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SOME REMARKS ON PYLON RESONANCE MEASUREMENTS ON PZL-SOKÓŁ HELICOPTER

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SOME REMARKS ON PYLON RESONANCE MEASUREMENTS ON PZL-SOKOL HELICOPTER

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ABSTRACT

This paper presents the development effort undertaken to find the best solution for the elimination of pylon resonance on PZL-Sokol helicopter in the early testing stage.

Special attention has been focused on the pylon dynamic properties. The pylon is fitted to fuselage through a plate support, which appears to be a unique design.

PZL-Swidnik Helicopter Company is experienced in design and operation of pylons fitted in this way . Therefore, we present here one of the problems which permanently applies to the above. We present the results static and dynamic stiffness measurements of the pylon, and vibration data recorded in test flight. Examples of records of vibration on main rotor hub are presented as vibration vector hodografs to emphasize the advantages of this way of presentation.

NOTATION

AB	= height of main gearbox, 520 mm.
BC	= height of rotor shaft, 650 mm.
AO	= height of support plate, 240 mm.
M_x	= longitudinal bending moment on rotor head
M_z	= lateral bending moment on rotor head
N	= per revolution
P_x	= force on rotor head; longitudinal
P_z	= force on rotor head; lateral
r_1, r_2	= distance beetwen vibration pickups and rotor axis
(X,Y,Z)	= inertial system
(x,y,z)	= system connected with rotor head
t	= time
$\alpha(t)$	= angle beetwen (X,Y,Z) and (x,y,z)

1. BACKGROUND

Most of the currently manufactured helicopters have main gearbox attached to fuselage by means of a system of struts. These struts are distributed so as to provide, as far as possible, partial separation of the main forces generated in the main rotor, and to transmit these forces on to the fuselage bypassing the main gearbox casing. The casing of gearbox attached in that way does not participate, even partialy, in the force transfer from the main rotor.

The pylon on PZL-Sokol is installed in a different way, Figure 1. The engines and the main gearbox are assembled on one main support plate. This is a

geometrical element made as a single alluminium alloy forging. In this configuration, both the casing of the main gearbox and the main support plate directly participate in all main rotor load transmission. The pylon with the main support plate has its advantages, as also disadvantages in relation to pylon installed by means of a strut system. One of the adventages is the possibility of complete removal of the engine/main transmission assembly from the roof when four bolts fastening the support plate to the fuselage are unscrewed, the control system disconnected, as well as the fuel and oil lines, etc. Gearbox allignement with relation to the engines is technologically easy, and fuselage deformation does not affect it. Nevertheless, all forces from the main rotor are transferred through the gearbox casing and support plate. Therefore, these assemblies must be made with special care, and testing their static and dynamic strength should requirs special thoroughness.

2. STATIC STIFFNESS MEASUREMENTS

Figure 2 shows a diagram of rotor shaft tip static stiffness in rotation plane, which was received from average of a number of measurements. The diagram has a configuration similar to the ellipse, whose short and long axes correspond to the longitudinal and lateral axes of the helicopter, respectively. The difference between strength results in the direction chosen is 15%. For such a system, one can expect a certain frequency range, in which bending resonance of the pylon is possible. The difference between these strength values determines the width of the range.

Figure 3 presents the bending curve of the pylon over its full length, resulting from P_c force acting in the blade rotation plane. The main component in the bending of the pylon is the shaft bending and the rigidity of the shaft installation in the gearbox. Small deformations on the CA section indecate high rigidity of the connection between the support plate and the gearbox casing, providing stability of engine location relative to the main gearbox.

3. DYNAMIC STIFFNESS MEASUREMENTS

The dynamic stiffness functions of the rotor shaft tip has been determined through measurements, with relation to the main loads from the rotor in the range of major frequencies transferred from the rotor on to the fuselage. Some of those functions are shown in Figure 4. As can be seen from the Figure 4, there is a possibility of pylon bending resonance of 16.8 Hz in the longitudinal direction, and of 17.2 Hz in the lateral direction, respectively. It should be pointed out that the four-blade rotor was rotating at 4.25 Hz, which caused that 4N frequency was located exactly between these two natural frequencies. The effects of resonance were apparent already during first test flights. A high vibration level was observed in the cockpit. The level of the vibration was strongly related to the rotor r.p.m. and to the direction and value of the force perpendicular to the rotor shaft - see Figure 6.

