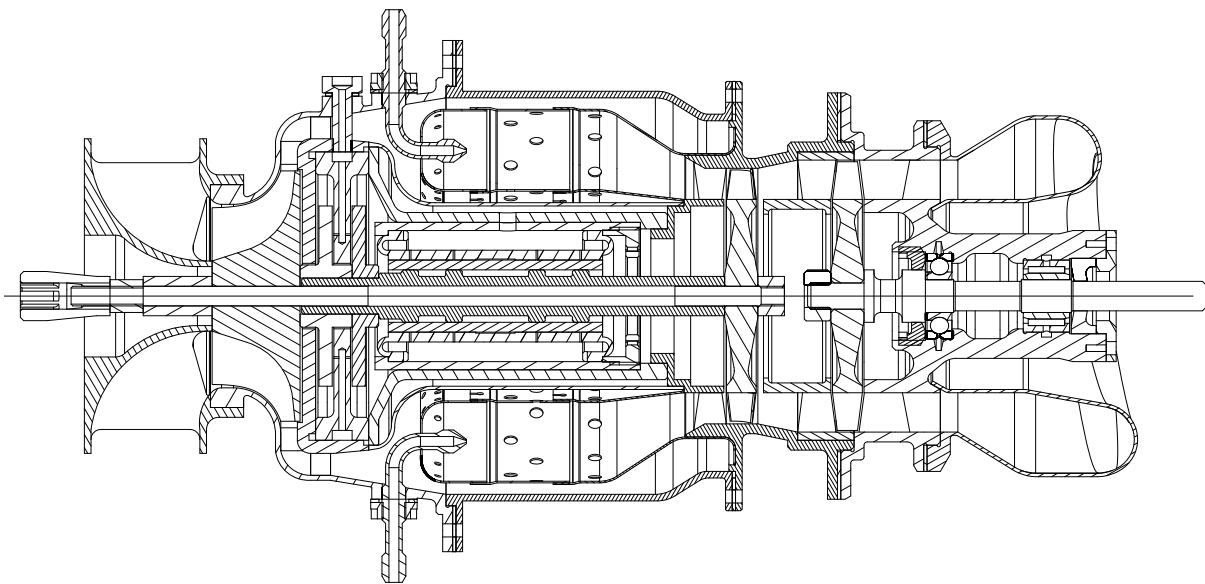


Fig. 1. A turbine engine FSTC-1 for the unmanned helicopters [3]

The scope of this work includes the analysis of loads during deceleration to dash maneuver. This maneuver involves horizontal braking and acceleration from the execution of the steady flight at the speed of 222 km/h. When the velocity reached 92 km/h, inclination of the helicopter was dynamically changed to the maximum acceleration, power to almost maximum, and held until it reached the initial speed. The justification for the use of this maneuver is the ineffectiveness of shots at major cruising speeds. Therefore, it is important to reduce the velocity to the optimum, as quickly as possible after giving a shot to return to the initial velocity (cruising). Diagram of deceleration to dash maneuver has been shown in Figure 2 [2].

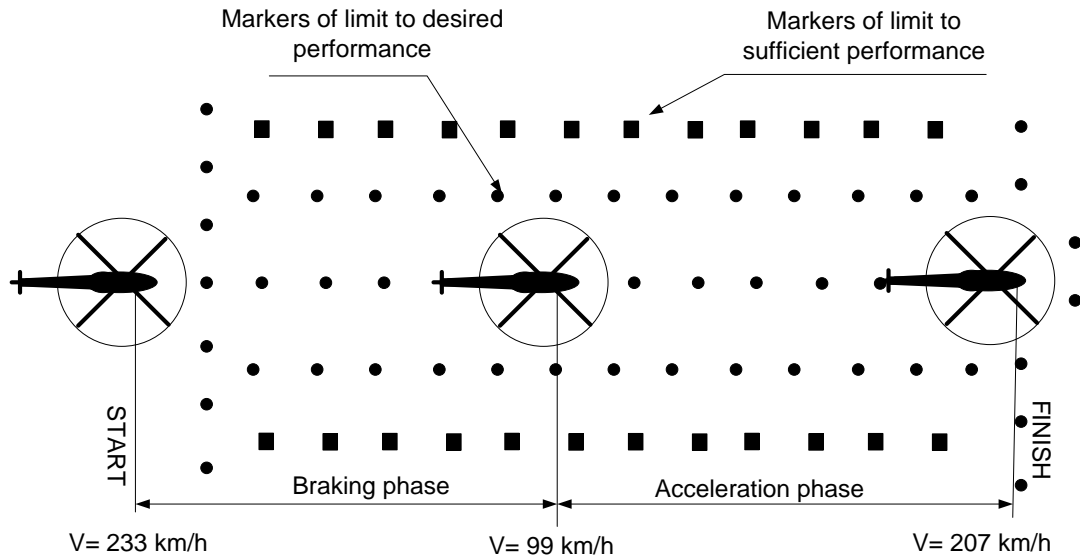


Fig. 2. Diagram of deceleration to dash maneuver, own study based on [2]

