RUSTY DIAMOND

Could ‘damage tolerance’ be as useful for corrosion as it is for fatigue?

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Abstract: An experienced civil aviation safety regulator reviews if ‘damage tolerance’ could be as useful for corrosion as it is for fatigue. The answer is ‘yes’. Operators, manufacturers and regulators could save time, money and lives. Examples, recommendations and draft regulatory guidance show how.

INTRODUCTION

How well are we managing corrosion? Modern Corrosion Prevention and Control Programs (CPCPs) have certainly improved safety, so far. But, how will they handle the increasing commercial pressure to relax them, even as aircraft get older? How do operators know what is safe to relax, and what is not, when there is a frustrating dearth of technical guidance (including from regulators)? Are operators getting the most from them commercially?

At ICAF 2005, in Rough Diamond, Bob Eastin and I proposed a simple damage tolerance model we light-heartedly called the ‘diamond’ [1]:

Figure 1: The diamond's five facets of 'damage tolerance'. In the civil rules, damage tolerance is a method to develop maintenance, not a prescription for fracture mechanics, rogue flaws or particular design. Many prefer the term 'safety by inspection' to avoid these unnecessary associations, but 'damage tolerance' seems entrenched.
The paper was simple; we feared it was simplistic. But, *Air Safety Week* praised it [2], the Royal Aeronautical Society reprinted it [3], and its diamond model still helps us understand and explain even complex situations. This sequel and companion, *Rusty Diamond*, reviews whether damage tolerance, with the same simple model, could also be useful for corrosion.

![Figure 2: Corrosion doesn't look like fatigue. But, can we still manage it by damage tolerance?](image)

The paper's three main sections are questions:

- **Is there a problem?**
  - To see if there is anything 'broke' to 'fix' (to rephrase Bert Lance)
- **Is damage tolerance applicable to corrosion?**
  - To see if corrosion is too different to fatigue (or, if it matters)
- **Is damage tolerance useful for corrosion?**
  - To see if the theory is practical

The answers may surprise you. An Annex proposes new regulatory guidance.

Finally, as we use more composites (part of ICAF 2007's theme), are you wondering if corrosion is dead? Don't stop reading; we can't ignore corrosion yet. For a while, 'composite' aircraft will still have metal that is structural and corrodible by carbon fibres [4]. We try to separate them, but, even if we design well, we err on assembly. On the wing of one military transport, aluminium trailing edges corrode where the fasteners weren't properly sealed. And, on the fuselage of one civil airliner, workers ground off the fibreglass layer that insulates a carbon-fibre bulkhead from its aluminium frame, to improve the fit!

![Figure 3: In 'composite' aircraft, one small slip during design or assembly can unleash the corrosive power of 'cathode-to-anode ratios' far higher than the 'lead' pencil marks we worried about years ago. 'Composite' aircraft are not very 'damage tolerant' for corrosion.](image)

**IS THERE A PROBLEM?**

Let's look under three headings: 'division', 'duplication' and 'danger'.

**Division**

In the beginning, the United States Federal Aviation Administration (FAA) made them equal: in the first civil rule for damage tolerance, corrosion was there, next to fatigue [5].
Similar rules followed. Yet, we use them for fatigue, but not for corrosion. We hope that someone, somehow, is ensuring 'their' corrosion won't affect 'our' fatigue. In 2002, the FAA lamented this, and proposed a solution [6]. But, in 2004, they withdrew it! [7]

One problem is professional rivalry: engineers jealously guard fatigue and damage tolerance; mechanics do the same for corrosion. For the FAA, it’s Aircraft Certification versus Flight Standards. For this paper, it’s writing alone, because Bob Eastin covers fatigue and damage tolerance, but not corrosion. For large airliners, it’s Certification versus MRB (Maintenance Review Board), FAR 25.571 versus MSG-3 [8], and Airworthiness Limitations versus MRB reports and CPCPs.

Another problem is the division between civil and military. The military are sponsoring far more research on corrosion and its interaction with fatigue and damage tolerance (with 'corrosion' and 'damage tolerance' even in the same sentence on one consultant's web site! [9]). The problem is convincing the civil world. Conferences like 'Aging', ASIP and ICAF, which we share, are not enough: the jargon seems alien, the programs unaffordable.

