DEVELOPING SMALL-AIRCRAFT SERVICE AND RE-CONSTRUCTION OF LANDING-GEAR LEG SUPPORT

R. Lefánti, G. Kalácska, I. Oldal, K. Petróczki

Faculty of Mechanical Engineering, Szent István University, Gödöllő, Hungary
www.geti.gek.szie.hu

Abstract
The programs of air-operation and service in the aviation engineering - within this at light-aircraft too - take place according to rigorous regulations [6, 7]. There are such machine units and parts which regulation are incomplete, for instance such is the landing-shaft seating. We have developed a new maintenance model based on the traditional ones, which offers new information exchange modul for e.g. weak point re-construction and uses paper based documentation and modern remote maintenance as well. Beside the new model we have worked out a renewing solution of the often failed landing-gear leg support applying field and laboratory test and FEM modelling to fill up as an engineering example for the information modul of the new maintenance model.

Keywords: small-aircraft, re-construction, FEM model

1 INTRODUCTION

The programs of air-operation and service in the aviation engineering - within this at light- aircraft too - take place according to rigorous regulations [6, 7]. Its reason is to increase the safety of aviation and the aircraft reliability. For the sake of these such operating and service programs have been worked out by both the manufacturer and the aviation authority, and nevertheless the maintenance personnel of airworthiness that those programs to be suitable for the technical requirements and regulations alike. There are such machine units and parts which regulation are incomplete, for instance such is the landing-shaft seating.
This paper written from our research work reviews briefly the problem and analyses of the landing-shaft and its development.

2 REPEATED BREAKDOWN

As a practical problem the silent-bloc (elastic longitudinal-seating support) at the attachment of landing-shaft in a Cessna 172-type aircraft manufactured in the years of 1970 broke down repeatedly, many times.
The characteristically repeated breakdown allows to come to conclusion that this is one blot (weak-point) of the aircraft. This aircraft is often used to train learner pilots generally taking place on grassy runway (the landings and take offs, however the quality of the grassy runway is not ideal in every event). These facts mentioned contribute on a large scale to the breakdown of silent-bloc. The Cessna 172-type is put into circulation with two construction landing-shafts [1]. One type has got rectangular cross-section, of uniform strength part reminding of solid arched plate-spring. The other type has got circular ring cross-section uniform strength part (tubular shaft). The breakdown mentioned is characteristic to the latter type.
In case of breakdown metallic contact can take place between the landing-shaft and the support (inasmuch the elastic element totally got ruined). In this case the depth of damage on the landing-shaft (for example scratch, knockout) can be at most 0.01 inch. If this happens the loading-shaft has to be replaced.
The condition mentioned is very dangerous considering the aviation safety because the silent-bloc serving to support the landing-shaft and to elastic damping, does not perform its task so the degree amount of damping and support is not appropriate. It can happen such event that the breakdown is not recognized in time, so the stress in the material increases at certain parts of the landing gear and in the framework as the effect of operation load changes. This situation is extremely accidental.
The deterioration of PUR-seating at Cessna 172-type means the blot (weak-point) to be repaired by reconstruction. Signs referring to breakdown could be observed in the setting - in place, too (Figure 1.). The plastic between the outer steel-bush of silent-bloc and the landing-shaft almost crumbled away because of repeated load. Figure 2. shows the damaged part in disassembled position. It can be seen in the Figure 2. that the original PUR-seating totally deteriorated. The inner part of the PUR bush extenuated, cracked and the material protruded towards the outer flange of the silent-bloc, surely here it could freely deformed.

