Automated eddy current Inspection of aircraft wheels

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Abstract

The Hazards resulting from failure of an aircraft wheel during landing, or explosion in flight, are self-evident. After a number of accidents regular Non-Destructive Inspection of wheels has been mandatory for many years. This is most often done using the eddy current technique and traditionally has been performed manually using pencil or special purpose shaped probes.

While effective in the hands of a skilled operator it is always difficult to confirm that such an inspection has been performed adequately, and operator fatigue and loss of concentration may become a problem if it is desired to inspect more than the most critical part of the wheel. A number of attempts have been made to automate the process, but most have been bulky or expensive or both.

A machine is now available which can be installed easily, requires only A.C. power and occupies less than one cubic meter of space,
Innovative "Autotrak" software follows the wheel profile without complex programming and allows operators with minimal NDT experience to carry out effective and repeatable inspections of a wide variety of wheels, checking the full surface of the wheel in a few minutes.

INTRODUCTION

In this paper I will describe the problems that have been found with aircraft wheels, some of the inspection techniques which have been used in the past, and how we at Hocking attempted to address these problems in creating a machine that was simple and cost -effective while meeting the highest performance specifications.

Modern Aircraft wheels have a very exacting task to perform. A few wheels must transmit the landing and braking forces of an aircraft weighing typically 200 tons at 200 kph. Much design work has been expended to create wheel assemblies that will carry out this function thousands of times without failure.

Normally this is achieved. However, as with any part suffering repetitive stress, small imperfections or damage may grow into cracks. Usually these will cause an air leak and thus become apparent due to wheel deflation. In more serious cases a wheel may break on landing. Figure 1. shows a wheel that disintegrated during taxiing.

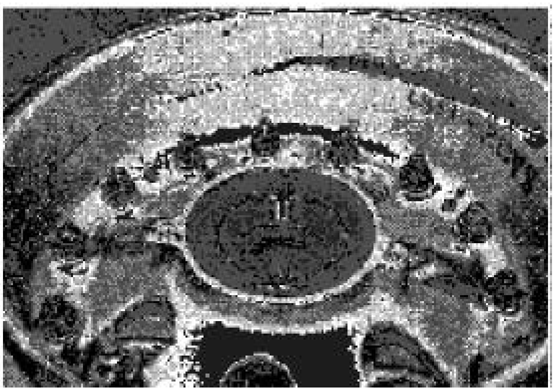


Figure 1: Aircraft wheel outboard half showing major crack

Wheel failures while the aircraft is on the ground are expensive, inconvenient and embarrassing. The results of wheel failure in flight can be tragic. One such case occurred in the late 1970's when the wheel of an L1011 aircraft exploded at high-altitude. Parts of the wheel went through the passenger cabin, causing immediate decompression and loss of life.

The aim of wheel inspection is to prevent all such incidents from happening.

Wheel overview

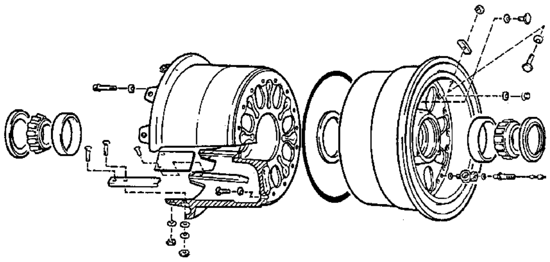


Figure 2: Exploded view of typical aircraft wheel

A typical aircraft wheel assembly consists of the following main parts:

- An 'outboard' wheel half containing the inflation valve.
- An 'inboard' wheel half containing the brake assembly.
- A tubeless tyre, inflated to a high pressure
- Bearing assemblies, one in each half.
- High-tensile fasteners holding the two wheel halves together, with a rubber seal.

In typical airline use a tyre may last up to 300 landings. When the tyre is replaced an opportunity exists to inspect the wheel. It is vital that any inspection technique used can locate small defects that may, during those 300 landings, grow to a potentially dangerous size.

As tyre technology has improved, the interval between tyre replacement has increased, meaning that smaller defects in the wheel must be reliably located.

