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LIFT FORCE MEASUREMENT IN LANDING GEARS DYNAMIC TESTS

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Abstract

As one of the key components of the aircraft in terms of both operation and safety landing gears are of special interest of the aviation regulations. During the touch down landing gears need to dissipate as much of the energy as possible maintaining the lowest volume and weight as required by the aviation design restrictions. According to the aviation regulations landing gears have to be tested in order to prove the dissipation of the calculated landing energy and to evaluate actual loads acting on the fuselage via the mounting nodes of the landing gears. The tests need to replicate the real landing conditions as closely as possible – including the lift force (or lift) acting on the aircraft during landing. The lift force during landing is not sufficient to maintain the aircraft in flight but acts as the relief force to the aircraft weight resulting in lowering loads applied to the fuselage and decreasing landing energy needed to be dissipated. The lift force or lift has to be taken into account during laboratory tests of landing gears. The lift force needs to be simulated in all of the landing gears dynamic tests: performance optimization, proof of the operation for the certification, and the fatigue evaluation. There are two main methods of applying the lift during the tests: equivalent/effective mass or direct lift application. The latter is used at the Landing Gear Laboratory of the Lukasiewicz Research Network – Institute of Aviation (where author works on daily basis). The lift is applied by the pneumatic cylinders built in the test stand. Until recently the control of the lift force value was performed indirectly by the measurement of the pressure inside the pneumatic system. Recently the experimental direct measurement system using force transducers was introduced in order to directly measure the lift force during every test. In the presented paper, the author gives an overview of the lift force measurement system including its design and the results of the preliminary use evaluation.

Keywords: fatigue, Landing Gears, laboratory tests, dynamic testing, lift force measurement
Article Category: Research Article

INTRODUCTION

According to Merriam-Webster [3] landing (Fig. 1) is ‘an act or process of one that lands; *especially*: a going or bringing to a surface (such as land or shore) after a voyage or flight’.

The landing manoeuvre can be divided into phases which include: approach, touch-down (commonly understood as landing), braking, and ground manoeuvres.

Figure 1. Example of landing (source: [5])

During the landing there is a lift force present which is not sufficient to maintain the aircraft in flight but acts as the relief force (Fig. 2) to the aircraft weight resulting in lowering loads acting on the fuselage and landing energy needed to be dissipated. If the lift force is gone – for some reason – during landing, it would result in an uncontrolled fall of the aircraft to the ground causing damage to destruction of the aircraft structure and injuring or killing the crew and passengers onboard.

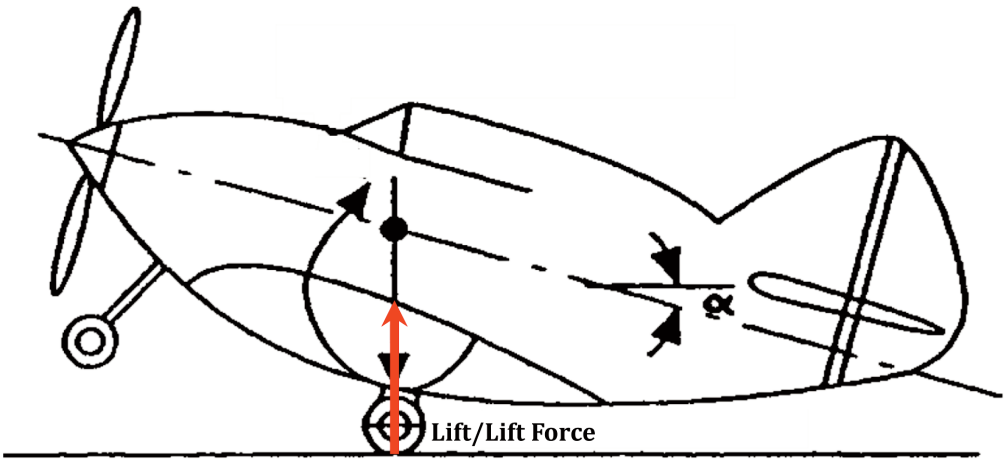

Figure 2. Lift acting during landing (source: [4], [L-ILOT])

The lift force can be referred to as lift which is a unitless ratio of lift force generated by the aircraft wings or rotor blades to the aircraft mass/weight.