**Duplication**

Division often means duplication. We waste time and money on the program when:

- We *assess* twice: materials; coatings; access; criticality; even loads;
- We *publish* twice: separate fatigue and corrosion programs that overlap; or
- We *teach* twice: the management principles, which are common (as we will see).

Then, there is the waste of the program not working as *efficiently* as it could, because we didn't develop it as *scientifically* as we could.

**Danger**

Division means danger from corrosion if:

- We *guess*: because there's no scientific method or guidance;
- We *ignore*: the interaction with fatigue; or
- We *neglect*: if corrosion is not in the mandatory Airworthiness Limitations.
Figure 4: In the 1980s, division in CASA endangered Aero Commanders (left). The corrosion specialists let them fly for years with untreated exfoliation corrosion in their wing spars (middle). When the fatigue specialists found out, they stopped the practice, fearful that corrosion would worsen fatigue they were managing in the same spars (right – the arrows show a crack) [10]. We learned the lesson. One section now manages fatigue and corrosion.

So, is there a problem?
I don’t want to exaggerate the division, duplication or danger. But, if they are unnecessary, aren’t they unacceptable? ’Broke’ or not, we could do better.

IS DAMAGE TOLERANCE APPLICABLE TO CORROSION?

Many damage tolerance experts say it can’t be applicable, because corrosion is too different to fatigue. I have heard them say things like:

- Fatigue is scientific, but corrosion is not;
- Fatigue is predictable, but corrosion is not; and
- Fatigue is deterministic, but corrosion is probabilistic.

Given the division already mentioned, those views are understandable. But, are they relevant? I would like to suggest they are not. Damage tolerance is not unique to fatigue, or even aviation. Its method is universal. It can manage any deterioration, in any discipline. It is how I manage weeds in my lawn, how the pest inspector manages termites in my house, and how my gastroenterologist manages polyps in my bowel. So, corrosion doesn't have to be like fatigue, it just has to be deterioration. That is the only condition for it to be manageable by damage tolerance and the diamond’s five facets (Figure 1).

Obviously, we must know the diamond's two Ss:

- 'Site': where will it grow?
- 'Scenario': how will it grow?

Then, just as obviously, for every site and scenario, if we want to know how long the 'inspection window' will be safely open, we must know the three Ds:

- 'Detectable': what can we find?
- 'Dangerous': what can we bear?
- 'Duration': what's the time from one to the other?
Although the scenario may differ from fatigue, graphing it with the three Ds still looks like classic damage tolerance – because it is:

![Figure 5: Classic damage tolerance for corrosion](image)

Some points to note:

- Those familiar with fatigue must look more broadly for sites. They are lavatories as well as laps; skins as well as spars, bilges as well as bolts.
- With prediction hard by analysis (structural models can't yet show the 'hot spots' for corrosion), the experienced mechanic is an essential member of the development team.
- This is the simplest scenario, which doesn't consider the coating deteriorating or corrosion interacting with fatigue (more on those later).
- Corrosion scenarios are hard to predict, but we are learning [11]. There is now software, like ECLIPSE [12]. But, if we can't analyse the scenario, we should:
  - Test;
  - Manage within a part of the scenario we can analyse; or
  - Manage by a method other than inspection.
- Corrosion often slows as its products restrict ion flow, especially if it’s confined. Arrest is total in fibre-metal laminates, like GLARE, when corrosion hits the fibres.
- Like fatigue, what is 'detectable' depends on factors like method, lighting, size, distance, congestion and cleanliness (including inhibitor – the term I use to avoid TLAs – three-letter acronyms – like CPC for corrosion preventive compound).
- We must be able to analyse the residual strength of corroded structure. One paper is [13].

Now, back to what we hear many damage tolerance experts say: even if their comparisons with fatigue aren't relevant to damage tolerance's applicability to corrosion, are they true? Although loads drive one, chemistry the other, both follow natural laws. So, in theory, both are scientific and predictable. It is just that, in practice, our science is immature for corrosion. With more research, predictability (and estimating uncertainty) will improve (as it will for fatigue).

Both fatigue and corrosion involve random variables (many of them), so both are probabilistic. But, our knowledge of its statistical distributions is immature for corrosion. With more research, risk analysis will improve (as it will for fatigue).
IS DAMAGE TOLERANCE *USEFUL* FOR CORROSION?

