TESS Research in Research and Reviews

Open Access
Research Article
Volume 2:1

The Modelling Between Propulsion Force, Speed and Blade Rotation and Radius Parameters in Five Blades of Helicopter

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Received date: 12 April 2023; **Accepted date:** 13 April 2023; **Published date:** 16 April 2023

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Abstract

As the blade radius and pitch angle increases the propulsion speed and force has increased, which has been proven through modelling in this study. With increasing the inclination θ and angle ϕ the propulsion will increase, while increasing the time it will increase in proportion. The propulsion force and speed will increase when the inclination θ and pitch angle b & attack angle a increases. It increases with increasing blade radius secondly. It will increase too with the increasing angle f and rotation thirdly. The turn is β> ϕ> r i.e. Pitch angle β is first and then angle ϕ, final radius in this paper. The propulsion speed and force of helicopter will increase when the pitch angle b、the inclination θ, attack angle α and angle ϕ increase respectively. Meantime the speed will decline when the pitch angle and radius of helicopter increases from 10º to 20º and from 5.7m to 6.7m respectively. That's saying the speed increases which is caused by big pitch angle and radius. In order to promote the propulsion speed through parameters. It has been controlled through pitch angle and radius too.

Keywords: Propulsion modelling; Blade; Helicopter; Inclinationθ; angleϕ; radius R; propulsion speed and time; Rotation; Pitch angle β; Angle of attack α

Introduction

The helicopter is prevail in modern society because it has rapid flight than other usual motorcycle and vehicle. It accommodates more people to proceed transportation task in passenger's loaded large helicopter. For example the injured one and substantial is needed rapidly arrangement. So in critical environment it can dominate over the situation rapidly like building and forest flame disaster. It can wield its effect in modern war due to its swiftness and mobile. It has attacking capacity in large scope. So it is investigated for the purpose of this utility. The propulsion of helicopter is studied to search its effect on its speed which is important simulation in dynamics of helicopter. It is known that the high speed change will increase the propulsion. So the long blade length will be searched further because of its influence on the high helicopter speed. The propulsion determines the speed change directly [1-21]. On the other hand, it will be affected by load mass so it is determined by a rated load. To promote the rated load it will be designed to be big for example the blade radius length, quantities and other factors like angle f and rotational speed & inclination. So as to raise the rated load and speed it is investigated three parameters in this paper i.e. pitch angle β,, angle ϕ and radius R mainly. Through comparing with each other the advantage is searched in this study to further investigation later. On the other side, the speed of helicopter is also important one for us to search further in this paper because it is significant property to evaluate its function. The speed is a key factor to complete its task rapidly, thereby here the detail situation is discussed to model its function. Overview, the propulsion force and speed of helicopter is important factor so its effectiveness is needed to search in detail. The general turn is concluded in total according to this modelling. In this paper the acceleration is computed in terms of theoretical dynamics to be used in this research. It is supposed that five blades exist in helicopter for the sake of its stability. The propulsion speed is main factor to be considered because of its important role. The helicopter propulsion force is another factor to be modelled for looking forwards to finding its relationship between them. It is to promote the property of helicopter through these modelling parameters is our destination finally.

Modelling and Equation

In the schematic graph as Figure 1 O is blade center; θ is inclination, º; F_L is lift force, N; F_n is normal force, N; F_t is rotational force, N; F_p is propulsion force, N; M_c is the mass center, kg. The model equation has been deduced as below. Figure 2 shows the relationship between the propulsion force and rotational one in rotational plane of blades. It is known that the plane is vertical to the Figure 1 plane.

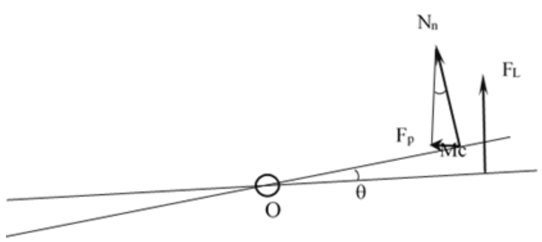


Figure 1: *The schematic of propulsion force in a blade of helicopter.*

Figure 2: *The schematic of propulsion force in rotational plane.*

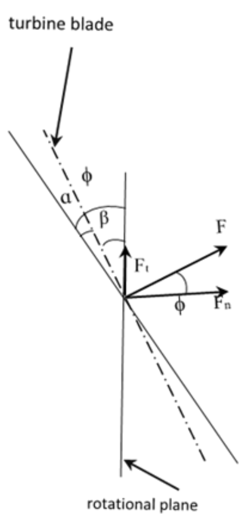


Figure 2: *The schematic of force and speed in blade of helicopter.*

Meantime the force and speed relation is as seen in Figure 2. F is force, N; ϕ is angle $\alpha+\beta$, º; α is angle of attack, º; β is pitch angle, º.

