ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0012.4816

STRAIN GAUGE MEASURING PLATE FOR DYNAMIC TESTS

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Abstract

In dynamic tests, especially landing gears, it is necessary to measure and record load levels. In this article, authors present measurement methods used in the landing gear tests on the 10-Ton Drop Test Machine, which is capable of simulating conditions similar to real landing in landing energy dissipation tests. Possible test objects include dampers, shock absorbers, and crash structures and devices. In described case load measurement can be done by several methods where one of them is strain-gauge plate based load measurement. This type of measurement is weighting system under the test object where all forces acting on it are measured. Strain gauge plate is usually tailor-made measurement system, which is composed out of mechanical device (plate itself) equipped with strain gauge force sensors, strain gauge amplification system and recording system. In addition, differences between static and dynamic measurements are described as well as influence of dynamic test conditions on strain gauges behaviour. In the article, authors describe general layout of the system, advantages and disadvantages of the test stand and problems that may appear during measuring. Authors also emphasize how the accuracy of the design affects to the quality of measurement. At the end of the article, advantages and disadvantages of the test stand and problems that may appear during measuring are described.

Keywords: *dynamic tests, strain gauges, measuring plate, test stand*

1. Introduction

Resistive strain gauges are characterized by high accuracy and the ability to measure very small deformations. These measurements can be made even at a considerable distance from the tested element (safety factor for landing gear tests). Moreover, there is the possibility of simultaneous measurement of loads in several points of the structure. In addition, due to the negligible inertia of the measuring system, they are perfectly suited for measurements of fast-changing deformations – dynamic tests.

The measuring system consists of [8]:

- sensor for transferring and converting the mechanical size (deformation) to electrical quantity,
- supply system,
- amplifying circuit,
- recording device.

Strain gauges can be used to measure static and dynamic strains. In dynamic strain measurement, temperature effects are usually less important than in static strain measurements and the high level of the output signal of the semiconductor gauge is an asset. Main advantage of strain gauges is small size and weight, operation in a wide temperature range, and a possibility to respond to static and dynamic strains. Strain gauges have wide application and approval in measurements as well as in stress analysis.

Most general purpose strain gauges are made of Constantan and are not temperature compensated. These gauges can be used individually for measuring dynamic strain or for measuring short-term static strains where the temperature is held constant over the test period.

In variable temperature better option are Bakelite gauges [2]. The latest catalogues of strain gauges manufacturers offer sensors dedicated to dynamic or static tests – it is one of the most important criteria during strain gauges selection. One of the solutions, which provides temperature compensation and enables using basic strain gauges, is connecting them in pairs – bridge systems.

The dynamic tests issues presented in this article are based on the authors experience obtained during the landing gears tests. There are many of force measurement techniques. They are differing in the placement and type of the sensor used. For the Landing Gear force, measurement direct and indirect approaches are used [7].

In the direct approach, measurement methods are ground plate (loading platform) and sensors on landing gear mounting nodes.

Direct approach based on strain gauges forces measurement on the ground plate which can simulate the real load conditions of the landing gear (Fig. 1). Plate based load measurement using strain gauge sensors sums up forces acting in specific direction [7, 9].

