MAGNET ASSISTED TAKE-OFF

An innovative way of taking to the skies

It is theoretically possible to launch civil aircraft with a magnetic levitation catapult system. Such a system uses a magnetic force to levitate the aircraft on a rail and to accelerate it during take-off. When landing, this system can be utilized to decelerate the aircraft and recover its kinetic energy. This allows the engine to operate at lower thrust settings during take-off, reducing noise and fuel consumption. More importantly, it provides the opportunity to completely remove the conventional landing gear from the aircraft which can weigh about 5.5% of the total aircraft weight. Thus, the gross weight of an airplane can be reduced significantly, increasing capacity and fuel efficiency.

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INTRODUCTION

Since the first powered flight more than one hundred years ago, aircraft have evolved into an indispensable tool for transportation in the life of many people. However, it has a negative impact on the environment, with noise and pollutant emissions, particularly during the take-off phase. The European Union aims to reduce NO_x emissions by 80% and to reduce CO_2 emissions by 50% by the year 2020 [1], and with increasing demand for air travel, this is a challenge which requires new innovations in current aircraft design [2]. One idea is to assist the take-off and landing phase of civil aircraft by magnetic levitation (maglev) and propulsion technology. This concept is being investigated in a European research project called GABRIEL; an integrated ground and on-board system for support of safe aircraft take-off and landing. The faculty of aerospace engineering participates in this project and the current PhD research is conducted in its context.

PRINCIPLES AND METHODOLOGIES

The GABRIEL concept is trying to completely remove the undercarriage from the aircraft, hook up and levitate the fuselage by some device, and then catapult it, as is done with fighter aircraft when they take off from an aircraft carrier. Steam catapult systems are used on aircraft carriers in order to shorten the take-off distance because the length of the deck is limited. The main drawback of the steam catapult system is its low efficiency (around 5%) [3]. The complex system wastes a considerable amount of power when transferring energy and thus it is unwise to consider this as an option for the launch of civil aircraft. Other disadvantages include the maximum energy limitation: the energy limitation for a normal steam catapult system is approximately 95MJ, which is enough for fighter aircraft but not powerful enough to launch civil aircraft. If more power is required from a steam catapult system, the scale of the system will have to increase, making it very complex [3], and resulting in large costs. The technology used within the GABRIEL concept does not have the drawbacks of the steam catapult.

When the airplane is in the final approach phase, the ground based system must align itself with the aircraft in order to retrieve it and decelerate it by an electromagnetic force. Currently, the design of the ground based elements is still undetermined. However, it seems that the best option is to integrate the catapult and retrieval system to improve the feasibility and economic benefit of the overall system. So a good choice for the catch system is utilizing a sledge, which can also be used in the catapult phase. An artist impression is given in Figure 1. The safety of this concept has to be investigated in detail since not all airports will have such a system available. The emergency landing for airplanes without a landing gear is thus an important technical problem that needs to be solved. Currently, all options are still open for this issue, including airbags and parachutes.

OBJECTIVES

Three main objectives are defined in the current research.

Objective 1: The traditional landing gear should be redesigned to be compatible with the innovative maglev catapult system. It is an option to completely remove

