

Joint Challenge 3: The Economics of Jointed Structures

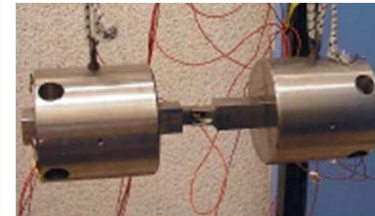
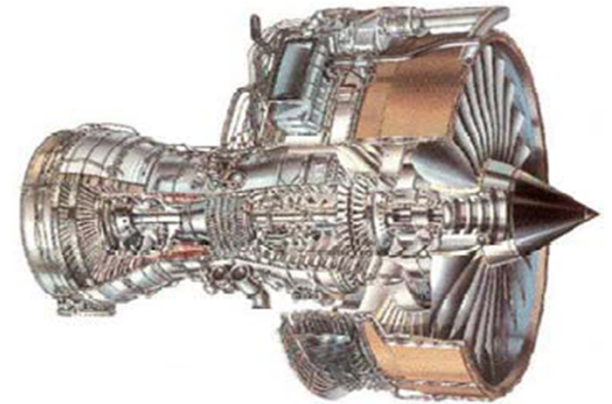
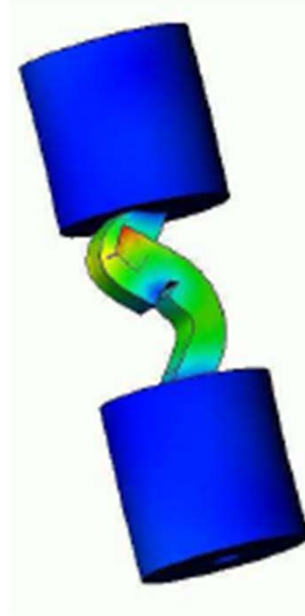
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The Economics of Designing Structures With and Without Joints

- Why not design and build monolithic structures?
- Do we need jointed structures?

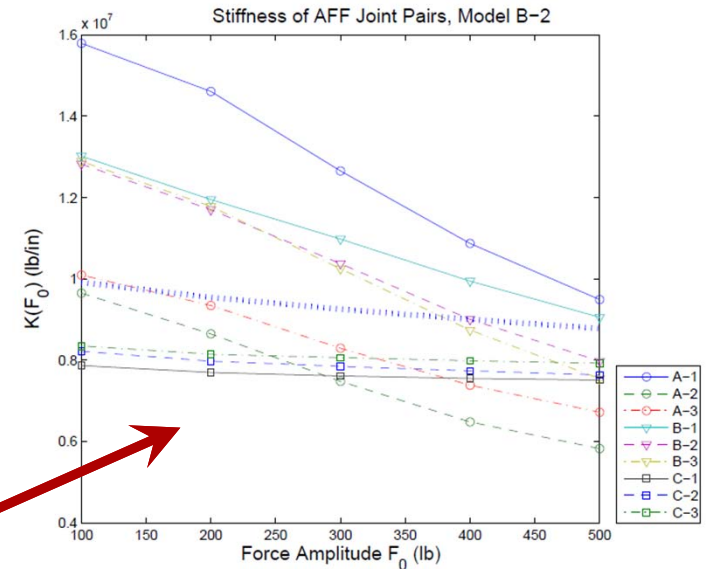
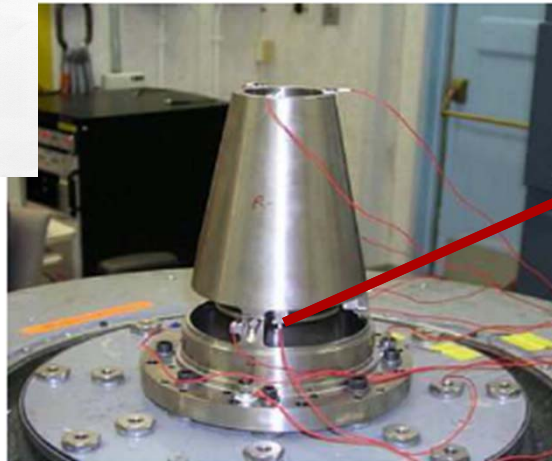
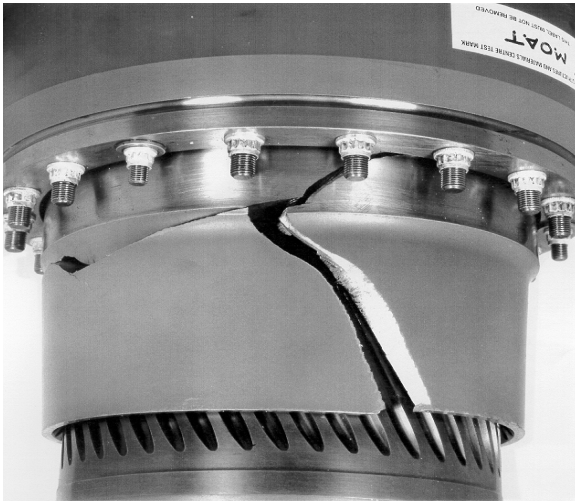


