Encounters of Aircraft with Volcanic Ash Clouds

VAAC “Best Practice” Workshop 2015
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- Compilation and Analysis of Encounters
- Volcanic Ash Encounter Severity Index
- Occurrence Reporting
- Other Activities
- Outlook
Volcanic Ash Research at DLR

- Project VolcATS – Volcanic Ash Impact on the Air Transport System
  - Project manager: Dr. Hans Schlager, Institute of Atmospheric Physics

- DLR-wide project (duration until September 2016) including
  - Institute of Atmospheric Physics (Oberpfaffenhofen near Munich)
    - Institute of Air Transportation Systems (Hamburg)
    - Institute of Propulsion Technology (Cologne)
    - Institute of Materials Research (Cologne)
    - Institute of Flight Guidance (Braunschweig)
    - Institute of Flight Systems (Braunschweig)

- Institute of Flight Systems:
  - Compilation and analysis of encounters of aircraft with volcanic ash clouds
  - Investigation of the effects on navigation and communication systems
  - Assessment of volcanic ash impact on aircraft performance by contamination of engines
Compilation and Analysis of Encounters


- Contact established with Marianne Guffanti (USGS)
  - Collaboration and joint evaluation of new known incident reports
  - Updating the existing database with minor adjustments
  - Regular contact and information exchange
  - One common database
Compilation and Analysis of Encounters

• Only new incident reports from 2010 onwards were considered

• The following sources were sighted and evaluated (→ number of reports)
  • EVAIR – EUROCONTROL Voluntary ATM Incident Reporting → 186
  • The Aviation Herald (http://avherald.com/) → 2
  • Internet News → 2
  • Confidential written and oral communications → 2

• Incident reports without real volcanic ash encounter were disregarded

• Remaining reports were classified according to an existing severity index
Failure Descriptions and Overview Encounters (2010+)

- Engine bleed failure
- Engine fluctuation
- Abrasion on edges of engine fan blades
- Blocked drain hole of pitot probe, pitot head replaced
- Erosion of passenger cabin windows (69 out of 76 replaced)
- Restriction in breathing and speech, dryness in the throat
- The co-pilot appeared to be sick due to the smell
- ...

<table>
<thead>
<tr>
<th>Class 0</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Class 5</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>~42</td>
<td>~36</td>
<td>~11</td>
<td>~6</td>
<td>-</td>
<td>-</td>
<td>~95</td>
</tr>
</tbody>
</table>

- Still preliminary since evaluation in progress! (New incidents can be amended)
- No reports during Grimsvötn in 2011 found!
- Health problems input for IAVWOPSG/8 No. 7/34?
Volcanic Ash Encounter Severity Index

• Severity index was formulated in 1994 by Tom Casadevall and Karin Budding (in consultation with engine and airframe manufacturers and the Air Line Pilots Association) and endorsed by ICAO (Doc 9691 2nd Edition, Appendix G)

• Minor adjustments by ICAO in 2007. Currently six classes from 0 (lowest) up to 5 (loss of control)

• No classification available for (including incident reports before 2010):
  • Health problems of persons on board
  • Temporary failure of navigation-/communication systems
  • Engine failure with permanent shutdown of one/multiple engine(s)
  • Reduced engine thrust by contaminated engine(s)

• Some pilots (and aerospace engineers) were asked to review and amend the severity index.
<table>
<thead>
<tr>
<th>Class</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| 0     | Sulfur odor noted in cabin.  
       | Anomalous atmospheric haze observed.  
       | Electrostatic discharge (St. Elmo’s fire) on windshield, nose, or engine cowls.  
       | Ash reported or suspected by flight crew but no other effects or damage noted. |
| 1     | Light dust observed in cabin.  
       | Ash deposits on exterior of aircraft.  
       | Fluctuations in exhaust gas temperature with return to normal values. |
| 2     | Heavy cabin dust.  
       | Contamination of air handling and air conditioning systems requiring use of oxygen.  
       | Abrasion damage to exterior surfaces, engine inlet, and compressor fan blades.  
       | Pitting, frosting, or breaking of windscreen or windows.  
       | Minor plugging of pitot-static system, insufficient to affect instrument readings.  
       | Deposition of ash in engine. |
| 3     | Vibration or surging of engine(s).  
       | Plugging of pitot-static system to give erroneous instrument readings.  
       | Contamination of engine oil or hydraulic system fluids.  
       | Damage to electrical or computer systems.  
       | Engine damage. |
| 4     | Temporary engine failure requiring in-flight restart of engine. |
| 5     | Engine failure or other damage leading to crash. |
# Volcanic Ash Encounter Severity Index

