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Mission Statement

The aim of the Australian Transport Safety Bureau is to maintain and improve transport safety and public confidence through excellence in

- *independent investigation of transport accidents and other safety occurrences;*
- *safety data research and analysis; and*
- *safety communication and education.*

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Challenges in Material Selection for Repair and Re-manufacture

A study of the sometimes hidden complications associated with the selection of materials for customised repair, re-manufacture or restoration schemes.

Nev. Blyth
Materials Failure Analyst
Australian Transport Safety Bureau

Repair, remediate, rectify, restore.....

Definition – ‘Repair’

“To restore and renew by any process of making good”

Why repair (and not replace…) ?

- OEM or PMA replacements unavailable
- OEM or PMA replacements costly
- Non- replaceable component or structure
- Questionable performance of the OEM component
  - *Life extension*
  - *Function improvement*
  - *Maintenance reduction*

remanufacture, renew, reclaim, replenish.....

"To restore and renew by any process of making good"

The legal situation - CAR 1988 part 35

"A person may apply to CASA or an authorised person for approval of the design of a modification or repair of an aircraft component or aircraft components included in a type of aircraft component."

"Where an applicant furnishes evidence relating to the design to which the application relates (including evidence of the effect of the design on the safety of an aircraft) as CASA or the authorised person requires; and"

"Satisfies CASA or the authorised person that the design conforms with any relevant design standard in respect of the type of aircraft component to which the application relates; then

CASA or the authorised person shall give approval to the design"

rebuild, reform, retouch, recover....

"To restore and renew by any process of making good"

Consideration in repair design

- Physical arrangement
- Manner of fabrication
- Material selection
- Method of assembly / disassembly
- Methods of maintenance
- Methods of operation
- Environment of operation.

re-life, re-work, revive, redeem ....

"To restore and renew by any process of making good"

Considerations in material selection

- Strength (tensile, compressive, shear)
- Fracture (toughness, fatigue strength & limit)
- Corrosion resistance
- Weight
- Compatibility – environmental, adjacent materials
- Wear resistance (abrasive, galling)
- Bearing (lubricity, embeddability, hardness)

rehabilitate, rejuvenate, reinstate, regenerate....

"To restore and renew by any process of making good"

Intent

Is the intent 'like-for-like' replacement?

Need sufficient information as to the original design of the product, i.e. specifications, drawings & detail.

Often not available, or not provided due to commercial proprietary rights considerations.

rescue, reface, revamp, refurbish....

"To restore and renew by any process of making good"

Changes ? Improvements ?....

Is the intent to change or improve the component during the repair process?

When does a repair become a modification? Is it simply when any changes to the OEM design are made?

Type certification considerations?

recondition, re-create, revitalise, resuscitate....

"To restore and renew by any process of making good"

Reverse engineering

If the OEM design engineering is not available, sufficient analysis and testing must be undertaken to ascertain all relevant and necessary detail.

If materials, forms, fits or manufacturing processes cannot be replicated, the impact on the functionality and reliability of the item must be considered.

Functional testing or re-certification may be required.

A Case in Point:

