IDENTIFICATION AND ANALYSIS TAKE-OFF AIRCRAFT OPERATIONS

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Abstract

Air transport plays a major role in the development of world economic activity and remains one of the fastest growing sectors of the international economy. One of the key elements that contribute to the maintenance of civil aviation development is to secure safe, efficient and environmentally sustainable means of transport, at the global, local and regional level. At airports communication air operations take place at intervals of tens of seconds to several minutes. A very important operation that the aircraft has to perform before coming to a safe standstill is take off. One of the most important operation is take off the aircraft. Security is an integral factor in determining the movement of the aircraft.

The paper contains identification and analysis take off aircraft operations. The paper presents an analysis of the take-off operations including the rejected take-off. It is used in the analysis of the operation-taking place at the aerodrome of computer tools and methods. The result is the mathematical models form the basis for computer simulation. The aim of the article is modelling of the various stages of launch operations and identify basic models of these steps based on the parameters recorded by the flight data recorder aircraft. Constructed models imitating actual aircraft operations in the vicinity of the airport, will could be used in the practice of aviation.

Keywords: *air transport, ground operation, infrastructure of airport*

1. Introduction

In case of a take off operation, segmentation of this phase has been made and the made segments are not an exact reflection of the following phases: take off-run, lift-off, take- off climb. They were chosen to minimize the problem of function continuity on the intervals limits; which is the most significant defect of the computer identification method. There are six segments. These segments are: the first concerning beginning of take-off run, the next is take-off run until the moment of reaching the decision velocity (V_1), then the rotation velocity (V_R) until the moment of lift-off and take-off climb at safe velocity. The next segment concerning further take-off climb and undercarriage retracting. Retracting landing flaps is the fourth segment. The fifth concerning flight from the moment of retracting landing flaps until the moment of reaching the velocity of 210 knots and the last: flight until the moment of reaching the velocity of 250 knots (Fig. 1).

After determining the function form within all the segments for all the described variables, and after evaluation of this analysis through calculation of quality and identification coefficient, the model of the start phase is ready to be used.

This particular analysis allows analysing various parameters, with respect of demand and specific use of the model. We can also make complex identification of aircraft's movement dynamics at the start phase through identification of forces and moments of force, which affect the aircraft at take-off. This kind of projection can be used to build up for example flight simulators, used for training of air staff, [4]. In the example showed below, the model consists of real and vertical velocity of an aircraft at the start phase, which gives a basic representation of an aircraft's movement, its altitude and time of the operation. This analysis is sufficient to investigate the airstrip occupancy or to make another type of investigations aiming at the increase in the capacity and safety of motion within an airport area.

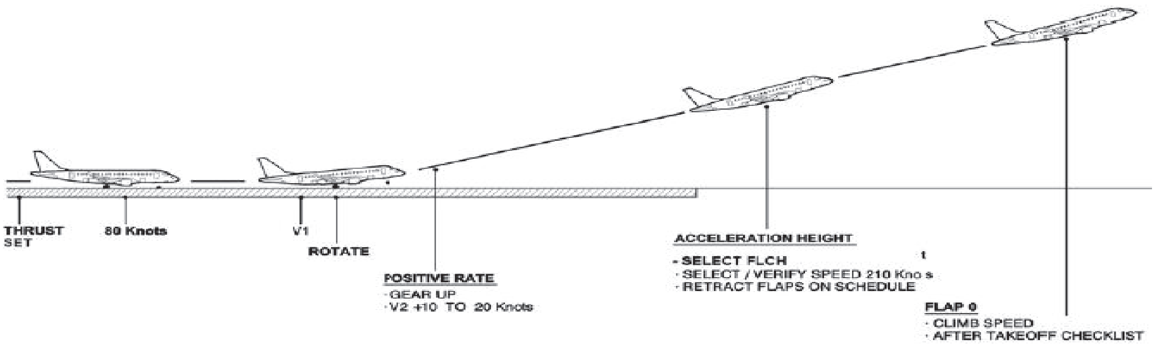

Fig. 1. The aircraft's take-off diagram

On Fig. 1, the division of the take-off phase into segments has been shown as well as the description of the area covered by particular segments. The division is also visible on Fig. 2 and 3, which demonstrate the time course of the real and vertical velocity of the aircraft at take-off.