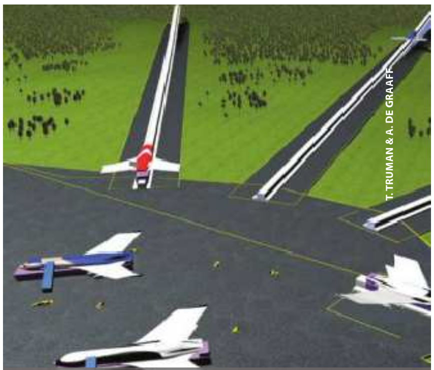

Figure 1. An artist impression of electromagnetic catapult system at airport

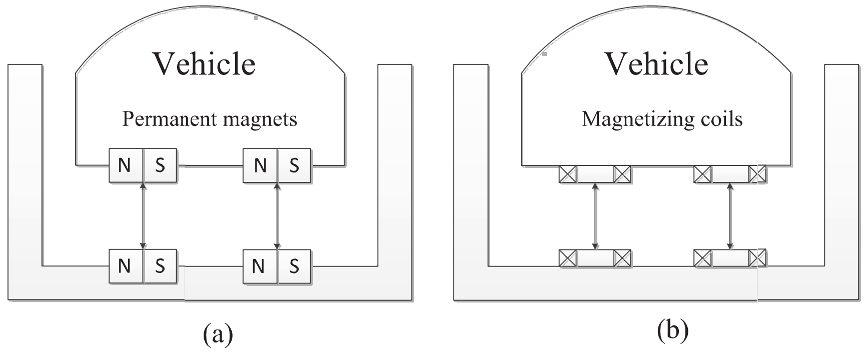

Figure 2. Permanent magnets electrodynamic suspension (a) and superconducting magnets electrodynamic suspension (b) [4]

the landing gear system from the fuselage. However, several design challenges need to be overcome if this concept is chosen, such as emergency landings at airports which are not equipped with a maglev catapult system.

Objective 2: Design a new type of runway for the airport with an integrated maglev launch system. The runway should be compatible with different kinds of aircraft take-off and landing.

Objective 3: In order to verify the flexibility and feasibility of the preliminary design of the complete system, detailed simulation studies will be conducted to analyze the performance benefits of the maglev catapult system compared to the airfield performance of conventional aircraft.

MAGLEV LEVITATION AND PROPULSION TECHNOLOGY

When dealing with the conceptual design of the Electromagnetic Aircraft Launch System (EMALS), it is very important to determine which type of levitation and propulsion technology should be used [3] [4]. There are two types of levitation systems being developed right now:

Electromagnetic suspension (EMS)

This type of levitation is generated by the attractive force between the electromagnets on both the moving craft and guideway. Right now, there are two types of EMS under investigation. The first one is integrated levitation and guidance while the other one is separated levitation and guidance. Because the latter uses separate systems for levitation and guidance, it can be used at higher speeds.

Electrodynamic suspension (EDS)

Electrodynamic suspension is a different kind of levitation which uses a repulsive force to generate suspension rather than an attractive force. This form of levitation does not work if the sledge's velocity is zero or moving slowly as the induced current is not strong enough to generate a force which can levitate the aircraft and sledge. There are two types of EDS (Figure 2): electrodynamic suspension with permanent magnets and electrodynamic suspension with superconducting magnets. The first type can only be utilized in small systems since there is only limited availability of high powered permanent magnets. The latter needs cooled helium to operate the system, so it is more complex.

When military aircraft take off from aircraft carriers by means of a steam catapult, the aircraft is hooked up by the catapult on the nose gear and the power of the appliance is generated by compressed steam. Based on the same concept, the aircraft can be accelerated by a device which is powered by electricity. Traditional maglev propulsion motor principles have a rotary motor, however this can be restructured such that it operates in a linear fashion. The structure is different, but the principle is similar to the conventional rotary motor and seems to be the most suitable method for this application.

BENEFITS

Decreased emissions during take-off:

Requirements on the available maximum engine thrust typically depend on the take-off and cruise flight conditions. Since the airplane is accelerated by the maglev system, the take-off requirements are significantly reduced and potentially an engine can be selected which is smaller than for a conventional aircraft configuration. So the fuel consumption will most likely reduce by 1% to 2% and the amount of exhaust emissions per take-off will decrease.

Reduce the level of noise generated by the engine:

The engines generate a lot of noise when operating at high power levels. This is a main source of noise pollution in and around airports. The maglev launch system can help to reduce the noise level during aircraft take-off in two ways: (1) The engine can potentially operate at a lower power level and (2) the aircraft can fly at a higher airspeed and climb rate which means that the noise source can move away from airports and nearby regions faster.

Improve the efficiency and capacity of the airport:

Airports have a limited number of runways and the capacity of a runway depends on the average taxi, take-off and landing time of an airplane. Sometimes this period can reach ten to fifteen minutes. This new launch system potentially has the ability to decrease the average taxi, take-off and landing time of an airplane to four minutes. As a result, airports can handle more aircraft in a limited amount of time.

Enhance efficiency of the aircraft:

Because the aircraft is levitated by the system, it is possible to completely remove the landing gear from the fuselage. As has been estimated, the undercarriage system usually accounts for almost 5.5% of the gross weight [5]. When choosing this technology, almost 5% of aircraft gross weight can be reduced. The fuel consumption per passenger per kilometer therefore decreases significantly.

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