a) *b)*

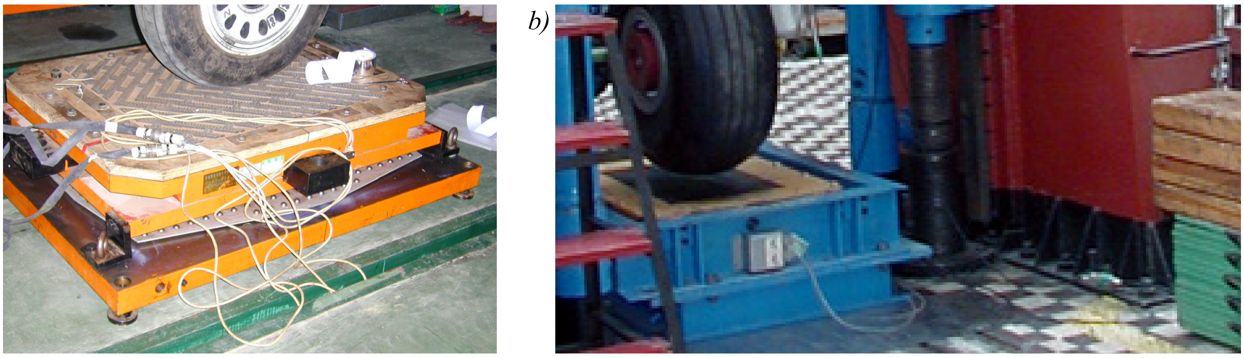

Fig. 1. Ground plate is a well know way of loads measurement: a) loading platform/plate [9], b) ground plate in Institute of Aviation, source Ilot

Direct approach based on strain gauges forces measurement [8] on the landing gear mounting nodes. This method is less universal than plate but gives opportunities to measure same forces.

Both of mentioned measurement methods are concerned tests in laboratory conditions. Test of landing gear may be carried out during flight test, in this case the strain gauges are placed directly in selected landing gears points. Such a solution requires placing the measuring system inside the flying object [3].

Indirect approach is based on the acceleration of the tested object and determinate ground force value [7].

2. Loads (forces) measurement using measurement plate

The basic principle of measurement plate based forces measurement is to create correct weighting system. In most of the cases, plate is stand-alone measurement device equipped with strain gauge based force sensing system. It can be designed as separate force sensors or parts of the larger device e.g. strain gauge-equipped pins.

The layout of the plate is usually composed out of frame (Fig. 2, pos. 1) connected to the ground or other base surface, plate or table (Fig. 2, pos. 2) on which loads are acting during the measurement and force measurement devices connecting frame and table (Fig. 2, pos. 3).

Measurement itself is performed by the strain gauge equipped force sensors, which can be made as exchangeable or fixed where latter one is preferable due to the measurement accuracy. The number of measurement point varies with plate design and its function but due to the global nature of the measurement, all of the signals have to be summed up for one load direction and threated as one in the end.

Number of measured forces can be limited to the one force or can cover number of forces usually: vertical (F_z), horizontal (F_x) and side (F_y) (Fig. 3) [7]. Less usual designs cover forces on desired angle. They are made to fit special test needs. Most of the plates are made as universal measurement devices, which can cover commonly defined force range.