2. Characteristic of take-off aircraft

Due to the high potential areas of passengers, as well as high speed through, today's airplanes must meet the highest safety standards. Verification of these standards can be charged with two sources: the European Aviation Safety Agency CS (Certification Specialisation 25) – 25 or JAR OPS 1 (the Joint Aviation Requirement for the operation of commercial air transport, aeroplanes).

In aviation, there are several classes of aircraft: Class A, B and C. Class A airplanes are all having a turboprop aircraft power unit with 10 or more passenger seats or take-off weight 5701 kg or more, and all the planes with turbojet power plant. Class B propeller planes having 9 seats or less, and their take-off mass does not exceed 5700 kg. However, a Class C aircraft are all combustion-powered aircraft that take-off weight is 5701 kg or more and have 10 or more seats. Aircraft Class A shall comply with the technical assumptions for engine failure during all phases of flight as well as planes Class C. However, the requirements for engine failure in airplanes Class B applies only to phases of flight above 300 feet.

All the rules and requirements are detailed in the regulations JAR. It is clear from the provisions of JAR need to consider the possibility of engine failure in each of the phases of flight. The rules are specified JAR the procedures that must be made before take-off operations.

Requirements for all classes of aircraft may seem similar, but in fact vary considerably. One of the major differences between the planes of Class A and Class B airplanes is a unique provision in the JAR of the need to take account of engine failure at any stage of the flight, as opposed to class B aircraft in which the engine failure was considered less than 300 feet. The result of such a restriction was necessary to introduce a number of new restrictions on speed at the start of operations, as well as greater emphasis lies on the remote control to make sure that the aircraft take-off mass does not exceed the maximum take-off weight for the corresponding values of temperature and pressure. These values are exactly as described in the operating manual.

The next step required the pilot before the flight is to make sure that the distance ASD (Accelerate-stop distance) is greater than the distance ASDA (Accelerate-stop distance available) and off distance is greater than available. The first and most important, from the point of view of security and performance at a speed V_1, also called speed decision-making. The basis of a security standpoint is that it determines the need for a critical decision when engine damage or other serious fault plane, which endangers the safety of the crew and passengers. This rate is defined as the maximum speed at which the pilot must take action to stop the aircraft, with the remaining distance available. But there is also a minimum speed during the accident, at which the pilot can continue the take-off distance available at other off. If the engine fails before reaching V_1 speed, the start will be aborted pilot decision. The reason for this is the fact that only one efficient engine, a distance that remains available is insufficient to continue the take-off and reach a safe height of 35 feet. If the engine fails at speeds above decision, the pilot must continue to start, since the plane crash when moving too fast, that it can be slowed down with available distance ASDA. Fig. 2 shows all the speed that must be achieved during the first phase of the launch.