The lift force (lift) must be taken into account during the tests of landing gears as these tests aim to directly simulate the landing process in order to prove the correctness of the design and operation of the landing gears.

LIFT FORCE SIMULATION IN DYNAMIC TESTS

There are two main methods of applying the lift during tests: equivalent/effective mass/weight or direct lift application:

- Equivalent/effective mass method uses the drop mass/weight calculated with formula given by the aviation regulations (e.g. CS-23.725(b) [4]):

$$M_e = M\frac{h+(1-L)d}{h+d} \tag{1}$$

where:
M_e – the effective drop mass/weight for the drop test [kg];
h – drop height [m];
d – total vertical deflection of the landing gear (tyre deflection + vertical component of axle travel) [m];
M – static mass/weight acting on given landing gear (main, nose or tail) [kg];
L – wing lift to the aeroplane mass/weight ratio.

This method of applying the lift during drop tests is preferred by the regulations due to the ease and low cost of implementation. However, it requires the changing of the drop mass/weight for every landing speed (drop height) and is, consequently, being time and labour intensive.

- Direct lift application is the method of directly applying the lift as the force acting against the drop mass/weight during tests. As the drop mass/weight and lift force are the same for all of the landing speeds this method is more time and labour efficient. The method is approved by the regulations but requires a much more complicated test stand and is less commonly used. The lift can be applied by the pneumatic cylinders built in the test stand.

DIRECT LIFT FORCE MEASUREMENT SYSTEM CONFIGURATION

The direct lift method is applied at the Drop Tests stand M10T at the Landing Gear Laboratory of Lukasiewicz Research Network Institute of Aviation (L-ILOT) [2].

The lift force application is achieved via two pneumatic cylinders integrated with the test stand which act on two screws being part of the drop carriage – one of the pneumatic cylinders can be seen on the left in the Fig. 3 (blue cylinder). The other one is on the opposite side of the carriage – hidden behind the landing gear.

Although the lift simulation at the L-ILot drop test stands is based on the direct method, recently the lift force has been measured indirectly via the pressure in the pneumatic system. The measurement involves calculating the lift force based on the applied pressure and the geometry of the lift force system. The method is accurate and has been proven to be effective over the years of use but due to overall not-so-typical operation – comparing to the majority of the test stands used in dynamic tests – of the test stand, it was decided that the additional, direct lift force measurement system would be needed.

The main use of the system is for provide the direct lift force measurement when it is needed by the Laboratory customers or for the scientific purposes. The secondary use is for the controlling the indirect system operation by comparing the measurement results – the measurement methods redundancy is one of the key procedures of test quality assurance.

