Theoretical Model of the Methodology of Landing Gear Bracket Design Taking into Account the Adjusted Calculation for Shear Bolt Design

Egor Titov[1,*] and *Sergey* Serebryansky[1]

[1]Moscow Aviation Institute (National Research University), Moscow, Russia

Abstract. The subject of this paper is the methodology of main landing gear (MLG) design, in particular, the algorithm. The new algorithm considered in this paper is intended for designing modern structures of the MLG using a large number of methods of mathematical modelling of the stress-strain state and maximum autonomy of this process. The initial conditions of this algorithm are the Airworthiness Standards for Transport Category Airplanes (NLG25).

1 Introduction

The design of any aircraft component is based on the requirements of the Airworthiness Standards (NLG). Transport category aircraft must be in accordance with the requirements of NLG25 [1].

After reviewing the requirements of NLG25, a list of chapters that have a direct impact on the design decisions when designing the design of the MLG supports [2] has been formed in Table 1. Most of them also affect the solution of the problem of the presence of weak links of the landing gears, the choice of their installation locations, material and basic geometric parameters.

Table 1. POINTS OF THE NLG, IMPOSING REQUIREMENTS ON THE DESIGN OF THE LANDING GEARS.

Points of the NLG	Title	Brief description
NLG25.471	Main provisions	Definition of test conditions, setting test assumptions.
NLG25.473	Landing loading conditions and assumptions	Determination of test boundary conditions and calculation cases.
NLG25.477	Landing gear location	The three-post chassis with a bow support is accepted as a common arrangement. For the others, the conditions from NLG25.485 are established.
NLG25.479	Horizontal landing	Requirements for structural strength of the landing

* Corresponding author: TitovEI@mai.ru

	conditions	gear from loads simulating a horizontal landing.
NLG25.481	Landing conditions with tail down	Requirements for the strength of the chassis structure from loads simulating a landing with a lowered tail.
NLG25.483	Seating conditions for one rack	Requirements for the strength of the chassis structure from loads simulating landing on one OSH.
NLG25.485	Lateral load conditions	Requirements for the strength of the landing gear structure from loads simulating a landing with a side wind and sliding on the wing.
NLG25.487	Landing rebound conditions	Requirements for the strength of the chassis structure from loads simulating a rebound from the strip.
NLG25.489	Conditions of controlled movement on the ground	Establishment of requirements for the design of the OSH for cases of aircraft movement on the ground.
NLG25.491	Taxiing, take-off and mileage	Determination of loading conditions in the simulation of tests of the construction of the OSH when moving on the ground.
NLG25.493	Rolling conditions with braking	Requirements for the strength of the chassis structure from loads simulating maximum braking loads.
NLG25.495	Centerfold	Requirements for the strength of the landing gear structure from loads simulating the turn of the aircraft.
NLG25.497	Tail wheel yaw	Tail wheel yaw conditions.
NLG25.499	Nose wheel yaw and control	Requirements for the strength of the chassis structure from loads simulating yaw of the nose landing gear.
NLG25.503	Rotation	Requirements for the strength of the chassis structure from loads that simulate the braking of one OSH, around which it rotates.
NLG25.507	Reverse braking	Requirements for the strength of the chassis structure from loads simulating reverse braking.
NLG25.509	Towing loads	Requirements for the strength of the landing gear structure from the loads simulating the towing of the aircraft.
NLG25.511	Ground loads: asymmetrical loads on multi-wheeled landing gear	Additional requirements for the structural strength of multi-wheeled chassis.
NLG25.515A	Shimmy	Requirements for the design of the chassis, establishing the prevention of the occurrence of shimmy.
NLG25.519	Ensuring lifting on jacks and braces	Requirements for the design of the landing gear, establishing the possibility of lifting the aircraft on jacks and replacing the wheels.
NLG25.571	Assessment of damage tolerance and fatigue strength of the structure	Determination of the basic requirements for the fatigue strength of the structure, as well as the determination of permissible damage.
NLG25.721	General Provisions	Requirements for the design of the chassis, establishing the prevention of the transfer of dangerous loads to critical places of the structure and the inadmissibility of fire during a rough landing.
NLG25.723	Depreciation tests	Chassis shock absorber design requirements and determination of chassis copra test boundary conditions
NLG25.729	Mechanism for retracting and releasing the chassis	Requirements for the chassis retraction system, emergency chassis release systems, tests of these systems and indicators.