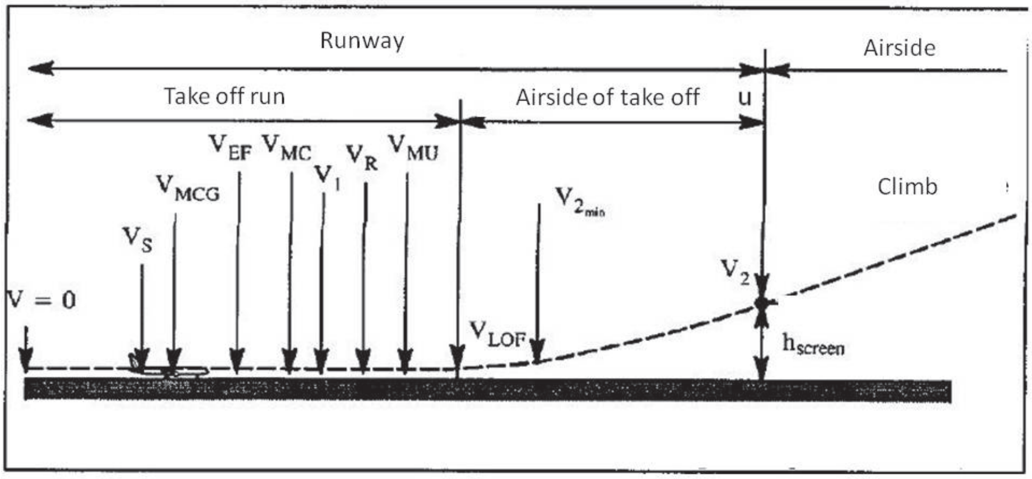

Fig. 2. The velocity of take-off aircraft [5]

The velocity V_{MU} is defined as the smallest CAS speed at which the airplane can safely away from the surface of the runway. However, when you reach the speed the aircraft is operated by remote control, thus delaying the moment of complete separation from the earth. The actual speed at which the plane loses contact with the ground is slightly larger than the textbook V_{MU} speed. This is due to the fact that the speed is close to the V_{MU} stall speed, and the ability to control the plane is very difficult. The actual total separation of aircraft at a speed of V_{MU} may result in dramatic situations, which probably could be very uncomfortable for both passengers and crew in accordance with Fig. 3.

Fig. 3. Airbus A340 at the detachment at a minimum velocity separation [6]

The actual velocity at which the aircraft is total detachment from the surface of the runway is the speed V_{LOF}, also known as speed of separation. CAS is the speed at which the first plane is in the air. The exact value of V_{LOF} are described in JAR and are as follows:

V_{LOF} not be less than:

1) 110% of V_{MU} (with all engines disabilities),
2) 105% of V_{MU} (with one engine inoperative).

Equally important at V_{MU} and V_{LOF} preceding the V_R. Reaching speeds of rotation is the moment when the pilot initiates action front wheel detachment from the surface of the runway, for subsequent separation of the total. As V_{LOF}, V_R has been carefully limited to JAR.
V_R must be not less than:
1) V_1,
2) 105% V_{MC},
and must allow for:
3) to reach a speed of V_2 before reaching a height of so-called safe: screen height,
4) the achievement V_{LOF} just after crossing the V_{MU}.

The final velocity in this part of the take-off speed is V_2, also known as safe start speed. The legislation is described in detail, as the target speed of the aircraft, which should be achieved during the flight with one engine inoperative. This speed is called safe, because the achievement of the plane is moving faster than the speed of drag and faster than the minimum maneuvering speed. It is the minimum speed, by which aircraft may have a sufficient supply within to achieve sufficient and appropriate angle of climb. Like all other speeds necessary to achieve take-off operations, V_2, also have their values specific guidelines:
V_2 be not less than:
1) $V_{2\ MIN}$
2) V_R
3) leads to the minimum speed maneuvering capabilities and V_{2MIN} be not less than:
4) 110% V_{MC},
5) 113% V_{SR} for two and three-engine turboprop and jet aircraft do not have to reduce the stall speed limit. However, this speed can be minimized to a speed of 108% V_{SR} for the four-jet and turboprop aircraft with stall speed limit reduction.

The velocity V_1 is given by the manufacturer of the aircraft and its value should be placed at the intersection graphs ASDR (ASDR – Accelerate – Stop Distance Available) and TODR (TODR – Take off Distance Required).

