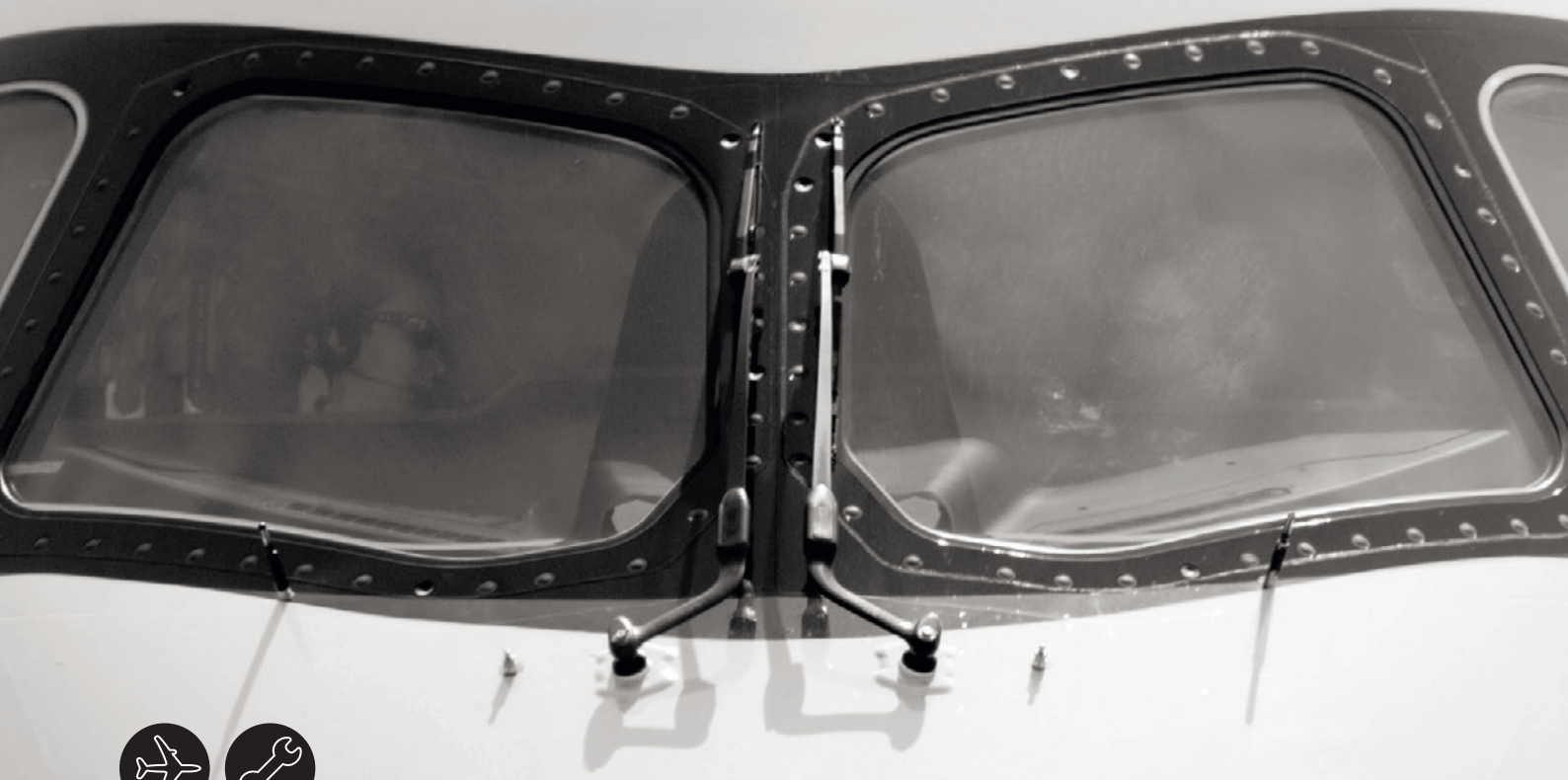


Troubleshooting Airframe Vibrations

As moveable structural components such as control surfaces and landing gear doors age, wear of hinges and actuators can sometimes lead to airframe vibrations. These vibrations can cause noise and physical discomfort in the passenger cabin.

To prevent further deterioration of components, the cause of vibration should be quickly identified and removed. For this, maintenance personnel require Flight Crew to make observations of the vibration using a Vibration Reporting Sheet (VRS).