Mass center M_c's orbit equation is

$$x^2 + y^2 = r^2 \quad (1)$$

Here it has

$$\begin{cases} x = r\cos\theta \\ y = r\sin\theta \end{cases} \quad (2)$$

It has been derived, it is

$$\begin{cases} \dot{x} = -r\dot{\theta}\sin\theta \\ \dot{y} = r\dot{\theta}\cos\theta \end{cases} \quad (3)$$

It has been secondly derived, it has

$$\begin{cases} \ddot{x} = -r\ddot{\theta}\sin\theta - r\dot{\theta}^2\cos\theta \\ \ddot{y} = r\ddot{\theta}\cos\theta - r\dot{\theta}^2\sin\theta \end{cases} \quad (3)$$

Since

$$a_M = \sqrt{\ddot{x}^2 + \ddot{y}^2} \quad (4)$$

It has

$$a_M = \frac{\pi n r}{30}\sqrt{\frac{1}{t^2} + \left(\frac{\pi n}{30}\right)^2} \quad (5)$$

Here $\dot{\theta} = \frac{\pi n}{30}$ (6) and $\ddot{\theta} = \frac{\pi n}{30t}$ (7)

$$\begin{cases} \sin\theta_1 = F_1/N_1 \\ \ldots \\ \sin\theta_n = F_n/N_n \end{cases} \quad (8)$$

$$\begin{cases} N_1 = F_{i1}\sin\phi \\ \ldots \\ N_n = F_{in}\sin\phi \end{cases} \quad (9)$$

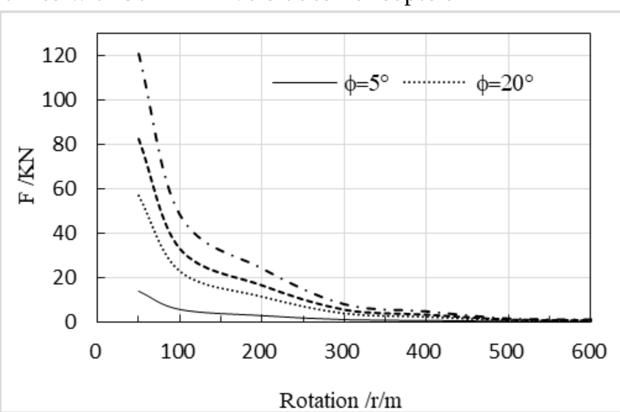
$$F_p = F_1 + \ldots + F_n = (F_{i1} + \ldots + F_{in})tg\theta \cdot \sin\phi \quad (10)$$

So it is $v_p = (F_1 + \ldots + F_n)t/m$ (11)

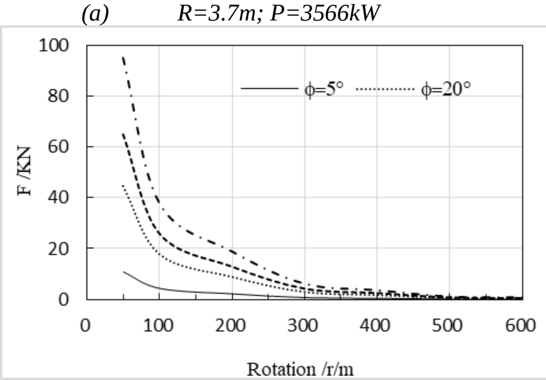
Here r is the radius of blade, m; n is the rotation, r/m; am is center of mass in blade, m/s^2; θ is inclination, º; ϕ is angle $\alpha+\beta$, º; v_p is the speed of helicopter, m/s^2; t is the time, s; m is the mass, Kg.

