

Evaluation of Advanced Cutting Tool Materials for Drilling Composite/Metal Stacks

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OUTLINE

- Background
- Preliminary Data
- Project Goal
- Issues

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Background: Composite/Metal Stacks

- Why Composite/Metal Stacks?
 - Composite structures are joined to metal fittings to form a hybrid assembly.
 - To enhance strength and performance
 - Drilled on assembly so that tight tolerance holes and patterns match when fastening.
 - Composite-Metal Stacks - CFRP/Al, CFRP/Ti, etc.

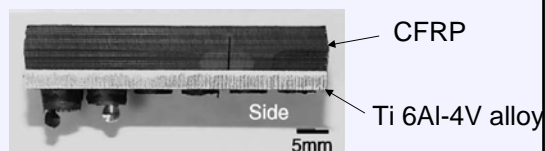


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Source: Boeing.com

Composite-Metal stacks

- Final assembly of composite-metal stacks requires drilling.

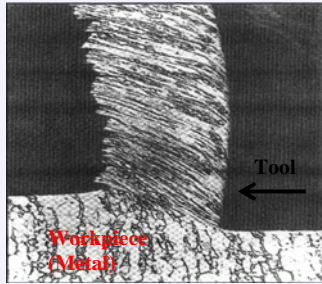


- Conflicting drilling conditions for dissimilar materials: **Most challenging combination → Carbon composite and Ti alloys**
 - Carbon composites – high speed and low feed
 - Ti alloys – low speed and high feed

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Metals vs Composites

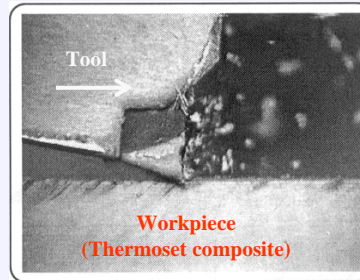
■ Machining of Metals



(S. Kalpakjian, 1997)

- Continuous plastic deformation on shear plane
- Chip formation

● Machining of Composites



(D. Arola, 1996)

- Series of brittle fracture
- Shearing and cracking of matrix materials
- Brittle fracture across the fiber
- Dust type chips

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Possible Wear Mechanisms

Mechanical wear

- **Abrasive wear**
 - The sliding and rolling of hard second phase on the work/tool materials interface
- **Delamination Wear**
 - Continual loading leads to subsurface cracks propagation
- **Adhesion (Al)**
 - Welding of asperity junctions

Thermochemical wear

- **Dissolution Wear**
 - Thermally activated mechanisms - Atomic transport across the interface
- **Diffusion wear**
 - The component of tool materials can be diffused into chips
- **Chemical reaction (Ti)**
 - Chemical reaction between tool and work material

- Thermomechanical fatigue

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Preliminary Data:

Tool wear in Gr/Bi – Ti Composite Stacks

- Objectives: conduct drilling experiments on CFRP/Ti stacks to find the effect of drilling conditions (speed and feed) on machinability of CFRP/Ti stacks.
- Workpiece Material
 - ✓ IM-6 graphite bismaleimide composites and Ti 6Al-4V alloy
- Tool Wear Test Conditions
 - Tool material
 - ✓ Carbide, Standard C2 grade solid carbide drill
 - Drilling conditions
 - ✓ Drilling speed(rpm): 660, 1115, and 1750.
 - ✓ Feed(mm/rev): 0.08, 0.13, and 0.20.
 - ✓ Water-soluble machining coolant used

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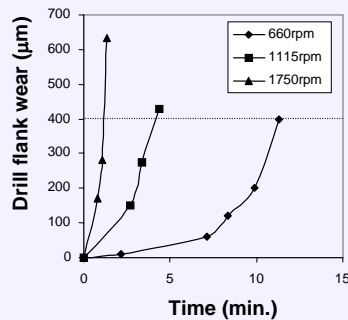
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Preliminary Data:

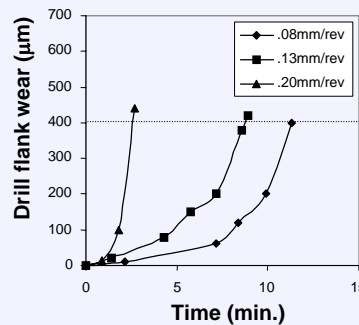
Tool wear in Gr/Bi – Ti Composite Stacks

- Tool Wear Test (Carbide)

Constant feed (0.08 mm/rev)



Constant speed (660 rpm)



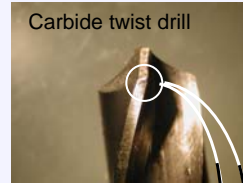
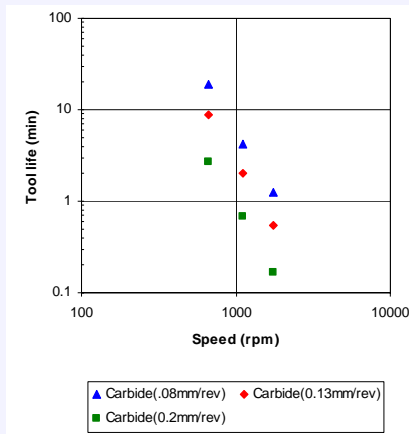
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Preliminary Data:

Tool wear in Gr/Bi – Ti Composite Stacks

- Tool Wear Test (Carbide)



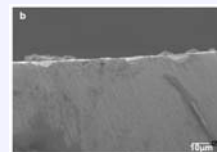
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Preliminary Data:

Tool wear in Gr/Bi – Ti Composite Stacks

- Findings

- Abrasive cutting of Gr/Bi composites
 - ✓ Local damage on the tool edge
- Low thermal conductivity of Gr/Bi composites (approximate 0.25 - 0.58 W/m-K) & Ti64 alloys (approximate 6.7 W/m-K)
 - ✓ Heat generation around the drilling region
 - ✓ Increasing tool temperature



Severe tool wear

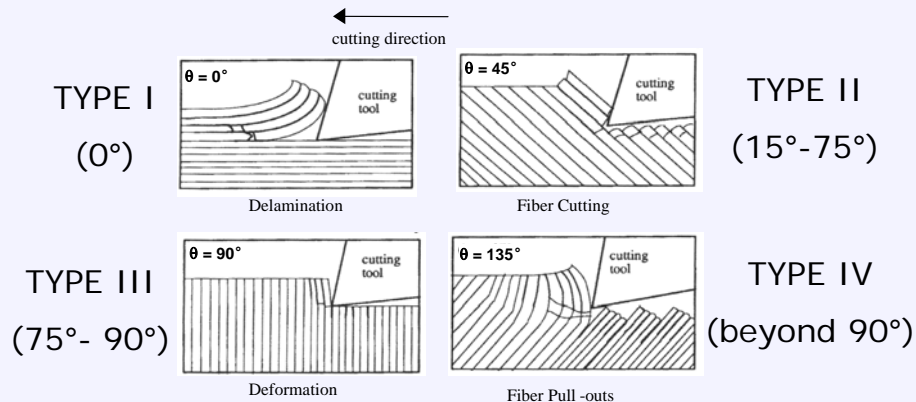
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The Project Goal (Long-term)