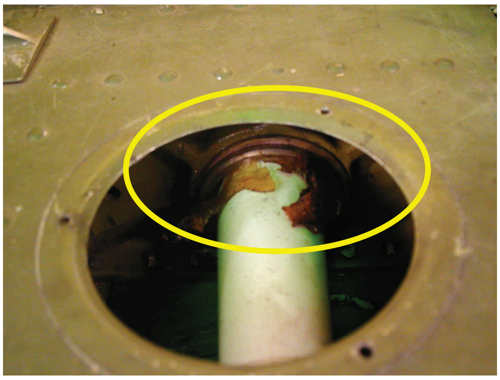

Figure 1. The damaged machine element installed position

Figure 2. The damaged machine element in disassembled position

3 THE SERVICE INSTRUCTION AND ITS LACK, OBJECTS.

The outer support has to be checked at Cessna 150-type after each 1000 hour or every 3 year, at 172-types after each 1000 hour but only at plate spring constructions concerning the landing-shaft. The manufacturer doesn't take measures in no kind of instructions concerning the service of elastic support (seating) in case of pipe cross-section landing-shaft [1]. The landing-shaft seating susceptible to breakdown means risk from aviation safety standpoint. The question can be raised with good reason whether the blot (weak point) can be replaced with solution containing new, up-to-date materials, where the operation load doesn't result returning breakdown.

Objects:

- To propose replacing the original PUR material with elastic seating by other plastic or by plastic mating.
- Further aim is to determine that characteristic load and limit based on which it is necessary checking the machine-element given, independently that just in which period is the aircraft service. It reaching the value determined it is proposed to supervise the machine-element, maybe its replacement. By this characteristic parameter the incomplete service instruction can be completed.

4 RECONSTRUCTION EXAMINATION OF LANDING-GEAR LEG SEATING

Figure 3. shows the process of the complex testing and evaluating of the machine-element deteriorated. We have marked the main activity points in the Figure. These are:

- Determining the material models;
- Measuring the load in real conditions;
- Preparing the mechanical finite-element analysis;
- To carry out rapid fatigue-wear tests in laboratory conditions;
- Preparing the mechanical finite-element analysis;
- Evaluating the results.

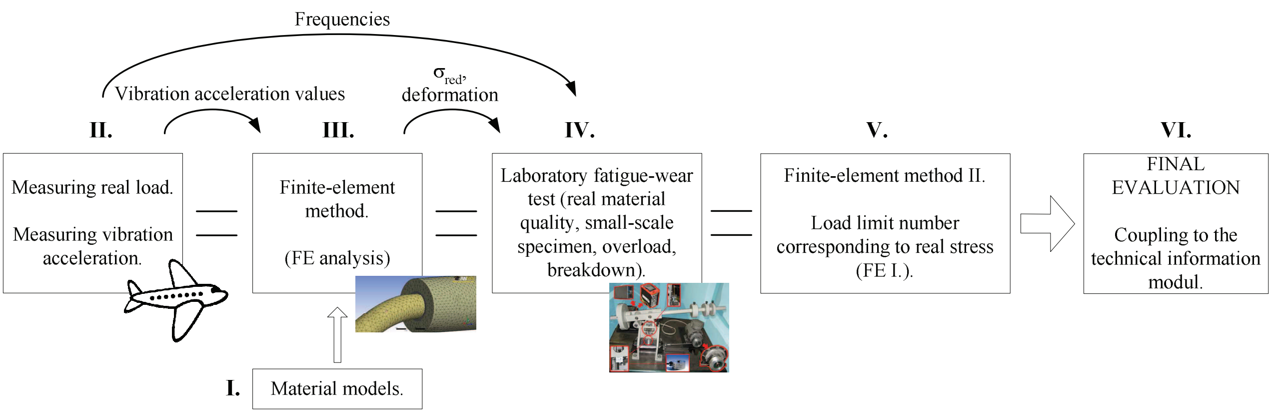

Figure 3. Complex testing, evaluating system

4.1 Determining original material and material desired for tests.

The elastic seating material resulting manifold breakdowns corresponds in mechanical properties to the cast polyurethane basic material presently into circulation as PUM 70A symbol.
Considering that the PUM 70A-type basic material characteristic breakdown is the fatigue and the wear because of this the PUM 60A and PUA 90A basic materials have been chosen as replacing materials having near similar elastic but better fatigue and wear and tribological properties.
To determine the mechanical and strength properties of the materials tested are needed to carry out further tests. Because of these hardness, tensile - and compression tests were carried out on these basic materials. The results and evaluation of the tests gave the input parameter of the FE - analysis.

4.2 System suitable for measuring the real load.

It is very complex task to measure the loads befalling to the aircraft to the landing-shaft and from this to the silent-bloc. Several procedures are widely used in practice to measure the stresses and strains in a construction [2, 4].
We have developed and made a measuring-system capable to measure acceleration/vibration-acceleration determining the load befalling to the certain machine-element (Figure 4.).