Discussions

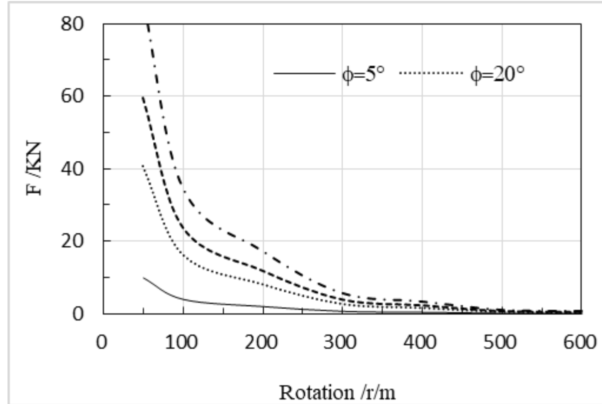
The relationship between propulsion and time is investigated as below with different parameters. Three conditions of pitch angle β, angle ϕ and blade radius R as correspond parameters to compute for helicopter's blade. It gains three groups of value to estimate theses. In this paper all the relational parameters have been calculated on the helicopter and its blades. It is tried out that finding intrinsic relationships happens in helicopter flight in order to simulate the data changing conditions. The propulsion force and time is searched here according to different pitch angle, angle ϕ & blade radius in helicopter while the speed and time is in research of the rotation of blade and mass of helicopter with different inclinations. The main task has grasped the force and propulsion speed with the time. The other parameters like blade pitch angle β, angle ϕ, blade radius r & inclination θ are used to proceed as well. The detail discussions are shown as below. In Figure 4 with increasing blade radius R from 3.7m to 4.7m the propulsion will decrease from 50kN to 25kN with angle ϕ of 47° and rotational speed of 100r/m. Meantime, with increasing angle ϕ from 5°, 20°, 30° to 47° it will increase as well. It is noted that it is better to adopt big angle ϕ for promote propulsion. On the contrary it is better to use bigger angle ϕ. The average propulsion change is about 20kN with these adjacent angles ϕ in the whole conditions. When the power decreases from 3,566kW to 2,566kW the propulsion will decrease as well as mentioned above value. It corresponds to logic well. Here the propulsion is low about 10kN at rotational speed 200r/m because the one blade is calculated, so the total propulsion is 5 times with 50kN in five blades helicopter.