Summary of Inspection requirements

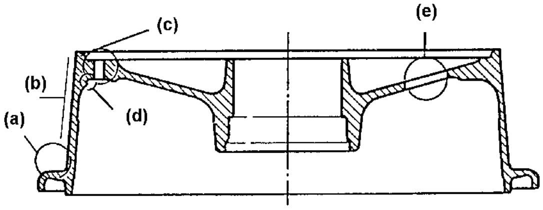


Figure 3: Areas requiring eddy current inspection

The most highly stressed area of the wheel is the rim and tyre seat (a) and it is here that most problems have occurred. Most wheel manufacturers require that this be inspected at every tyre change. When eddy current is used a typical reference defect size is 0.75mm deep and 1.50 mm long.

The barrel (b) is also prone to some problems, particularly on the inboard half where the brakes are attached. While not often mandatory, many operators, particularly those with automated machines, are carrying out inspections here also - and finding cracks.

Other parts of the wheel, such as boltholes(c), the counterbore around boltholes(d), and the ventilation holes(e) also require inspection. This is normally carried out when the wheel is stripped down and fully overhauled. Airline practice and wheel manufacturer's recommendations vary, but this is typically carried out every three to five tyre changes.

In addition, supplementary inspections such as conductivity or hardness testing are normally carried out when there is any indication that the wheel has overheated.

One point which should be borne in mind is that modern aircraft wheels are expensive items and are designed to withstand thousands of landing cycles. They will be serviced many times during this long and arduous life, and will inevitably sustain much minor surface damage such as scratches, minor dents, and corrosion due to the conditions they operate in. They will inevitably gather residues of oil, dirt and rubber. This is perfectly normal and any inspection technique must take it into account, In the competitive world of air travel operators cannot afford to scrap wheels that are perfectly serviceable.

MANUAL INSPECTION METHODS

Dye Penetrant Inspection

The wheel is stripped of paint, cleaned and coated with penetrant. After an interval the penetrant is removed and the wheel coated with a developer. Small traces of dye retained by cracks in the wheel are visible against the contrasting background of the developer.

Advantages:
- Conceptually simple method- limited training required
- Low capital investment - cost savings for small volume operators.

Disadvantages
- Very time consuming
- Inspection is adversely affected by dirt, oil or other contamination
- Won't always find tight cracks- Dye may not penetrate cracks closed by residual stress
- Can be very difficult to reliably identify cracks in recesses etc., for example the bead seat radius which is the most critical area.
- Reliability is very operator dependant.

Manual Eddy current inspection using a pencil probe.

A standard high-frequency eddy current crack detector, such as the HOCKING **Locator UH**, is used with a pencil probe which is scanned around the surface of the wheel.

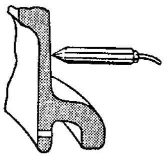


Figure 4

Various aids may be used in achieving a regular scan pattern. A turntable either powered or manual helps regular rotation and allows the operator to concentrate on scanning and observing the instrument response. A suitable coating (such as penetrant developer) may be applied to the wheel before scanning, then the probe will leave a 'trail' allowing the operator to see where he has scanned. Alternatively a suitable guide block with several probe holes may be used to ensure regular scanning of the bead seat area.

Advantages
- Low capital investment - operators will probably have a suitable eddy current instrument already.
- Unaffected by moderate oil or dirt, removal of firm paint is unnecessary
- Good results if used carefully
- An excellent backup method for investigating indications and checking other parts of the wheel.

Disadvantages
- Time consuming, it is usually impractical to inspect more than the bead seat area.
- On ameter type instrument it can be difficult to distinguish small cracks from surface roughness or corrosion.
- No guarantee that all areas have been inspected - Inspection quality is dependant entirely on operator skill and integrity. Operator fatigue is a major concern.
- No record of results.

Manual Eddy current inspection using a contoured 'bead seat' probe.

A phase plane eddy current instrument such as the HOCKING **Phasec 1.1** is used with a specially designed probe to scan the bead seat area of the wheel

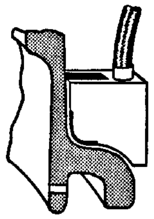


Figure 5

Advantages
- Inspection of the entire bead seat region in a single rotation.
- Can distinguish between crack and corrosion on the impedance plane display.
- Consistent scan can be easily achieved.
- Unaffected by dirt, paint, oil, etc.

