ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0012.2852

STRAIN GAUGE PIN BASED FORCE MEASUREMENT

Zbigniew Skorupka, Agnieszka Sobieszek

Institute of Aviation
Department of Transport and Energy Conversion Division
Krakowska Av. 110/114, 02-256 Warsaw, Poland
tel.:+48 22 846 00 11, ext. 657, ext. 224, fax: +48228464432
e-mail: zbigniew.skorupka@ilot.edu.pl
agnieszka.sobieszek@ilot.edu.pl

Abstract

In this article authors present force measurement method based on strain gauge measuring system installed inside pin, which is a part of light helicopter Main Landing Gear Shock Absorber. Strain gauges in full bridge configuration were installed inside the mounting pin (upper one – fuselage side). Placement and type of strain gauges were selected during the preliminary tests, which verified the validity and conditions of the force measurement. Preliminary tests allowed verification and selection of an optimal measurement system by testing two types of them. The impact on force according to the angle of force vector direction was also verified. Preliminary tests of the strain gauges equipped pin were performed using quasistatic tests stand – 40 T hydraulic press for applying force acting on shock absorber and pin. Whole measuring system is planned to be used in real time analysis of shock absorber force acting on fuselage mounting node.

The strain gauges allows measurement of force in any place of the structure, the article presents the advantages of the system located inside pin. Additionally, the installation technologies of strain gauges in hard-to-reach places are presented. The article is summed up with an analysis of the problems, which arise during the installation and measurement process using strain gauges installed in such a specific place.

Keywords: *strain gauges, landing gear, test stand, measuring system*

1. Introduction

Forces acting on the Landing Gear are calculated using assumed aircraft parameters provided by the design team. The results must be provided for acceptance to the aviation authorities (e.g. ULC in Poland, EASA in EU or FAA in USA) in order to become the base for aircraft design. As the proof of the correct design and in order to certify the complete aircraft, level of loads acting on the fuselage via landing gear must be (according to the regulations i.e. CS-23.723, 725) confirmed by laboratory tests [5] or approved simulations. In most of the cases, this is enough to estimate of total force level acting on the landing gear.

The use of strain gauges for this type of tests allows the measurement of stresses at a specific point of the Landing Gear without interfering with its structure. Strain gauges can be installed on any, properly prepared surface [7]. The most important advantages of using strain gauges are low price, the ability to install the sensor in almost any point of the structure without interfering with the system, a wide range of sizes, uncomplicated technology of installation. Preparing the dedicated sensor of other type, which has the same properties, would be costly and time-consuming.

In some cases, it is necessary to know loads acting on Landing Gear in specific points in order to estimate full behaviour of the system [6]. This can be achieved by using strain gauges mounted directly on landing gear parts surfaces or inside mounting pins. Mounting pins placement can be also used in normal operation of the aircraft (not only laboratory tests) due to better and simpler environmental separation of strain gauges in contrary to ones mounted directly to the landing gear surface. Mounting node method can be used on an aircraft for real time force estimation; it can help to perform health monitoring (forces, fatigue, and strength).

2. Strain gauge installation

Technology of strain gauge bonding has been known since the middle of the 20th century. Instruction of installation may vary with the type of adhesive that has been selected (two-part epoxy need to be mixed, clamped and cured at an elevated temperature, 1-part glues are general purpose cold-curing). In the tests the cold-curing solution installation method was used, which is the most commonly used adhesives for strain gauges and based on cyanoacrylate glue, which cure in 1 minute, but require 24 hours to set. Rest of the steps during installation process are similar and commonly known [2, 3]:

1. Surface Preparation – Cleanliness is important for successful strain gage bonding,
2. Coarse Cleaning – Rust, scale, paint and other contaminants must be removed;
3. Smoothing Surface – Pitting, scratches, protrusions, can be removed by grinding or other suitable methods to smooth the surface where strain gages will be installed;
4. De-Grease the Surface – Remove all excess oil and grease using special solvents;
5. Clean Surface with Metal Conditioner and Neutralizer;
6. Bonding Procedure;
7. Clean Tools and Surfaces – Clean and degreased work surface it's a necessity, experience and experiments allow authors to state that piece of glass is best choice. It is important to do not handle strain gauges or bondable terminal pads with hands because of contaminants, use only clean tools.
8. Orienting, Handling, and Bonding the Strain Gauge – The most demanding process requiring precision and accuracy. Manufacturers of strain gauge and gluing kits give instructions how to properly install a strain gauge step by step, each of them may be slightly different.
9. Inspect the Strain Gauge Installation – Inspection of loose edges, bubbles, consistent colour on installed strain gauge, resistance is required. If any of problem is found it is necessary to replace strain gauge.
10. Wiring;
11. Complete the Strain Gauge Installation – Check the strain gauge resistance at the end of the instrumentation lead wire, apply protective coating.