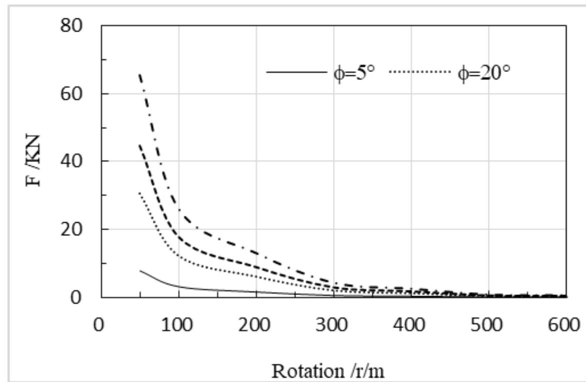
(a) R=3.7m; P=3566kW



b) R=4.7m; P=3566kW



c) R=3.7m; P=2566kW

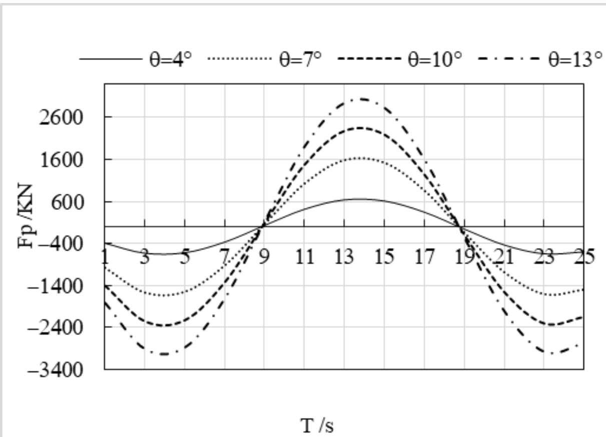


d) R=4.7m; P=2566kW

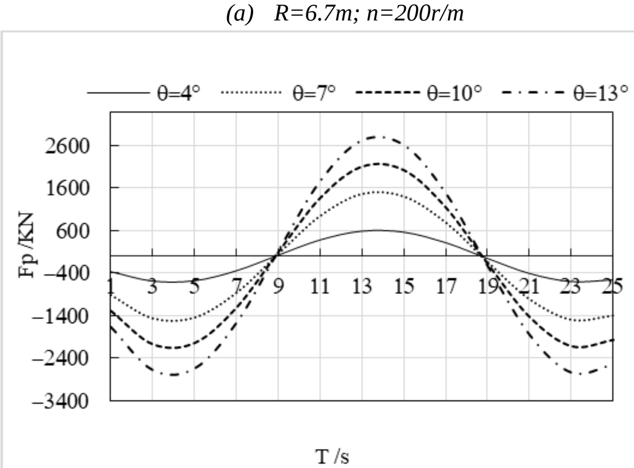
Figure 3: *The relation of propulsion and rotation with various angle ϕ= 5º, 20º, 30º &47º when different power and radius in one blade of helicopter.*

As seen in Figure 5(a~d) the propulsion speed will increase with time when the radius and rotational speed increases in the ϕ=20º. In another word when the radius increases from 3.7m to 4.7m and the rotational speed increases from 220r/m to 280r/m the propulsion speed will increase from 300m/s to 500m/s at the 0.5s as well. The maximum speed attains 500m/s at θ=13º and R=4.7m & n=280r/m at this time as seen in Figure 5(b). As seen in Figure 5(a) the lowest one is about 300m/s at R=3.7m and n=220r/m & R=4.7m and n=220r/m which is equal to the lowest radius and rotational speed in helicopter. It means that with increasing blade radius to be R=4.7m the propulsion speed will increase to the minimum 300m/s at angle θ to be 13°. The whole propulsion will maintain a increasing value in proportion with the time with increasing time from 1s to 1.2s. Here, it is known that the propulsion is loaded at one blade so the total propulsion becomes 5 times of the curve one due to 5 blades in one helicopter. Therein the 500kN i.e. 50 tons at the conditions of rotation 50r/m、power 3,566kW, ϕ=47º & radius 4.7m has become maximum as aeen in Figure 4(b). The change trun is as below, 200kN, 100kN, 40kN & 25kN i.e. 20tons, 10tons, 4tons & 2.5tons as the rotation becomes 100r/m, 200r/m, 300r/m & 400r/m respectively at the same conditions. As ϕ=30º that will become 300kN, 100kN, 50kN, 30kN

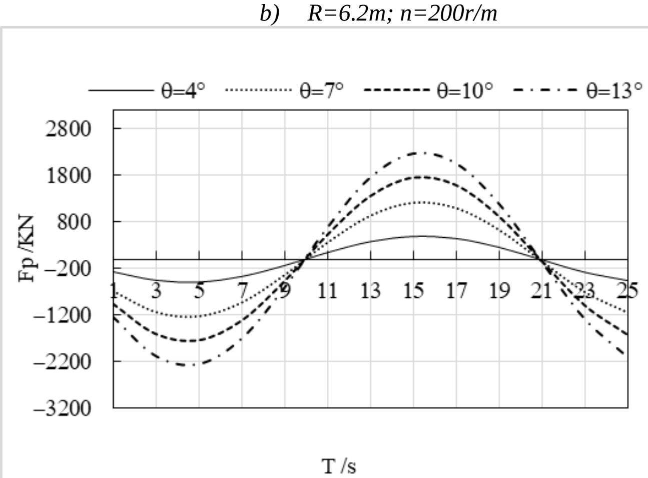
& 20kN with the rotation to be 50r/m, 100r/m, 200rr/m, 300r/m &400r/m respectively, which is lower than the former because of its small angle. On the other hand, as ϕ=4º that will become 50kN, 25kN, 10kN, 5kN & 4kN with the rotation to be 50r/m、100r/m、200rr/m, 300r/m &400r/m respectively, which is lower than above two. That has become the lowest force due to its smallest as seen in Figure 4(b). In the same way others may be observed so that we can see the similar tendency in other conditions.



