出國報告(出國類別：其他(會議))

參加 2008 年秋季尖端材料科技研討會心得報告

服務機關：國防部軍備局中山科學研究院
姓名職稱：聘用技士　孫士璋
派赴國家：美國
報告日期：97.09.30
出國時間：97.09.07 至 97.09.14

國防部軍備局中山科學研究院出國報告建議事項處理表

報告名稱	參加 2008 年秋季尖端材料科技研討會心得報告		
出國單位	中山科學研究院 五所複材組	出國人員級職/姓名	聘用技士 / 孫士璋
公差地點	美國	出/返國日期	97.09.07 / 97.09.14
建議事項	1.複合材料表面裂紋、斷裂、脫層及低速衝擊常是複合材料的最脆弱且最應被避免的現象。深入瞭解何種形式缺陷及其影響，將有助於工件設計、分析及製程安排。若本院可利用現有之相關破損裕度(Damage Tolerance)分析及測試能力，並能進一步深入研究，未來可提昇釋商計畫參與廠商之複材設計、分析及製造能力，可衍生其他民生使用之複合材料工業，如高壓容器等結構件製造，將可提昇國家複材產業之發展水準。 2、目前在奈米高分子材料開發中，奈米碳管與黏土材料的應用佔很大比例，此與目前本組在奈米複合材料技術之研發方向相符，但如何準確的控制材料的添加方式及瞭解相關之機制，在本次研討會中有許多相關學者的研究值得本組學習應用。使用奈米複合材料技術能有效提昇本院及釋商計畫相關複合材料工件之熱力及機械性質，未來將相關技術技轉民間廠商能扶植複材產業技術，提昇複合材料製品之技術水準。		
處理意見	1. 破損裕度(Damage Tolerance)分析及測試技術的提昇可增強複材設計、分析及製造能力。目前本組已有初步之破損裕度(Damage Tolerance)分析及測試技術，可進一步深入研究，以提昇釋商計畫相關軍品之品質及技術能量，亦可提昇參與廠商之研製能量。 2、本所在奈米複合材料技術中，黏土材料添加於複合材料已有相當多的研究，在奈米碳管添加於複合材料仍需進一步研究探討。但以目前國際上的研究成果顯示，奈米材料添加於複合材料中確可提昇其熱力及機械性質方式。未來若能將其應用於院內工件，並技轉民間廠商，將可提昇國家複材產業之發展水準。		

國防部軍備局中山科學研究院
九十七年 度 出 國 報 告 審 查 表

出國單位	第五研究所 複合材料組	出國人員 級職姓名	聘用技士 孫士璋

單　　位	審　　查　　意　　見	簽　　　　章
一級單位		
計 品 會		
保　　防 安 全 處		
企 劃 處		

批　　　　　　示

國外公差人員返國報告主官（管）審查意見表

本院執行經濟部科技專案計畫，主要目的之一即是將本院國防尖端科技能量，注入國內民生產業，以指導民間廠商突破研發瓶頸，產製高科技、高技術層次、高單價及高附加價值之先進產品，促進我國經濟持續蓬勃發展。爲達此一目的，本院科專計畫執行人員必須隨時了解國際上最新的技術發展現況、商情資訊及產業市場動態等資訊。因此，各科專計畫於每一年度計畫擬定之初，即規劃相關人員派赴歐、美、日等先進國家地區參加學術研討會議並參訪國際知名專業廠商，蒐集科技新技術、新產品、新趨勢等重要資訊，以便掌握先機，與國際同步發展。

本所聘用技士孫士璋奉派於 97.09.07 至 97.09.14 赴美國參加 2008 年 SAMPE 秋季科技研討會及展覽會(SAMPE Fall Technical Conference and Exhibition) ，其主要目的即爲蒐集經濟部科技專案計畫「材料與化工領域軍品釋商第二期計畫」之相關商情資訊。本次公差出國研討有關複合材料、奈米複合材料、多功能材料之設計分析理論、實驗方法、產品製程及應用等相關技術並蒐集現今材料發展及未來趨勢資訊，可作爲科專「材料與化工領域軍品釋商第二期計畫」後續執行與規劃之參考。

