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HELICOPTERS

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VIBRATIONS ABSORPTION SYSTEM

- Analysis of vibration and frequency modes:
  - during bending displacement (both during flapping and in drag), and
  - in torsional.
- In general, it is assumed they are independent of each other.
- There are certain flexible and inertial couplings; cases of blade torsion or when the elastic and mass axes do not coincide.
  - The flutter of blades is a classical coupling between aerodynamic and inertial forces.
- The aerodynamic loads on a helicopter blade varies significantly over one cycle (along the azimuth ψ), and in hover flight, these loads are periodic.

HELICOPTER VIBRATIONS

- The forces and torques of the rotor cause vibrations in the fuselage:
  - they are transmitted from the blades to the rotor head,
  - from there to the transmission shaft of the rotor,
  - to the bearings of the main gearbox,
  - from there to the housing of the main gearbox, and
  - finally to the fuselage, through the attachments with it.
- These forces are both aerodynamic and inertial ones, generated by the flapping and drag (lead/lag) movement of the blades.

HELICOPTER VIBRATIONS

- The fluctuating forces on the tail rotor can also act.
- In the majority of cases, the main rotor is the main cause of undesirable vibrations.
- The control of the vibrations is important for many reasons:
  - Improves the performance of the crew, and the operation safety.
  - Improves passenger comfort.
  - Improves the reliability of the avionics and equipment.
  - Improves the fatigue life of the airframe structural components.

- The rotor type influences the load system applied to the fuselage.
- The vibration torques generated in pitching and rolling by the articulated rotor:
  - are significantly smaller than those produced in teetering rotors or hingeless rotors.

- The choice of the number of blades is also important:
  - The level of load aerodynamic oscillations tends to decrease as the order of the harmonics increases.
  - Since the term **bΩ** is the first cause of vibration in the fuselage, the greater the number of blades, the lower the basic aerodynamic vibration input will be.
  - The **correct dynamic design** of the helicopter blades is essential for two fundamental reasons:
    - To minimize the amplification of the aerodynamic vibration load on the rotor blade that transmits to the fuselage, and
    - To minimize the total vibration load of the blade to achieve an acceptable fatigue life.

- The generation of **aerodynamic oscillatory loads at frequencies that are multiples of the rotation velocity:**
  - important in the operation of helicopter flight.
- The forced vibrations of the helicopter cannot be totally eliminated.

HELICOPTER VIBRATIONS

- The forces and momentum on the helicopter body axes: **X, Y, Z, L, M, N**.
  - The total force **Z** only has harmonics **multiples of the number of blades,**
    - (with rotors perfectly balanced and on correct tracking; but even so, other harmonics appear).
  - The forces **X**, **Y** are harmonic **multiples of the number of blades ±1,**
    - That are cancelled out so that the rotor head only transmits multiples of the number of blades.

- For many years, helicopters used blades with a basically constant distribution of **mass and rigidity.**
- Not very good dynamic characteristics but acceptable in the cases of:
  - Rotor heads of low offset value of the flapping hinge, and moderate cruising speeds.
- However, due to:
  - Systems with higher values of this eccentricity (real or virtual),
  - Higher cruise speeds,
- This has led to the need to redefine the structural design of the blades to reduce the aerodynamic loads.

- Modern blades in composite material:
  - With an adequate mixture of fibreglass and carbon,
  - Allow to obtain adequate values of bending and torsional rigidity, almost independently.

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Main transmission mounting systems

- In order to minimise the vibration forces felt on the fuselage, various methods have been used of mounting the main rotor's gearbox.
- Some examples of passive systems that have been used:

Main transmission mounting systems

- **Soft mounting between the rotor, reductor and turbine.**
  - A soft suspension, derived from the simple systems of one degree of freedom or a spring-mass model. The force transmitted through the spring to the support is reduced, as the natural frequency of the spring, relative to the excitation frequency, decreases.
  - Since the static deflection of the suspended system can be unacceptably large if the soft suspension system is mounted on the base of the main transmission, it may be necessary to isolate the mass, as much as possible.

