ATSB

Australian Transport Safety Bureau

ENGINEERING ANALYSIS

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Garrett TPE 331 engine turbine failure

The engine was fitted to a Metro II aircraft engaged in a freight run.

Just after the top of descent, some 20 nm from destination, the pilot heard a loud bang.

The engine instruments indicated a right engine failure.

It was not the last problem the pilot had to face. While on final, a few feet above the ground, a bird was ingested into the opposite engine.

However, the pilot landed the plane safely.

Fragments of the turbine punctured three holes into the right engine cowling indicating that the turbine disintegrated into three major fragments.

Their location was indicative of a 2^{nd} stage turbine failure.

One hole was directly opposite the fuselage.

A fragment remained embedded in the fuselage, becoming caught between the outer skin and the inner lining.

It was the only fragment of a substantial size recovered, the other two major fragments were lost.

The 2nd stage turbine has 39 blades; the recovered section contained the remains of 7 blades.

The operator's maintenance crew changed the engine on the tarmac, under the open sky.

Uncontained failure of the 2^{nd} stage turbine disc was confirmed.

A further two fragments, consisting of three blades, and a number of smaller fragments were found caught under the cowling and later during the engine strip.

The engine was transported to the approved facility to be strip examined.

In the meantime the remnants were examined for any clues as to the reason for the break-up.

A few theories were discussed.

The presence of a pre-existing defect, such as fatigue, precipitating separation of a part of the turbine disc or loss of a blade, was the favourite, with the turbine disintegration being a direct result of the out of balance forces the turbine was subjected to.

Stress loads in the turbine discs are primarily derived from centrifugal loads.

They increase progressively towards the disc centre.

The Garrett engine operates at approximately 36,000 RPM.

The recovered fragments, however, contained no evidence of any pre-existing defect.

Was the critical part of the turbine containing evidence of a pre-existing failure lost?

Were we just unlucky in having a few meaningless fragments with no story to tell?

It was observed that the wheel cross section near the transition from the wheel hub to web was significantly reduced.

The fracture ran through the thinnest part of the disc.

The reduction of the cross section took part along a smooth, regularly formed surface line.

It gave an impression of having been purposefully made during disc manufacture.

The surface appearance and finish were identical to those of the rest of the disc.

Recognising the disc stress pattern, reducing the cross section in the most critical part of the disc defied logic. It went against good design philosophy.

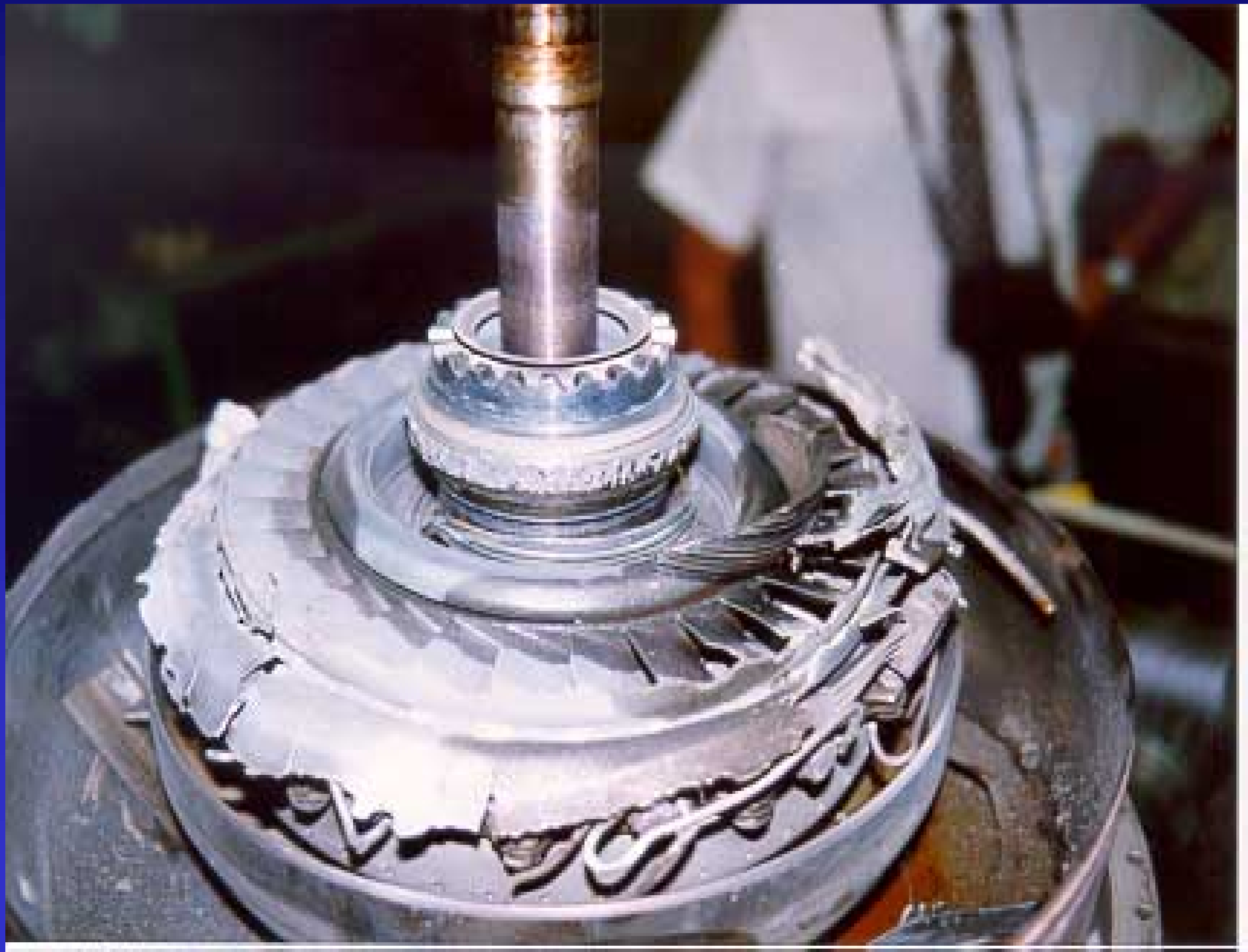
Why would the manufacturer do that?