3. PYLON VIBRATION MEASUREMANTS

To study the phenomenon in detail, two vibration pickups (V1,V2) were installed on the rotor shaft tip. They were installed as presented in

Figure 5. Vibrations were measured in directions corresponding to the (x,z) axes of a moving system of coordinates originating from the rotor shaft axis. Components of the vector of vibration were converted in real time into components in another system of coordinates (X,Y,Z), related to the fuselage, taking into consideration the current angle of rotation ot the moving system $\alpha(t)$.
This angle was measured by means of another measuring system synchronized with vibration measurement. The tip of the vector (X,Z) plotted a hodograph curve representing rotor head vibration in rotation plane. Examples of hodographs obtained in this was are shown in Figure 7. Observation of such records in an oscilloscope is convenient. The graphic presentation is readable and permits easy assessment, both qualitative and quantitative, of the especially when the resonance amplification is low. The hodographs presented in Fig. stages of approaching resonance. Hodographs obtained for stages remote from resonance cover only a small area, and their character is that of a multi-harmonic function. As resonance approaches, the area covered by a hodograph grows, and the hodograph shape gets more and more ellipse-like. The axes of the ellipse can be used to determine the direction of main rotor hub vibration.

5. METHODS OF RESONANCE ELIMINATION

In this situation it was necessary to decide what steps should be undertaken in order to eliminate the problem of resonance. Changes in pylon design meant a signifficant delay in the program and an increase in its costs. The decision was taken to adopt an intermediate solution consisting in placing 50 and 100 kg weights on the rotor hub. This addition caused an increase in the dynamic rigidity of the pylon in the operational range of frequencies, which is shown in Figure 4. During test flights of helicopter with the weights on the rotor hub, a decrease of vibration and loads on the rotor was noted, Figure 6. This permitted the initial test flight program to be completed within the time scale planned and at no extra cost. After an in-depth analysis of the results, plans to redesign the pylon were abandoned, and instead a decision was taken to install a dynamic roller vibration absorber on the rotor hub. This type of vibration absorber was then used for the first time on a helicopter. The application of the vibration absorber proved to be so effective that the helicopter meets the requirements of all the relevant standards and enjoys specialist opinion to be one of the best in its class in this respect.

6. CONCLUSIONS

- The method presented in this paper gives a very simple way of pylon resonance elimination by increasing the dynamic stiffness of the rotor shaft by adding a vibration-damping weight on the rotor hub. This method proved to be effective and cost-effective at the same time.
- Observation of some vibration processes, especially slowly increasing ones, is convenient when using hodographs of their vector, e.g. when observing stall flatter in tests.

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FIGURES & GRAFS

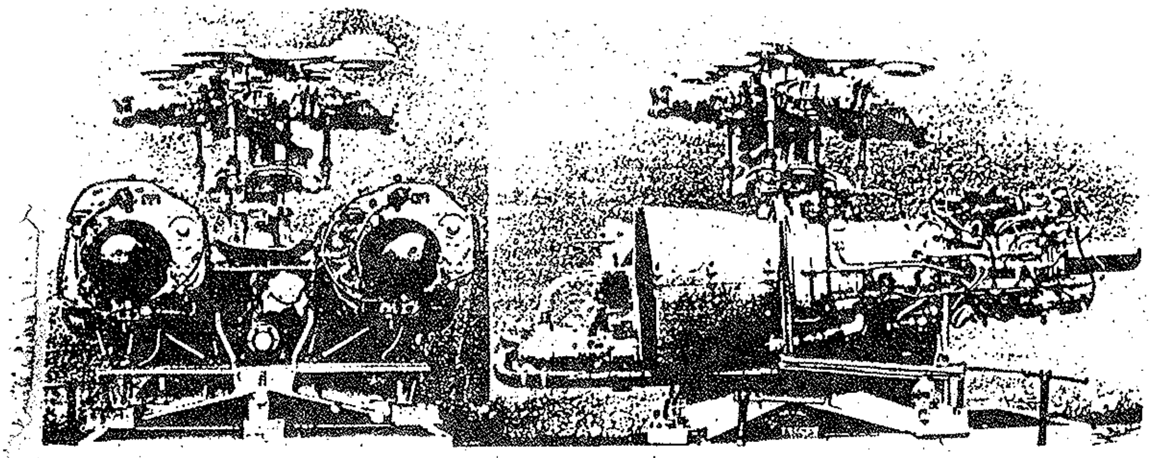

Figure 1. PZL-Sokol engine and transmission system.