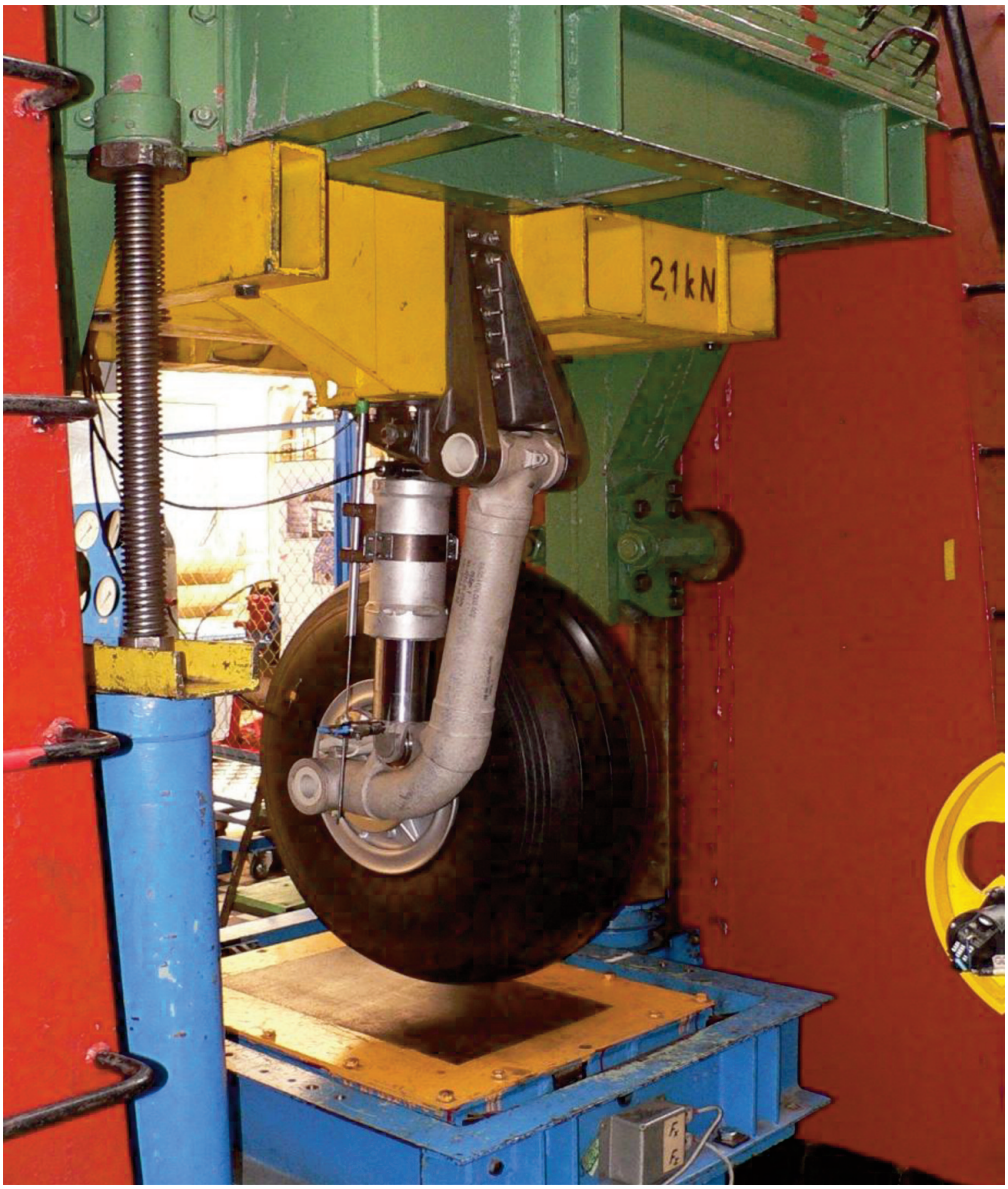

Figure 3. 10 Ton Drop Test Stand. (Landing Gear Laboratory, L-ILOT)

The new system was designed using force transducers with amplifiers mounted to the lift force system screws (Fig. 4, Fig. 5). The complete system is composed of two 50 [kN] force transducers with amplifiers – total lift is the sum of readings from the both transducers.

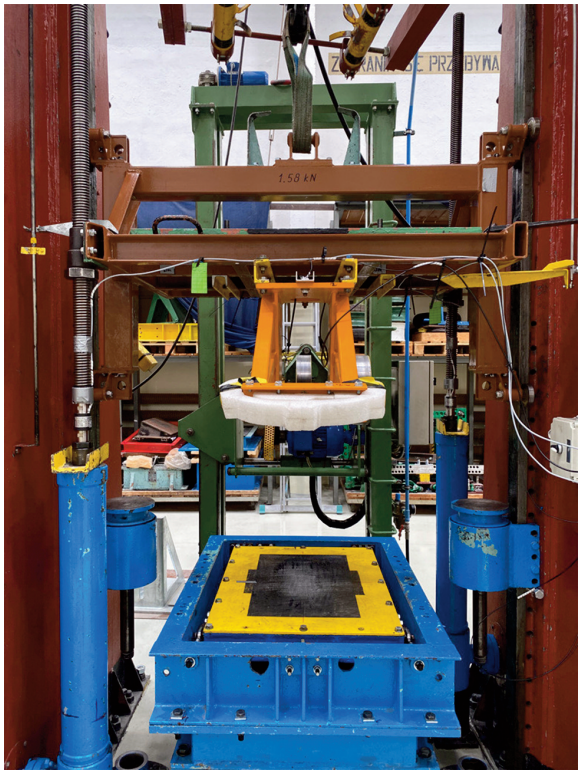

Figure 4. 10 Ton Drop Test Stand with lift force measurement system.
(source: Landing Gear Laboratory, L-ILOT)