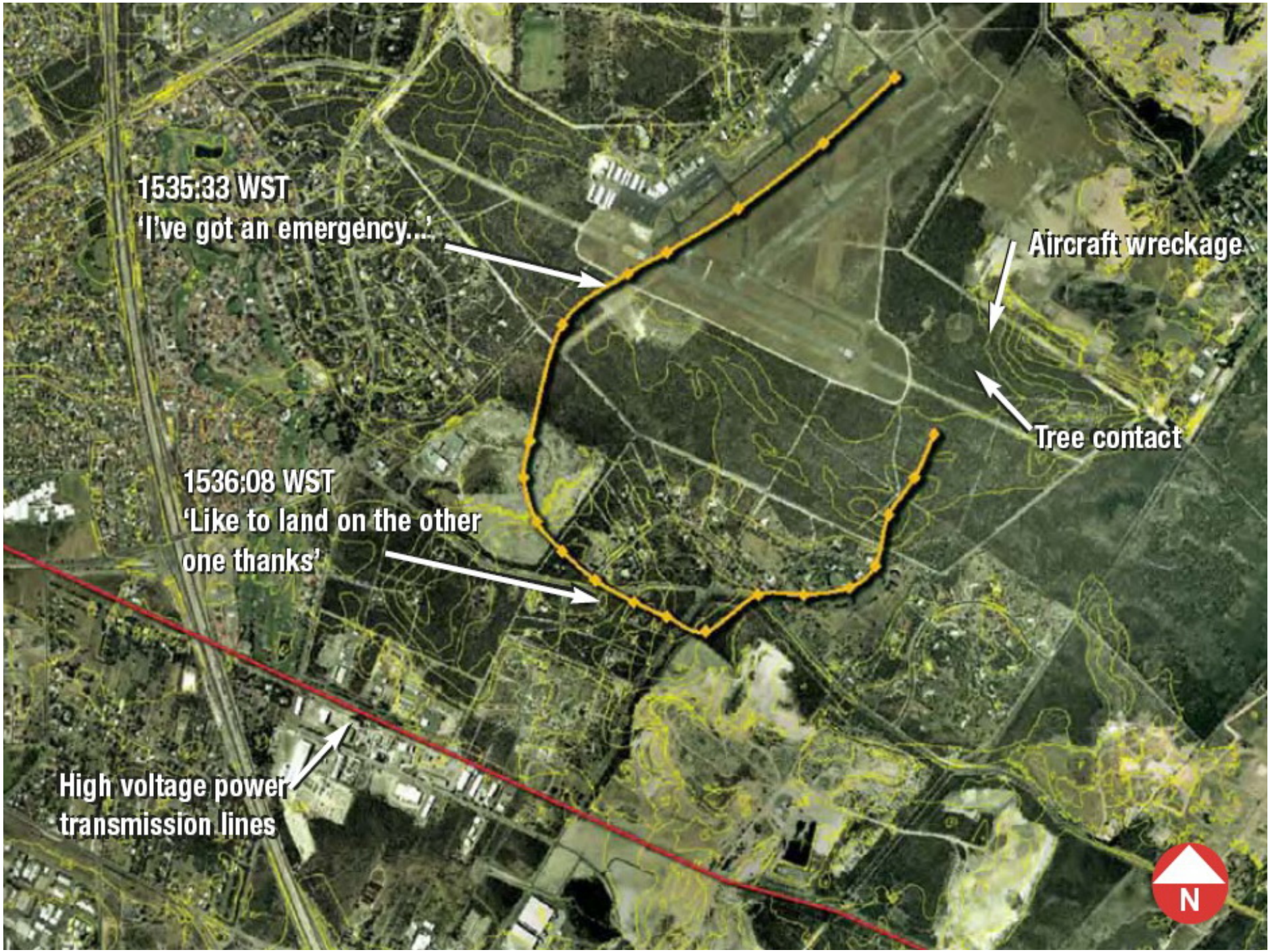
Cessna 404 *Titan*, VH-ANV
Jandakot Airport, WA
11 August 2003

Photo used by permission of Neville Murphy, Neville Murphy Aviation Images

Cessna 404 *Titan*, VH-ANV

Sequence of Events:

- Departed Jandakot on a geotechnical survey flight, 6 pob + equipment - estimated MTOW margin 37 kg
- Right engine lost power soon after rotation & was secured
- Partial circuit completed, aircraft lost altitude and impacted trees and terrain
- 4 pax and the pilot escaped aircraft with burns – one died from injuries 85 days later.


