

ANALYSIS OF ELECTRIC-DRIVE APPLICABILITY IN MECHANICAL BRAKE FOR THE COMMUTER CLASS AIRPLANE

Paweł Grygorcewicz

*Institute of Aviation, Landing Gear Department
Krakowska Av. 110/114, 02-256 Warsaw, Poland
tel.: +48 22 1883885
e-mail: pawel.grygorcewicz@ilot.edu.pl*

Abstract

This article presents selected issues related to the design methodology of the electric brakes during the construction process as well as other factors which are important in the design process. It is a very important issue due to affect on the airplane and automotive brake design. Nowadays when new solution of brakes is being designed there is a need to take into account various factors influencing the design such as: weight, compatibility and flexibility of use in various aircraft, reliability and durability, ease of installation and maintenance, low-cost operation and low cost components, braking efficiency, short braking distance. All of these factors are taken into account when designing a prototype of the electric brake as well as economical factor of the design. It is also necessary to verify the design during its creation using experimental and laboratory test data from other similar designs.

The aim of the paper is to discuss design process from the very beginning (i.e. by comparing features of the electric brakes with other types of brakes in order to show advantages and disadvantages of chosen solution) to the creation of a working demonstrator in future. Author of the paper in his electric brake design bases on the experience of the Warsaw's Institute of Aviation Landing Gear Department.

Keywords: *transport, airplanes, brakes, landing gear, construction process*

1. Advantages and disadvantages of electric brakes

The purpose of this article is to describe electric brakes and also the construction methodology of airplanes brakes. During the last few years we can see a variety of modern electric solutions in airplanes. One of the most important function in every vehicle is braking efficiency which has influence on passenger safety. Nowadays the new solution of brakes is taken into account, for example brakes with electric motors instead of hydraulic drive. The new solution of electric drive brakes has many advantages and disadvantages.

Advantages of electric brakes:

- Plug and Play – the electric solution is easier to install than hydraulic devices,
- Lighter than hydraulic brakes – because there is no hydraulic pump,
- High reliability – because in construction which described the author the motor is doubled, so in situation that one motor doesn't work is possible to stop the plane.
- Simplified maintenance,
- Control – in the future could be better than hydraulic,
- Cleaner than hydraulic – no polluting oil,

Disadvantages of electric brakes:

- New construction – isn't so popular like hydraulic,
- Defects – because of the novelty of construction,
- Unknown long term reliability of the design – due to the novelty of the construction and shortage of the research.

The comparison between hydraulic and electric brake designs is significant because it will show advantages and disadvantages of the selected solution. Advantages of electric brakes seem to

be beneficial to creator.

It is very important that in the new prototype designer should predict model of the risk applicable to operation of aircraft. Risk and uncertainty included in plans for operation and maintenance of aircrafts results from the unavoidability of the following rough estimations – lack of certainty [5]:

- future demand for availability of the operation system,
- future desired handling of the operation system, both in the area of regular tasks as well as maintaining the flying and technical capacities with backup and overhaul facilities,
- future possibilities to supply the operation system (e.g. with fuel),
- qualifications and motivation of person conducting operation procedures,
- future economic and financial circumstances,
- approval by social environment and co-existence with natural environment,
- ability to take control under emergency conditions, e.g. after an accident or an avionic catastrophe,

The term of risk is associated with uncertainty, with possible detrimental consequences or losses under various reliability states. The status of airworthiness enables the completion of an avionic task (ZL). In turn, the status of air worthlessness, or technical inoperability, may lead to several hazardous circumstances – depending on the phases of the flight, i.e. whether the incident happens on the ground (during a standstill period SP, during taxing or a landing run) or in air (during any phase of the flight). Such circumstances may lead to the following consequences:

- prevention from commencement of the avionic task (ZL) execution,
- withholding execution of the avionic task (ZL),
- occurrence of an avionic accident or catastrophe that lead only to material damage, or to material damage and human injuries or even fatalities (among the crew, passengers or people on the ground) [5].

The other important thing which the designer need have to take into account is reliability of the design of the brake. The reliability is very close connected with passengers' safety, so it is very important to consider it. Reliability $R(t)$ of the object it is ability to proper work in defined conditions $\{w\}$ and in time t . The dimension of reliability of the object $R(t)$ it is the probability P of the damage U in time t and conditions $\{w\}$, so [7]:

$$R(t) = P\{U(0, t)\}_{\{w\}}. \quad (1)$$

The working life of object T it is the ability to keep the applied properties in defined conditions $\{w\}$ and defined time t . This subject is more precisely concerned in articles [5-7].