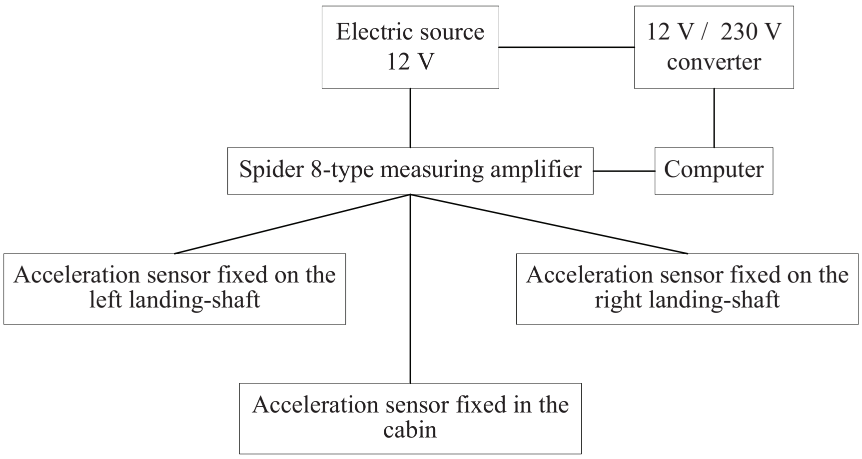

Figure 4. Sketch of the measuring-system suitable measuring accelerations arising in the light-aircraft

We have got permission and technical assistance after consulting with the operator to fix the acceleration sensors on the aircraft as well as the appliances needed to carry out the measurings.
On the spot of measurings the airport has got concrete cover and grassy fields can be found. Five-five landings and take offs were made on the concrete cover and grassy fields. The flights took place according to the regulations required by aviation authority and by the operational instructions of the light aircraft.

4.2.1 Evaluating the acceleration results

From the acceleration results measured in the framework and in the landing-shafts the results measured in the framework were used in further examinations and use for mechanical modelling. The reason of this is that to complete the mechanical model later the connection between the landing-shaft and the silent-bloc is not rigid surely the landing-shaft has got elasticity/damping by which the model to be prepared should be enlarged. This would make more difficult to complete the model as the elasticity/damping of the landing-shaft is unknown. Because of this we disregarded the results measured on the landing-shaft. The connection between the framework and the outer bush of the silent-bloc is rigid and the sensor in the cabin was fixed at such place (real seat frame) which has got proper rigid contact with the framework.
Among the measuring directions at the vertical „z" direction it could be unambiguously separated the various characteristic aeronautic conditions.
That six sections can be seen in Figure 5. which can be separated during measuring and flight.

The names of certain sections:

I. Landing process, in the air;
II. Moment of landing;
III. Section of decelerating taxiing on the field;
IV. Section of accelerating taxiing on the field;

V. Section after the moment of take off;
VI. Take off process in the air.

The examination of sections after these happened separately. We used Fourier transformation (FFT) examining the sections. Is a results of FFT we got vibration acceleration-frequency values from the vibration acceleration-time functions [5].
This guaranteed for us that we could determined the repetition member (frequency) of load belonging to the characteristic acceleration values. An example pricked out of Fourier transformation can be seen in Figure 6. The characteristic acceleration values are marked in the Figure so, as an exposed value (A), as well as a characteristic section (B).