1535:33 WST
'I've got an emergency...'
Aircraft wreckage
Tree contact
1536:08 WST
'Like to land on the other
one thanks'
High voltage power
transmission lines
N

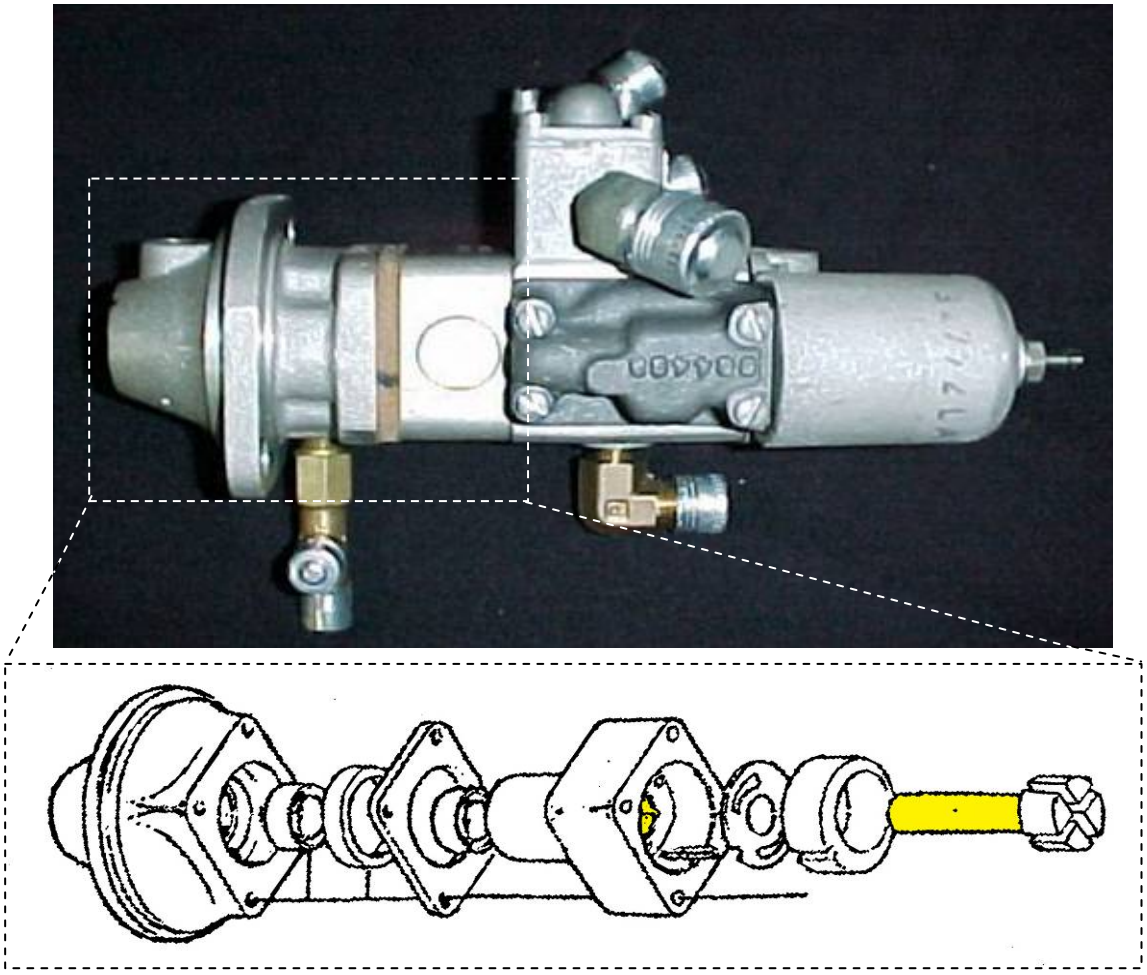
Cessna 404 *Titan*, VH-ANV

Investigation Findings:

- Right engine lost power due to fuel starvation, after the seizure of the right engine-driven fuel pump (EDFP)
- The pilot did not recognise the signs of EDFP failure, thus did not switch the right auxiliary fuel pump to 'HIGH', as recommended by the flight manual
- An earlier manufacturer's service bulletin had removed an original design feature that provided automatic switching of the aux pump to HIGH following a decrease in fuel pressure