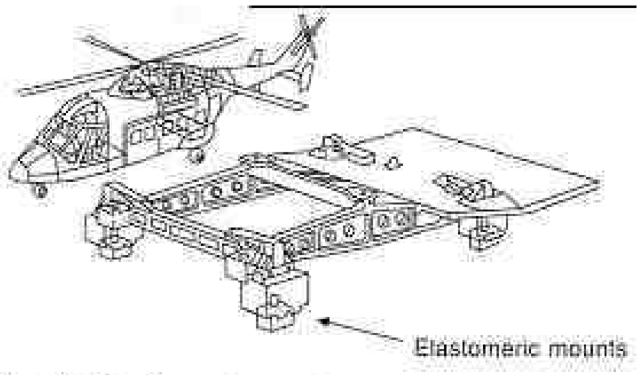


Fig. 8.7 Westland W-30 raft mounting system

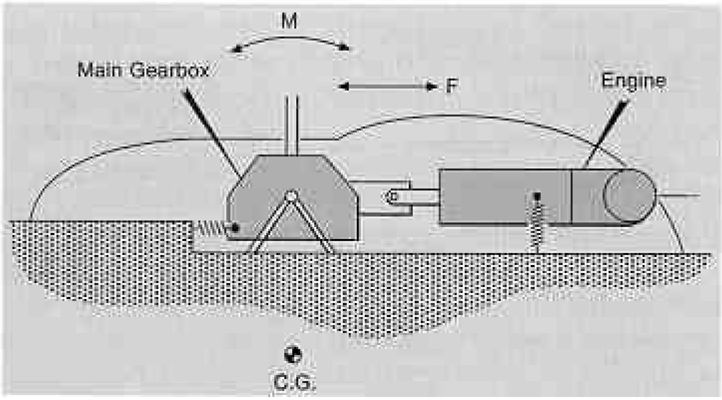


Fig. 8.8 Flexibly mounted gearbox and engine system

Main transmission mounting systems

- In this way, the main gearbox with the turbines, are mounted on a platform. The platform is fixed to the fuselage using the fittings selected.
- However, the attenuation of the vibration forces in this way is quite modest, and certain loads will be transmitted without any reduction.

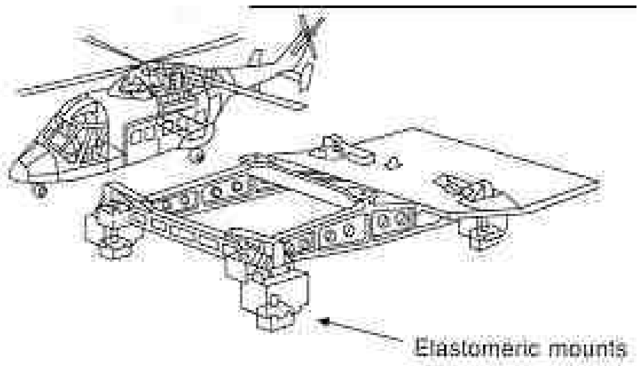


Fig. 8.7 Westland W-30 raft mounting system

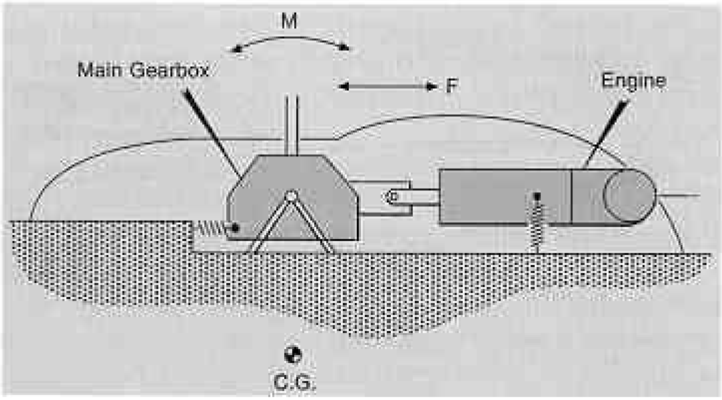


Fig. 8.8 Flexibly mounted gearbox and engine system

Main transmission mounting systems

- A mounting -rotor/main transmission/engine- system is designed to respond to the forcing frequency, **bΩ**, so that the forces of inertia and stiffness generated by the response are cancelled, as much as possible, the generated effects forced in the rotor.
  - For example, a possible design criteria for a system may be to minimise the frequency **bΩ** of the helicopter's pitching moment with respect to the CG.
  - The attenuation efficiency of the system would only be optimal for a specific flight condition having a determined ratio between the forces and the moments of the rotor head.

Main transmission mounting systems

- Systems that use *DAVI (Dynamic Anti-Resonant Vibration Isolator)*.
  - Originally developed for the crew seats by the *Kaman* company, it has been successfully applied to the main transmission.