此報告對於本所正投入發展的複合材料、奈米複合材料及多功能材料等，作了一詳盡的介紹。其中複材相關之重要課題介紹與研討會的最新研究發展方向探討，使本組可瞭解各項技術的最新發展趨勢，配合本所組過去蓄積的複合材料製造與分析能量，相信未來對國內產業界與本院相關研發工作之推展將可做出具體貢獻，確已完成預定工作目標，達到派遣出國之目的。

出國報告審核表

<table>
<tr><td colspan="4">出國報告名稱：參加 2008 年秋季尖端材料科技研討會心得報告</td></tr>
<tr><td>出國人姓名（2 人以上，以 1 人爲代表）</td><td>職稱</td><td colspan="2">服務單位</td></tr>
<tr><td>孫士璋</td><td>聘用技士</td><td colspan="2">國防部軍備局中山科學研究院</td></tr>
<tr><td>出國類別</td><td colspan="3">□考察 □進修 □研究 □實習
■其他 國際會議 （例如國際會議、國際比賽、業務接洽等）</td></tr>
<tr><td colspan="2">出國期間：97 年 09 月 07 日至 97 年 09 月 14 日</td><td colspan="2">報告繳交日期：97 年 09 月 30 日</td></tr>
<tr><td>計畫主辦機關審核意見</td><td colspan="3">□1.依限繳交出國報告
□2.格式完整
■3.無抄襲相關出國報告
□4.內容充實完備
□5.建議具參考價值
□6.送本機關參考或研辦
□7.送上級機關參考
□8.退回補正，原因：□不符原核定出國計畫 □以外文撰寫或僅以所蒐集外文資料爲內容 □內容空洞簡略或未涵蓋規定要項 □抄襲相關出國報告之全部或部分內容 □電子檔案未依格式辦理 □未於資訊網登錄提要資料及傳送出國報告電子檔
□9.本報告除上傳至出國報告資訊網外，將採行之公開發表：
□辦理本機關出國報告座談會（說明會），與同仁進行知識分享。
□於本機關業務會報提出報告
□其他____________
□10.其他處理意見及方式：</td></tr>
<tr><td rowspan="2">審核人</td><td>出國人員</td><td>初審</td><td>一級單位主管</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

說明：

一、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

二、審核作業應儘速完成，以不影響出國人員上傳出國報告至「政府出版資料回應網公務出國報告專區」爲原則。

報　　　告　　　資　　　料　　　頁

<table>
<tr><td colspan="2">1. 報告編號：
CSIPW-97Z-D0004</td><td>2.出國類別：
其他(會議)</td><td>3.完成日期：
97.9.30</td><td>4.總頁數：
95</td></tr>
<tr><td colspan="5">5.報告名稱：參加 2008 年秋季尖端材料科技研討會心得報告</td></tr>
<tr><td rowspan="2">6.核准
文號</td><td>人令文號</td><td colspan="3">國人管理字第 0970009372 號　97.07.25</td></tr>
<tr><td>部令文號</td><td colspan="3">國備科產字第 0970008641 號　97.07.11</td></tr>
<tr><td colspan="2">7.經　　　費</td><td colspan="3">新台幣：105,753 元</td></tr>
<tr><td colspan="2">8.出(返)國日期</td><td colspan="3">97 年 9 月 7 日至 97 年 9 月 14 日</td></tr>
<tr><td colspan="2">9.公 差 地 點</td><td colspan="3">美國</td></tr>
<tr><td colspan="2">10.公 差 機 構</td><td colspan="3">秋季尖端材料科技研討會(SAMPE Fall Technical Conference)</td></tr>
<tr><td colspan="2">11.附　　　記</td><td colspan="3"></td></tr>
</table>