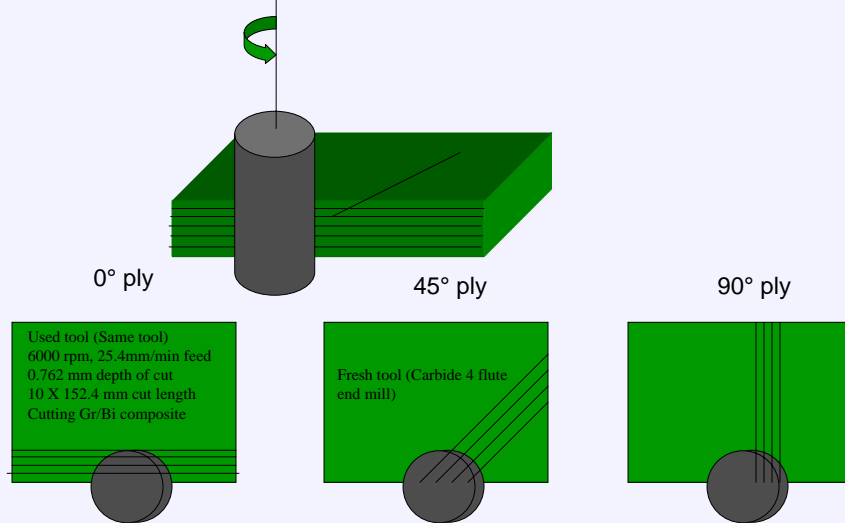
- Evaluation of Advanced Cutting Tools for Drilling Composite/Ti Stacks.
 - Conduct fundamental studies on characteristics of advanced cutting tools (carbide, PCD, and BAM) in composite/Ti machining. (I.e. chemical affinity, chip formation, tool wear mechanisms).
 - Investigate tool wear of cutting tools in machining composite/Ti.
 - Better understand manufacturability of cutting tools (drills, reamers, inserts, etc.) using advanced materials such as BAM, CBN, and PCD (in cooperation with cutting tool manufacturers).
 - Optimize tool design for drilling composite/Ti stacks.

Tool wear in FRP composites

- Composite Cutting Mechanisms (Wang, Ramulu, and Arola)



Preliminary Results (Edge Milling)



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Tool wear in FRP composites

- Tool wear studies in drilling of fiber reinforced plastic (FRP) composites.
 - Influence of fiber orientation on tool wear



- Tool damage due to abrasive fibers

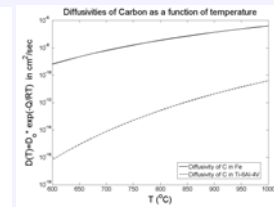
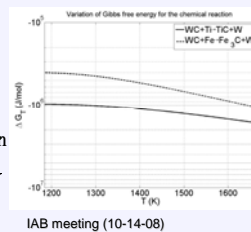
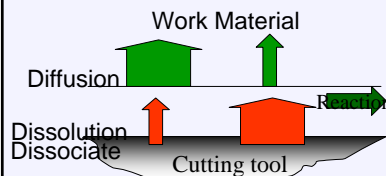
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Tool wear in Composites & Ti

- Tool wear in machining Composites
 - Abrasion by fibers anchored in matrix & tool chipping
- Tool wear studies in machining of Ti.
 - Diffusion driven Tool Wear
 - Chemical reaction between Ti and tools (in particular, carbon from PCD or WC tools).
 - Abrasion due to inclusions (TiC).

Traffic Jam Analogy



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The Project Goal (08-09)

- Experimental tool wear studies in drilling of titanium alloys and fiber reinforced plastic (FRP) composites.
 - Conduct literature survey on manufacturability of advanced cutting tools (carbide, PCD, and BAM) in machining Ti and FRP composites.
 - Conduct tool wear experiments using the commercially available carbide and PCD tools in drilling Ti and FRP composites (not stacks).
 - Investigate the availability of BAM tools and conduct preliminary tool wear experiments in machining Ti and FRP composites.

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Overview of Proposed Work

- Preliminary Edge Trimming of Composites to Understand Tool Wear as a function of
 - Fiber Orientation (Why is - 45 degree fibers most damaging? Elastic constraint)
 - Tool Geometry (Helix angle, Cutting edge geometry etc.
 - Tooling Materials (carbide, PCD, and BAM)
- Drilling (Machining) of Ti alloys to Understand Tool Wear Mechanisms for
 - Advanced tools such as carbide, PCD, and BAM.
- Designing of Drill Geometry and materials

Milestones

	2008 Sep/ Oct	2008 Nov/ Dec	2009 Jan/ Feb	2009 Mar/ Apr	2009 May/ Jun	2009 July/ Aug
Literature survey	█					
Carbide, PCD drilling of Ti		█				
Carbide, PCD drilling of FRP composites			█			
BAM machining of Ti				█		
BAM machining of FRP composites					█	

Budget

■ Subcontract:	\$15,000
■ Labor:	\$15,000
■ Supply & Services:	\$10,000
■ Total:	\$40,000

Thank you!

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