## 1. Reference Information
- **Operator**
- **Airline**: [Name of airline]
- **Type of Aircraft**: [Type of aircraft]
- **Registration**: [Registration number]
- **Flight Number**: [Flight number]
- **Departure Airport**: [Departure airport]
- **Arrival Airport**: [Arrival airport]

## 2. Conditions of Encounter
- **Flight level**: [Flight level]
- **Geographic Position**: [Geographic position]
- **Meteorological Conditions**: [Meteo conditions]
- **Light Conditions**
- **Weather Description and Encounter Phase**

## 3. Severity of Encounter
1. **Visual encounter**
2. **Level of damage**
3. **Description of encounter**

## 4. Contact Information
- **Name**: [Contact name]
- **Email**: [Contact email]
- **Telephone**: [Contact telephone]

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**Notes**: These completion instructions relate to the use of EASA Volcanic Ash Report for the reporting of technical occurrences.
Volcanic Ash Encounter Severity Index

• Different general comments received
  • criteria for the classification unclear (potential hazard to the aircraft, mission fulfilment, repair costs, economic impact,…)
  • simultaneous occurrence of system failures not considered, but likely (matrix instead of table?)
  • Complete new structure recommended, which has to be simple
  • Two-scale index
    • level of impact on the airframe etc. ↔ degree of evidence that ash is there
    • potential hazard to the aircraft ↔ economic impact

• Comments in respect of wording
  • Leading to crash → resulting in loss of control / loss of aircraft
  • “Air handling and air conditioning system“
    • “Air handling” not a common expression → to be deleted
    • Remaining “air conditioning system” is in line with ATA chapter 21
Volcanic Ash Encounter Severity Index

- Five responses from pilots received so far

<table>
<thead>
<tr>
<th>Pilot</th>
<th>Ratings</th>
<th>Additional Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ATPL(A) / CL604 / PIC</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>CPL-IR(A) / A330/A340 / COP</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>ATPL(A) / A320 / PIC</td>
<td>Experimental Test Pilot, TRE(A)</td>
</tr>
<tr>
<td>D</td>
<td>CPL-IR(A) / A320 / COP</td>
<td>Test Pilot</td>
</tr>
<tr>
<td>E</td>
<td>ATPL(A) / B747 / PIC</td>
<td></td>
</tr>
</tbody>
</table>

ATPL – Airline Transport Pilot License / CPL-IR – Commercial Pilot License with Instrument Rating / PIC – Pilot in Command / COP – Co-Pilot / TRE – Type Rating Examiner
Volcanic Ash Encounter Severity Index

• Opinions of the five pilots are quite unambiguous

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interference of navigation or communication systems</td>
<td>3-4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td>Engine failure requiring in-flight permanent shutdown of engine</td>
<td>4-5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4-5</td>
<td>4.4</td>
</tr>
<tr>
<td>Reduced engine thrust due to contaminated engine(s)</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>Health¹ problems of flight crew (e.g. due to sulfur odor/dust)</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4-5</td>
<td>4.1</td>
</tr>
<tr>
<td>Complete loss of VHF communication</td>
<td>2-3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2.7</td>
</tr>
</tbody>
</table>

• In addition, pilot A recommends to increase the class of six existing criteria by one.

¹sickness, restrictions on breathing and speech, dryness of throat
Volcanic Ash Encounter Severity Index

- Another opinion was to introduce a complete new index which systematic has to be simple.

- Only four instead of six levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Volcanic Ash encountered reported by Crew → Stage 1 inspection on the ground</td>
</tr>
<tr>
<td>2</td>
<td>Stage 1 inspection with result VOLCANIC ASH FOUND</td>
</tr>
<tr>
<td>3</td>
<td>Aircraft emergency declared or diversion, for whatever reason, due to volcanic ash effects on persons, engines, electronics or other systems</td>
</tr>
<tr>
<td>4</td>
<td>Loss of control</td>
</tr>
</tbody>
</table>
Volcanic Ash Encounter Severity Index

<table>
<thead>
<tr>
<th>Level</th>
<th>Descriptor</th>
<th>Severity description (customize according to the nature of the product or the service provider's operations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insignificant</td>
<td>No significance to aircraft-related operational safety</td>
</tr>
<tr>
<td>2</td>
<td>Minor</td>
<td>Degrades or affects normal aircraft operational procedures or performance</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Partial loss of significant/major aircraft systems or results in abnormal application of flight operations procedures</td>
</tr>
<tr>
<td>4</td>
<td>Major</td>
<td>Complete failure of significant/major aircraft systems or results in emergency application of flight operations procedures</td>
</tr>
<tr>
<td>5</td>
<td>Catastrophic</td>
<td>Loss of aircraft or lives</td>
</tr>
</tbody>
</table>