Disadvantages
- Only inspects bead seat Region
- Sensitivity limited (but adequate for some current standards) as a large area of metal is inspected at once.
- Can be difficult to identify exact position of defect.
- Specific probe required for each wheel type.

General problems of manual inspection

- Effective inspections are very time consuming.
- A high level of operator skill is required.
- Operator fatigue can seriously affect the quality of inspection
- It is difficult to distinguish between small crack indications and general surface noise and corrosion

Financially the labour dependance of manual inspection methods means that the cost for large volume operators is a significant factor in wishing to automate the process. From a safety point of view, while manual inspection has found many large defects, small flaws are likely to be overlooked. Even after manual inspection wheel failures have still occurred.

AUTOMATED EDDY CURRENT INSPECTION

To address these problems many approaches have been tried. Some have been very complex, using multichannel probe arrays or specially programmed industrial robots.

Perhaps one of the more effective was that developed by British Airways in the 1970's. Variations on this design have been marketed by a number of companies. This employed a pneumatic ram to lift the wheel which was then rotated at constant speed. A probe was then applied by a gravity/spring loaded arm and scanned across the wheel on a leadscrew. Results were recorded on a chart recorder.

General advantages

- Consistent scan pattern over entire flange, beadseat and tubewell area
- Considerable improvement in effective sensitivity. Detection sensitivivity is the eqaul of pencil probe inspection, but noise can be considerably improved due to even rotation.
- Minimal operator skill required once equipment set up.
- Probes are Universal - work with any wheel
- Printed (Chart) Record from each inspection.
- Minimal operator time - extremely cost effective for large volume use

General disadvantages

- Relatively high initial cost discourages small operators
- Permanently installed - difficult to move for field use. (Normally installed in Wheel shop process) even if it could be moved, it requires an air supply.
- Generally single purpose; the Eddy current machine cannot be used separately.
- Can only be used with the wheel flange down - imposes constraints on other processes or requires manhandling.
- Because it still uses an amplitude type crack detector it can be difficult to distinguish between cracks and minor surface denting or corrosion, particularly as:
- The spring loaded arm tends to skip off the surface if it is rough or corroded, Although this can be controlled by increasing the pressure this causes increased probe wear.
- It can be quite difficult to find the crack after inspection.

The Hocking Approach - *WheelScan 700*

In 1989 Hocking NDT began development of a new wheel inspection system, primarily for the RAF. (British Royal Air Force) The intention was to address these disadvantages, and to create a machine which would be the natural choice of all medium and high volume aircraft maintenance operators.

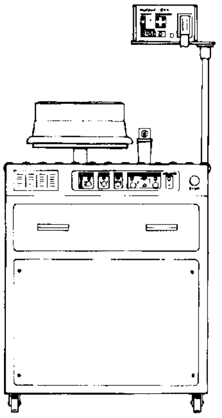


Figure 6 : Hocking *Wheelscan 700*

Construction

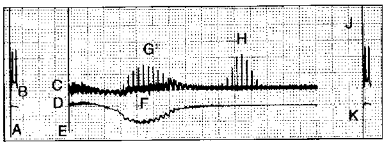
A major requirement of the military was transportability. It was vital that the machine could be easily deployed to meet rapidly changing needs.

To meet this requirement several things were crucial: weight, bulk, strength, lack of special supply requirements and ease of setup. To achieve the necessary strength without excessive weight we used a rugged aluminium alloy frame. By making full use of modern electronic and mechanical technology we were able to reduce the volume to less than one cubic metre. By the same methods we ensured that the only supply required is from a standard power socket 110 or 220 V 50 or 60 Hz, available in any workshop or office in the world.

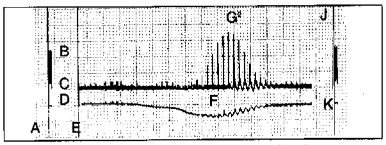
Instrumentation

To improve the performance and convenience of the eddy current instrumentation several significant features have been incorporated. While an impedance plane display gives good segregation of different types of indication it requires considerable experience to interpret. We wished to make the instrument as simple as possible. We solved this by providing a second 'liftoff' trace on the chart recorder, allowing results to be easily understood: if it shows up mostly on the main trace it's a crack, if it shows up more on the liftoff trace it's probably corrosion or probe lift-off.