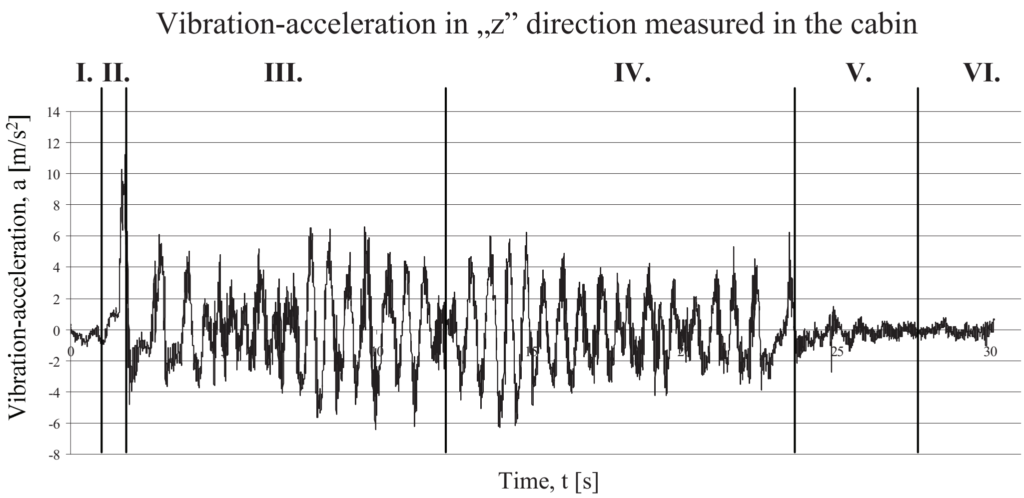

Figure 5. Characteristic sections of vibration-acceleration in „z” direction in the function of time measured in the cabin

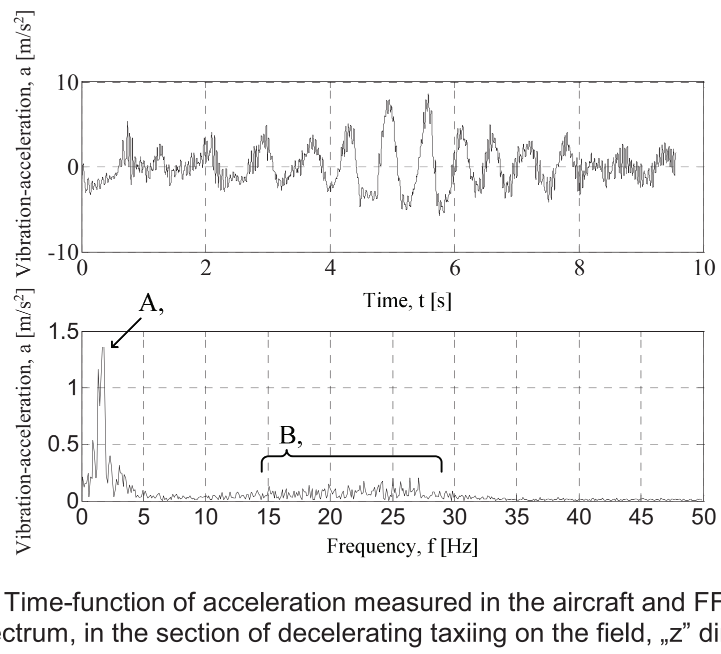

Figure 6. Time-function of acceleration measured in the aircraft and FFT frequency spectrum, in the section of decelerating taxiing on the field, „z” direction

It can be stated by knowing the results that the breakdown of the silent-bloc then happens sooner if the load is accompanied with much higher repetition number.
Knowing this it can be established that fact the critical sections considering the silent-bloc are the decelerating/accelerating taxiing on the ground (III., IV. section) and not the moments of landing as well as take off. The characteristic values of acceleration and frequency of decelerating/accelerating taxiing on the ground had to be applied for the further examinations.

4.3 Mechanical examination of the landing-shaft with simulation

The measurings with real time carried out on the aircraft and their results as well as the results of material testing give due base to carry out mechanical simulation examinations (Finite-element method, FEM) on the landing-shaft silent-block unit. The aircraft industry is among those domains applying FEM in practice [3]. We have used the Ansys Workbench 11 program for the FEM simulation. Some steps of using the program are shown in Figure 7. and 8.