Nowadays designers in the world designed few electric brakes which are used in airplanes. More electric brakes were designed in cars but in this article author focuses only on electric brakes which are used in airplane.

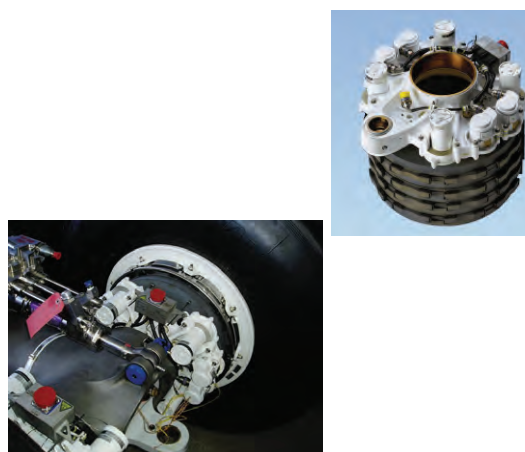


Fig. 1. The example of the electric brakes of Boeing 787 Dreamliner the construction of Messier-Bugatti-Dowty company [8]

Above (Fig. 1.) and below (Fig. 2.) there are examples of electric brakes in Dreamliner 787 and Bombardier global 5000.



Fig. 2. The example of the Meggitt's Ebrake tested on Bombardier global 5000 [9]

2. The construction of brakes

The brakes which are used in vehicles can be divided to two main types: disk brakes and drum brakes. This article focuses on disc brakes due to this type is used in prototype.

Disc brake consists of a rotating disc (part of the wheel in airplanes, part of an axle in cars) and a static caliper with clamp jaws to give braking force by using brake pistons which press brake pads against brake disk. As a result of the pressure is the friction which transforms kinetic energy of the movement into thermal energy. To apply the force to the piston it can be used hydraulic fluid or nowadays electric motors.

3. The construction process and various factors influencing the design

The three most important groups in the construction process are: design, analysis and research. These groups are connected with each other in different stages (Fig. 3). An operational prototype is a target of a construction process. These groups are very useful in designing process and fasten the full cycle.

Nowadays the entire design process is possible to do using a computer aided design (CAD) process by using specialized programs such as Solid Edge ST2. During the design process every part of the future brake is modelled in 3D using program mentioned above. This allows to make changes easily and to adjust the model as needed. In this phase models are used to check the design, to gain better understanding of problem areas, to display kinematics and to evaluate the whole mechanisms. After finishing 3D modelling next is to create design documentation: assemblies drawings and technical recommendations [1].

It is also necessary that the designer should always consider the most important factors which influence the prototype. Sometimes is difficult to reconcile conflicting demands (ex. costs with quality) so the role of designer is to choose the best solution and to find the compromise. The main factors influencing the design of the brake are: weight, compatibility and flexibility of use in various planes, reliability and durability, ease of installation and maintenance, low-cost operation and low cost components, optimal braking distance. All of these factors were taken into account when designing a prototype of an electric brake.