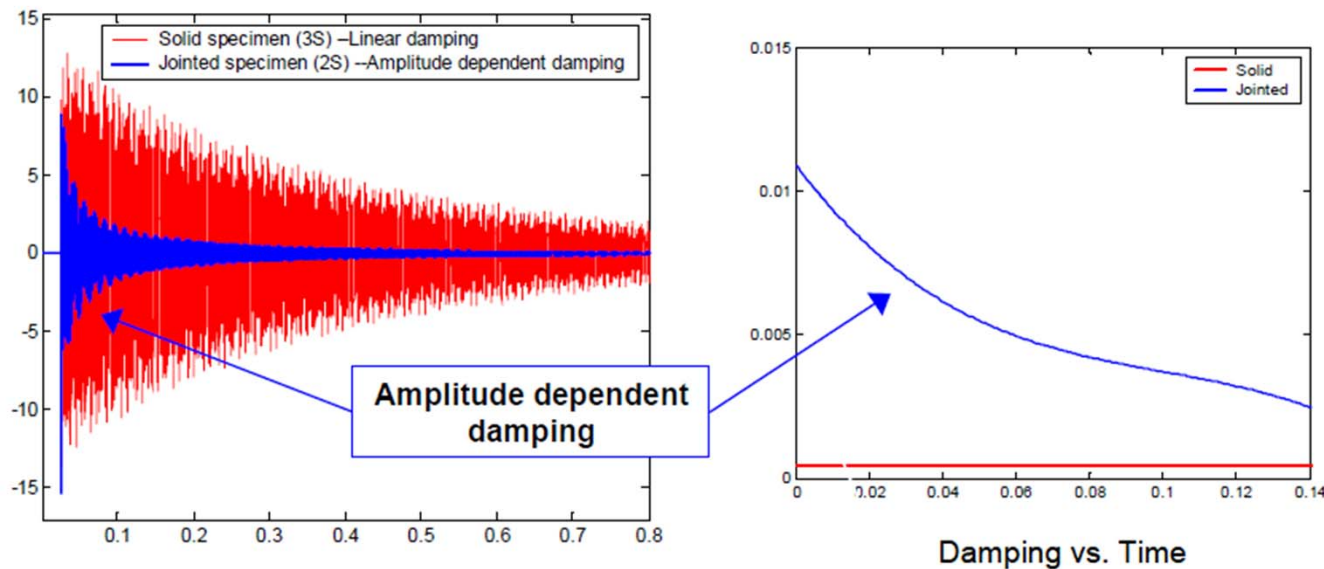
Figure 12.15. Stiffness of AOS Joint Pairs.

The thick dotted line is the stiffness of the four-parameter Iwan model, calibrated to reproduce the dissipation curve with fidelity and to match the stiffness of a load of 400 lb.

From the joint handbook (SAND2009-4164)

Layers of Questions

- What are the economics of designing structures with and without joints?
 - Is it better to have a monolithic or a jointed structure?
 - How do joints affect the dynamic performance of a structure?
 - Ex: Is it better to manufacture one casing or three smaller components that are jointed together?
 - Is there/what is the cost benefit of joints?