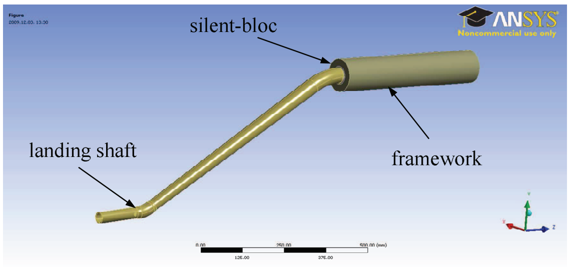

Figure 7. The geometric model

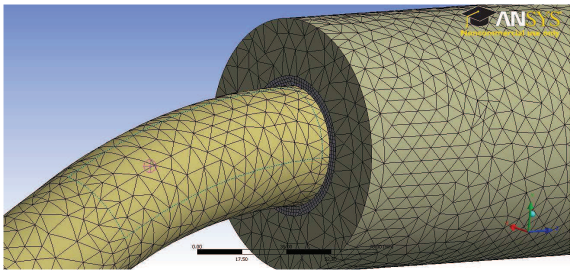

Figure 8. Making the mesh for the model

During the program we have completed the real model of the landing-shaft and silent-bloc. Among the parameters to be set for the run of the simulation the various material properties and the acceleration values in different directions measured occurred.
By executing the simulation we determined the reduced stress arisen in the plastic bush of the silent-bloc as well as the magnitude of deformations.
The characteristics determined appeared as input parameters at the laboratory rapid fatigue test.

4.4 Laboratory fatigue test

We have made an equipment for laboratory fatigue test capable to clamp a small- scale specimen to model the ruin of the silent-block. The construction and form of the equipment had to be capable carrying out rapid fatigue tests with construction materials in a reproducing system that the load should be suit the experiences at real measurings respectively with the FET calculations.
The DIN 50322 standard gave the basis of the test, within we took the 6. testing category into consideration, namely the model test with specimens having simple shape.
The directions of strain and load agrees with each other at real construction. The direction of strain and load however is perpendicular at the laboratory fatigue-test equipment. This doesn’t disturb the laboratory comparing tests, the reproducing capability - as a characteristic of 6. category -. The amount of the fatigue work introduced into the specimens and the other load parameters can be controlled.
The theory of fatigue test was given by the “Locati” rapid fatigue test applied for steels. During the test the material to be fatigued is exposed to 10^5 repeated load at each increasing load level. During these loads the material tested is ruined [8].
The fatigue test applied by us differs from the previously mentioned that we adapted the test theory to high elasticity elastomer.
The fatigue of the specimen to be tested is carried out with a carriage making straight line reciprocating motion, on the other hand the specimen is pressed by a load vertically to steel base plate (Figure 9.). This is a complex mechanical and tribological fatigue where the contact surfaces also deform and also rub (stick) as in the real landing-shaft seating.

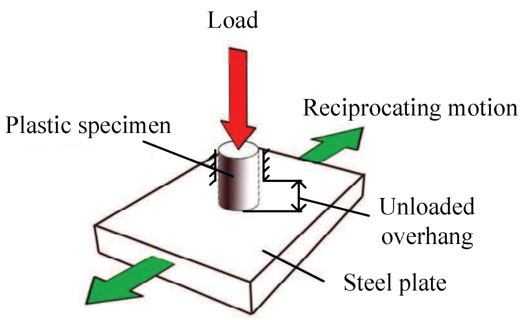

Figure 9. The specimen loads

The equipment built and its parts can be seen in Figure 10. The equipment was suitable to carry out the needed rapid fatigue tests.