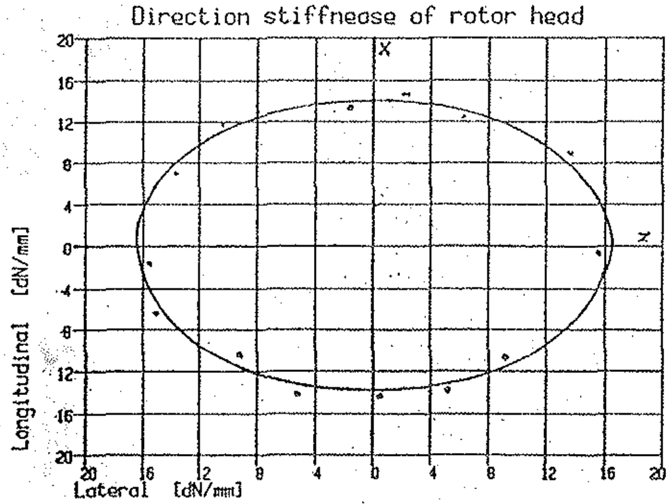

Figure 2. Static stiffness anisotropic curve versus rotor plane forces.

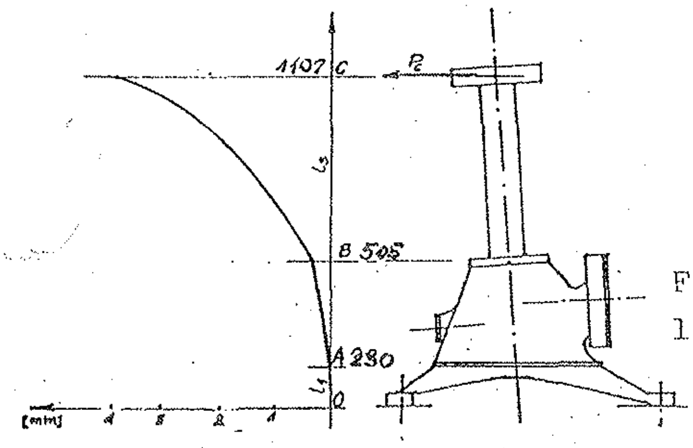

Figure 3. Pylon deformation line under force measured during test flight, P_c=7.5 kN.