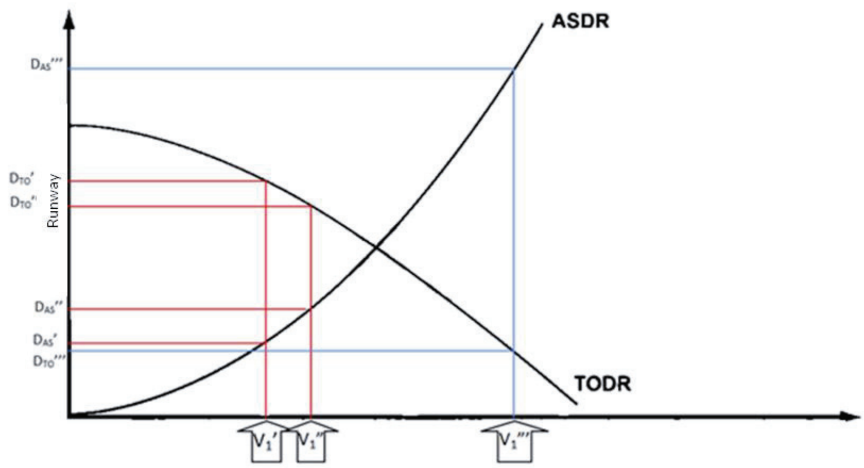

Fig. 4. The relationship between speed and road accidents stop

Figure 4 shows the possibility that the pilot will have a predetermined value depending on the speed of V_1. Determining the speed V_1 as V_1' should be noted that the distance ASDR for this speed is small (D_{AS}' – Distance to stop aircraft), while the length TODRA at the same speed is much higher. Slightly increasing the speed V_1 to the value V_1'' is seen that the distance required to stop ASDR (D_{AS}') increased as compared with the distance (D_{AS} ') at a speed V_1', and the distance required TODRA (D_{TO}'') decreased compared to the D_{TO}'. Ultimately, increasing the speed V_1 to the value at the point of V_1''' get a little distance required TODR and a very considerable distance required to stop the aircraft ASDR. In Fig. 4 also shows that the best value for V_1 is the value for which the curves ASDR and TODR intersect, giving equal value ASDR and TODR.

The value of V_1 speed is affected by many factors, and the size of the rate for basic changes in external factors can be found within every individual utility aircraft. V_1 Velocity depends on how the engine is mounted in the aircraft, the air temperature and the altitude at which the runway is located.

Another factor that has a direct impact on the speed V1 is the configuration of the aircraft. In textbooks use referred to above, can also find airplane configuration depending on the speed V_1, and the length of the runway.

3. Segments

Segment I

Running take-off of the plane is one of the phases of the start of operations, including the movement of the aircraft from zero speed until the wheels detach from the runway. When run on plane different forces interact. Coefficient of resistance to the wheel movement μr substrate surface depends mainly upon the condition and type of surface, on which the motion of the aircraft. Can assume values μ_r using, depending on the type of substrate. Heavy passenger and transport planes taking off from airports only concrete surface. Two important factors in flight mechanics are the drag force and the lift force expressed by formula:

$$P_x = \frac{\delta s V^2 C_x}{2}, \tag{1}$$

$$P_z = \frac{\delta s V^2 Cz}{2}, \tag{2}$$

where,

δ – air density,

S – bearing surface of the wings,

V – the velocity of the aircraft,

CX – coefficient of aerodynamic drag forces,

CZ – lift coefficient.

Using the given compounds aerodynamic forces are obtained:

$$\frac{dV^2}{ds} = \frac{1}{m}\left(P_s - \mu_r mg - \frac{\delta s V^2}{2}\left(C_x - \mu_r C_z\right)\right). \tag{3}$$

Following the method of separation of variables, the whole equation may be integrated to give the model equations on the road are:

$$s_1 = m\int_0^{V_{LOF^2}} \frac{\delta V^2}{\left(P_s - \mu_r mg - \frac{\delta s V^2}{2}\left(C_x - \mu_r C_z\right)\right)}. \tag{4}$$

The calculation of integrals with in the general case, it is possible only by numerical methods. However, making a small error (in the range below 10%) These equations can be simplified so as to calculate them effectively and receive the finished patterns on time and duration of acceleration. To this end, an analytical dependence of the rate (including the assumption of a constant orientation of the body relative to the ground plane).