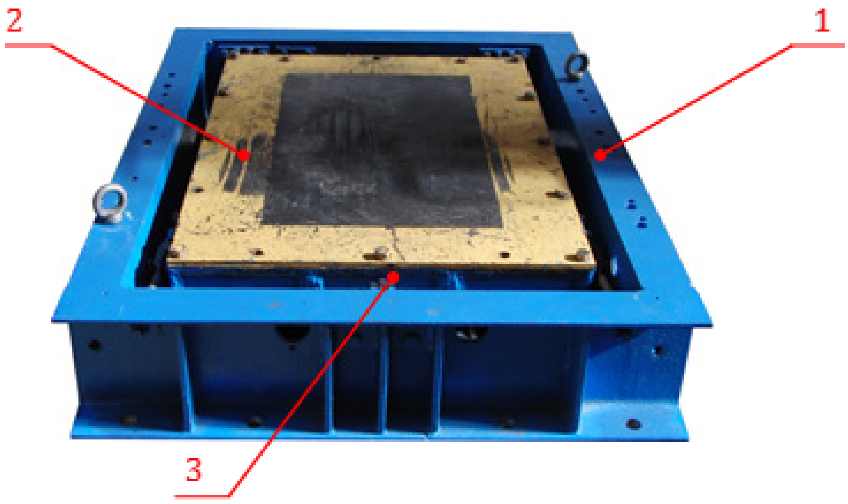

Fig. 2. Ground plate layout, source: ILot

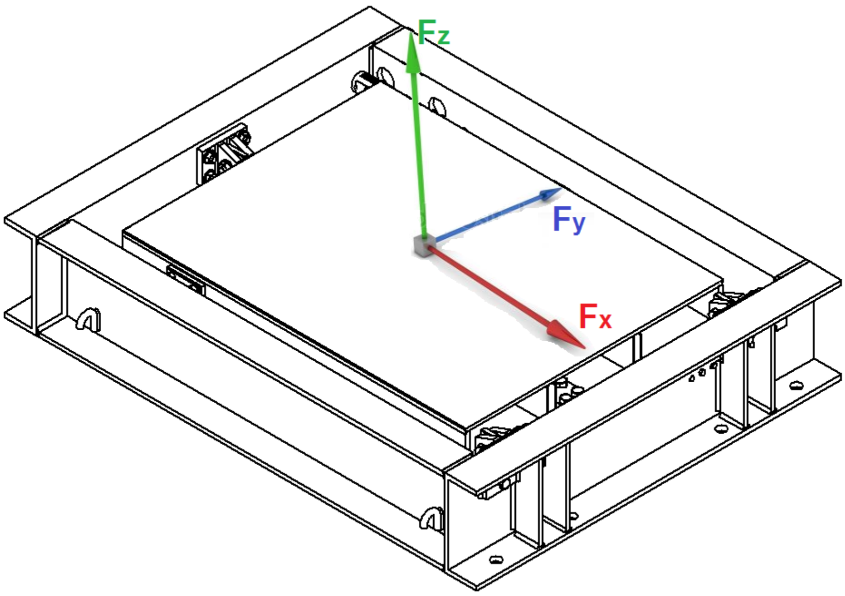

Fig. 3. Force directions on ground plate

Plate based load measurement gives knowledge of sum of the forces acting in specific direction on landing gear without possibility of estimation their distribution between mounting nodes.

Ground plate and strain gauge instrumentation system was designed, installed, tested, and calibrated in Institute of Aviation. Strain gauges in full bridge configuration were installed on six mounting nodes (2 in the direction of the x-axis, 1 in the direction of the y-axis, 3 in the direction of the z-axis) (Fig. 4). Two sizes of mounting nodes were designed according to the loads calculated using the finite element method. Four strain gauges have been installed. Two are active in the direction of acting force and two passive ones. Full bridge has been created on each of the 6 mounting nodes. This solution provides temperature compensation and linear sensor display. The important part of the strain gauges installation is to protect against mechanical damage and electrical noise. To provide such protection and thus a long service life of the device strain gauges were protected by special shielding tape protecting with rubber layer.