In this section, I would like to show examples of how I think damage tolerance and the diamond method could be useful, under these headings:

- Considering the interaction with fatigue;
- Lessening corrosion;
- Preventing corrosion (by inspection and by restoration);
- Exposing uninspectability;
- Investigating service experience;
- Extending an inspection interval;
- Flying with corrosion;
- Unifying structural maintenance development;
- Balancing structural maintenance development; and
- Consolidating the research.

Considering the interaction with fatigue

We all know that corrosion and fatigue can worsen each other. Hoeppner lists how in [14]. Another classic on the subject is Walter Schutz's Planema Memorial Lecture at ICAF 1995 [15]. The diamond helps us start a checklist:

- **Site**
  - Could corrosion promote fatigue where stresses are normally low?
  - Could fatigue promote stress corrosion, or crack coatings or sealants?
  - Could corrosion *inhibitor* change crack sites by lessening frictional load transfer? [16]

- **Scenario**
  - Could corrosion - *or the inhibitors we use* - quicken fatigue scenarios?

- **Detectable**
  - Could corrosion - *or the inhibitors we use* - hide cracks?

- **Dangerous**
  - Could corrosion weaken residual strength for fatigue?

*Figure 6: Corrosion can start fatigue cracks 10 to 100 times sooner than normal (Clark [17]).*
Lessening corrosion
The damage tolerance rules let strength fall to limit before calling it 'dangerous'. But, for corrosion, airlines willingly aim for something more 'desirable' for business. They aim for ultimate strength (150% stronger than limit), by aiming for 'Level 1' ('corrosion damage that does not require structural reinforcement or replacement') in MSG-3 (the Air Transport Association's standard).

On the same damage tolerance graph as Figure 5, if we lower the upper 'sill' of the 'inspection window' from 'dangerous' to 'desirable', we shorten the 'duration' (so shorten the inspection interval):

![Figure 7: Damage tolerance if we want to lessen corrosion](image)

As well as reparability, we improve safety by:
- Lessening the chance corrosion will affect fatigue; and
- Allowing more for the uncertainty and variability we find so hard to estimate.

Preventing corrosion (by inspection)
Even more 'desirable' than easy repair is no repair. This time, our damage tolerance graph is for the coating, not the metal, and for properties, not a dimension:

![Figure 8: To prevent corrosion by inspection, we must show damage tolerance for the coating](image)

The above 'scenario' is arbitrary, just to show the idea. There are really two scenarios (one for each property). And, it doesn't apply if sudden accidental damage is likely. 'Desirable' is when the coating has deteriorated so far, corrosion is imminent. For deterioration to be 'detectable' before then, we probably need better than the usual 'visual' inspections. Komorowski lists some NDI in [18]. Others are thinking of hardness tests. Even better may be permanent sensors, which allow 'structural health monitoring' (SHM). An Aerospace Industry Steering Committee for SHM is now guiding research and standards development. Corrosion is on their agenda.
Preventing corrosion (by restoration)
Another way to prevent corrosion is to regularly restore the coating with inhibitor. Figure 9 only differs from Figure 8 by:

- The 'scenario' being the deterioration of inhibited coating;
- There being no 'detectable' zone because there is no inspection; and
- The 'desirable' limit being when corrosion is imminent, or when the inhibitor can no longer restore the coating, whichever occurs first.

Exposing uninspectability
By forcing us to determine what is 'detectable' and what is 'dangerous', and to compare them, damage tolerance is an important check against uninspectability, which is common, especially in small aircraft. CASA’s web site describes a potentially dangerous uninspectability in the wings of single-engined Cessnas [19]. For uninspectability, we must revise the inspection method or the design, regularly restore the coating or regularly replace the part.

Investigating service experience
In Rough Diamond, we saw how the diamond’s facets form a simple checklist to help manufacturers compare prediction with practice, to improve their programs:

<table>
<thead>
<tr>
<th>Site</th>
<th>Prediction</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dangerous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detectable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What did the designers assume?</td>
<td>Compare</td>
<td>What did the defect or crash investigator find?</td>
</tr>
</tbody>
</table>

Figure 11: Damage tolerance’s five-faceted checklist for investigating service experience
Air Safety Week liked this idea for fatigue [2]. It is even more important for corrosion, because, for most small civil aircraft flying today (even small airliners), the left column is blank – there was no prediction! So, investigating maintenance findings may be our last chance to fill in the right side before the crash investigator does. Some manufacturers don't do this well. They put their best people where the money is: designing and certifying new aircraft. I say more on 'continuing airworthiness' in [10], [21] and [22].