Figure 5. Lift force system screw with force transducer.
(source: Landing Gear Laboratory, L-ILOT)

DIRECT LIFT FORCE SIMULATION SYSTEM TESTS

The direct lift force measurement system tests were made for one – available at the time of the tests – landing gear configuration. The assumptions for the tests were made according to the L-ILOT Landing Gear Laboratory researchers' experience gained from the dynamic tests conducted up to date:

- Theoretical Lift (force) is 2.28 [kN] – 0.67 weight of the reduced weight over the landing gear – including the weight of the landing gear itself.
- The mean value of the Lift from the point where the wheel touches the ground (lift force system screws start acting on the pneumatic cylinders) up to the maximum landing gear deflection (U_k) is within 10% of the theoretical Lift.

The results of the direct lift force measurement system tests are shown in Figures 6 to 8:

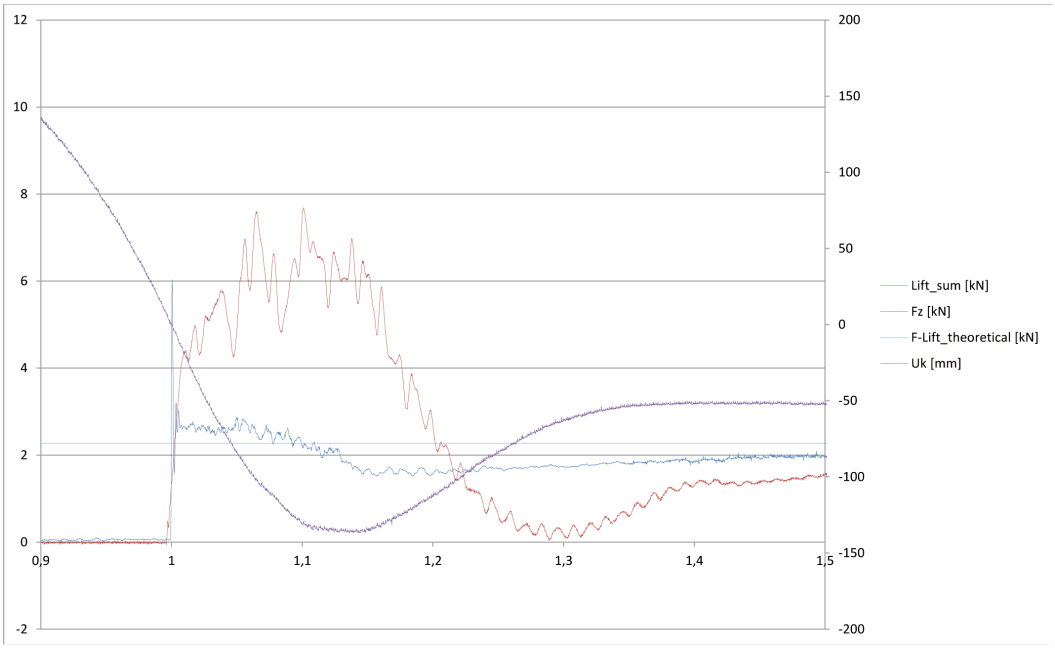

Figure 6. Results for the landing speed of 1.82 [m/s].
Measured mean Lift is 2.45 [kN], the difference from the theoretical value is 7.14%.
(source: Landing Gear Laboratory, L-ILOT)