(a) R=6.7m; n=200r/m



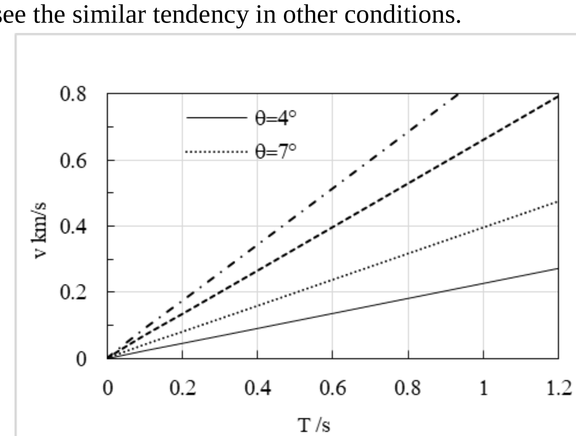
b) R=6.2m; n=200r/m



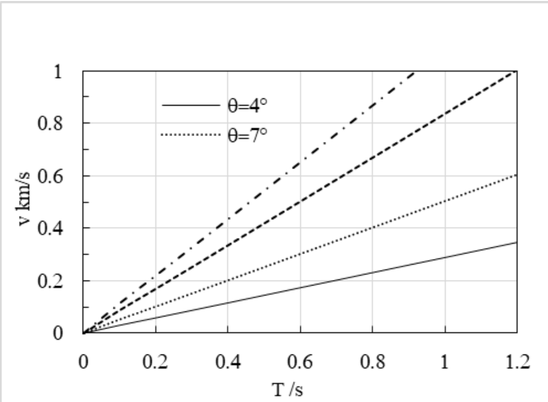
c) R=6.2m; n=180r/m

Figure 4: *The propulsion force and time with different θ when the blade radius and rotation is different under 23tons of helicopter.*

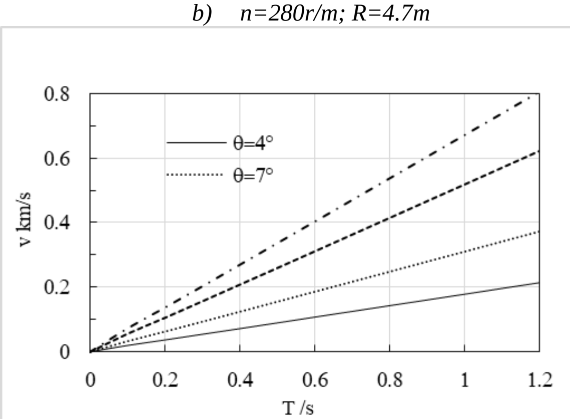
As seen in Figure 5(a~d) the propulsion speed will increase with time when the radius and rotational speed increases in the ϕ=20º. In another word when the radius increases from 3.7m to 4.7m and the rotational speed increases from 220r/m to 280r/m the propulsion speed will increase from 300m/s to 500m/s at the 0.5s as well. The maximum speed attains 500m/s at θ=13º and R=4.7m & n=280r/m at this time as seen in Figure 5(b). As seen in Figure 5(a) the lowest one is about 300m/s at R=3.7m and n=220r/m & R=4.7m and n=220r/m which is equal to the lowest radius and rotational speed in helicopter. It means that with increasing blade radius to be R=4.7m the propulsion speed will increase to the minimum 300m/s at angle θ to be 13°. The whole propulsion will maintain a increasing value in proportion with the time with increasing time from 1s to 1.2s. Here, it is known that the propulsion is loaded at one blade so the total propulsion becomes 5 times of the curve one due to 5 blades in one helicopter. Therein the 500kN i.e. 50 tons at the conditions of rotation 50r/m、power 3,566kW, ϕ=47º & radius 4.7m has become maximum as aeen in Figure 4(b). The change trun is as below, 200kN, 100kN, 40kN & 25kN i.e. 20tons, 10tons, 4tons & 2.5tons as the rotation becomes 100r/m, 200r/m, 300r/m & 400r/m respectively at the same conditions. As ϕ=30º that will become 300kN, 100kN, 50kN, 30kN & 20kN with the rotation to be 50r/m, 100r/m, 200rr/m, 300r/m &400r/m respectively, which is lower than the former because of its small angle. On the other hand, as ϕ=4º that will become 50kN, 25kN, 10kN, 5kN & 4kN with the rotation to be 50r/m、100r/m、200rr/m, 300r/m &400r/m respectively, which is lower than above two. That has become the lowest force due to its smallest as seen in Figure 4(b). In the same way others may be observed so that we can see the similar tendency in other conditions.



