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PLASTIC MACHINE ELEMENTS OF SMALL AIRPLANE: EXAMINATION OF THE LANDING-GEAR LEG SUPPORT OF CESSNA 172

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Abstract: *Our daily life is strongly connected to the modern materials e.g. polymers and composites. These materials play more and more important role in airplane and aviation technologies. Not only the common places but load-carrying machine elements are produced of light-weight and wear resistant plastics as well. In the aviation the machine reliability especially is important, so, the good friction and wear properties together with increased corrosion resistance and vibration damping ability, as well low mass features are essential. There are many sorts of technical polymers available of which sliding and load-carrying elements can be produced. To choose proper polymers for a given tribological application is not a simple task owing to many different parameters influencing the performance of a polymer sliding element.*

1. PLASTIC APPLICATIONS IN THE AVIATION ENGINEERING

Plastic machine elements are often used in the aviation engineering. A special segment of the engineering activity at that field is the maintenance of single-engined- or small aircrafts having some critical elements. The figure 1. shows a new single-engined polymer aircraft, which is designed and built on different composite polymers. The previous releases of such a kind of planes are considered as transitions between the traditional metal-based constructions and the new composite models. That means in the age between 20 – 30 years of a small aircraft we can already find some hardwearing, strongly loaded polymers elements.

2. PLASTIC MACHINE ELEMENTS ARE IN SMALL PLANE

Based on the list of the elements produced in the 1960-70-years regarding the commonly used CESSNA family, we can classify the plastic applications.

- Average contact pressure (10 – 50 MPa) applications (e.g. cable sheaves coming from the civil and mechanical engineering). Mainly tough polyamides are applied for that. (fig.2. aileron, side and depth rudder plate moving rope disc)

- High contact pressure moving surfaces: typical the rolling or rolling/sliding polymer surfaces mainly mating with steels. (fig.3.)
- Pure sliding surfaces subjected to severe dynamic impacts (e.g. slide bearings and linear supports of landing-gear leg silent block)
- Covers and housing elements (PP, PE). Typically they are not mechanically loaded but light-weight is essential for them.

Figure. 1. Polymer aircraft

It is a fact that many of the small airplanes between 20 – 30 years are still in use worldwide. Comparing the engineering materials built in those old aircrafts to the new design versions shown in fig.1. we can find some typical engineering places to be resolved or redesigned during the maintenance.

Figure 2. Polymer rope disc

Figure 3. Polymer spur gear

3. LANDING-GEAR LEG SUPPORT

Studying the register of the maintenace activities a weak point can be found at CESSNA 172 aircraft. As time goes by the reliability of the landing-gear leg support (fig.4 and fig.5) becomes critical and after a certain number of friction load the original support pad craks and wears extremely fast. This part is considered to be important aviation safety point, nowadays we a good engineering possibility to renew the old structure with better and higher performance engineering polymers.

Figure 4. Position of longing rein on Cessna 172 type aircraft

The fig. 5. and fig. 6. show the landing-gear leg support.

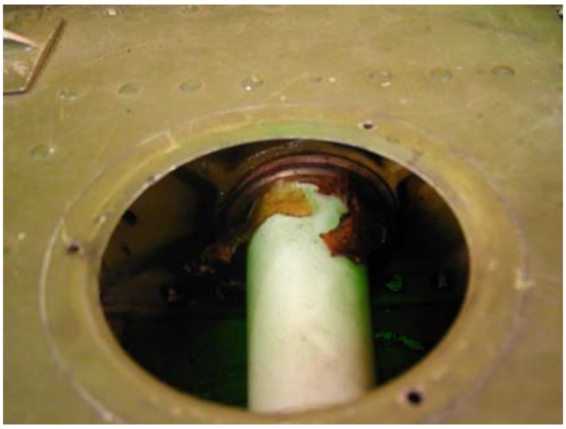

Figure 5. Landing-gear leg support in the aircraft

Figure 6. The failed PUR component

5. CASES OF LANDING-GEAR LEG LOAD

There are three main condition categories of the operation of landing-gear support. These cases origins from the normal use of aircraft:

- Rolling on runway

We can characterize this case with the following:

- The aircraft rolls to take off and rolls after landing on service road (taxi). This road may be grassy, concrete or asphalt covered.
- The aircraft speeds up on the runway to take off.
- The aircraft slow down after landing.

- Flying

The landing-gear leg has two loads:

- aerodynamic drag
- vibration of engine

- Landing

- The landing causes the biggest load and impact with sliding at landing-gear leg support.