$$P_s = const = (0.85 - 0.95)P_{\max}. \tag{5}$$

The values for the coefficients of lift CX and CZ aerodynamic drag forces in the above equations are dependent on the angle of attack. The values of these coefficients change dynamically during the run. In the initial phase of acceleration, factors are equal the parking angle of attack, but at a speed of separation V_{LOF} must be determined just from the speed, which for safety reasons is described in equation:

$$V_{LOF} = 1.15 D_{s0} , \tag{6}$$

where V_s is the stall speed during take-off equal:

$$V_s = \sqrt{\frac{2mg}{\delta S C_{z\_max}}} . \tag{7}$$

Segment II

Segment of take-off run until the moment of reaching the decision velocity, then the rotation velocity until the moment of lift-off and take-off climb at safe velocity cover operations smooth transition from horizontal movement to rise, the fixed angle of the flight path. For simplicity, in the following discussion, I will assume that this maneuver takes place with the participation of V_{WZ} constant speed, and that the centre of gravity of the aircraft moves in a circular arc.

Segment III

Another segment is the take-off climb of aircraft. This section begins with a plane reaches the height of 35 feet and continues until it reaches an altitude of 1,500 feet above the runway surface ground (AGL). During the climb is distinguished by the following requirements:

1) the airplane must achieve a minimum angle of climb
2) the airplane must maintain adequate independence from erecting barriers.

Operation climb can be made through the building of continuous or segmented ascent. Erection segment appears both from the standpoint of the procedures and technical requirements easier to carry.

This is the take-off phase, when it moves to the rectilinear path at a constant speed with a constant V_{WZ} and flight path angle Y_{wz}.

4. Identification

The identification has been made for three selected flights made on 14th (lot 1), 29th (lot 2) and 31st (lot 3) of December 2008. For each segment there were values of polynomial coefficients chosen, identified for one of the three flights mentioned above, with respect to the value of quality identification coefficients. The following data was obtain for the second segment:

Tab. 1. Coefficients of the real and vertical velocity function of the EMB 170 aircraft in segment III of the take-off phase

	14.12.2008		29.12.2008		31.12.2008	
coeff.	V_{m3}	w_{m3}	V_{m3}	w_{m3}	V_{m3}	w_{m3}
a_{23}/a_{33}	1.64E+02	-	1.67E+02	-1.16E+00	1.57E+02	-9.87E+02
b_{23}/b_{33}	-1.90E-01	-1.75E+01	-2.89E-01	1.03E+02	-1.41E-01	5.49E+01
c_{23}/c_{33}	-	8.34E-01	-	-2.11E+00	-	-9.56E-01
d_{23}/d_{33}	-	-7.08E-03	-	1.08E-02	-	7.00E-03
e_{23}/e_{33}	-	-1.08E-03	-	1.28E-04	-	-5.37E-05
f_{23}/f_{33}	-	1.32E-06		-1.22E-06	-	4.64E-07

As the result of the identification of the polynomial coefficients, as well as the verification of the value of the quality identification's coefficients, we obtained the functions describing the change in the aircraft's real and vertical velocity in the III segment of the take-off phase, based on the model flights of the EMB 170 aircraft, for flights 2 and 3 from December 29 and 30, 2008 (Fig. 5 and Fig. 6).

Tab. 2. Coefficients for the quality identification of the segment III in the EMB 170 aircraft's take-off phase

		14.12.2008		29.12.2008		31.12.2008	
		V_{m3}	w_{m3}	V_{m3}	w_{m3}	V_m	w_{m3}
Generalized coefficient of correlation ρ		0.7613	0.9460	0.9628	0.9213	0.7102	0.9867
Remnant variance σ^2		1.43E+00	2.92E+00	7.41E-01	2.31E+00	1.28E+00	1.21E+00
Confidence intervals	a_{23}/a_{33}	3.34E+00	-	1.63E+00	-	12.82E+00	-
	b_{23}/b_{33}	6.33E-02	-	3.12E-02	-	5.40E-02	-
	c_{23}/c_{33}	-	-	-	-	-	-
	d_{23}/d_{33}	-	-	-	-	-	-
	e_{23}/e_{33}	-	-	-	-	-	-
	f_{23}/f_{33}	-	-	-	-	-	-