NLG25.729A	Wheel reversal mechanism	Requirements for the wheel turning mechanism and its tests
NLG25.733	Tires	Basic requirements for tires and their testing
NLG25.735	Brakes and braking systems	Requirements for the design of the chassis brake system

2 Ways of proving the points of NLG25

All NLG points should be confirmed either by testing or by mathematical modelling of the test. Most of the points are proved using static finite element (FE) calculation [3]. But the problems of proving some of the points are dynamic calculations [4, 5]. Among all points, special attention should be paid to NLG25.721, which refers to avoiding damage to the aircraft fuel system during an emergency landing. The proof of this point of NLG25.721 is a dynamic calculation [6] of simulation of emergency landing with destruction of landing gear structure and verification of stress-strain state of the tank- caisson.

Static calculations are less time consuming than dynamic calculations, but they have assumptions such as simultaneous application of all forces, absence of inertia forces and impossibility to calculate successive collapse of the structure [7].

There are classical and developmental approaches for solving the problem of design of the MLG weak links structure. By "classical" approach in this paper it means the approach to the design of MLG weak links structure using only static calculations [8], analytical or finite element method.

2.1 Classical method

The classical method involves analytical strength calculations of landing gear linkage assemblies followed by the addition of analytically calculated weak links [9]. The locations of the weak links are usually chosen based on statistics.

As an example, the schemes of designs of the main landing gears (MLG) of modern airplanes are presented in Figure 1. The locations of weak links are shown in red [10].