Extending an inspection interval
A common argument to extend an inspection interval is repeatedly not finding corrosion. But:

- A slow start doesn't always mean it won't start. Corrosion gets more likely with age – unless we regularly restore the coating.
- A slow start doesn't always mean slow growth. It could be just a better than average coating, which will make no difference when it's gone.

So, be wary of the 'nil findings' argument, especially as pressures increase to cut maintenance. It can be just as specious for corrosion as Rough Diamond warned, by example, for fatigue.

But, MSG-3-based corrosion programs may let us experiment, by leaving room for error, if we extend an interval hoping our aircraft will corrode more slowly than the manufacturer assumed, but it doesn't. If we graph damage tolerance for strength instead of corrosion depth:

By similar triangles:

\[
\frac{\text{Duration 2}}{\text{Duration 1}} = \frac{(110 - 67)}{(110 - 100)} = 4.3 \quad \text{(Higher if strength decays exponentially instead of linearly)}
\]

This is a crude analysis, with crude assumptions. And, we don't want too much corrosion, for too long, in case it promotes fatigue. But, it suggests the arbitrary extensions regulators now allow (to about 1.2 times, or a 20% increase) are conservative. It seems we could allow mature, informed operators more freedom.

Reversing this damage tolerance analysis, but assuming strength decays exponentially instead of linearly, could also help operators quantify how much to shorten an inspection interval if they find more corrosion than they expected.
Flying with corrosion
Sometimes, we don't want to repair corrosion immediately. We want to wait for a more convenient maintenance opportunity. We will want to do that more often as we get better at finding corrosion. Sometimes, we don't want to repair corrosion at all. We fear the cure could be worse than the complaint [18]. Aggressive grinding and sloppy reprotection recently returned corrosion so severe, so soon, it scrapped a small turboprop airliner in Australia. Sometimes, it is better just to treat light corrosion with inhibitor, so it won't grow.

If we want to know if we can keep flying, damage tolerance's 'diamond' helps us start a checklist (especially the first two facets):

- Site
  - The full extent, not just what we found first
- Scenario
  - If we inhibit, how long will it arrest growth?
  - If we can't inhibit, how will it grow?
  - Could pits cause cracks?

Unifying structural maintenance development
If damage tolerance is applicable to corrosion, we could end the division, duplication and danger an earlier section mentions. We could:

- Reunite corrosion with the damage tolerance rules (like FAR 25.571)
  - We would not need MSG-3 for structure
  - We would need damage tolerance-based guidance
- Unite corrosion with the damage tolerance experts
  - We would not need MRB Structures Working Groups
  - We would need to bring their experienced airline mechanics to Certification
- Unite corrosion management with the damage tolerant maintenance
  - We would not need separate CPCPs
  - We would need to blend corrosion into the Airworthiness Limitations

Balancing structural maintenance development
When I get damage tolerance evaluations from manufacturers, modifiers and repairers, I look first for completeness and balance. For example, for fatigue, the best fracture mechanics-based crack growth and residual strength analyses won't help those who skimp on scouring for sites (so miss some) and ignore inspectability (so don't know if there is any safe 'duration'). I talk more about balance in Gnats and Camels [21]. Corrosion is the same.

![Figure 13](image-url): Damage tolerance helps us balance the program - not like on the right.
Consolidating the research
Many are researching and proposing new-sounding concepts. But, can we also think of them as improving an old one? For example:

- Corrosion Reliability Centred Maintenance (CRCM) [23]
  - Isn't it using damage tolerance to better prevent corrosion (as before, this section)?

- The 'science based probability approach' [24]
  - Isn't it using science and statistics to better predict 'scenarios' and their variability?

- Holistic Structural Integrity Programs (HOLSIP) [25]
  - Isn't it using materials science to better predict 'sites' and 'scenarios'?

Wouldn't it help to consolidate the research in terms of damage tolerance? I like the Canadian National Research Council calling their development of HOLSIP, Probabilistic Damage Tolerance Analysis [26]. I like what a monk, William of Ockham, said 700 years ago:

*What can be done with fewer assumptions is done in vain with more. In explaining any phenomenon, we should use no more explanatory concepts than are absolutely necessary (Ockham's Razor).*

In short, I like to keep things simple.