3. Analysis of the results

The analysis was performed taking into account the characteristics of the helicopter speed during the flight. From the Figure 3 coordinates of the points presented in the Table 1 was read. Then, using the Approximation v1.5.9.2 software, the approximated function was made by the least squares method.

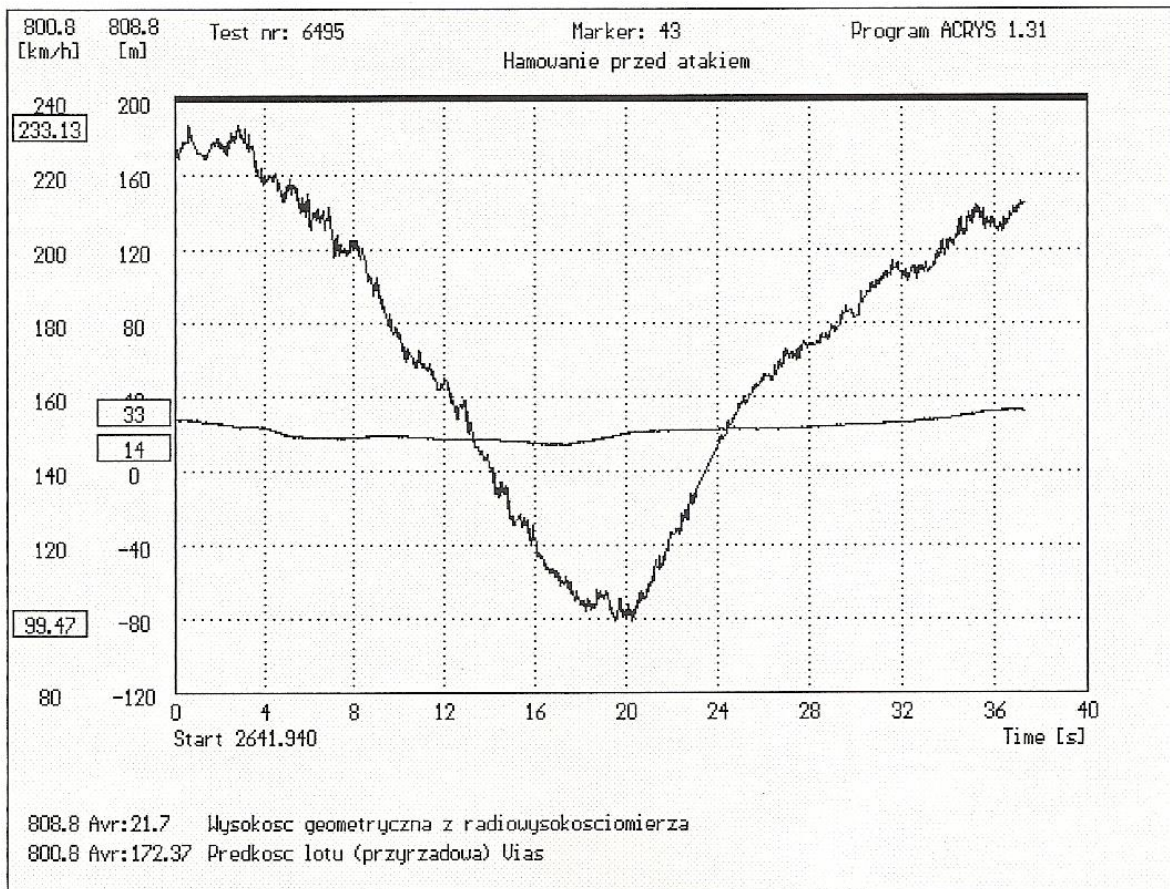


Fig. 3. Characteristics of selected parameters during deceleration to dash maneuver. The horizontal axis presents time [s] while the vertical axis shows the helicopter flight velocity [km / h] and altitude [m], [2]

The coordinates shown in the Table 1 are approximated by the least squares method presented below, to give the 13-degree polynomial. The degree of the polynomial is contingent upon receiving the least mistakes.