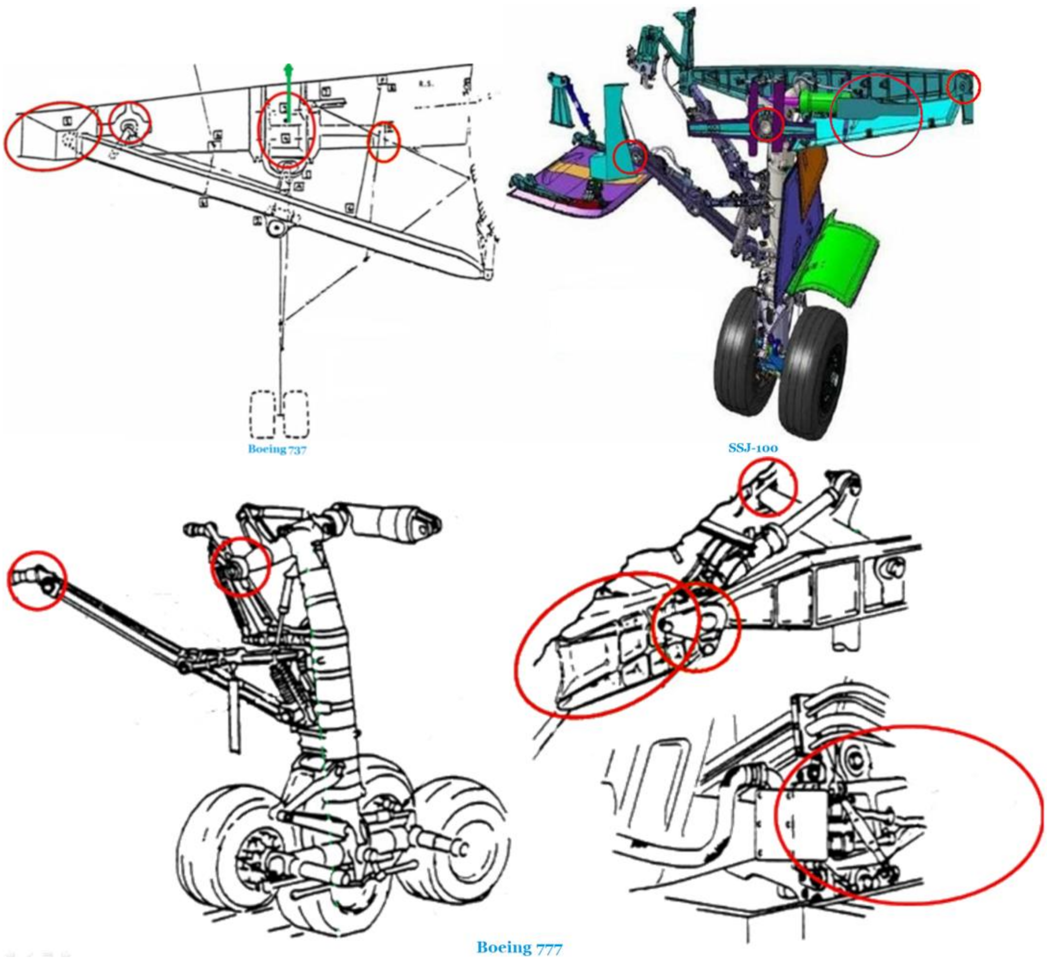

Fig. 1. Classical MLG schemes of modern passenger airplanes.

This method involves the calculation of weak links after the design of the MLG has been approved as a particularly responsible but additional unit. This approach has a number of limitations and disadvantages, such as:

• Inability to design the weak link as a complex part. The weak link is a shear bolt.

• Excessive design weight with relatively low service life (due to the introduction of the weak link).

2.2 Method under development

The developed method is based on the simultaneous calculation of MLG linkage assemblies and iterative selection of weak link design in order to optimize the design of MLG linkage assemblies. The algorithm of the developed methodology is shown in Figure 2. The calculation is performed by simulating the design behaviour using finite element method, which is also a proof of compliance with the NLG requirements [11].