Strain gauge installation is based on rigid rules, but for each case has to be taken individually, considering material of tested element, shape, size, availability of a place where the stresses will be examined. And then technology of strain gauge installation needs to be customized. The case considered in this article applies the strain gauges installation inside the pin of 30 mm inner diameter. The key issue was installation along correct axes in difficult to reach area. Authors have developed and verified the method of strain gauges installation inside of pin by using a rubber device, which positions strain gauge in proper place. The device should be made of a flexible, not changing dimensions under pressure material, providing the ability to match up to the surface on which the strain gauge will be installed. The appropriate geometrical dimensions and the axes marked on the rubber device will ensure the correct positioning of the strain gauges provide the possibility to install repetitively number of strain gauges on a small and hard to reach surface [1].

3. Forces/Loads acting on the pin

In described work, strain gauges were placed inside (Fig. 1) the shock absorber mounting pin in order to estimate forces acting along its main axis. Whole measuring system is planned to be used in real time analysis of shock absorber force acting on fuselage mounting node.

In the Fig. 2 and 3 forces/loads acting in SG installation area are presented. The main expected reaction in this area is the bending force (radial deflexion of the pin) on the area where pin is in connection with spherical plain bearing surface of the Shock Absorber mounting. In the real-time operation conditions, there is an expectance of angular movement of the force around main axis of the pin. The impact of this movement is to be evaluated in the tests.

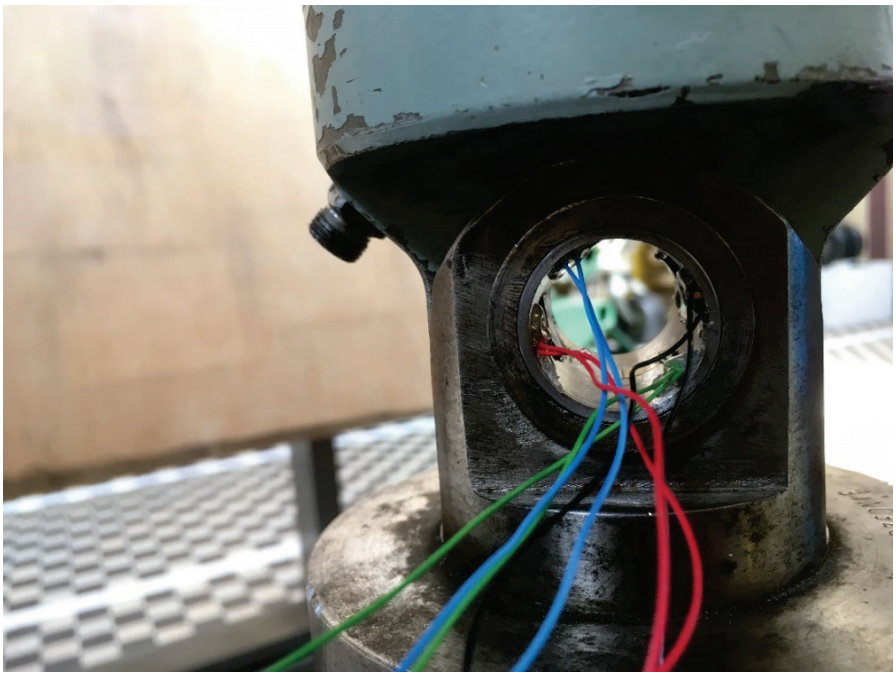

Fig. 1. Strain gauges inside shock absorber mounting pin, source ILot

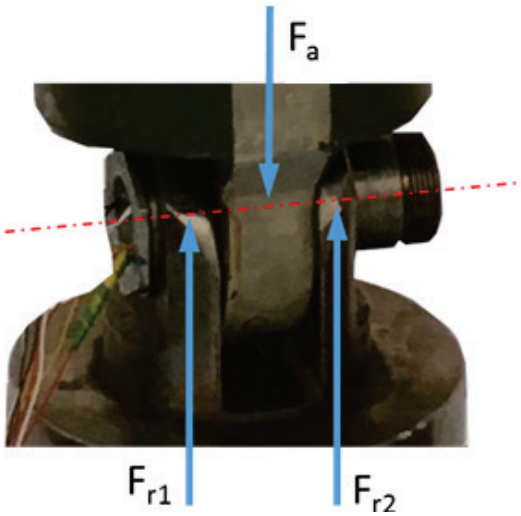

Fig. 2. Loads/forces acting on the SG pin (F_a – Shock Absorber force F_{r1}, F_{r2} – reaction forces on the fuselage mounting node), source ILot

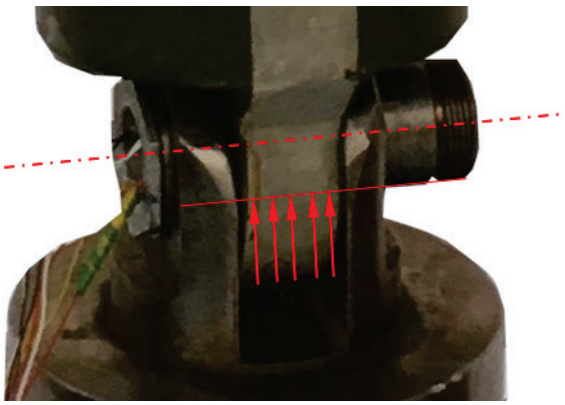

Fig. 3. Reaction on the outer area of the pin when Fa force is applied in SG area, source ILot

4. Test stand

Tests of the strain gauges equipped pin were performed in Landing Gear Laboratory of Warsaw Institute of Aviation using quasistatic tests stand – 40 T hydraulic press (Fig. 4) used for applying force acting on shock absorber and pin. Strain gauges inside the pin were connected to the data-logging computer via strain gauge (tensometric) amplifier and signal acquisition system (Fig. 5).