The engine strip examination was carried out in the Garrett approved workshop by a number of workshop engineers.

Those present included representatives from the manufacturer, engine overhaul shop, operator, regulator and ATSB.

The engine was found to have been correctly assembled.

The components surrounding the 2nd stage turbine were extensively damaged by liberated turbine pieces.



Also broken was the air or labyrinth seal between the 1st and the 2nd stage discs.

Two large pieces were recovered.

The examination found no clue as to why the turbine failed.

Part and serial numbers of all components were noted, checked and found to be applicable to the engine.

Serious concern was raised as far as the past history and total time in service of some components, in particular of the 2nd stage turbine disc.

The observed reduction of the disc cross section surprised, but did not alarm those present.

It was not found on any disc present in the workshop at that time.

It was speculated that it might have been an early model of the disc.

The manufacturer's assistance in resolving the problem was sought.

The manufacturer advised that no disc was ever manufactured with a reduced cross section and requested the failed disc and other components for examination.

Was the disc a bogus or reclaimed part?

Given the mechanical properties of the material the disc was made from, any post manufacture machining was not considered to be easy.

The engine had accumulated almost 3000 hours and as many cycles, so why did the turbine fail now?

The problem appeared to be quite a difficult one, the answer was not coming out easily.

The regulator fearing another problem with the engine type interpreted the lack of progression as procrastination and requested that the parts be forwarded to the manufacturer.

The ATSB material specialist recognised that the cross section reduction might have been a product of a sliding contact between the disc and fragments of the split labyrinth seal.

The pieces could be positioned so that they matched perfectly with the shape of the disc.

The sliding contact would have to be present over an extended period of time.

Reduction of the cross section increased the stress loads within the disc, until the stress exceeded the remaining material load bearing capabilities and the disc failed.

The turbine failure became secondary to the labyrinth seal failure.

Why and when did the labyrinth seal, fail?

The operator was asked if there had been an event in the past that may have indicated the seal failure.