A clear understanding of how to complete the VRS is important before starting the observations. Some parts of the VRS require manual control inputs with Autopilot OFF and therefore cannot be performed in RVSM airspace.

AIRFRAME VIBRATIONS DURING FLIGHT

In-service experience

Today, the Airbus fleet benefits from many years of accumulated in-service experience, and is relatively free from reports of airframe vibration during flight. However, airframe vibrations are still sometimes reported.

When an airframe vibration occurs, it can be identified by people inside the aircraft. Depending on the source of the vibration, it may be experienced either as a physical movement, or as noise, or as both a movement and noise. These experiences can cause passenger concern and discomfort. Additionally, any vibration indicates increased wear of components. For both these reasons, identification of the cause of the vibration should be established quickly.

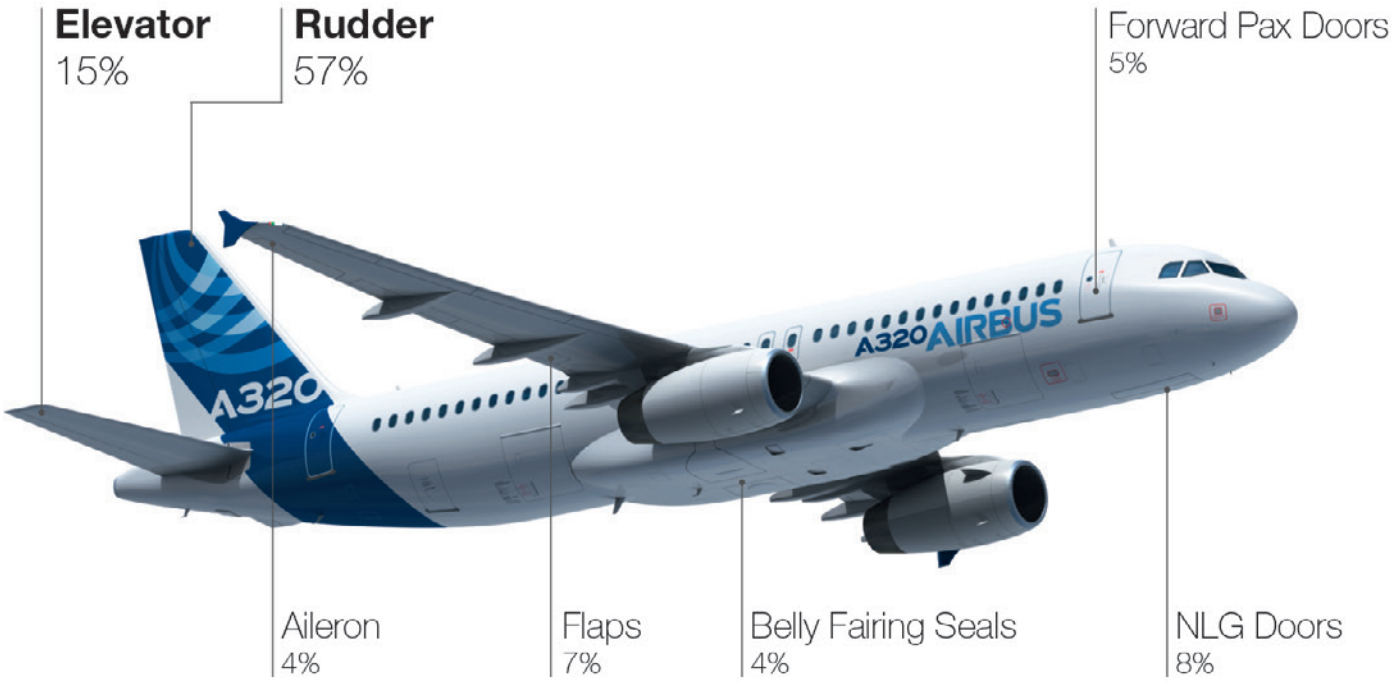
Causes of vibration

Due to the size of the fleet, the majority of reports of airframe vibrations on Airbus aircraft are received on A320 Family models. To identify the causes of vibration, Airbus organised a four year working group with airlines and equipment manufacturers, which focussed on the A320 Family fleet. This work identified that the majority of vibrations arise in the aircraft tail section, including 57% of vibrations from the rudder, and 15% from the elevator. Moveable control surfaces in the wings together account for only 11%, whereas sources in belly fairings, passenger and landing gear doors account for 17%.

> “Vibrations experienced on board an aircraft can lead to passenger concern and discomfort.”