During landing at the moment of touching the ground a complex load arise at the landing-gear. During landing the aircraft flies with rectilinear steady motion above the path. The flapping angle is set according to the landing method selected by the pilot preliminary. The body of the aircraft has max. 5° up to the horizontal level in the flattening out (fig.7.). The braking force is provided by the surface of airplane and by the wing flaps. In case of inoperative aerodynamic lift the airplane falls to the ground. Normally the altitude of this is about h = 0,10 -0,15 m. In extreme condition this altitude can reach 1 m. Based on the experienced pilots' opinion the falling down from higher can result the break of the aircraft's body.

- Beside the mentioned fact there is another load of the landing-gear, which comes from the turning wheel in the moment of ground touching.
- Third effect is the changing air resistance of the landing-gear.

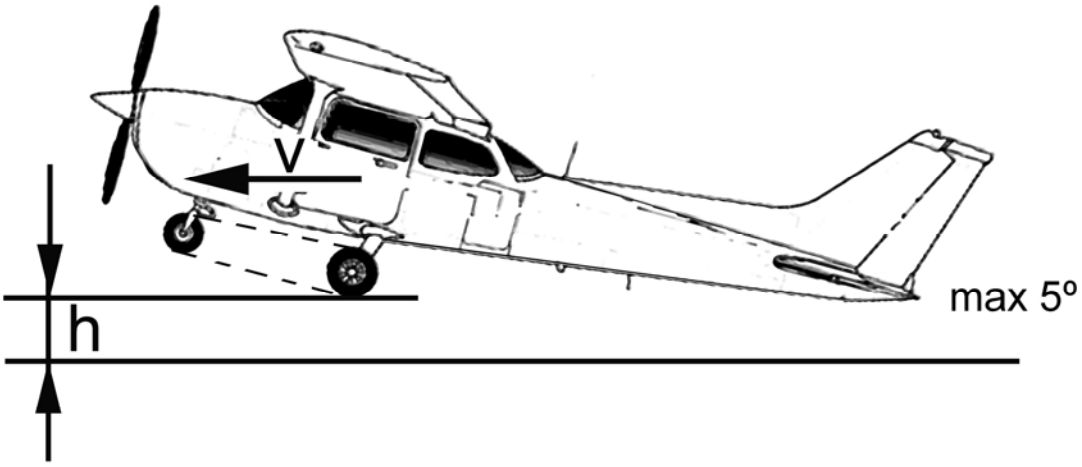

Figure 7. Landing (v-velocity, h-altitude)

6. THE LANDING-GEAR LEG SUPPORT TRIBOLOGY MODELLING

At first, we must measure the load and oscillation at landing-gear leg support with tree direction acceleration gages for the mentioned tree cases. After that we can calculate the model parameters, the normal load and the applied oscillation frequency.

Knowing these values we can compare preliminary selected polymers and composites for the landing-gear leg support pad.

The real data acquisition is being in progress.

In the meantime we developed the reciprocating testrig. The experimental set-up as pictured in fig. 8. is essentially a variant of the cylindrical specimen on plate reciprocating tribotest rig. The reciprocating sliding friction is created by an upright cylinder, which moves against a grinded steel plate in conformal contact. The cylindrical specimen is fixed to the specimen holder. The oscillating motion of the steel plate (0.1 – 20 Hz) is provided by a controlled variable speed electrical motor through an eccentrically power transmission for the adjustment of the stroke. The steel plate is fixed to the moving steel plate holder and is supported by a guide way of slide and nuts that allows the positioning of the mating plate. The horizontal movement (friction force) is impeded by the single point load cell. The machine is equipped with a manual loading system, which consists of the weights and the loading frame, mechanically pulled down loading arm.