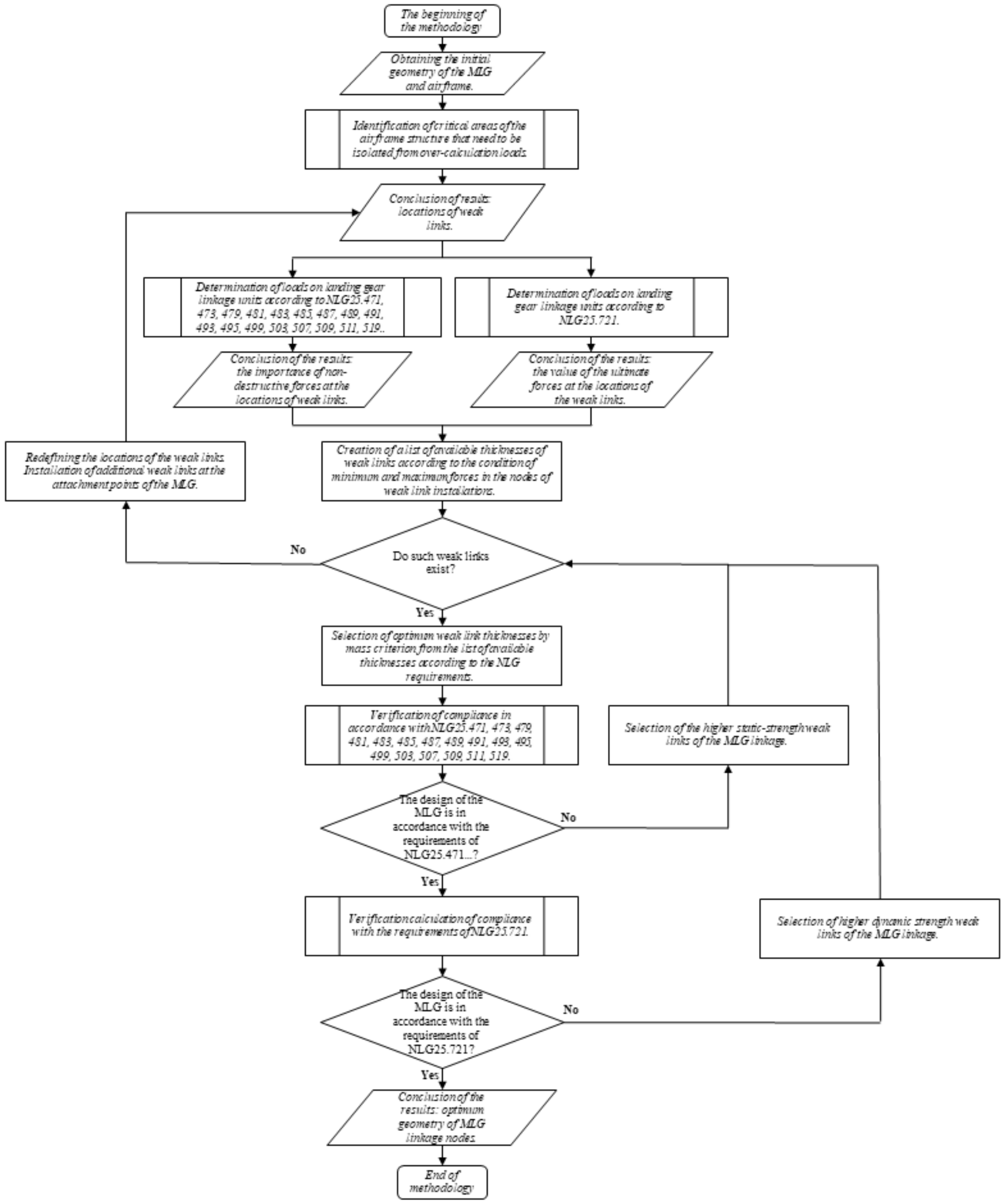

Fig. 2. The algorithm of the developed methodology.

The proposed algorithm is divided into 3 stages:

• The first stage involves making a design decision on the installation of weak links Figure 3. The installation locations are selected from the condition of the task of protecting the structural force elements of the airframe from impact during a rough landing of the airplane.

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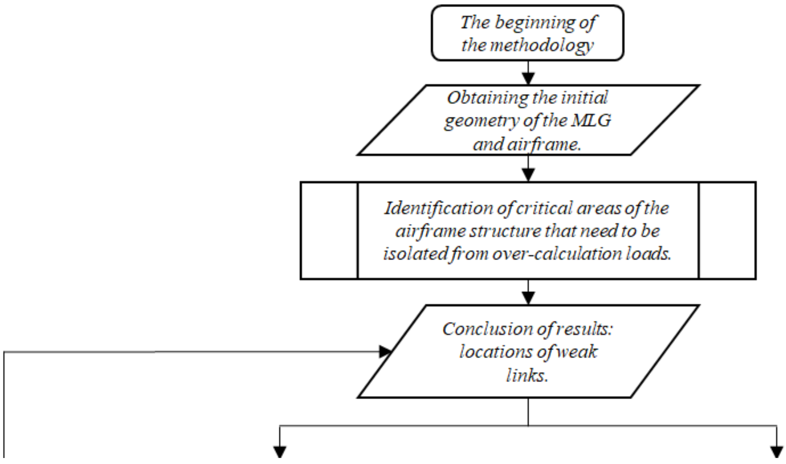

Fig. 3. The first step of the developed methodology in detail.

• At the second stage, the strength limitations of the weak links are determined Figure 4. It should be specified that the strength limits are set both for the minimum permissible values of the acting forces and for the maximum ones [12]. The outputs of the second stage are the available strength ranges of each weak link.

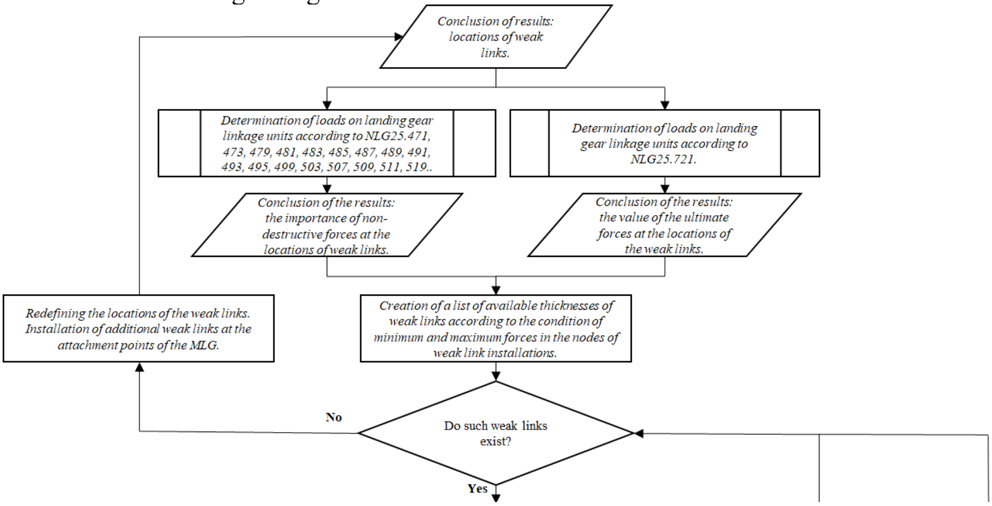

Fig. 4. The second step of the developed methodology in detail.