(fig.1)

Main sources of vibration on A320 Family aircraft, identified by the Airframe Vibration working group



> “Limited Cycle Oscillations do not create any handling or performance concern.”

The main contributor to vibrations, particularly on flight control surfaces, is free-play of servo-control bearings, servo-control attachments, and and/or surface hinge lines (bearings & attachment). Free-play is primarily caused by wear.

When free-play is present, the flight control surface or door will have a tendency to oscillate slightly within the space created by the free-play whenever the surface is at zero hinge-moment. When in this condition, an observable vibration will only start if an energy input is provided, typically from aerodynamic effects of a sufficiently high air speed. This phenomenon is called a ‘Limited Cycle Oscillation’ (LCO).

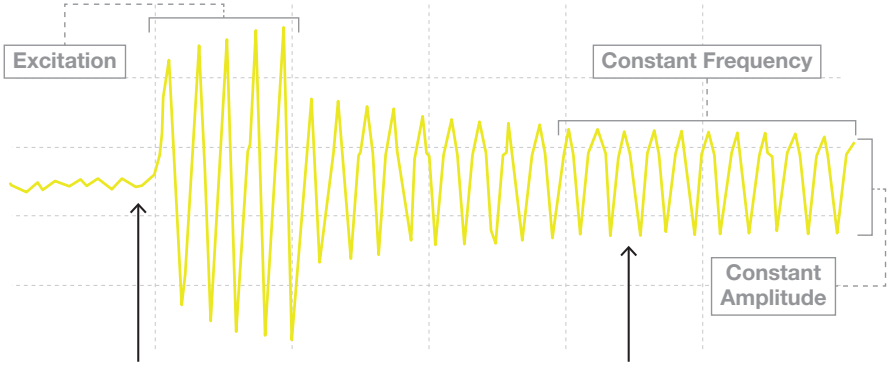
Limited Cycle Oscillations (LCO) and Safety

LCO are characterised by a stable and non-divergent vibration of constant amplitude and frequency, after initiation by the triggering input. LCO do not create any handling or performance concern, since surfaces and systems remain fully efficient during the vibration. It is a stable self-sustained non-diverging phenomenon.

An LCO vibration cannot diverge into flutter because whenever the LCO amplitude increases, the damping term involved in LCO mechanics also increases and leads automatically to a decrease of amplitude. The extra damping comes from the increased stiffness caused by the increased amplitude on the involved free-play area; the force of components pushing against each other. ■

(fig.2)
Waveform of a Limited Cycle Oscillation (LCO).

An LCO vibration cannot diverge into a flutter phenomenon because any increase in vibration amplitude is damped by the force of components pushing against each other.



Excitation
Energy such as sufficient airspeed is needed in order to excite a vibration

Constant oscillation
LCO vibration remains limited at same frequency & amplitude. Structural damping prevents divergence to flutter

> “Since airframe vibrations only occur during flight, maintenance personnel will need pilots to make observations of the vibration.”

TROUBLESHOOTING AIRFRAME VIBRATIONS

Reporting to maintenance personnel

Upon experiencing an airframe vibration, quick action is recommended in order to identify and resolve the cause of the vibration. It is therefore important that flight crew report the vibration to their maintenance personnel.

Maintenance personnel are provided with appropriate procedures in the Trouble-Shooting Manuals (TSM) for resolving the issue. However, since airframe vibrations only occur during flight, maintenance personnel will need pilots to make observations of the vibration.

The Vibration Reporting Sheet (VRS)

To collect pilot observations, a 'Vibration Reporting Sheet' (VRS) is provided within the TSM procedure 'Identification of the cause of In-Flight Airframe Vibrations and/or Noises'. A well completed VRS will provide sufficient information to maintenance crew to help them complete a Decision Tree and Decision Table, so that they can identify the specific part of the aircraft which is vibrating.

As can be seen in **(fig.3)**, the VRS is split into four sections as follows:

1. Flight conditions when the vibrations and/or noise occur
2. Observations when the vibrations and/or noise occur
3. Parameter changes with AP ON that have an effect on vibration
4. Parameter changes with AP OFF that have an effect on vibration

Section 1 of the VRS collects basic flight information. Sections 2 to 3 include further data collection fields which do not require pilots to make any specific control inputs.

> "If a control input is made and the vibration stops, knowing which control surfaces have been commanded helps identify the source of the vibration."