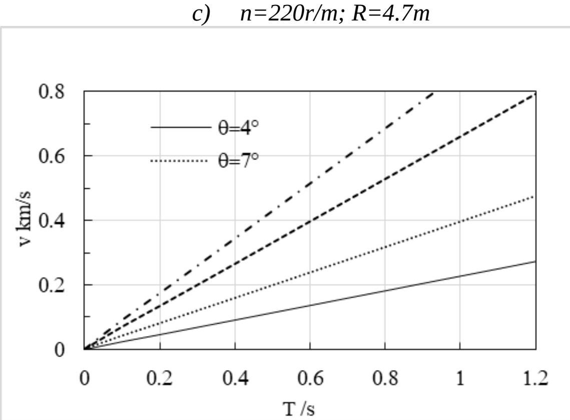
a) n=220r/m; R=3.7m



b) n=280r/m; R=4.7m



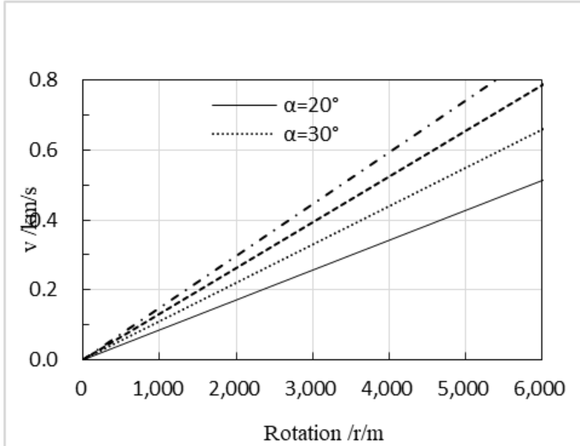
c) n=220r/m; R=4.7m



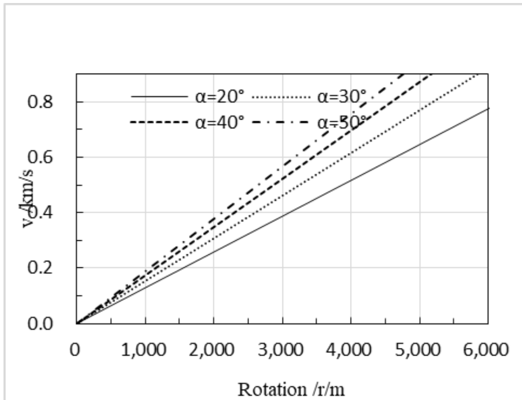
d) n=280r/m; R=3.7m

Figure 5: *The relation of propulsion speed and time with various inclinations and ϕ= 20º when different rotation and inclination in 5 blades of helicopter*

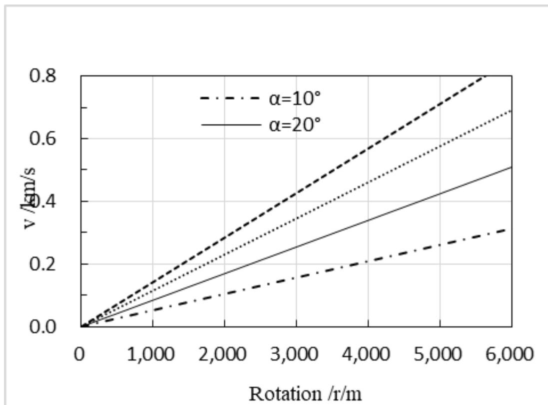
In Figure 6(a &b) the propulsion speed and rotational speed are exhibited with various angle of attack a from 20º~50º. The propulsion speed increases from 300m/s to 400m/s with the rotational speed increases at the pitch angle β from 10º to 20º and blade radius R from 5.7m to 6.7m & a of 50º under 2,000r/m in Figure 6(a). The average propulsion speed has been 50m/s in line with adjacent a from 20º, 30º, 40º to 50º. As seen in Figure 6(c &d) the maximum propulsion speed has been 160m/s to 120m/s with the angle of attack α=40º and n=1000r/m at the same pitch angle β=5º and various radius R=6.7m and 5.7m in a blade of helicopter. It means that the high radius results in high speed. The radius influences the speed since its value change is not little it has its effectiveness. In Figure 6(e) the propulsion speed attains 180m/s at the pitch angle β=25º and R=5.7m with the same others. It expresses that pitch angle causes the high speed with pitch angle β=25º to compare with β=5º. With increasing radius R and pitch angle b the propulsion speed will increase here. On the other side as the rotation speed enhances the propulsion speed increases in general. Furthermore, with increasing the angle of attack a it will increase too.