Fig. 4. Quasistatic test stand example, source ILot

Fig. 5. Pin force measurement system, source ILot

5. Tests

Tests were carried out in 4 steps. First, authors prepared two different strain gauge full bridge systems, where the strain gauges were installed in different directions. The way the loads acted on the bolt was assumed with high degree of certainty; therefore, it was necessary to verify which

system would be the best in this case. Both systems have been tested in the same manner in order to verify how the direction of force application affects the measurement. In the first step, at the points marked in Fig. 6, response of the strain gauge bridges was checked.

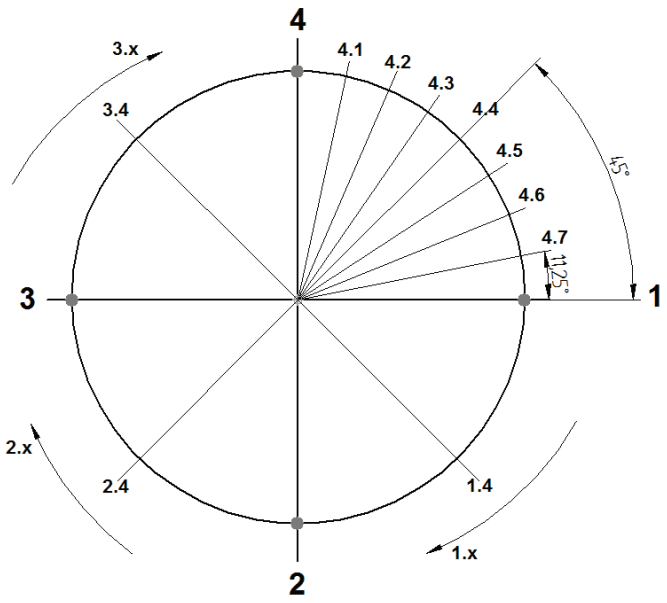

Fig. 6. Points of force application on the pin circumference, grey points represent the strain gauge axis

Next, one of the systems was selected and verification tests have been carried out. The authors focused on the influence of the angle of the force application in the exact angular range, which is ± 4.5° around the axis of the strain gauge No. 4 (Fig. 6). These tests have proven that the angle of force application in this angular range does not affect the measurement.

In addition, tests of the temperature influence on the measurement system were carried out. These tests were required due to necessity of taking into account that in normal operating conditions the pin may change temperature.

The last step was calibrating of the measurement system and re-checking its correct operation before installing the sensor on the Landing Gear.

6. Summary

The use of a self-made force sensor, located inside the pin is a promising solution. There are many advantages of using a strain gauge force sensor located in pin: low price, the ability to install the sensor inside the mounting pins (if the space allows doing so) without interfering with the system due to the wide range of possible strain gauge sizes. An important part of the described process was the development of a strain gauge installation technology that will ensure correct sensors operation.

In conclusion, tests have proven that the angle of force application in the selected measurement system, in range ±4.5° on strain gauge axis does not affect to the measurement. A properly selected system ensures no temperature effect. For this angle range, the linear characteristic is assumed, noting that similar systems works nonlinearly with loads in a wider angle range.

References

[1] Conard, L. M., *Strain gauge installation tool*, United States Patent, Patent Number: 5,767,416, 1998.
[2] Hoffmann, K., *Applying the Wheatstone Bridge Circuit*, HBM materials.

[3] Keil, S., *Technology and Practical Use of Strain Gages: With Particular Consideration of Stress Analysis Using Strain Gages, Installation of strain gages* pp. 109-134, Berlin 2017.
[4] Kowalewski, Z., Szymczak, T., *Podstawy tensometrii elektrooporowej oraz praktyczne jej zastosowania*, Dziewiąte Seminarium Nieniszczące Badania Materiałów, Zakopane 2015.
[5] Paprzycki, I., Skorupka, Z., *Laboratoryjne badania podwozi lotniczych*, Transport przemysłowy i maszyny robocze, 2014.
[6] Skorupka, Z., *Laboratory Investigations on Landing Gear Ground Reactions (Load) Measurement*, Journal of KONES, Vol. 24, No. 2, Warsaw 2017.
[7] Sobieszek, A., Paprzycki, I., Tywoniuk, A., *Landing gear dynamic tests with strain gages*, Journal of KONES Vol. 22, No. 3, pp. 221-227, 2001.

Manuscript received 02 February 2018; approved for printing 22 May 2018