Cessna 404 *Titan*, VH-ANV

Fuel Pump Failure: Assembly



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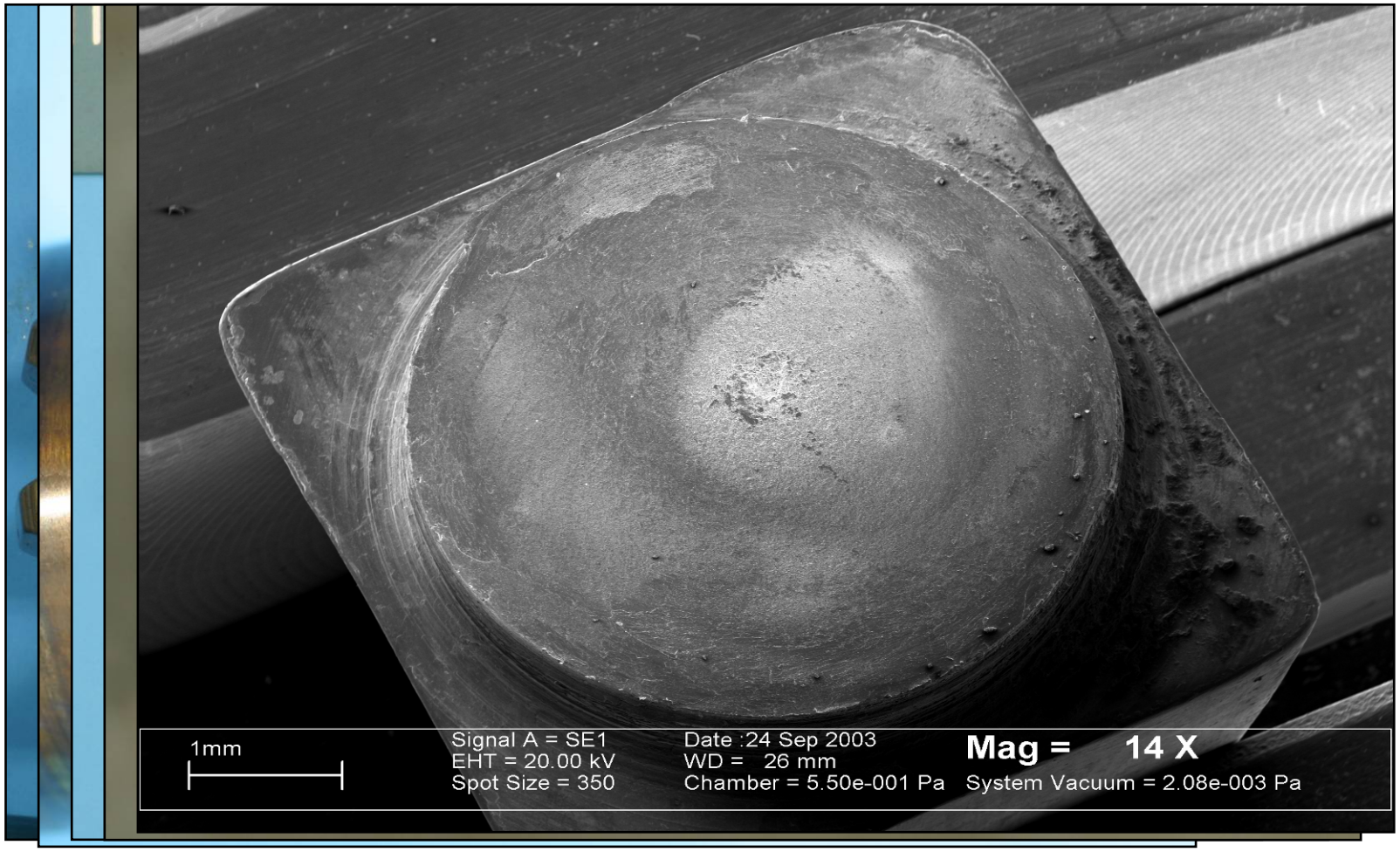
Fuel Pump Failure: Coupling