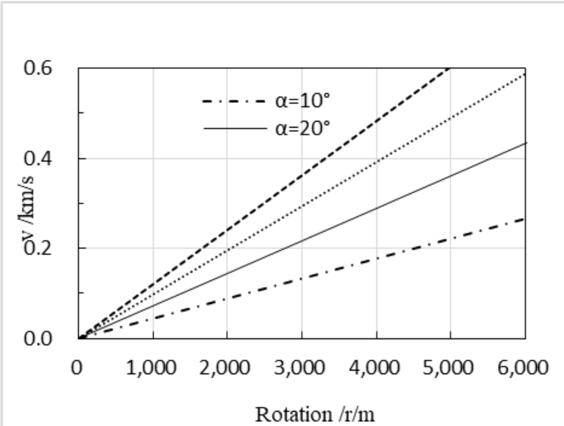
(a) β=10º, R=5.7m



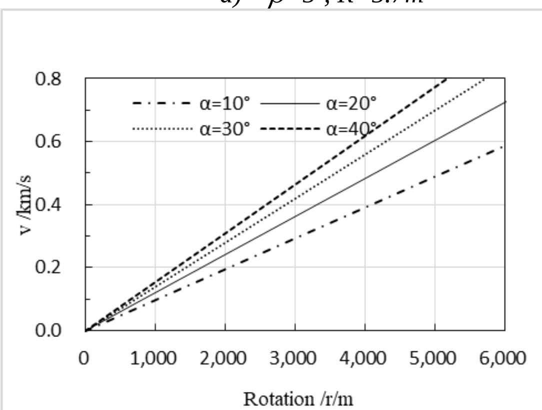
b) β=20º, R=6.7m



c) β=5º, R=6.7m



d) β=5º, R=5.7m



e) β=25º, R=5.7m

Figure 6: *The relation of speed and rotation with various angle of attack a= 10º~50º when different pitch angle β= 5º~25º and blade radius R=5.7m ~6.7m in a blade of helicopter.*

In short, it is found that the speed of helicopter will increase when the rotation and the inclination increase respectively. Meantime the speed will increase when the pitch angle and blade radius of helicopter increases from 10º to 20º and increases from 5.7m to 6.7m respectively in helicopter. That's saying the speed with rotation increases from 300m/s to 400m/s which is caused by pitch angle and radius. There is big difference in here which expresses the speed is changed with inclination from 4º to 13º. It expresses the speed is been controlled easily through inclination. The speed at 0.11km/s is 400Km/h which is near maximum speed in AH-64 Apachi Attack Helicopter so in order to promote the speed through inclination. It has been controlled through rotation and blade radius R & pitch angleβ. Thereby that the effective turns can be searched to regulate these parameters in order to promote its property has been essential. As the rotational speed raises to 5,000r/m the propulsion one may attain beyond 1,000m/s which attains near three times of voice speed 346m/s.

Conclusions

The propulsion force and speed will increase when the inclination θ and pitch angle β & attack angle α increases. It increases with increasing blade radius secondly. It will increase too with the increasing angle f and rotation thirdly. The turn is β> ϕ> r ie. Rotation is first and then angle ϕ, final radius in this paper. The propulsion speed and force of helicopter will increase when the pitch angle β, the inclinationq、attack angle α and angle ϕ increase respectively. Meantime the speed will decline when the pitch angle and radius of helicopter increases from 10º to 20º and from 5.7m to 6.7m respectively. That's saying the speed increases which is caused by big pitch angle and radius. In order to promote the propulsion speed through parameters. It has been controlled through pitch angle and radius too.

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