附件二

系統識別號

行政院及所屬各機關出國報告提要

出國報告名稱：參加 2008 年秋季尖端材料科技研討會心得報告

頁數 95 含附件：■是□否

出國計畫主辦機關/聯絡人/電話

中山科學研究院/孫士璋/03-4712201#357034

出國人員姓名/服務機關/單位/職稱/電話

孫士璋/國防部軍備局中山科學研究院/聘用技士/03-4712201#357034

出國類別：□1 考察□2 進修□3 研究□4 實習■5 其他：會議

出國期間：

97.09.07 至 97.09.14

出國地區：

美國

報告日期：

97.09.30

分類號/目

關鍵詞：多功能材料、奈米複合材料及複合材料

內容摘要：

本次任務係赴美國參加 2008 年秋季尖端材料科技研討會，以瞭解美國等先進國家多功能材料、奈米複合材料及複合材料科技研發方向及作法，並藉由參與國際會議之機會，與國外學者專家進行交流，吸取先進國家在奈米及複合材料開發之經驗，做為本單位多功能材料、奈米複合材料及複合材料研發參考。

藉由參加本次研討會，除了對複合材料相關的專業知識有極大的增進與收穫外，更藉此機會認識了多位國外長期從事複合材料研究的專家，尤其是利用討論、休息及用餐的時間與多位專家作廣泛的交談，彼此間相處的氣氛十分融洽，也因此得到不少寶貴的意見與幫助，更建立了良好的友誼，提供日後不少諮詢的對象與管道，也使得本次參訪得以順利進行且成果豐碩。

目　　　次

參加 2008 年秋季尖端材料科技研討會心得報告

壹、目的

本院為推廣軍民通用科技，執行由經濟部委辦「材料與化工領域軍品釋商第二期計畫」，以建立科技產業所需之材料與化工領域技術開發等能量，為瞭解國外先進國家新材料與製程發展及市場需求，赴美國參加 2008 年秋季尖端材料科技研討會，研討最新發展複合材料、多功能材料及奈米複合材料之設計分析理論、實驗方法、產品製程及應用等相關技術並蒐集未來發展趨勢資訊。

本次公差主要是參加於美國曼菲斯舉行之 2008 年秋季尖端材料科技研討會，此研討會係全球最具規模的國際研討會議之一，本次會議共計有德國、美國、日本、英國、奧地利、加拿大、法國、義大利、韓國、瑞典、土耳其、印度等 20 餘國，800 餘位學者專家共同來參與此盛會，其中有相當多位係來自全球各地的頂尖學者專家，分享其一年來在材料科學領域之研發成果與經驗，會中共計有 400 餘篇論文發表。本次研討會研討主題非常廣泛，主要探討複合材料、多功能材料及奈米複合材料等材料結構之設計、分析、製程及檢測，其中與本單位執行計畫相關之議題包含：奈米複合材料製程、奈米複合材料分析與特徵、奈米複合材料應用、多功能材料設計能量與應用、電磁多功能材料、多功能材料非破壞檢測、複合材料設計與分析、複合材料疲勞與破壞、非破壞檢測及結構健康偵測、複合材料的測試等前瞻研究。藉由此次參與國際會議之機會，收集材料設計、分析、製程及檢測最新資料，並了解各先進國家在材料領域最新發展趨勢，且透過與國外專家及學者直接交換研究心得及進行實務問題討論後，可提昇本院在相關議題的研究能力，以突破現有技術瓶頸，並協助產業界材料技術的研發，為跨足材料領域的產學研界提供堅實後盾。

貳、過程

一、參加研討會過程

此項全球知名之研討會由尖端材料科技協會(Society for the Advancement of Material and Process Engineering)每年分春季及秋季舉辦二次，本次研討會場地位於美國田納西州曼菲斯市(Memphis, Tennessee)的 Convention Cook Center，自 0908 至 0912 爲期四天，研討主題涵蓋廣泛，共有 62 個議題論文發表、8 個專業課程、5 個議題討論，會議議程如表一尖端材料科技協會秋季科技研討會及展覽會會議議程及附件一 2008 年 SAMPE 秋季尖端材料科技研討會手冊所示；另外有 2 天展覽會參觀，約有 50 個公司的展示。