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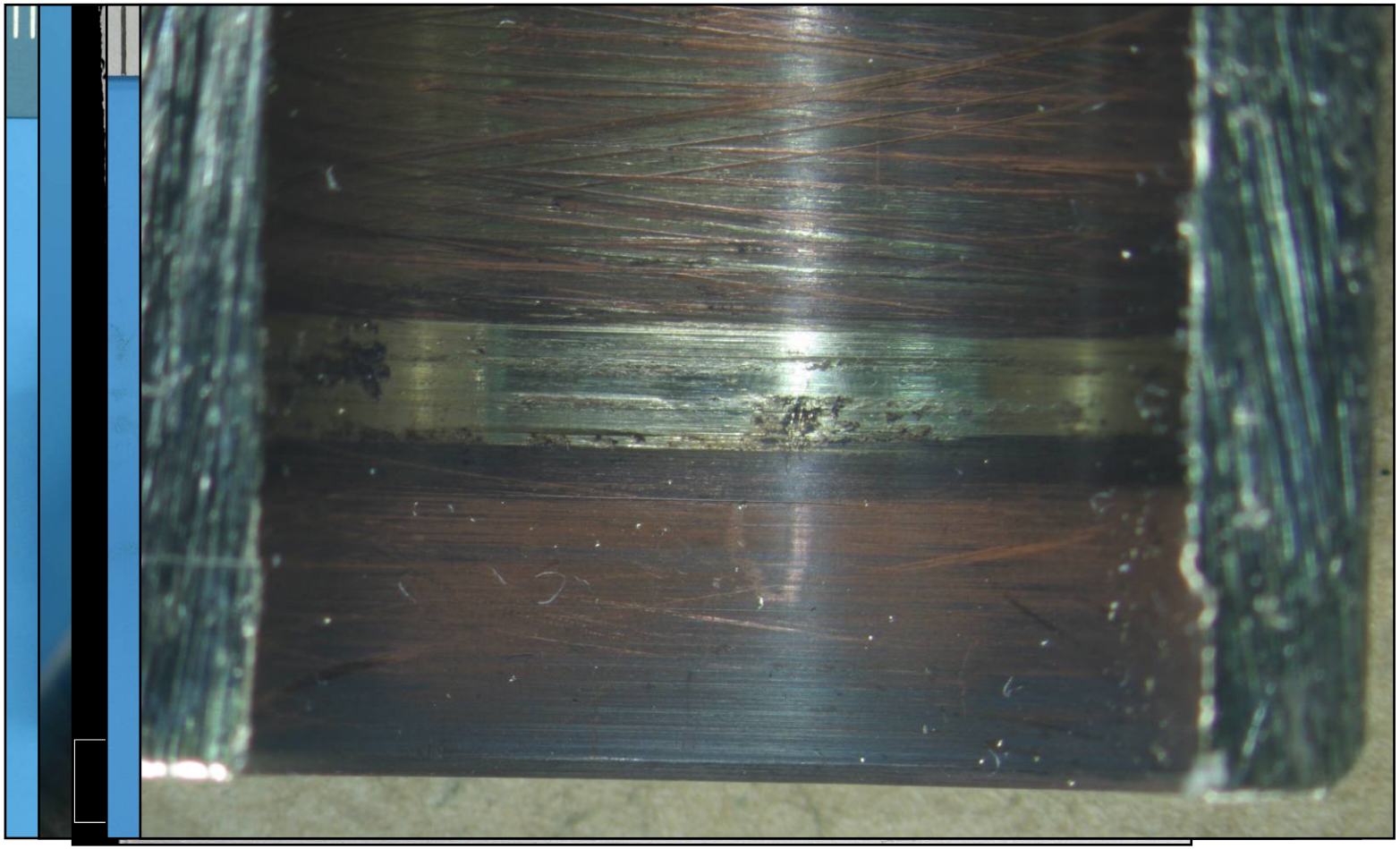
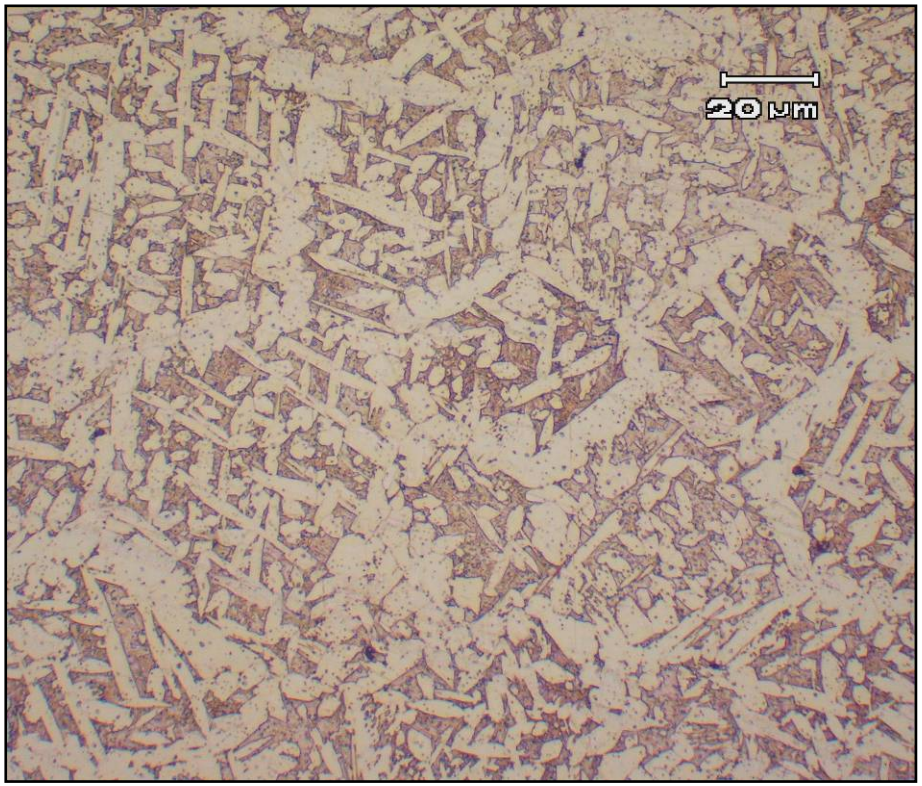
Fuel Pump Failure: Bearing