• At the third stage, the weak links are verified and the set of weak links for the given school is finalized Figure 5. Moreover, the obtained set should satisfy both the conditions of strength under static loading, for example, landing with maximum weight, and the conditions of strength under dynamic loading at rough landing. I.e. weak links should provide protection of the airframe structure under any loading conditions at the expense of destruction of the MLG structure.

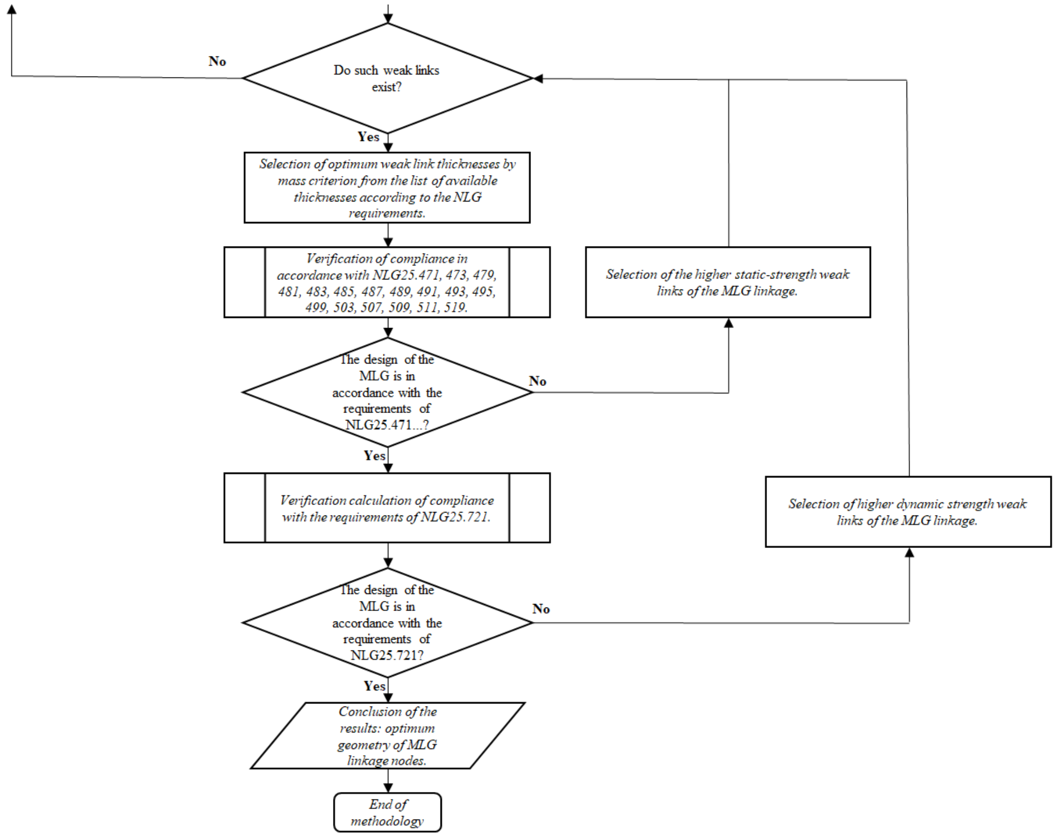

Fig. 5. The third step of the developed methodology in detail.

Using this methodology together with more accurate simulations of static and dynamic loading of the real structure, it is possible to achieve the most optimal stiffness/mass ratio of the structure. Moreover, it is possible to use this algorithm as a stand-alone optimization program for existing chassis designs. Then the algorithm will work only for the last 2 steps, without the need to determine the locations of weak links.

3 Conclusions

The objective of this paper is to create an algorithm for a new methodology for designing weak links of the MLG linkage, to determine the boundary conditions for designing the MLG design and to find solutions for optimizing the existing design approaches for modern MLG designs. The main issue of design still remains high costs of computer power and time when using modern methods of mathematical modelling. However, the developed method will allow not only to autonomously create the design of the MLG attachment, but also to optimize the existing designs, which can be economically advantageous during the modernization of the aircraft fleet [13].

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