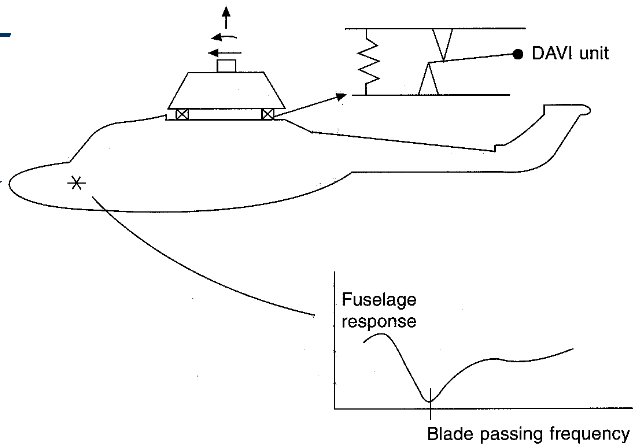


Fig. 8.9 The DAVI gearbox mounting system

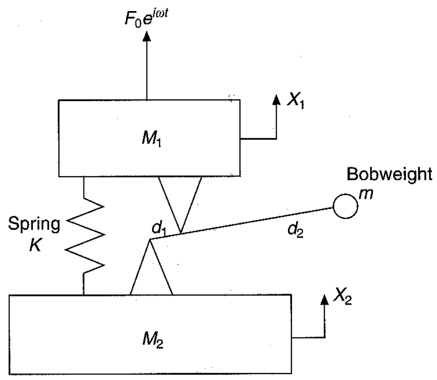


Fig. 8.10 Simplified DAVI model

Main transmission mounting systems

- Between the main gearbox, the engine and the fuselage mass, a rigid arm is placed that carries a small centrifugal mass (*bobweight*).
- A great attenuation can be supplied in a narrow frequency range.
- For this, values of stiffness should be used that eliminate the problem of excessive static deformation.

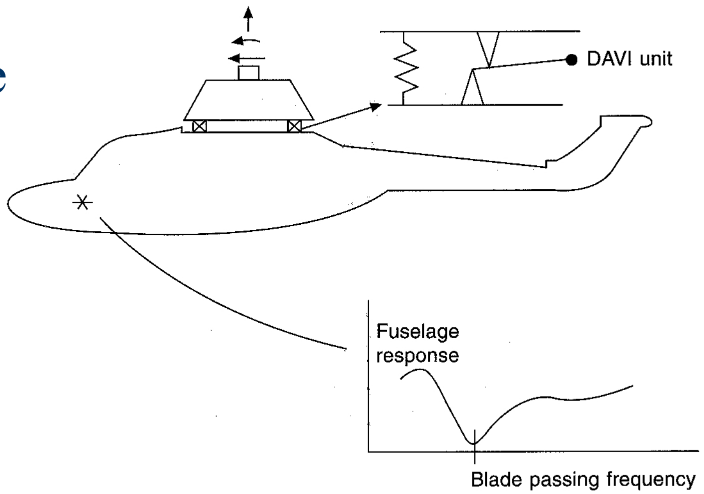


Fig. 8.9 The DAVI gearbox mounting system

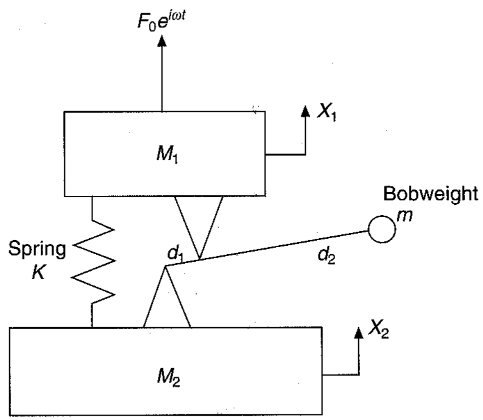
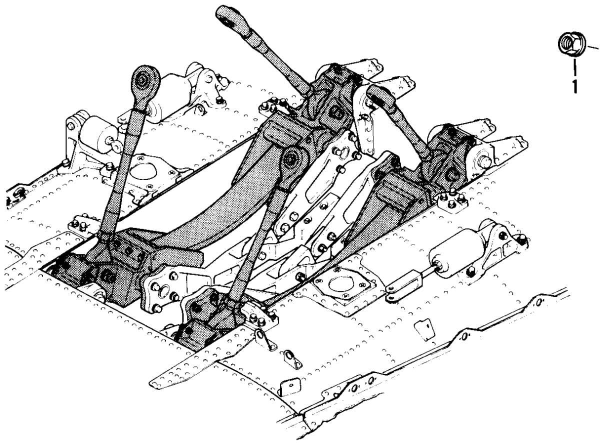


Fig. 8.10 Simplified DAVI model

Main transmission mounting systems

- *Nodamatic* Transmission System, by Bell.
  - A beam is inserted between the transmission and the fuselage.
  - The assembly is set up while suspended from the nodal points of the beam, when it is vibrating in response to the loads forced from the rotor.