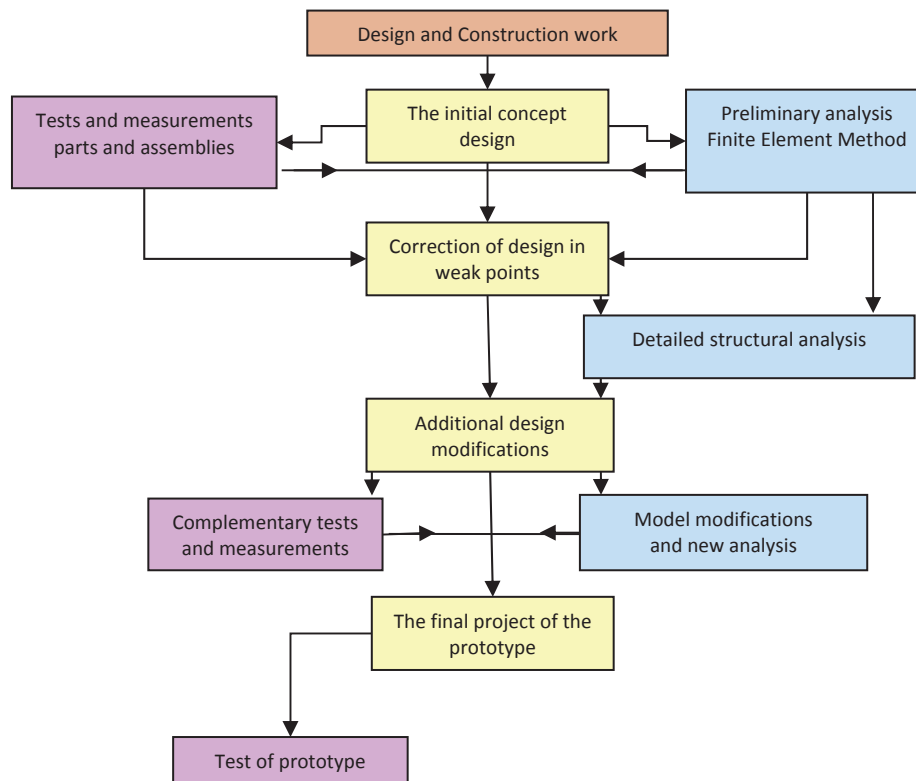


Fig. 3. The construction process[2]

Tab. 1. Comparison of the important factors in constructions[3]

Main factor	Examples
Geometry	Dimensions, height, width, length, diameter, space requirement, the number, arrangement, connection, extension and enlargement
Kinematics	Type of motion, rotation, speed, acceleration
Forces	Direction of the force, the frequency of the force power, weight, load, strain, stiffness, elasticity, strength, mass, stability, resonance frequency
Energy	Power, efficiency, loss of energy, friction, ventilation, state, pressure, temperature, heating, cooling, power connected, power and energy conversion
Material	Material flow and transport material, physical and chemical properties of the product of the input and output materials, materials in accordance with the regulations, quality
Signal	The input and output of measured values, the shape of the signal, indication, supervision and control instruments
Safety of exploitation	Direct safety technology, safety systems, safety and environment
Ergonomics	Dependence of man – machine: support, the amount of operating positions, how to handle, comfortable seating, the lighting, the type of industrial
Production	Restrictions on the part of the plant, the largest feasible size, the preferred method of production, means of production, attainable quality, and tolerances, the percentage of missing
Control	It is possible to measure and verify; specific rules (norms and prescriptions of the various levels of the organization DIN, ISO, etc.)
Installation	Special installation prescriptions, assembly, building, assembly on place, foundation
Transport	Limitations kind of lift, profile rail or road transport types, the permissible size and weight, the manner and conditions of transport of consignments
General use	Low noise, wear and tear because of use, and disposal of land, the place of use (ex. sulfur vapor atmosphere, tropical climate)
Service	Redundancy maintenance jobs ,the number of maintenance activity ,the time required for maintenance, inspection, replacement and repair, coating, cleaning
Costs	Maximum allowable costs of production, the cost of utilities, investment and depreciation
Deadline	Completion of design and development, site based intermediate steps, delivery

The progress of electric brake construction creation is shown in the picture below. First the brake had one strong motor. Later the idea has been developed and the last concept consists of two motors.

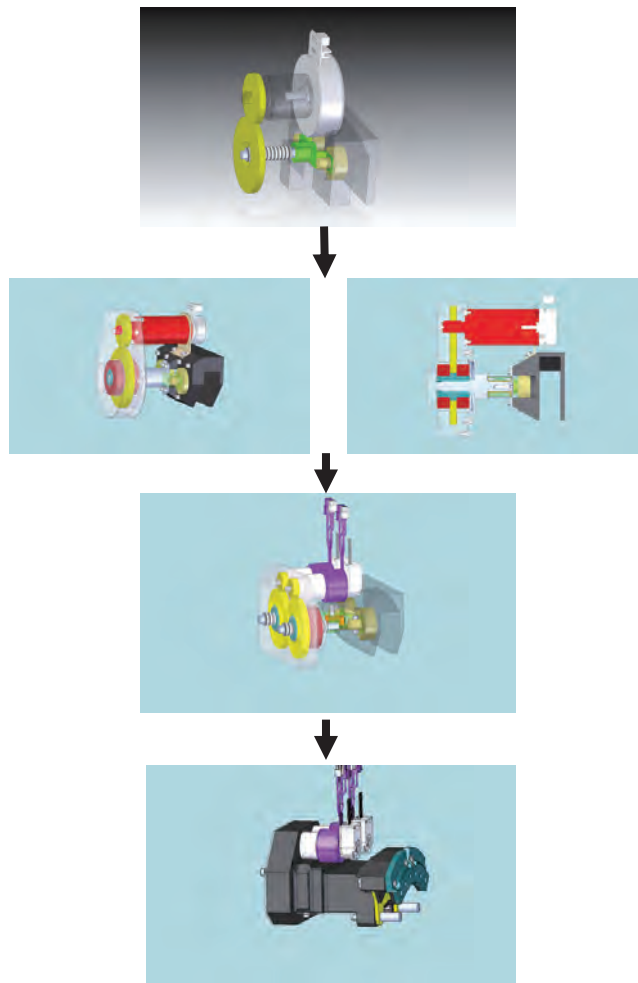


Fig. 4. The construction progress of electric brake

Due to large possibility of airplanes construction the brake could be used in commuter class of airplanes. The most important factors in this case are mass and energy of braking.