Cessna 404 *Titan*, VH-ANV

Fuel Pump Failure: Bearing Materials

Analysis of the failed right pump sleeve bearing material showed it to be a Cu-Al-Fe-Ni alloy (**Aluminium Bronze**), with a typical hardness of ~190 HV_{10} and microstructure of Widmanstatten α-phase, in a β-phase matrix.



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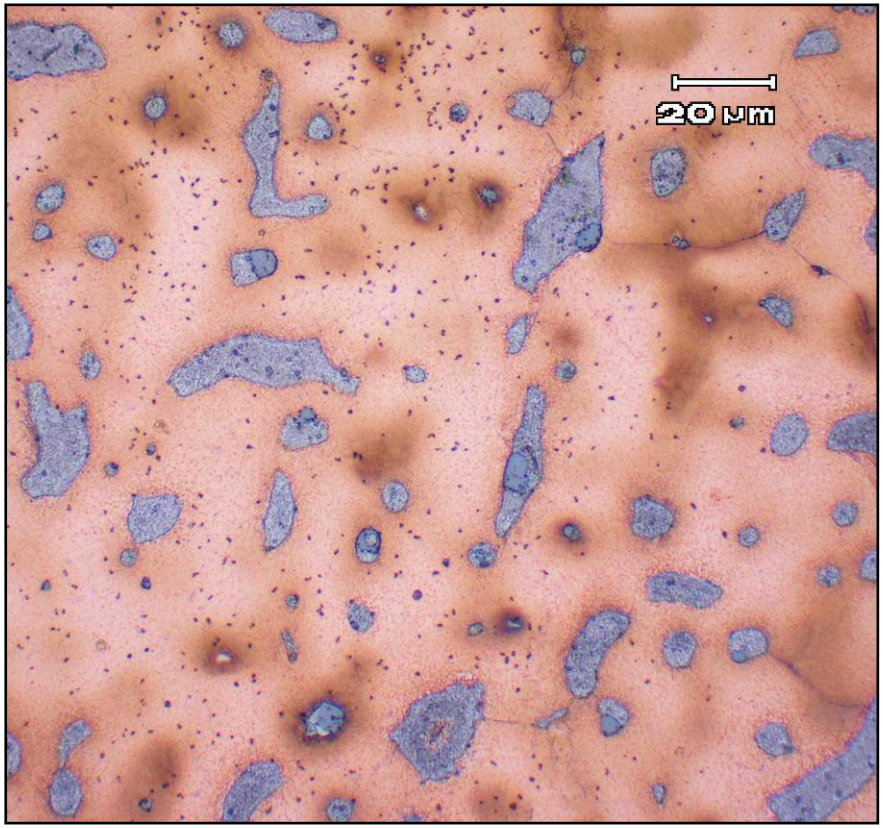
Fuel Pump Failure: Bearing Materials