Table. 1. Velocity changes according to the time for the deceleration to dash maneuver read from figure 3

No.	Time [s]	Velocity [km/h]	No.	Time [s]	Velocity [km/h]
1	4	220.00	18	21	124.33
2	5	215.47	19	22	133.69
3	6	211.40	20	23	144.40
4	7	206.87	21	24	157.83
5	8	201.14	22	25	167.19
6	9	191.33	23	26	173.22
7	10	181.52	24	27	179.26
8	11	173.22	25	28	180.77
9	12	165.68	26	29	183.79
10	13	158.13	27	30	188.31
11	14	149.53	28	31	194.35
12	15	140.03	29	32	197.37
13	16	131.73	30	33	198.88
14	17	124.18	31	34	203.4
15	18	118.9	32	35	210.95
16	19	116.79	33	36	207.93
17	20	118.75			

Below are shown the polynomial which describes the relationship velocity between the time V (1) and acceleration a in the performance of the deceleration to dash maneuver (2):

$$\begin{aligned}
 V = f(t) = & ((1.3818195369598E - 6) * x^{13}) + (1.95527473904951E - 12) * x^{12} + \\
 & (-1.23412468831081E - 10) * x^{11} + (2.52904203249817E - 9) * x^{10} + \\
 & (7.497954108331E - 8) * x^9 + (-4.67352740995412E - 6) * x^8 + \\
 & (4.41275670366536E - 5) * x^7 + (0.00263382667970332) * x^6 + \\
 & (-0.102943314401678) * x^5 + (1.75344066877127) * x^4 + \\
 & (-16.8373507704778) * x^3 + (92.9729339246315) * x^2 + \\
 & (-273.948650603326) * x^1 + (392.356140535162) * x^0
 \end{aligned} \tag{1}$$

$$\begin{aligned}
 a = \frac{\partial V}{\partial t} = & (13 * (1.381819536959E - 6) * x^{12}) + (12 * 1.955274739049E - 12) * x^{11} + \\
 & (11 * (-1.23412468831081E - 10) * x^{10}) + (10 * 2.52904203249817E - 9) * x^9 + \\
 & (9 * 7.497954108331E - 8) * x^8 + (8 * (-4.67352740995412E - 6) * x^7 + (7 * \\
 & 4.41275670366536E - 5) * x^6 + (6 * 0.00263382667970332) * x^5 + (5 * \\
 & (-0.102943314401678) * x^4 + (4 * 1.75344066877127) * x^3 + \\
 & (3 * (-16.8373507704778) * x^2) + (2 * 92.9729339246315) * x^1 + \\
 & (-273.948650603326) * x^0
 \end{aligned} \tag{2}$$

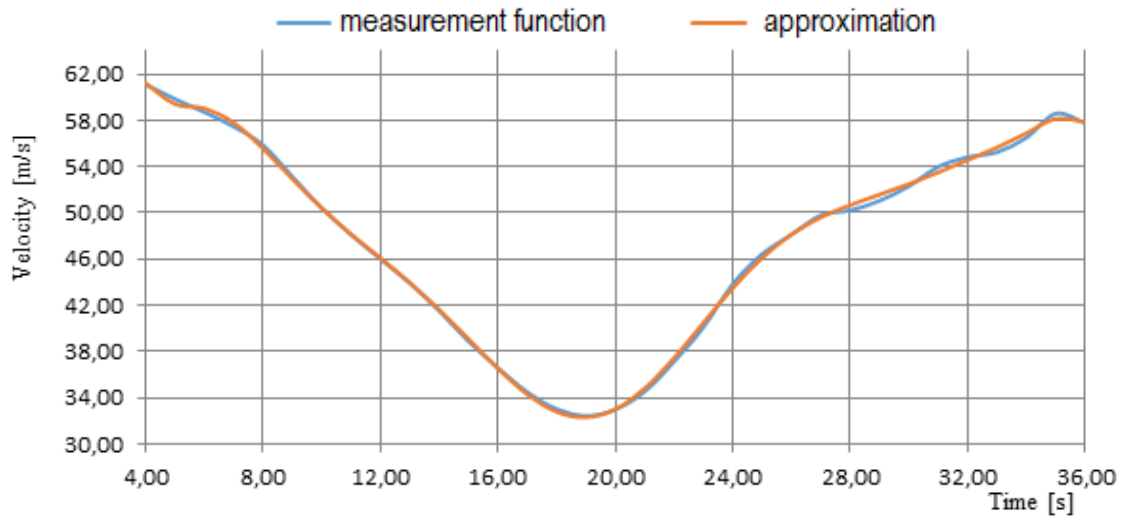


Fig. 4. Measurement and approximating functions form the velocity of the helicopter PZL W-3 Falcon flight depending on the time during deceleration to dash maneuver