The most recent version of the electric brake looks like in the picture below.

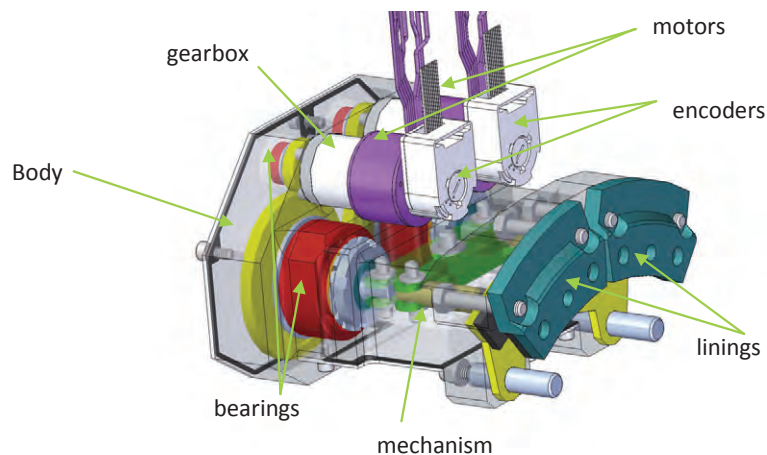


Fig. 5. The electric brake 3D model

Brake consists of the following parts:

- motors,
- gearboxes,
- encoders,
- bearings,
- drive nuts,
- driven screws,
- mechanism,
- pistons,
- linings,
- body.

All these elements are the parts of the electric brake construction and are necessary for the proper work of the brake. As it can be seen the design of the electric brake calliper prototype is similar to standard disc brake calliper. In hydraulic calliper there is pressure which flows through the cylinder and drives the pistons. In the electric brake instead of the hydraulic pressure electric energy is used. The linings are forced by pistons and there is friction between disc and linings. The process of braking transforms kinetic energy of the movement into thermal energy. Due to aircraft regulations it is needed to have high level of reliability the electric motor is doubled (redundant) but even one motor allows the pilot to stop the plane. In such case the braking road is longer than normal.

In airplanes we have main landing gears, nose landing gear or rear landing gear. The brakes are mostly mounted in the main landing gear.

If science and technology improve it will be inevitable that some systems will become outdated. That's why the electric systems in airplanes will be more and more popular.

The laboratory tests are the last step after the design phase. The Laboratory tests should be done because the brake should be checked. Sometimes it's need that after test the construction is modified. The tests are required by regulations and should be completed before the first flight.

4. Summary

The main target of this article was to show how looks the design process of the new solution electric brake. The knowledge of design process of the brakes is based on the experience Landing Gear Department and also from books about designing. As the reader can see the design process lasts long time and during designing is always a lot of changes. The designer have to consider many factors to choose the best solution of design. The other target was to show the electric brake design and in what airplanes is applied nowadays. Although the electric brakes are new construction it seems to be good solution to use in airplanes in the future.

The author hopes the rest important things which are needed to end electric brakes project: documentation, prototype, tests will be done in the future. This article includes only part of knowledge which is needed to design brakes to airplanes.

References

- [1] Dietrich, M., *Podstawy konstrukcji maszyn*, WNT, Warszawa 1999.
- [2] Jachimowicz J., *Metoda elementów skończonych*, Wykłady, 2012.
- [3] Beitz, G. P. W., *Nauka konstruowania*, WNT, Warszawa 1984.
- [4] Currey, N. S., *Aircraft Landing Gear Design Principles and Practices*, Washington AIAA 1988.
- [5] Lewitowicz, J., *Uncertainty and Dependability of the risk model applicable to operation of aircrafts*, KONBiN, 1, 2010.
- [6] Lewitowicz, J., Kustoń, K., *Podstawy eksploatacji statków powietrznych*, ITWL, Warszawa 2003.
- [7] Czajgucki, J. Z., *Filozoficzno-naukowo-dysertacyjne problemy modelowania i symulacji relacji niezawodnościowych w wieloaspektowych systemach*, 2010.
- [8] <http://www.safranmbd.com/wheels-and-brakes-176/>
- [9] <http://www.flightglobal.com/blogs/runway-girl/2008/10/photos-allelectric-braking-sys.html>.