Comparative analysis of the serviceable left pump sleeve bearing material showed it to be a Cu-Pb-Sn alloy (**Leaded Bronze**), with a typical hardness of ~50 HV_{10} and microstructure of lead islands in a copper-tin matrix.



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Fuel Pump Failure: Bearing material comparison

Both Aluminium and Leaded Bronzes can be used as sleeve bearing materials, however they have markedly different properties.

Property	Aluminium Bronze	Leaded Bronze
Compressive Strength (provides load bearing capacity)	Higher	Lower
Wear Resistance (resistance to abrasive erosion)	Higher	Lower
Galling Resistance (natural lubricity)	Lower	Higher
Embeddability (ability to embed particles)	Lower	Higher
Corrosion Resistance	Higher	Lower

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Fuel Pump Failure: Bearing material comparison

For a high-speed, spindle shaft bearing without an independent lubrication system (i.e. fuel pump) certain properties are critical for resistance to seizure.

Property	Aluminium Bronze	Leaded Bronze
Compressive Strength (provides load bearing capacity)	Higher	Lower
Wear Resistance (resistance to abrasive erosion)	Higher	Lower
Galling Resistance (natural lubricity)	Lower	Higher
Embeddability (ability to embed particles)	Lower	Higher
Corrosion Resistance	Higher	Lower

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Fuel Pump Failure: why different materials?

•Maintenance records showed that a CAR 35 authorised organisation had prepared and approved an engineering order (EO) for the replacement of the sleeve bearing in the EDFP, after suitable OEM replacement parts were not available.

•For commercial reasons, the specifications for the EDFP construction were not available from the OEM.

•The EO specified Aluminium Bronze as the material for sleeve remanufacture, yet the intent was a like-for-like replacement.

•No analysis or investigation of the OEM bearing material had been undertaken.

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Fuel Pump Failure: why different materials?

•No functional or durability testing of the pump with new sleeve had been undertaken.

•Anecdotally, EDFP's of this type had a history of becoming unserviceable before TBO, due to wear of the sleeve bearing – hence possible desire to improve product using a material of higher wear resistance.

•General comments from some engineering organisations revealed the perception that the Aluminium Bronze had 'superior properties' to the Leaded Bronze in the EDFP application.

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Epilogue

•Another similarly repaired EDFP identified in April 2005. Different engineering order – same material substitution. Pump tracked down and removed from service by order of CASA.

•In both cases, the CAR 35 authorised persons that prepared the EO's for pump repair, had done so without specific knowledge of the differences in the bearing properties of the original and replacement bearing materials, and without knowledge of the precise range of conditions under which the fuel pump bearings operated.

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Safety Outcomes

•Education and awareness campaign –

- ATSB (see www.atsb.gov.au)

  Aviation Safety Investigation Report
  200501462 Engine-driven fuel pump bearing
  Material substitution

  ATSB Aviation Safety Investigation Report
  200303579 VH-ANV 11 Aug 2003

- CASA (see www.casa.gov.au)

  Flight Safety Australia Magazine, March/April 2005

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Safety Outcomes

- Coronial Inquest recommendations –
  - "...ensure that engineering orders contain sufficient information in each case to provide a clear indication as to the basis of the engineering order and specify whether the engineering order is proposing 'like for like' replacement of the construction of an entirely new item"
  - "…CASA ensure that reasonably comprehensive audits are in fact conducted in respect of all CAR 30 organisations and CAR 35 authorised persons on a regular basis..."

Thanks & Questions

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