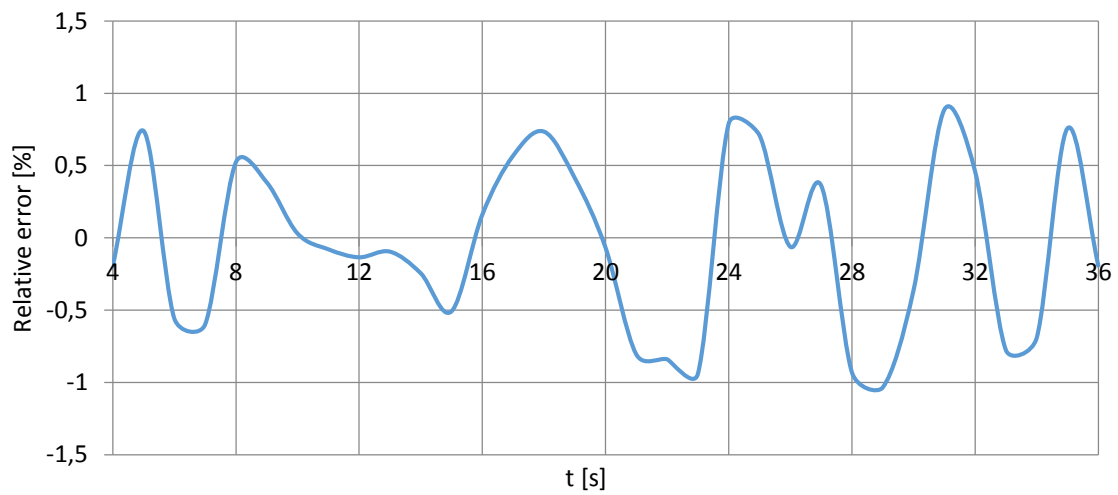


Fig. 5. Relative error of helicopter PZL W-3 Falcon velocity approximation according to the time during deceleration to dash maneuver

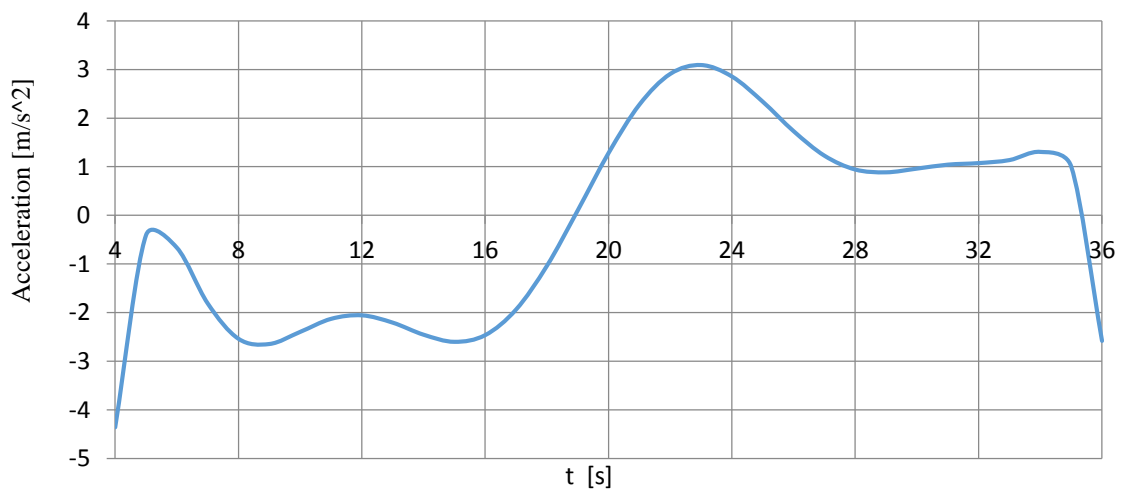


Fig. 6. Acceleration of helicopter W-3 Falcon for deceleration to dash maneuver

During deceleration to dash maneuver we have to deal with the forces:

R_{A1}^y/R_{B1}^y – the force of gravity of the rotor assembly,

R_{B1}^x – gas force of aerodynamics influence,

R_{B2}^x – force caused by axial acceleration during the maneuver.