Framework for a Cost Benefit Analysis

- Cost of Failure
- Cost Benefit of Saving Weight
- Cost Benefit of Using Joints as Design Tools
- Cost Benefit of Using Joints to Monitor Structures

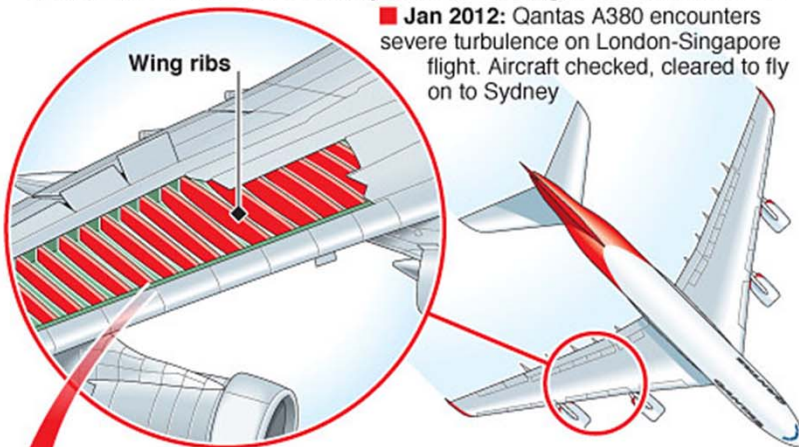


Cost of Failure

More cracks discovered on Airbus A380 wings

The European Aviation Safety Agency has ordered checks on the entire fleet of Airbus A380s for cracks on wing parts after Australian carrier Qantas discovered dozens of tiny fractures during maintenance checks

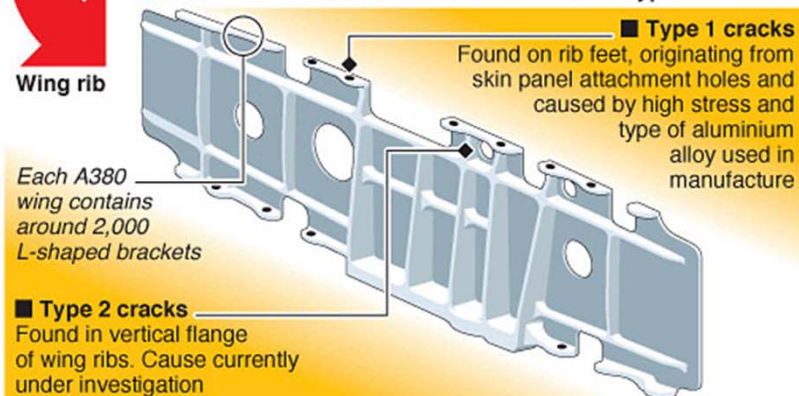
■ **Jan 2012:** Qantas A380 encounters severe turbulence on London-Singapore flight. Aircraft checked, cleared to fly on to Sydney



Aircraft: **VH-OQF** Airframe: **2010** Flight cycles: **399** Flight hours: **2,454**

■ **Feb 5:** Plane grounded in Sydney after further precautionary inspection finds 36 hairline cracks on **wing rib brackets**. They are similar to "Type 1" cracks found in previous A380 checks

■ **Recent EASA directive identifies two crack types:**



Sources: Wire agencies, FlightGlobal

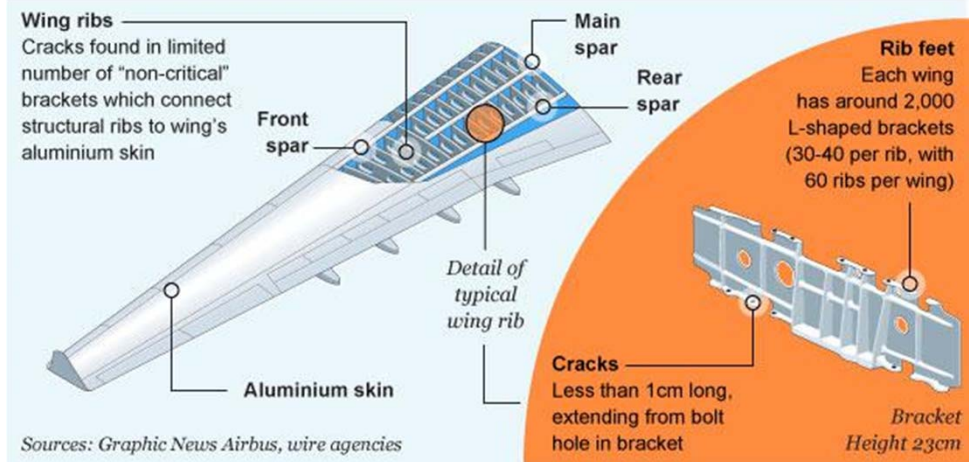
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■ An example: the Airbus 380