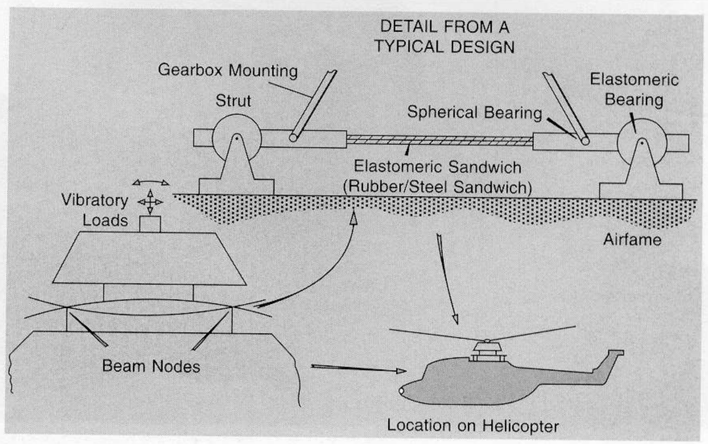


Fig. 8.12 Principle of the nodal beam mounting system

Vibration Absorbing Systems

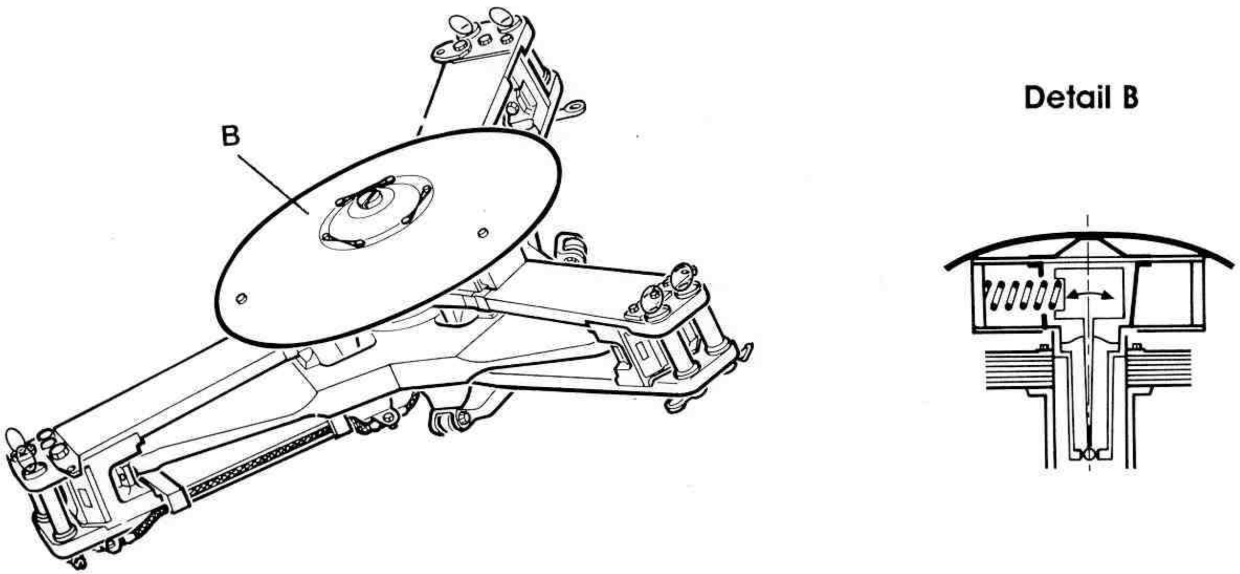
- It is divided into **two** categories:
  - Those designed to **reduce the vibration levels** along the fuselage.
  - Those designed to produce a **reduction in vibration in a localised area** of the fuselage.

Vibration Absorbing Systems

- Passive methods of the first category – to reduce vibration levels along the whole fuselage – are:
  - The rotor head is mounted on a vibration absorbing system, of which there are two types:
    - The centrifugal pendular absorber (**bifilar**) developed by Sikorsky.
      - The spring stiffness required is achieved by centrifugal force.
      - The natural frequency of the device varies with the rotation velocity of the rotor, as the forced frequency.

Vibration Absorbing Systems

- Fixed frequency absorber (*flexispring*) developed by Westland. The figure shows the system that mounts the rotor head of the Ecureil AS350.