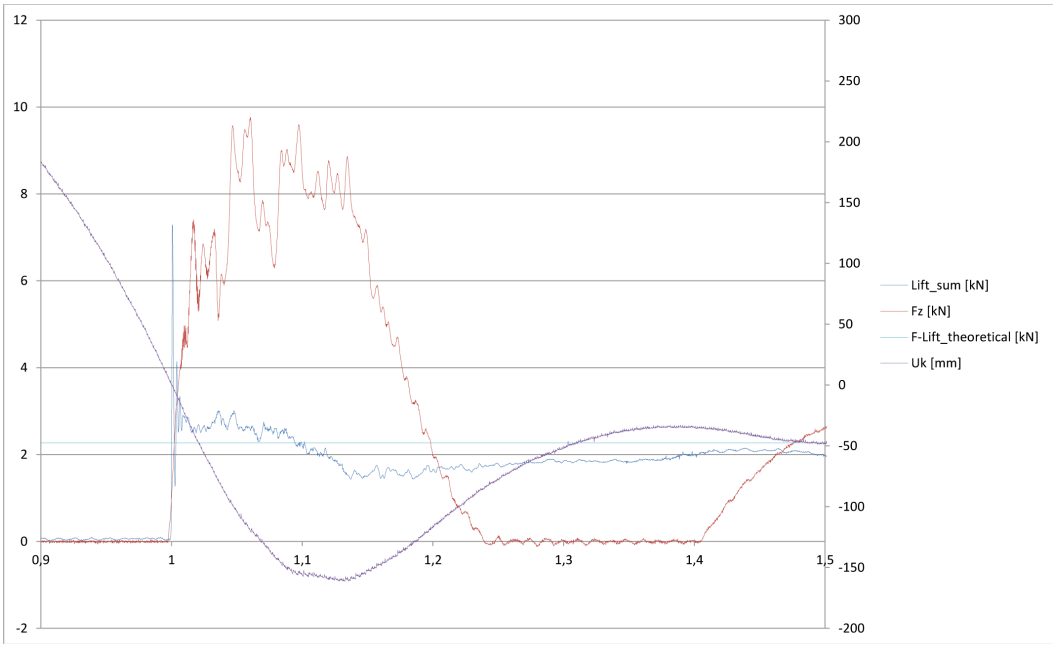

Figure 7. Results for the landing speed of 2.28 [m/s].
Measured mean Lift is 2.50 [kN], the difference from the theoretical value is 8.95%.
(source: Landing Gear Laboratory, L-ILOT)