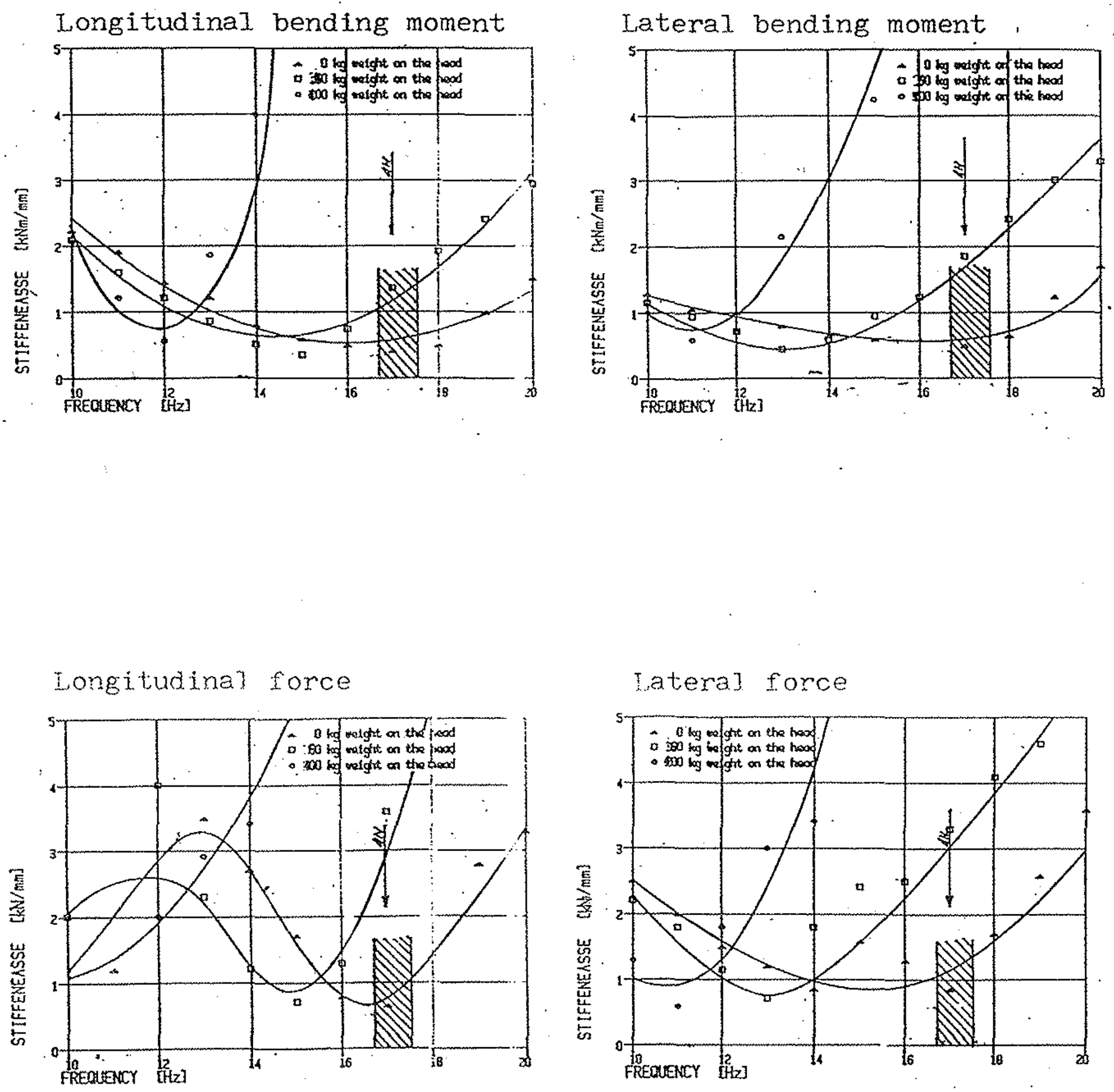

Figure 4. Dynamical stiffness of rotor head versus selected loads.

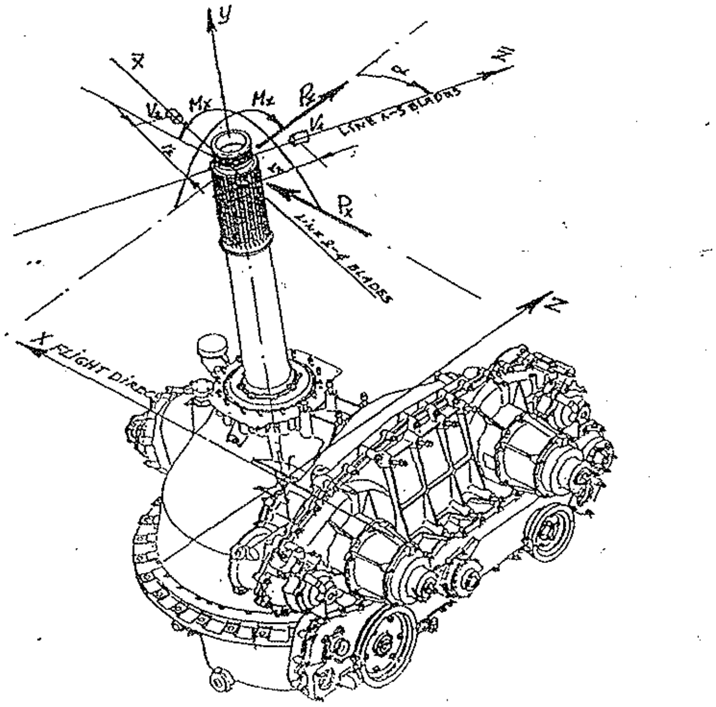

Figure 5. Scheme of measurements of pylon steffness and vibration.

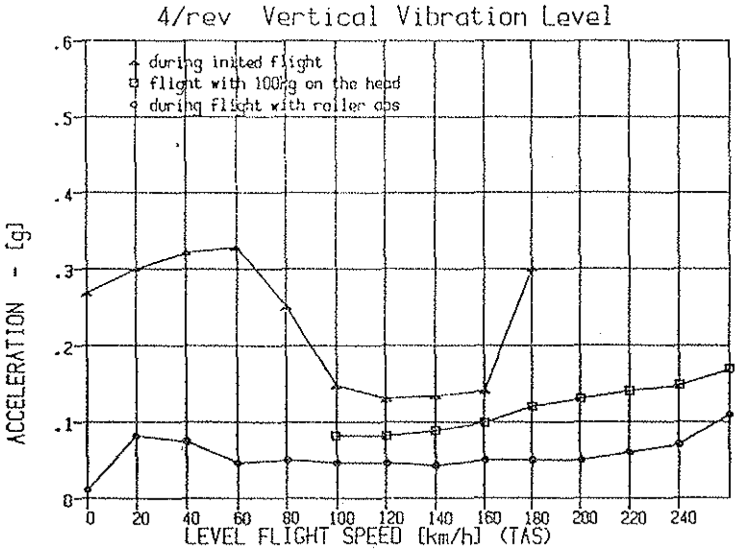

Figure 6. Level of vibration under pilot seat for successive test flight stages.