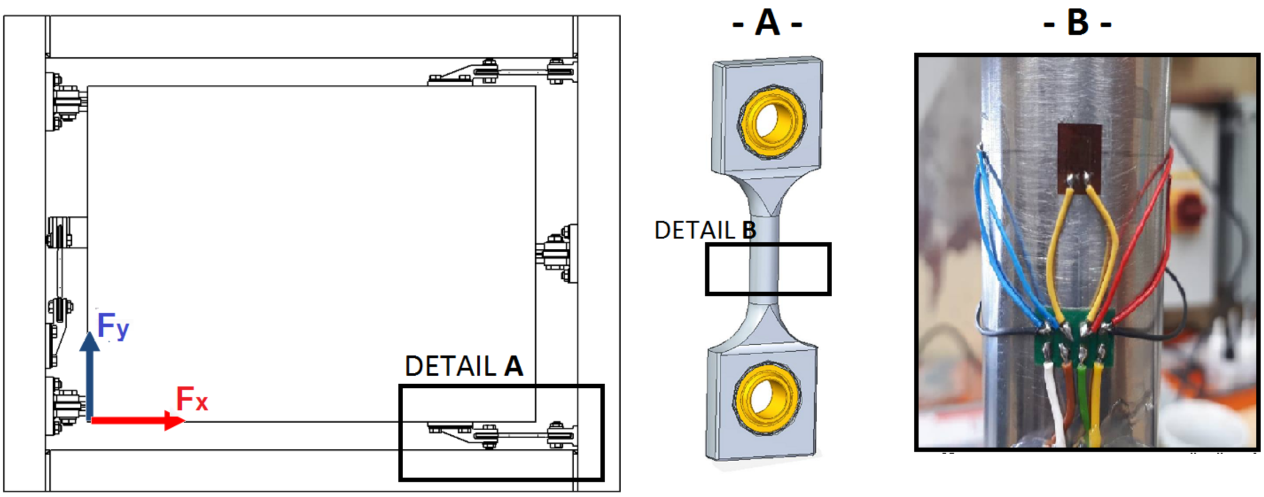

Fig. 4. Ground plate in a two-dimensional view, with detail A – one of 6 mounting nodes, on which strain gauges were installed – detail B

As the landing gear loads measurement devices plates are located under the tested landing gear in order to show landing forces (Fig. 5) [6]. Due to the nature of the measurement, this method can show only sum of loads/forces acting in one direction without their distribution for mounting nodes and is widely accepted for certification according to the aviation requirements [10].

Fig. 5. Landing gear drop test machine example – measurement plate is below the landing gear, source ILot

3. Challenges in plate based measurement

Measurement plate is a very versatile and useful device. As for every device there some challenges, which have to be addressed in order to perform reliable and accurate measurements:

1. Correct assembly of the plate. In this point, there are the numbers of possible errors, which result in wrong measurement. First is not proper plate support when both frame and table are touching the ground. In this case, measurement cannot be made due to the lack of free movement of the table resulting in no tension in force measurement devices. The same error can result in partial ability to measure when table is above the base surface but the gap zeroes when only partial load is applied comparing to full measurement range.
2. Parallelism. The correct position of the plate's measurement surface (table) is crucial in order to perform correct measurement of forces in desired direction. Most common error is not to maintain parallelism between table surface and base mounting surface of the plate's frame. This can be the result of wrong relation between table and frame of the plate or incorrect assembly of the plate and the base. As result, actual measured force will be resultant of the desired-to-measure force.
3. Susceptibility and elasticity of the measurement nodes. Measurement nodes of the plate can be the source of the serious errors when their design is incorrect. The measurement range can be correct bit the behaviour can be opposite. When whole system is too much elastic and susceptible, extensive measurement hysteresis can occur resulting in not consistent data when multidirectional loads/forces are applied.
4. Specific measurement device failure. The unusual failure can result in measurement errors, which are very hard to find while the recorded data look correct. One of such failures is disconnection of one of the measurement points in three-point measurement system. This results in repeatable but not correct force measurement in the middle of the plate. Even seem-to-be proper calibration procedure (where calibration load is applied to the middle of the plate) can be deceptive. The solution is to make calibration in more than one plate area and to measure not only summed force signal but also every node alone.

All of the described challenges and possible errors can result in wrong measurement but do not discard measurement plates as invaluable measurement system for all sorts of lads/forces.

4. Summary

From various measurement methods mentioned in this article authors focused on the ground plate. Test stand was designed, equipped with appropriate sensors and devices, and system was calibrated in order to evaluate responses of strain gauge bridges for desired load level. The use of strain gauges in such tests is common solution because of high sensitivity, fast response time, high signal stability, and linear response.

The strain gauge plate may be available in various versions e.g. two axis, three axes. Properly designed plate with appropriately protected strain gauges requires one-time strain gauge installation and can work on many types of landing gears, drop tests with different conditions. In contrast to mounting nodes, where is necessary to adjust nodes to the requirements of every tested landing gear (strain gauges installation process is repeated for each of the tested systems).

The described challenges in plate design, manufacture, calibration, and later usage are an important factor in quality measurements made, but properly resolved make the plate ideal measuring device for number of tests not only in aviation.

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Manuscript received 10 July 2018; approved for printing 31 October 2018