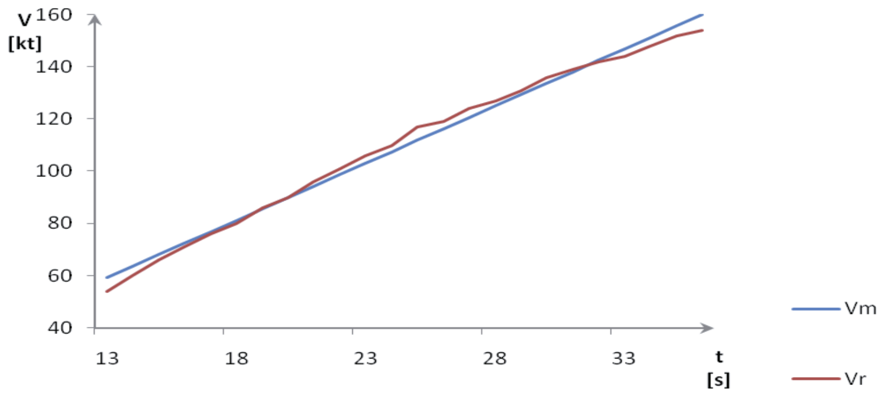

Fig. 5. Real velocity (V) recorded in real flight (V_r) and from aircraft model (V_m) in segment III take off phase for flight 2

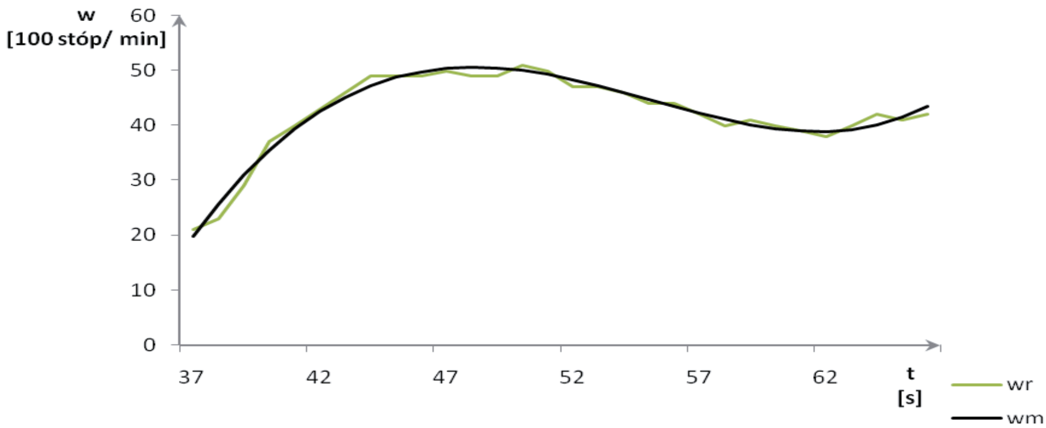

Fig. 6. Vertical velocity (w) recorded in real flight (w_r) and from aircraft model (w_m) in segment III take off phase for flight 3

5. Summary

Methods of identifying the computer are a great tool to map the aircraft. The analysis of a large number of parameters it is possible to image the dynamics of an aircraft during any phase of flight, or the entire course of the flight. The mathematical model describing the flight of can be used for many purposes, for example to build models that simulate flight and research capacity of the runway. A caveat, however, is the identification of computer necessary to divide the area of analysis stages variability, which generates problems with continuity test parameters within these ranges. To help you solve this problem turns out to normalize the data before the identification. The resulting figure sten as a model characterized by more favourable values of the quality factors of identification.

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