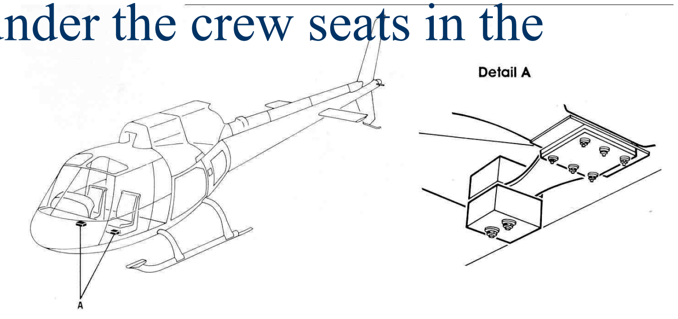
ROTOR HEAD ANTI–VIBRATION DAMPER

Vibration Absorbing Systems

- A **centrifugal pendulum- type absorber is mounted on the rotor blade**.
  - This type of absorber has been used in the BO105 and in the Hughes 500.
  - In the case of the Hughes 500 the set up consists of absorbers tuned to **3Ω** and **5Ω** for the 4 blade version:
    - To reduce the response of the 2 and 3 third mode of bending vibration of the blade, at **3Ω** and **5Ω** oscillatory frequency of the aerodynamic loads in the rotary system.

Vibration Absorbing Systems

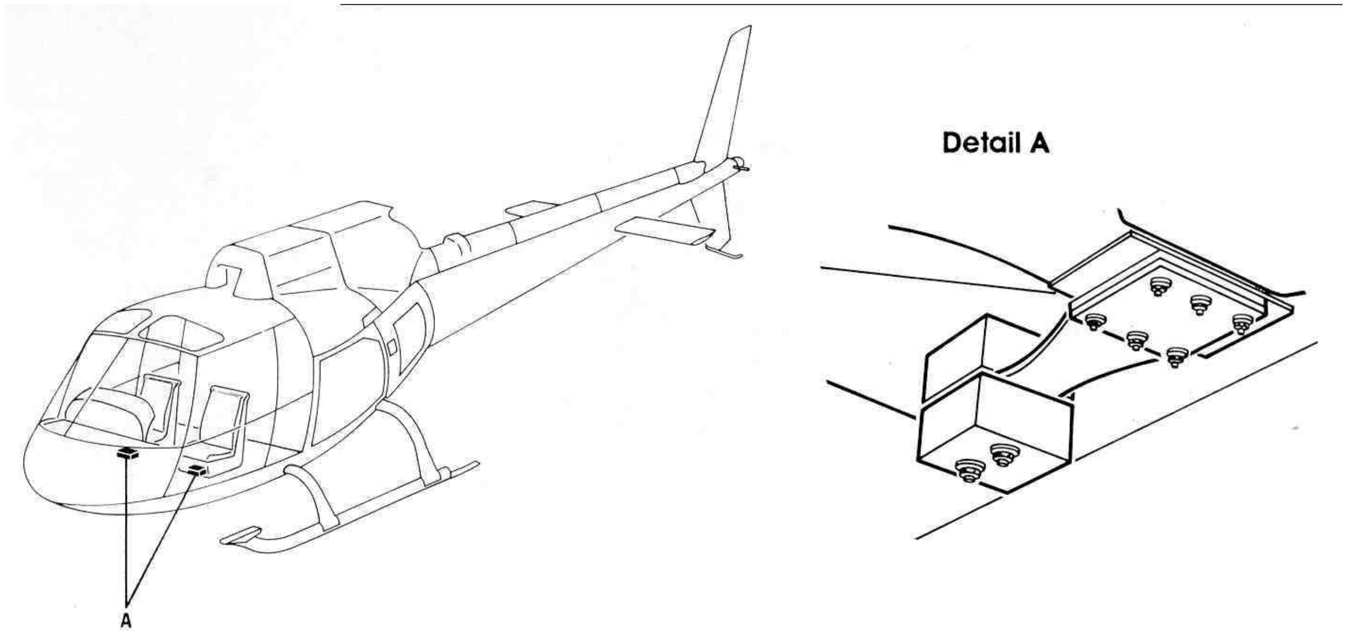
- Passive methods for the **second category** – reduction of the vibration in a localised area of the fuselage -:
  - The fuselage mounted on the classic spring-mass system.
    - Involves the installation of a system with a relatively heavy mass (for example, the battery or parasitic mass), generally on the cabin zone (close the crew and passengers), tuned to forced frequency **bΩ**.
    - The figure shows the mass mounted under the crew seats in the Ecureil AS350.



CABIN RESONATORS

Vibration Absorbing Systems

- The figure shows the mass mounted under the passenger seats in the Ecureil AS350.



CABIN RESONATORS

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