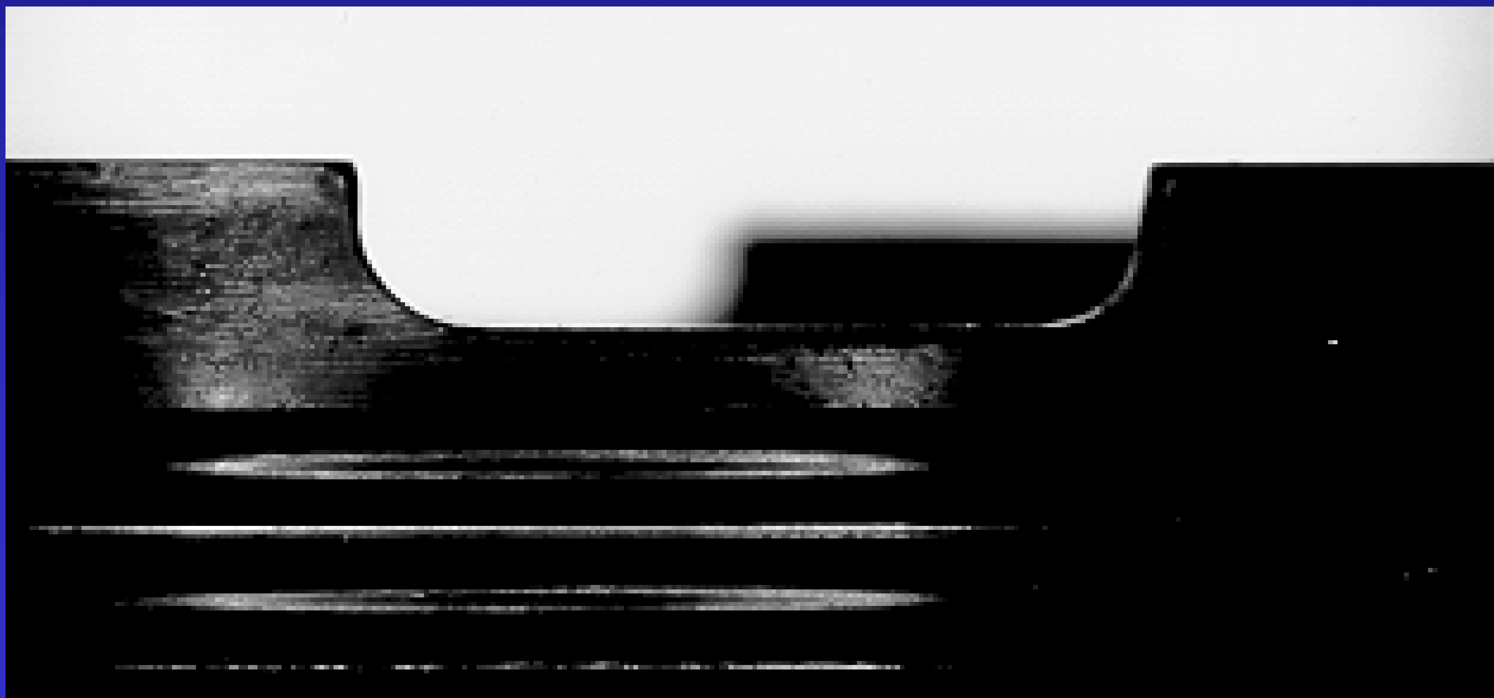
The operators trend monitoring data was examined – no indication was found of how long since the seal failed.

The seal is close to the disc axis, it is light and is not subjected to other then centrifugal loads.

The seal is pressed onto the turbine wheel during manufacture and it becomes an integral part of the turbine.

It is very difficult to replace the seal in service.

Two fatigue cracks were found initiating from the radius at the corner slots.



The radius at the corner was small.

The radius is quite loosely defined on the manufacturer's drawings.

The ATSB made recommendations to the engine manufacturer to review the labyrinth seal design criteria in respect of the corner radii and substantiation of fatigue life.

The manufacturer accepted the recommendation.

Summary:

The example demonstrates value of co-operation between various specialists within the investigative body.

Each member contributed according to their specialist knowledge.

Establishing correct assembly, history, design deficiency and knowledge of materials.

Given the problems faced during the investigation and doubts about the turbine disc service history, the case could have been easily dismissed on grounds that the disc was a bogus part.

It appears to have been only the second known case of a turbine disc failure.

The first one was attributed to blocked cooling holes in the stator, resulting in disc heat stress.

Handing the components over to the manufacturer would have placed the ATSB on the outside of the investigative process.

It would have prevented the ATSB from fulfilling one of its major roles - that is providing recommendations to improve aviation safety.

It would have taken away the value of independent investigation with the different viewpoints and ideas.

It, however, does not dismiss a need for close co-operation with the manufacturer, as their detailed knowledge of the product is essential to any successful investigation.

The ATSB and the manufacturer have different mixes of skills.

The manufacturer’s skill base is focused on design and production.

The ATSB skill base does not require intimate knowledge of the product, but centres on experience with investigation of failures.

The ATSB’s experience is in the area of recognition of the unexpected or out of ordinary tale-tail signs of damage and deformation.

Successful investigation requires the right mix of skills.

The persistence paid off.