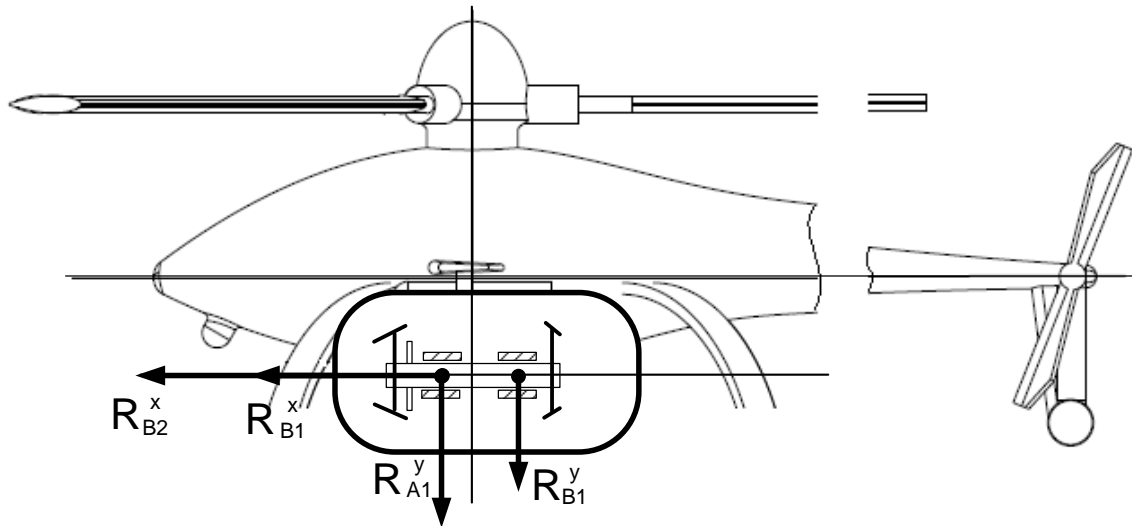


Fig. 7. Diagram of foil-air bearings load during deceleration to dash maneuver, own study

It is assumed that the working components of the gas generator are structured in the way, that the forces in axis formed by the aerodynamic phenomena equals 0. This fact causes that the forces R_{B1}^x is reduced to 0. While the gravity force is (as static calculation):

$$R_{A1}^y = P_{A1}^{st} = 5.638 \text{ N}$$

$$R_{B1}^y = P_{B1}^{st} = 1.631 \text{ N}$$

The forces acting on the radial bearings arise only from the weight of rotor parts of this assembling, thus:

$$a_{\Sigma} = g = 9.81 \text{ m/s}^2$$

$$k_1 = \frac{a_{\Sigma}}{g} = 1$$

$$P_{A1}^{y \text{ dyn}} = k \cdot P_{A1}^{st} = 5.638 \text{ N}$$

Inertial forces acting on the axial bearings are caused by acceleration during the maneuver and represent multiples of gravity of the whole parts of rotational set Q_c , where the multiples coefficient is overload factor k_2 . The analysis of the maximum acceleration reached $a_{\max} = 4.36 \text{ m/s}^2$, therefore:

$$a_{\Sigma} = a_{\max} \quad (3)$$

$$a_{\Sigma} = 4.36 \text{ m/s}^2$$

The overload factor is described by:

$$k = \frac{a_{\Sigma}}{g} = 0.44$$

$$P_{A2}^{x \text{ dyn}} = k \cdot Q_c = 3.2 \text{ N}$$

4. Conclusion

During deceleration to dash maneuver, we have to deal with the forces of gravity of the gas generator set, gas aerodynamics force and force caused by axial acceleration during the maneuver. If we assume that the working components of gas generator set are designed so that, they made an axial gas aerodynamic forces interactions to equalize, the remaining forces work with a value that results from motion profile of the helicopter. By basing it on the presented analysis we can make a results compilation. For this maneuver gravity forces (on the basis of statistical calculations) are, respectively, for bearing A=5.638 N and for the bearing B=1.631 N. As the coefficient k in this direction is equal 1, these forces result only from the mass of the rotor set. From Figure 9 the acceleration value was $a_{\max}=4.36 \text{ m/s}^2$. The coefficient k is 0.44. After multiplication of k factor and the mass of all components of gas generator set that act on the bearing, the R_{B2}^x axial force called axial acceleration during deceleration to dash maneuver is 3.2 N. In the maneuver jump up and jump down [3] this force was omitted, however in this case is one of the significant values. With respect to the radial forces, during the maneuver jump-up and jump-down radial bearing A is more loaded than the bearing B and the maximum value of the loading force radial bearings (bearing node A) is $P_p=17.1 \text{ N}$. In [4] the results of analysis for acceleration and deceleration maneuver. During this maneuver forces act similar as in the present work. The maximum acceleration in the axial direction reached 10.47 m/s^2 and axial force increased to 7.63 N.

5. References

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