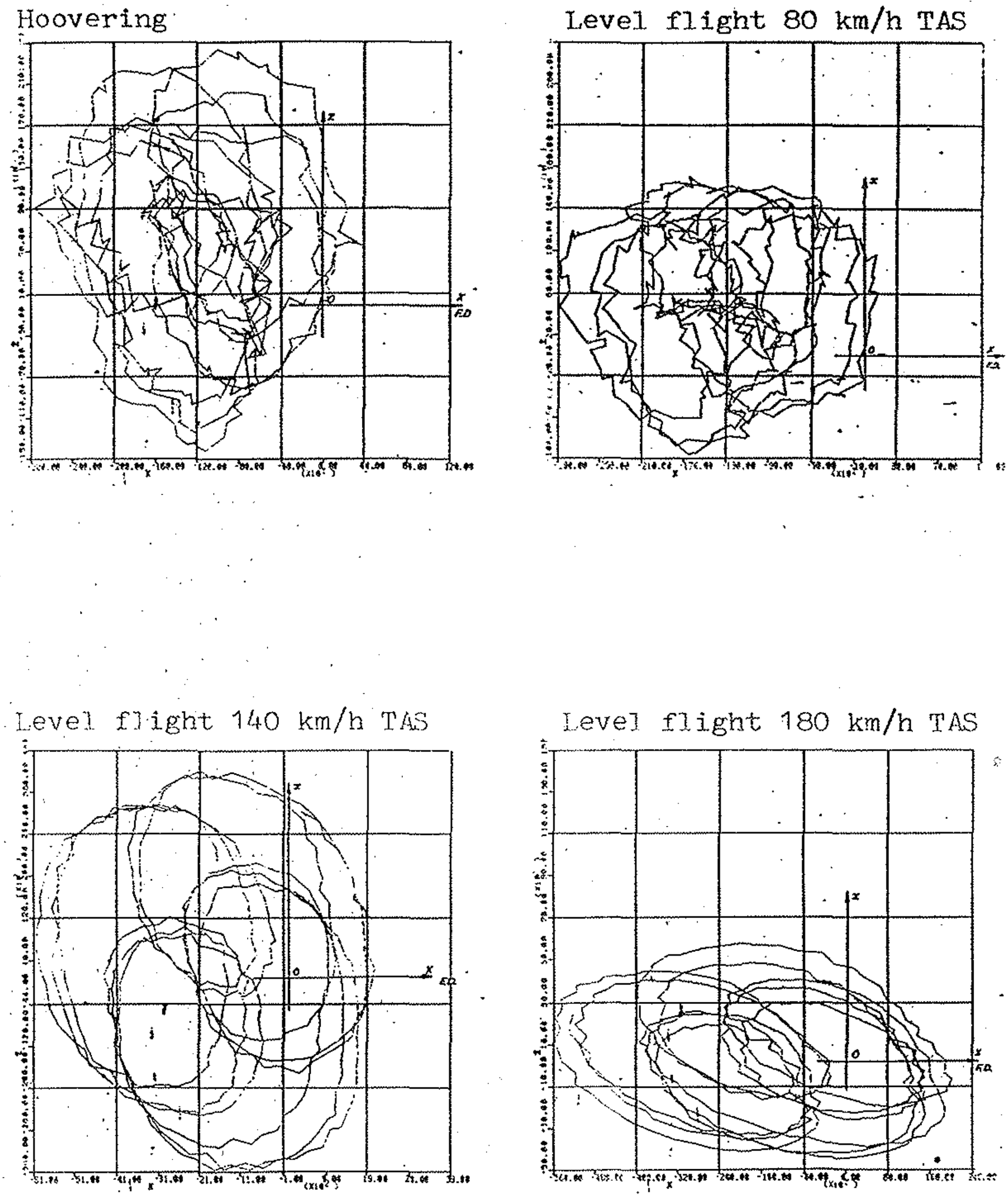

Figure 7. Typical hodographs of rotor head vibration recorded during test flight.