**CONCLUSION**

This short paper never tried to be 'all you need to know about corrosion'. Others are more qualified to explain the metallurgical and mathematical detail. But, I hope it shows damage tolerance is not only applicable to corrosion, it is useful – as it is for fatigue.

Jerzy Komorowsky, of the National Research Council of Canada, once said this about technologies like the 'technology' of damage tolerance for corrosion [18]:

*Transferring these technologies into the hands of the maintenance, repair and overhaul industry will no doubt be a significant challenge.*

The point is, researchers, like Komorowsky, and regulators, like me, aren't finished until we've persuaded the practitioners. We must simplify and standardise our messages if we want to 'sell' them to a complacent and cost-cutting civil world. After nearly thirty years, it is slowly accepting damage tolerance for fatigue. Let's try to build on that foundation for corrosion.

If we do, I hope to see fewer civil aircraft not having a corrosion program at all. I hope to see fewer operators not having the guidance and the methods they need to resist commercial pressure and make the most of the program they have. I hope to see less division, duplication and danger. I hope to see damage tolerance and its diamond helping operators, manufacturers and regulators save time, money and lives.
RECOMMENDATIONS

My main recommendation is simple:
1. We should use the damage tolerance rules for corrosion, not just fatigue.

In support, we should:
2. Write damage tolerance-based regulatory guidance (simple, conceptual, like this paper).
3. Give more freedom to operators with the right people, procedures and tools (Annex 2).
5. Encourage damage tolerance experts to show more interest in corrosion.
6. Teach corrosion and fatigue management together.
7. Research the deterioration, inspection and restoration of coatings.
8. Develop the analysis to support inhibiting instead of repairing light corrosion.

ACKNOWLEDGEMENTS

I thank the Australian CASA for supporting my preparation and presentation of this paper. Special thanks to Wayne Jones (the ex-mechanic who kept this boffin practical), DSTO's corrosion team (headed by Dr Bruce Hinton, whose PhD was about fatigue, so he understands both worlds) and Dr Graham Clark (Australia's ICAF delegate). Finally, I thank Kathy for still loving me while I again thought more about another 'diamond' than hers.

POSTSCRIPTS

1. My son, Nathan, was also studying diamonds – to propose to Tara. He told me diamonds don't rust and really have four Cs (cut, carat, colour and clarity). Thanks, son. I wish you, Tara, and your future family safety from corrosion, not just fatigue, when you fly.
2. This paper covers intervals (the times between inspections) but not thresholds (the times to the first inspections). I apologise, but in the space and time available, I will have to leave the thorny issue of thresholds for another paper, at another time. I hope to show how we could use damage tolerance more consistently and less prescriptively for thresholds, for both fatigue and corrosion, as Airbus longed for in their thoughtful ICAF 2005 paper [27].
3. If I err anywhere in this paper, please tell me. That's what great about ICAF. It's not just a conference; it's a caring community that puts aviation safety before personal pride.
REFERENCES


[22] Swift, S. (2003), Big Challenges for Little Airliners, 10th Australian International Aerospace Congress, Brisbane, Queensland, Australia.


ANNEX 1

CORROSIVE STRUCTURAL FAILURES

Is corrosion dangerous? The table below lists six fatal crashes from the Aviation Safety Network’s database. Hoeppner lists and mentions more in [28], a telling paper for anyone who doubts corrosion affects safety. Often, crash reports blame fatigue, when corrosion started it. In Australia, for airframes, corrosion causes 7% of Airworthiness Directives and 20% of defect reports. This is similar to what Hoeppner reports. The FAA is not alone predicting an increase as our aircraft age [6], like in Australia [29].

<table>
<thead>
<tr>
<th>Year</th>
<th>Aircraft</th>
<th>Country</th>
<th>Description</th>
<th>Dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>Vickers Viking</td>
<td>Tanzania</td>
<td>‘The… booms (of the wing) had…corrosion’.</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Central African Airways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VP-YEY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>Handley Page Herald</td>
<td>Canada</td>
<td>‘Failure of corroded skin area along the bottom centre line of the aircraft…resulted in structural failure of the fuselage and aerial disintegration.’</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Eastern Provincial Airways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CF-NAF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td>Vickers Vanguard</td>
<td>Belgium</td>
<td>‘An explosive decompression of the fuselage occurred…the tail surfaces subsequently failed…corrosion was found in the lower part of the rear pressure bulkhead.’</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>British European Airways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G-APEC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Boeing 737</td>
<td>Taiwan</td>
<td>‘Severe corrosion, which led to pressure hull rupture and the subsequent disintegration of the airplane.’</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Far Eastern Air Transport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B-2603</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>Boeing 737</td>
<td>USA</td>
<td>‘Contributing to the accident were…early production difficulties in the 737 cold bond lap joint, which resulted in low bond durability, corrosion and premature fatigue cracking.’</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Aloha Airlines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N73711</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Antonov 24</td>
<td>Russia</td>
<td>‘Massive corrosion of the fuselage…caused the tail section to separate.’</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Stavropol’skaya Aktsionernaya Avia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RA-46516</td>
<td></td>
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</tr>
</tbody>
</table>