To ensure a correct test the instrument automatically sets itself to the correct phase angle at the beginning of each test and performs a calibration scan over a reference defect (0.5mm slot) The calibration scan is repeated at the end of the test. providing a permanent record of the test sensitivity



B. F. Goodrich DHC-7 wheel with artificial flaws 0.5mm deep
WheelScan settings: 60rpm, 50dB, 1.5MHz



Dunlop BAC-11 wheel with 2mm long surface flaw
WheelScan settings: 30rpm, 50dB, 1.5MHz

A – Probe touches calibration block and auto-balances
B – Probe passes over calibration flaw before test
C – Flaw channel
D – Lift-off channel
E – Probe touches wheel
F – Probe passes through beat-seat radius
G¹ – Response from artificial flaw (0.5mm deep) in bead-seat radius
G² – Probe passes over natural 'corrosion' crack 2mm long on surface
H – Response from artificial flaw (0.5mm deep) in barrel
J – Probe touches calibration block
K – Probe passes over calibration flaw after test

Figure 7: Typical traces from Hocking Wheelscan

The chart records show another major advantage of the automated approach: if the helix is set to be smaller than the probe field then a defect will be seen on several successive scans, this gives a very high degree of confidence that a defect will not be missed.

To allow the auxiliary inspections to be carried out easily up to two additional probes can be permanently connected, for example a bolthole probe and a general purpose pencil probe. By pushing a button the operator selects the correct probe and a set of preprogrammed parameters, allowing an immediate test without spending time setting up the probe. When the auxiliary test is completed the button is pressed to revert to automatic operation. Thus the wheelscan is the only eddy current machine required in the wheel shop.

Additional features include the ability to operate at frequencies from 100 kHz to 3 MHz, and the 'FlawStop' mode of operation where the scan stops automatically when a flaw is indicated allowing the operator to investigate it.

Probe Guidance

Perhaps the most innovative feature of the wheelscan is the 'Autotrak' probe control system. We wished to allow the probe to move freely over variations in the wheel, while minimising any tendency to 'bounce' over rough areas. We solved this by making the probe mechanism pressure sensitive. At the beginning of the scan the probe moves towards the wheel centreline until it encounters resistance. It then moves up (or down) the wheel at a constant selectable helix. Because the probe moves only as the driving motors move any fast surface variations will be damped out, while giving a minimum static pressure and thus reducing probe wear.

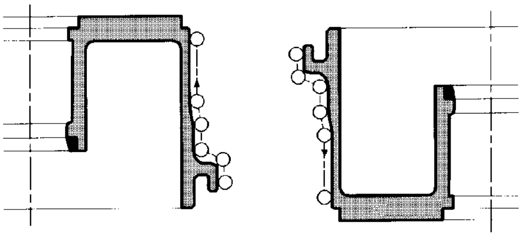


Figure 8: Scan paths on Hocking *Wheelscan 700*

As the probe moves under processor control the orientation is unimportant, the system can test as well flange up or flange down. The probe will automatically follow the wheel shape, without any additional programming.

Operation

Many otherwise excellent pieces of equipment are let down by a poor 'user interface'. We have tried to ensure that the task of the operator is understanding the application. The equipment should do its job unobtrusively.

All parameters relating to the eddy current inspection are set on the 'wheelscan E' eddy current instrument. Normally this is just frequency, gain and alarm level. It unlikely that these will be changed from one wheel to another.

On the wheelscan base unit the operator can set wheel lift height (as convenient to the wheel geometry), inspection speed and helix. For a given wheel the operator need set only the start (flange end) and finish heights as measured from the roller table surface,

In use the wheel is rolled onto the machine, positioned over the spindle. Then the operator presses the lift button, ensures that the wheel is correctly centred, presses start and comes back 2 minutes later when the test is complete. Few operators require such a speed, but 20 half-wheels per hour are easily achievable for the basic inspection.

CONCLUSION

As I said earlier we set out to address the technical and practical problems of the existing technology. We feel that we have now answered all of the technical objections for aircraft operators contemplating automated wheel inspection. Cost savings, reliability and safety improvements make automated inspection the only sensible policy for larger companies.

At Hocking we were very proud of our new machine when we launched it, but as with any product, it's the reaction of the customers that counts.

Three years later a customer list covering the map from Seattle to Sydney suggests that they share our opinion!