- Cracks found adjacent to joints
- Fleet grounded for several months
- \$330 million cost to repair
- \$30 million cost to airlines for not being able to use the planes
- Additional costs for redesigning

Crack in the wings

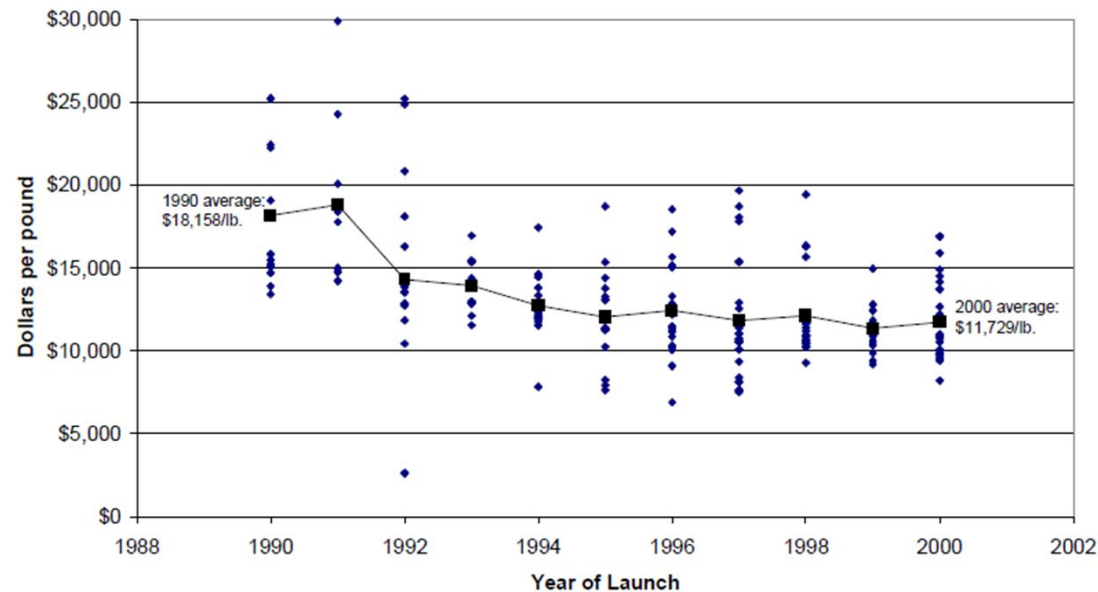
First cracks: Found late last year on wing of Qantas Airways A380 that was being refurbished following mid-air engine explosion in 2010. Similar flaws found in early January in five A380s, flown by Qantas and Singapore Airlines. Both the wings and the engines are manufactured in the UK



Sources: Graphic News Airbus, wire agencies

Cost Benefit of Saving Weight

Figure 1: Estimated Launch Price Per Pound for Commercial GSO Payloads (constant 2000\$)

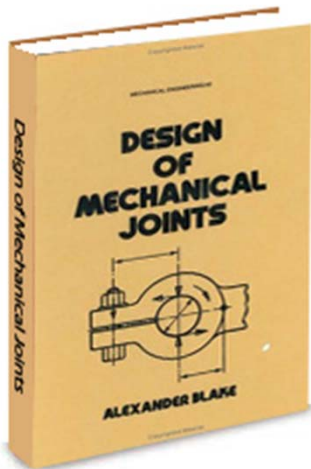


- Most prominently the savings is in fuel efficiency (automotive, aerospace, turbines, etc.)
- Example: in order to launch something into a low orbit, it costs \$4,000/pound, and for a geosynchronous orbit, it costs \$16,000/pound. (Approximately \$12,000/pound on average)
- Reducing weight of joints by X pounds in a satellite directly saves $\$12,000 \times X$ per launch.