Source: Aviation Safety Network [30]. Their database covers ‘civil multi-engine airliners of which the basic model has been certified for carrying 13 or more passengers’. The photos of the Vickers Viking, Handley Page Herald and Antonov 24 are of the same type, but not the same aircraft or airline. The photo of Vickers Vanguard G-APEC is from the Air Britain Photographic Images Collection (photographed by Stephen John Rendle).
ANNEX 2

DRAFT ADVISORY CIRCULAR

Airworthiness Limitations for Aircraft

1 Introduction

1.1 Who should read this Advisory Circular (AC)?
Anyone who wants an Australian:
• Type certificate (TC); or
• Supplemental type certificate (STC).
You will want a TC or STC if you are designing:
• An aircraft (TC); or
• A modification to an aircraft (STC).
This AC is not for those designing engines or propellers (even if the principles are the same).

1.2 Why should you read this AC?
This AC shows you how to develop the Airworthiness Limitations that the Airworthiness Standard in:
• CASR 21.017 requires for a TC; or
• CASR 21.101 requires for an STC.
For example, for small aircraft designed to the United States Federal Aviation Regulations, the Airworthiness Standard is FAR 23:
• §23.573 Damage-tolerance and fatigue evaluation of structure
• §23.575 Inspections and other procedures
• §23.629 Flutter
• §23.1529 Instructions for Continued Airworthiness
• Appendix G Instructions for Continued Airworthiness

1.3 What is new in this issue of the AC?
This is the first issue of this AC. It includes guidance for Airworthiness Limitations for corrosion and accidental damage, as well as for fatigue.

2 General

2.1 What are Airworthiness Limitations?
Airworthiness Limitations are instructions for maintaining the aircraft safe (to its type-certified Airworthiness Standard) against the threats of fatigue, corrosion and accidental damage.
They specify:
• What to do; and
• When to do it.

2.2 What about Instructions for Continued Airworthiness?
Airworthiness Limitations are part of the Instructions for Continued Airworthiness.

2.3 What must I show CASA?
As well as the Airworthiness Limitations, you must show us:
• How they comply with the Airworthiness Standards;
• How you will report and investigate anything unexpected found in service (see CASR 21.3); and
• How you will send amendments to operators (see CASR 21.50).
We also want to see and approve changes to your Airworthiness Limitations.

1 For discussion, not an official CASA proposal.
2.4 What about stiffness?
For fatigue, corrosion and accidental damage, think about their effect on stiffness, as well as strength. Check the flutter rule in the Airworthiness Standard.

2.5 What about 'grace periods'?
If changing your Airworthiness Limitations could affect aircraft immediately, consider a 'grace period'. As common as they are, we don't know of any rules or guidance. But, internationally, there seems a willingness to accept a bigger than normal risk, for a few aircraft, for a short time, if it will ease big costs and inconveniences. We are happy to discuss.

2.6 Can I add Airworthiness Limitations?
If the Airworthiness Standard for your aircraft type did not require Airworthiness Limitations, you may add them voluntarily. You will improve safety by:
- Raising structural maintenance to a standard; and
- Forcing operators to do it.

We just need to agree the standard and you just need to show us your Airworthiness Limitations comply. If you have a SID (Supplemental Inspection Document), it probably already complies. If so, we are happy to approve it as Airworthiness Limitations, to increase compliance.

3 Fatigue

3.1 What is fatigue?
Fatigue is progressive weakening by repeated loads.

3.2 What are the rules for fatigue?
The rules are the Damage tolerance and fatigue evaluation rules in the Airworthiness Standard for your aircraft. See 1.2.