(fig.3)
The Vibration Reporting Sheet (VRS)

A330 VIBRATION REPORTING SHEET

NOTE FOR FLIGHT CREWS (Also print all of paragraph 3.A.)
When permitted by time and flight conditions, the flight crew must complete the VRS correctly. This will help the maintenance personnel to find the post-flight corrective actions.
- All fields with the mark (*) are mandatory.
- You must give observations about vibrations (start or stop) in relation to the normal flight sequence (in stabilized flight or after a parameter change made to obey the flight plan).
In each box, make a mark in the applicable section.

NOTE: FOR MAINTENANCE PERSONNEL, REFER TO TSM TASK 05-50-00-810-819 FOR THE FAULT ISOLATION PROCEDURE.

(1) FLIGHT CONDITIONS WHEN THE VIBRATIONS AND/OR NOISE OCCURRED
GROSS WEIGHT: [ ] ALT: [ ] *SPEED (IAS): [ ] (kts)
ENG VIBRATION PARAMETERS: #1 [ ] #2 [ ] AP1: ON OFF AP2: ON OFF
*FLIGHT PHASE: INITIAL CLIMB CLIMB CRUISE DESCENT APPROACH
AIR TURBULENCE: YES NO L/G: UP DOWN
*SLAT/FLAP POSITION: 0 1 2 3 FULL

(2) OBSERVATIONS WHEN THE VIBRATIONS AND/OR NOISE OCCURRED
-*FLIGHT CONTROL OSCILLATION SEEN ON THE ECAM: YES NO
*-> IF YES, ON: RUDDER AILERON RH LH ELEVATOR RH LH
-*AFFECTED AREA:
COCKPIT FWD CABIN MID CABIN AFT CABIN
SPECIFIC LOCATION: [ ]
– * NOISE Y N
– VIBRATION INTENSITY: LIGHT MODERATE STRONG
– VIBRATION FELT: LATERALLY VERTICALLY UNKNOWN

(3) PARAMETER CHANGE (AP ON) THAT HAS AN EFFECT ON VIBRATIONS AND/OR NOISE (VIBRATIONS AND/OR NOISE START OR STOP)
THRUST Y N ALTITUDE Y N SPEED Y N

(4) PARAMETER CHANGE (AP OFF, FDs ON) THAT HAS AN EFFECT ON VIBRATIONS AND/OR NOISE
If permitted by time and flight conditions, the flight crew can apply flight control inputs (with AP OFF, which is not permitted in RVSM airspace during a level flight or during the altitude capture of the cleared FL) to identify the source of the vibrations. The flight control inputs must be small and smooth and applied on:
-The sidestick for pitch and roll to obey the FD orders
-The rudder trim (+/- 1.5° MAX) for yaw. Do not use the rudder pedals.
VIBRATIONS AND/OR NOISE WERE STOPPED BY SMALL FLIGHT CONTROL INPUT ON:
1-PITCH Y N 2-YAW Y N 3-ROLL Y N

– GENERAL CREW COMMENTS (FREQUENCY, SOURCE, NOISE, SPEED CHANGE EFFECT, VIBRATIONS STOP AT THE END OF THE CLIMB, VIBRATIONS START AT THE START OF THE DESCENT, AP STATUS,......, OTHER COMMENTS):
— —
— —

DATE: [ ] FLT N°: [ ] A/C IDENT: [ ] F/O: [ ] CAPT: [ ]

The VRS is found within the relevant maintenance documentation for troubleshooting airframe vibrations, as listed in the table below. The contents of the VRS are almost identical for each Airbus aircraft model. A350 XWB documentation is planned to be incorporated into Line Maintenance documentation by Q1 2018.

Aircraft Family	Manual	Task Reference
A320 Family	TSM	05-50-00-810-801-A
A330 / A340	TSM	05-50-00-810-819-A
A380	TSM	05-50-00-810-828-A
A300-600 / A310	TSM	05-50-00 Figure 101

> "The information needed in Section 3 of the VRS can be collected with the autopilot ON, whereas Section 4 requires the autopilot to be OFF."

The information needed in section 2 can be found when the vibration occurs, by observation of the aircraft, its instruments, and the vibration. Corroboration of flight crew with cabin crew observations of where the vibration is the strongest is recommended for a higher reliability of the reported information.

Vibrations can be caused when a control surface is in the zero hinge-moment position. Therefore, the principle for the information collected in sections 3 and 4 is to monitor the vibration when a control input is made and a control surface is moved out of the zero hinge-moment position. If a control input is made and the vibration changes, this gives a useful indication of the surface involved in the vibration.