Source:

www.futron.com/upload/wysiwyg/Resources/Whitepapers/Space_Transportation_Costs_Trends_0902.pdf

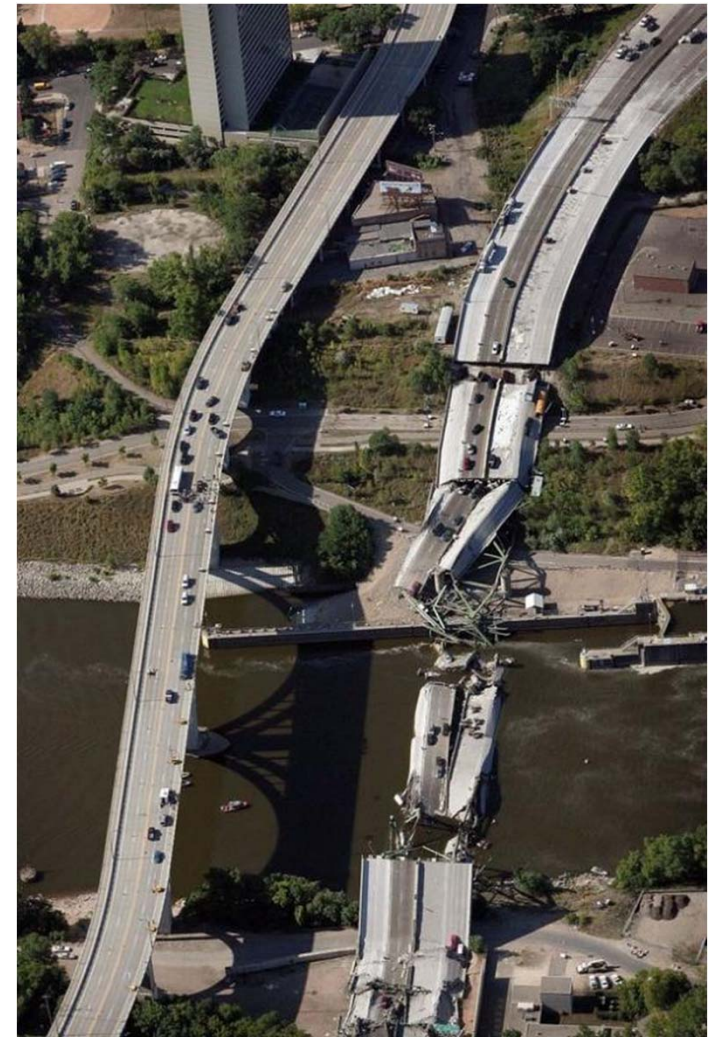
Cost Benefit of Joints as a Design Tool



- Ultimate goal: predictive model of joints
 - Pre-built model of joints with known performance
 - Handbook with easily understood metrics for how a specific joint performed
 - Ability to condition structural response by design of joints
- Impact on direct cost of design time, development cycle, product testing, and production
- If we had X capability from a better knowledge of joints, could we cut out a step in the design cycle?

Cost Benefit of Using Joints for Structural Health Monitoring

- Key idea: structural health monitoring built into joints
- Opportunity to optimally plan a repair cycle for a structure
- Early warning sign to avoid structural failures
- Many potential applications have catastrophic consequences associated with failures
- Cost benefit expected to be deduced from insurance company estimates



I-35 in Minnesota, August 1st, 2007

Concluding Thoughts

- High level question: What is the economics of designing a structure with and without joints?
- If joints are needed, what effect do they have on a system's performance?
- To answer some of these questions, a cost benefit is needed
- Several themes identified:
 - Cost of failure
 - Cost benefit of saving weight
 - Cost benefit of designing structures with joints
 - Cost benefit of using joints to monitor structures
- All of this is predicate on developing a predictive model of joint behavior



Some Points for Discussion

- What are the unknown economics of designing structures with joints?
- Are there any themes missing from the cost benefit framework?
- What are the appropriate next steps for developing a cost benefit analysis?
- What work in other fields can we leverage?