- Severity table (basic) – alternate version on next chart
- Basis for current volcanic ash encounter severity index?
<table>
<thead>
<tr>
<th>Level</th>
<th>Descriptor</th>
<th>Safety of aircraft</th>
<th>Physical Injury</th>
<th>Damage to Assets</th>
<th>Potential Revenue Loss</th>
<th>Damage to Environment</th>
<th>Damage to Corporate Reputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insignificant</td>
<td>No significance to aircraft-related operational safety</td>
<td>No injury</td>
<td>No damage</td>
<td>No revenue loss</td>
<td>No effect</td>
<td>No implication</td>
</tr>
<tr>
<td>2</td>
<td>Minor</td>
<td>Degrades or affects normal aircraft operational procedures or performance</td>
<td>Minor injury</td>
<td>Minor damage Less than $__</td>
<td>Minor loss Less than $__</td>
<td>Minor effect</td>
<td>Limited localized implication</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Partial loss of significant/major aircraft systems or results in abnormal flight operations procedure application</td>
<td>Serious injury</td>
<td>Substantial damage Less than $__</td>
<td>Substantial loss Less than $__</td>
<td>Contained effect</td>
<td>Regional Implication</td>
</tr>
<tr>
<td>4</td>
<td>Major</td>
<td>Complete failure of significant/major aircraft systems or results in emergency application of flight operations procedures</td>
<td>Single fatality</td>
<td>Major damage Less than $__</td>
<td>Major loss Less than $__</td>
<td>Major effect</td>
<td>National Implication</td>
</tr>
<tr>
<td>5</td>
<td>Catastrophic</td>
<td>Aircraft/hull loss</td>
<td>Multiple fatality</td>
<td>Catastrophic damage More than $__</td>
<td>Massive loss More than $__</td>
<td>Massive effect</td>
<td>International implication</td>
</tr>
</tbody>
</table>

Use the highest severity level obtained to derive the risk index in the risk index matrix table.
Occurrence Reporting

• Often missing information in the available occurrence reports
  • Inaccurate or no location information of the encounter (Lat, Lon, Alt)
  • Inaccurate or no time data of the encounter
  • Duration of encounter (exposure time)
  • Usually no detailed damage descriptions available

• No queries possible because (usually) no conclusions on operators, which have in addition restrictive information policy

• Key information is volcanic ash dosage / volcanic ash concentration correlated to the damage to the aircraft (or even not)

• Determination of the key information mostly not possible due to
  • missing or uncertain flight track
  • missing information about volcanic ash clouds and their concentration
Occurrence Reporting

• Capability at DLR Braunschweig to analyse occurrence reports with available flights tracks and volcanic ash clouds and their concentration

• Visualization with FATS (Future Arrival Traffic Simulator) from DLR Institute of Flight Guidance

• Example:
  • During a flight from Germany to Palma, an aircraft came close to or partly in the volcanic ash zone 2. During the outside check, the crew noticed grey areas at the fan blades, looking like ash, and gray water ran from the root tip of the blades. Further, the crew noticed grey-colored areas in the acoustic liners of the engine. Technical inspection revealed no damage.
  • Flight track available, volcanic ash clouds only graphics from 2010
Occurrence Reporting
Occurrence Reporting

- Establishment of a well known occurrence reporting procedure
  - Where to report an occurrence with volcanic ash?
    - e.g. EASA, National CAA, EVAIR,…
  - What are the required information for a reasonable analysis?
    - e.g. Flight track, volcanic ash dispersion information, damage,…
  - What happens with this (sensitive) information?
  - Who will do the reasonable analysis?

- Development of a volcanic ash encounter report system for scientific purposes
  - using LimeSurvey, a free and open source on-line survey application
  - access via a DLR website (URL can be distributed)
  - shared with selected persons for testing and opinion forming

- Will be demonstrated after the presentation
Other Activities

- NATO Science and Technology Organization (STO) (http://www.cso.nato.int/)
Outlook

• Revising of volcanic ash encounter severity index
  • New proposal mainly based on the compilation results and the opinion of pilots and aerospace engineers
  • Discussion with volcanic ash community (ICAO, IFALPA, IATA, ICCAIA,…)
  • Aim: broadly accepted updated severity index (e.g. by an amendment to ICAO Doc 9691, NATO AVT-213 Report,…)

• Operating of a volcanic ash encounter reporting system for scientific purposes
  • Prerequisite: supported by the volcanic ash community
Points of Contacts

• DLR Institute of Flight Systems // Braunschweig
  • Mr Carsten Christmann carsten.christmann@dlr.de
  • Dr Rafael Nunes rafael.nunes@dlr.de

• DLR Institute of Flight Guidance // Braunschweig
  • Ms Angela Rebecca Schmitt angela.schmitt@dlr.de

• U.S. Geological Survey
  • Ms Marianne Guffanti guffanti@usgs.gov
Thank you for your attention!

Any Questions?