However, there is an important difference between the pilot actions necessary for section 3 and the actions necessary for section 4.

The information needed in section 3 of the VRS can be collected by observing the aircraft with the autopilot ON, whereas the information in section 4 of the VRS can only be collected with the autopilot OFF. The goal is to observe any change in the vibration, including whether it becomes weaker or stops, or becomes stronger.

In section 3, observations are made whenever the autopilot itself commands a change in thrust setting, turn, climb or descent. The only manual action listed in this section of the VRS is selection of the speed brakes by a few degrees. A change of the vibration due to speed brake extension can indicate that the vibration originates in the elevator.

Either elevator or rudder would be implicated as the source of vibration if a change in the vibration results from a change in altitude setting or in thrust setting. Ailerons would be the principle structural element impacted if the vibration is changed during a turn.

Section 4 of the VRS is only intended to be used if sections 2 and 3 do not succeed in helping identify the source of the vibration. Observations of the vibration are made when the pilot flying directly makes small and smooth flight control inputs, using the side-stick for pitch and roll inputs, or the rudder trim for yaw inputs.

A change in the vibration due to a pitch input indicates that the elevator is the most likely source of vibration. A change in the vibration due to a yaw input indicates the rudder is the most likely source of vibration. And finally, a change in the vibration due to a roll input primarily indicates that the vibration comes from the ailerons.





THE VRS IN PRACTICE

RVSM airspace

Today, the vast majority of commercial aviation operations takes place within Reduced Vertical Separation Minima (RVSM) airspace. A regulated requirement of conducting operations in RVSM airspace is to maintain an Auto Pilot (AP) engaged in order to ensure that the aircraft does not deviate from its assigned altitude.

Sections 1 to 3 of the VRS can all be completed with the AP ON. However, section 4 can only be completed with the AP OFF, and therefore cannot be performed in RVSM airspace. This condition means that completing section 4 of the VRS may not always be appropriate in all airline operations.

Airline policy

Although flying with AP OFF is a normal task for pilots, some operators prefer to have only technical pilots complete section 4 of the VRS because it may involve non-routine manoeuvres. Some operators prefer to conduct VRS evaluations on a non-revenue flight.

> “Section 4 of the VRS can only be completed with the AP OFF, and therefore cannot be performed in RVSM airspace.”

In whichever way an operator chooses to complete section 4 of the VRS, the associated instructions in the TSM clarify the appropriate technique for implementing the procedure. This includes the following points:

Appropriate technique for applying section 4

- When permitted by flight conditions and airline policy, and when not in RVSM airspace, the flight crew can disconnect the Auto Pilot to try to identify the source of the vibrations
- All inputs must be smooth and follow the Flight Director (FD) bar guidance
- Usually only very small inputs are sufficient to stop the vibration
- Large control inputs are neither required nor recommended for the purpose of VRS evaluation, especially when flying with passengers on-board
- Apply the procedure in the sequence pitch, roll and then yaw
- If vibrations do not stop, apply small rudder trim inputs of +/- 1.5° MAX (yaw)
- Do not use rudder pedals
- When the reporting is completed, AP should be set back on again as required

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In-flight aircraft vibrations can sometimes be experienced, leading to passenger discomfort. The vibrations are caused generally caused by wear of components.

These vibrations do not create any handling or performance concern, and cannot diverge into flutter since they are damped by the surrounding structure and systems. However, to prevent further degradation of equipment, they should be resolved quickly.

To help identify the source of the vibration, observations must be made during flight. Maintenance personnel provide the flight crew with a Vibration Reporting Sheet (VRS), which structures flight crew observations of the vibration into a useful form for maintenance personnel.

Sections 1 to 3 of the VRS can be completed by pilot observation only, without any need for specific action. If sections 1 to 3 of the VRS do not allow to identify the source of the vibration, it becomes necessary to apply section 4.
Section 4 of the VRS can only be performed with Auto Pilot OFF, and therefore cannot be completed in RVSM airspace. An appropriate technique has to be applied for these evaluations. Some airlines prefer to have the section 4 procedures completed by technical pilots on a non-revenue flight.

Further reading

Document	Aircraft Type	Reference	Title
ISI	A320 Family	27.34.00002	Elevator vibrations prevention
ISI	A320 Family	27.24.00001	Prevention of the rudder vibration
FOT	A320 Family	999.0084/11	In flight vibrations reporting
FOT	A380	999.0004/14	In flight vibration and noise reporting



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