The FAA and EASA publish helpful Advisory Circulars and Acceptable Means of Compliance for their Airworthiness Standards.

For example:
- AC 23-13, Fatigue, Fail-Safe, and Damage Tolerance Evaluation of Metallic Structure for Normal, Utility, Acrobatic, and Commuter Category Airplanes
- AC 25.571, Damage Tolerance and Fatigue Evaluation of Structure
- AMC to 23.571 and 23.572, Fatigue evaluation: metallic pressurised cabin structures, metallic wing, empennage and associated structures

Also, see Rough Diamond, on our web site: www.casa.gov.au → Airworthiness → Technical Papers. It explains 'damage tolerance' as five simple steps - a handy checklist.

3.3 What strength must I assure for fatigue?
The damage tolerance rules say limit strength. Other rules say ultimate. Here's an explanation:
- Design the Airworthiness Limitations for limit strength for predicted threats; but
- Redesign them or the structure for ultimate strength if fleet findings confirm them.

The reason is we want:
- The least maintenance for threats that may not eventuate, but
- The best if they do.

3.4 May I offer operators flexibility?
Yes. For example, you may include choices that allow operators to trade inspection method for frequency.

4 Corrosion

4.1 What is corrosion?
Corrosion is progressive weakening by chemical reaction.

4.2 What are the rules for corrosion?
The rules are the Damage tolerance and fatigue evaluation rules in the Airworthiness Standard for your aircraft. See 1.2.

For years, for large airliners, Maintenance Review Boards (MRBs) have used MSG-3 to develop maintenance for corrosion (see FAA AC 121-22A). We would now prefer you to evaluate damage tolerance for corrosion directly to the Airworthiness Standard, and not to MSG-3, which is not explicitly damage tolerant. We hope to write an Advisory Circular soon to help you. Until then, the method is the same, in principle, as fatigue. See Rusty Diamond, on our web site: www.casa.gov.au → Airworthiness → Technical Papers.

We encourage you to involve experienced operators, as in MRB, for their practical wisdom.

If you publish the corrosion section of your Airworthiness Limitations separately, and call it a CPCP (Corrosion Prevention and Control Program), clearly also label it 'Airworthiness Limitations'.
4.3 What strength must I assure for corrosion?
The rules are the same as for fatigue. But, currently, we predict corrosion less well. So, our predictions must leave more margin for safety.

So, for corrosion, we want you to assure ultimate strength, right from the start, unless you can confidently estimate and allow for:

- Uncertainty and variability in your predictions; and
- The effect on fatigue of leaving more corrosion for longer.

An economic advantage of assuring ultimate strength is cheaper repairs.

4.4 May I offer operators flexibility?
Yes, as for fatigue (see 3.4), or even more, if you:

- Tell operators they first need our approval (we will only approve operators who have the right people, procedures and tools);
- Show them how;
- Warn about the 'nil findings' argument for extending inspection intervals;
- List the design, operational and maintenance factors to consider before adopting another aircraft's program; and
- Show how to correct a program if it finds more corrosion than expected.

5 Accidental Damage

5.1 What are the rules for Airworthiness Limitations for accidental damage?
The rules are the Damage tolerance and fatigue evaluation rules in the Airworthiness Standard for your aircraft. See 1.2.

Consider accidental damage during:

- Manufacture;
- Operation; and
- Maintenance.

But, only if it is 'likely' (at least a 50% chance in an aircraft's life).

Consider accidental damage:

- On its own;
- Affecting fatigue; and
- Affecting corrosion.

6 Airworthiness Limitations for STC Holders and others
If you want or hold an STC, the rules for the Airworthiness Limitations for your STC are the same as they are for holders of type certificates. Anyone may produce Airworthiness Limitations for any aircraft (or STC) if they can meet the rules. This is for individuals or groups (like 'type clubs') who can't get them from the holder of the type certificate (or STC).

7 Continuing Responsibilities

7.1 What are my continuing responsibilities?
Every 2 years, send us a report that shows us how you have met your continuing responsibilities (see 2.3) since your last report. We may also audit you and your Airworthiness Limitations at other times.

7.2 May I issue a service bulletin instead of changing the Airworthiness Limitations?
Yes, if a service bulletin will address a service problem more quickly and fully. But, please tell us. We may want an Airworthiness Directive.

Later, you may wish to incorporate service bulletins into the Airworthiness Limitations, so operators have one document for safety-critical structural maintenance.