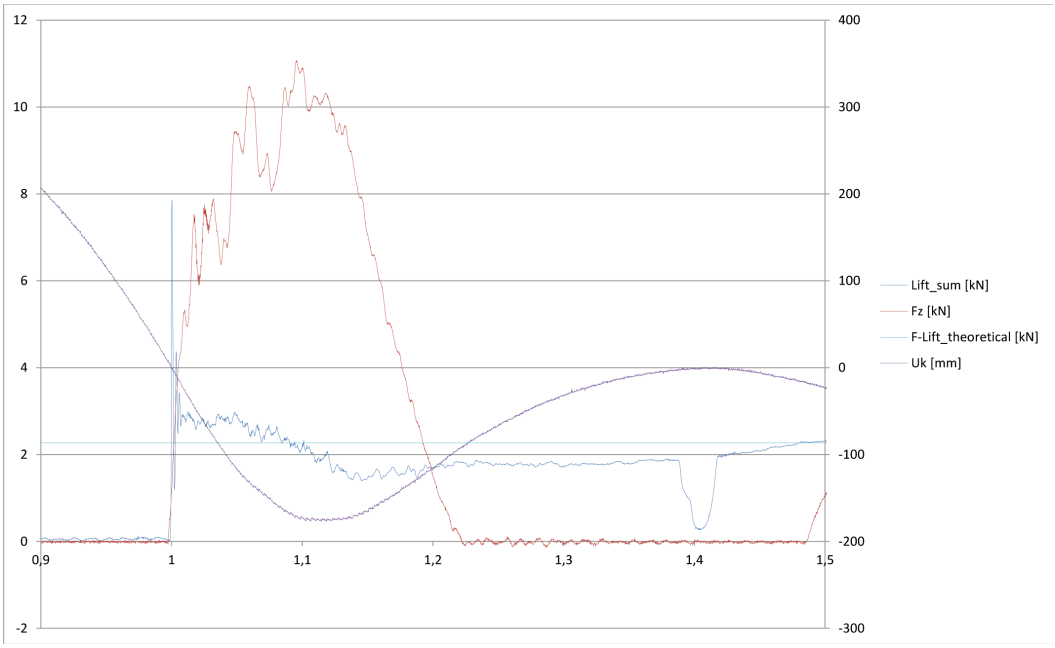

Figure 8. Results for the landing speed of 2.50 [m/s].
Measured mean Lift is 2.49 [kN], the difference from the theoretical value is 8.71%.
(source: Landing Gear Laboratory, L-ILOT)

WEIGHT FUNCTION OF THE SYSTEM

An additional function of the direct lift force measurement system is the weight function. It can be achieved by placing the drop carriage screws on the top surfaces of the cylinders. The weight (Q) of the carriage measured by the current method is 3.43 [kN] while using the direct lift force measurement system is: 3.47[kN] – Fig. 9.

The weight function can be used for weight measurement of the landing gear's drop mass which will double the existing system which relies on the external precision weighting system installed (each time the measurement is preformed) between the release hook and the drop carriage. As the new system is integrated with the drop carriage it will provide a possibility of fast weighting the carriage as well as the mentioned earlier redundancy of the measurement system.

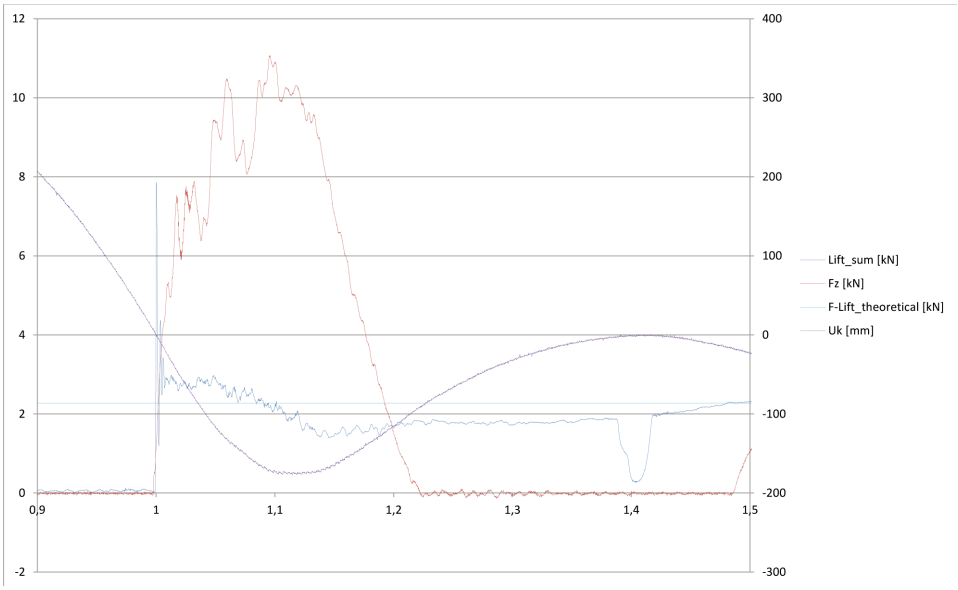

Figure 9. Weight function of the system. (source: Landing Gear Laboratory, L-ILOT)

SUMMARY

- The direct lift force measurement system is capable of measuring the lift force in real time during the drop test, providing the data needed for the control of this test parameter.
- The implemented system is complementary to the existing indirect measurement system. It can be used exclusively to measurement the lift force or provide the measurement method redundancy for test quality assurance.
- The direct lift force measurement makes it possible to fine tune the value of the applied lift force – to be investigated in further tests.
- The system has an additional function – the weight function, which can replace the external weighting system of the drop weight improving the efficiency of the testing process.
- The equipment and required researchers' experience for performing such tests are critical for obtaining reliable data.

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