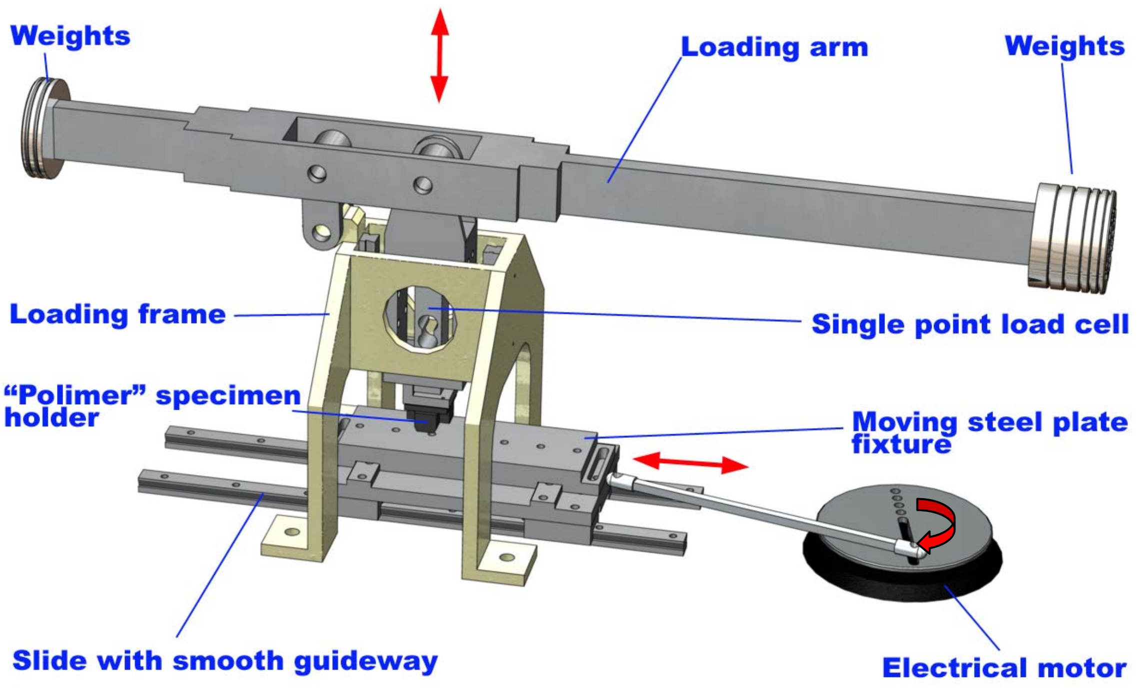

Figure 8. Upright cylinder on plate test rig

The normal displacement of the cylindrical specimen towards the steel plate, as a result of the wear, could be measured by a contactless sensor. The cylinder has a diameter of 8 mm and length of 15 mm while the steel mating plate sizes is arbitrary to maximum 80 mm – 150 mm. The loading system provides different normal loads: from 0 to 200 N.

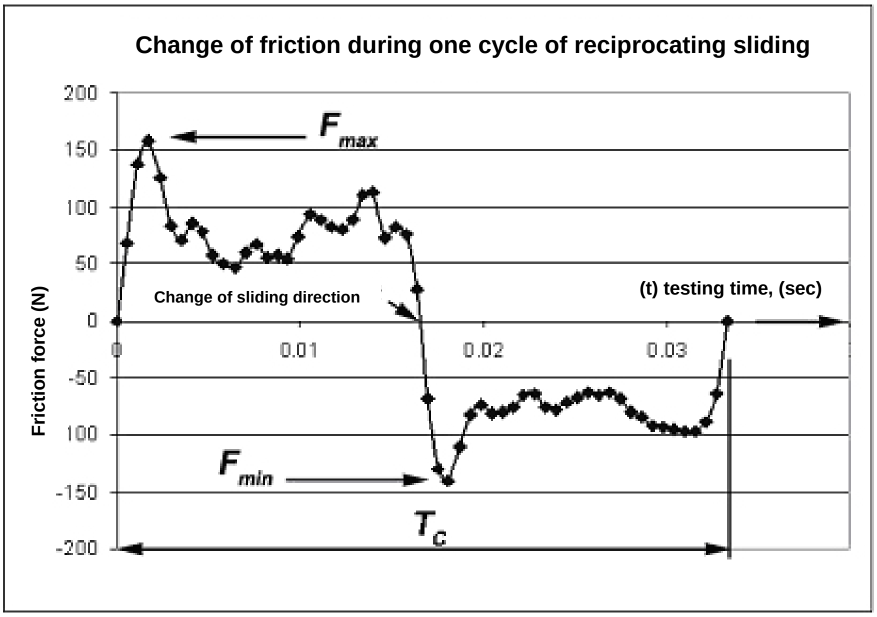

Fig. 9. Change of friction of PA 6 G / steel after 1 hour, Tc = 0.03 sec, L = 200 N

During the reciprocating movements the change of friction and wear/deformation together can predict the performance of different material pairs. We have already made some preliminary tests with polyamide 6 and steel surfaces. Some typical behaviour of friction can be seen in fig. 9. This measuring system ensures the comparison of static and dynamic friction, even stick-slip behaviour can be investigated at the near-static regime.

From the measured friction force (fig. 9) easy to count the static *(F_{stat})* and dynamic *(F_{din})* friction forces:

$$F_{stat} = \frac{|F_{\max}| + |F_{\min}|}{2} \qquad [\mathrm{N}]$$

$$F_{din} = \frac{1}{T_C} \cdot \int_0^{T_C} |F(t)| \cdot dt \qquad [\mathrm{N}]$$

where T_C is the periodic time.

Knowing the preliminary set normal load (F_N) the friction coefficient in case of static and dynamic regim:

$$\mu_{din} = \frac{F_{din}}{F_N} \qquad \mu_{stat} = \frac{F_{stat}}{F_N}$$

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