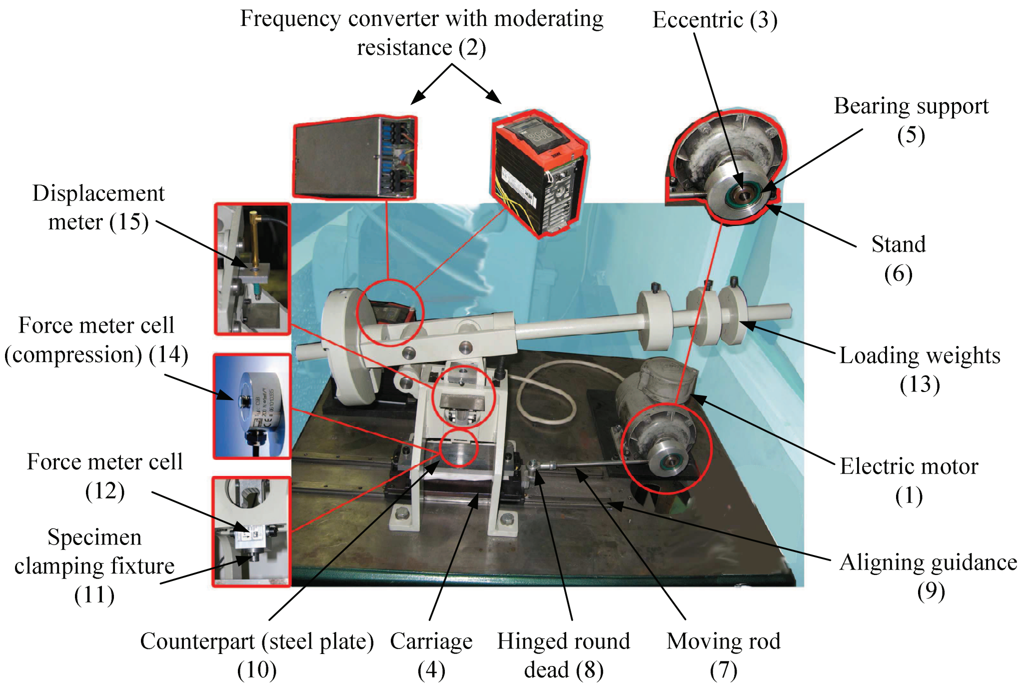

Figure 10. Equipment for fatigue-tribological tests

The results got form real time measurings carried out on the aircraft as well as got from FET-simulation gave the parameters to be set during fatigue tests on the equipment for fatigue test These are:

- The amplitude of the counterpart (10) movement with the help of eccentric (3);
- The frequency of the counterpart (10) movement with the help of the electric motor (1) and with the frequency converter (2);
- Vertical load with the help of loading weights (13);
- The length of unloaded overhang of the specimen from the specimen clamping fixture (11).

It could be established form the evaluation after carrying out laboratory measurings that in case of materials tested the functional reliability is the most favourable at PUA 90A. This is followed by PUM 70A then by PUM 60A.

4.5 Connection of the measuring results and of the real load repetition number (cycle- number)

During laboratory fatigue tests also bending and shear stress develop on the specimen beside vertical direction normal force because of this reduced stress has to be taken into consideration as a defined characteristic. It has to be determined the reduced stress in the specimen at load level given to decide the fatigue characteristic from measuring results of the silent-block elastic seating manufactured from the material tested. To determine this we have carried out mechanical modelling (FET).

After finishing the mechanical model we have determined fundamentally that:

- Bending and shear develop in the specimen beside compression.
- The σ_{red} value is multiple of the value calculated from compression at given load level and overhang length because of complex stress of the specimen. The fatigue test took place thus substantially at higher stress level comparing to operation condition.

We have obtained the following result using the results of real time aircraft measurings, the results of laboratory rapid fatigue tests furthermore the results of mechanical modelling (FET) of laboratory fatigue test:

- The elastic seating made of PUM 60A type plastic will be ruined probably at 2980 landings and take offs calculating with 20% factor of safety expecting 3727 take offs. The suspension of the landing-shaft and itself the silent-bloc have to be examined at reaching the limit number determined whether the breakdown started or ensued.
- The machine part original material corresponds to the PUM 70A commercial product. During our tests we established that with PUM 70A material higher service life and fatigue number of cycles can be reached than with PUM 60A- material. The basic material according to our tests is further suitable fulfilling its task, too. The results of fatigue-abrasion tests however come to the conclusion

that the elastic section of bed endures undoubtedly 2980 landings and take offs. At reaching the silent-bloc has to be checked whether the breakdown ensued or began. By this proposal such aggravation comes to the new service system which increases the safety. Further more the deficiency of the plant service instruction can be supplied with this information.

- The PUA 90A material is also suitable for the part as basic material. The results come to the conclusion that still greater improvement (higher service-life) can be reached than with PUM 70A material.

5 CONCLUSIONS

Summing up it can be established that we have created a complex measuring and evaluating system destined for executing reconstruction planning of a real construction. As a result of our research work we have determined a limit number suitable to give a reliability limit concerning the elastic seating of the landing-shaft (at a certain constructional condition) of the aircraft-type. We have hopes of helping the more safety aircraft operation with this completed reconstructional planning and with the complex evaluating process.

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