研討會中，主要分爲三大主題群組，包括多功能材料(Multifunctional Materials)、奈米複合材料(NanoComposites)及複合材料(Composite Material)等主題群組。與會者可充分瞭解最新材料與製程發展技術。本次研討會中講題相當多且廣泛，爲了獲得最大效益，均於前一天晚上即在投宿飯店內瞭解次日欲參加的場次。表二爲此次參加研討會之每日行程表。

二、社交活動

本次技術研討與產品展示會之議程安排項目相當多且密集，參觀行程緊湊，白天參加相關之技術與市場現況論文發表會及參觀材料產品設備展示會，夜間則於旅館研讀相關資料。

本次研討會，各國參與的人數相當多，在會場中沒有發現其他台灣去的學者、教授，無特別社交活動。惟在研討會期間除了和參展的廠商商討相關產品外，僅能在會場空檔、綜合討論、休息及用餐的時間與多位專家作廣泛的交談，彼此間相處的氣氛十分融洽，也因此得到不少寶貴的意見與幫助，更建立了良好的友誼，爲日後提供了不少諮詢的對象與管道，也使得本次參訪得以順利進行且成果豐碩。此外美國及法國也將分別於 2009 及 2010 年舉辦與複材科技相關的研討會，主辦單位學者專家也誠懇的邀請我們能繼續參加，且將陸續提供研討會相關資訊。

表一　尖端材料科技協會秋季科技研討會及展覽會會議議程

09/08	09/09	09/10	09/11
07:30-17:00 註冊及報到	07:30-17:00 註冊及報到	07:30-17:00 註冊及報到	07:30-17:00 註冊及報到
09:00 專業課程 ●航太結構用複合材料之設計 ●複合材料製造技術 ●複合材料介紹 ●複合材料的機械性質測試	08:00 專家講座 ●多功能材料自適應系統總覽 09:15 論文發表 ●奈米複合材料製程 1A ●多功能材料設計能量與應用 1A ●航太結構應用 1A ●公共工程結構應用 1A ●製造與製程進階 1A 09:15 議題討論 ●多功能材料在國防上的應用 11:00 論文發表 ●奈米複合材料製程 1B ●多功能材料設計能量與應用 1B ●航太結構應用 1B ●公共工程結構應用 1B ●製造與製程進階 1B 11:00 展示 ●多功能材料在國防上的應用	08:00 專家講座 ●待訂 09:15 論文發表 ●奈米複合材料應用 1A ●電磁多功能材料 1A ●複合材料疲勞與破壞 1A ●複合材料的自動化生產 1A ●膠合與黏著 1A 09:15 議題討論 ● 多功能材料在工業上的應用 11:00 論文發表 ●奈米複合材料應用 1B ●電磁多功能材料 1B ●複合材料疲勞與破壞 1B ●複合材料的自動化生產 1B ●複合材料的測試 1B 11:00 展示 ●未來多功能材料的研究方向	08:00 專家講座 ●待訂 09:15 論文發表 ●奈米複合材料之電與熱 1A ●奈米複合材料分析與特徵 1A ●熱塑複合材料 1A ●三明治結構 1A ●製造與製程進階 3A 09:15 -170:00　DOD 展示 ●結構能量整合儲存 09:15 議題討論 ●下世代之複合材料工程 11:00 論文發表 ●奈米複合材料之電與熱 1B ●奈米複合材料分析與特徵 1B ●熱塑複合材料 1B ●三明治結構 1B ●多功能材料非破壞檢測 1A
14:00 專業課程 ●奈米複合材料科技 ●熱固性複合材料科技 ●複合材料結構製造程序 ●複合材料的損傷容許分析及實驗	14:00 論文發表 ●奈米複合材料製程 2A ●奈米結構多功能材料 1A ●多功能材料設計能量與應用 2A ●公共工程結構應用 1A ●製造與製程進階 2A ●複合材料設計與分析 1A 15:45 論文發表 ●奈米複合材料製程 2B ●奈米結構多功能材料 1B ●RTM/VARTM/SCRIMP 應用 1B ●製造與製程進階 2B ●複合材料設計與分析 1B	13:15 專家講座 ●日本在多功能材料及結構健康偵測的研究 14:00 論文發表 ●奈米複合材料應用 2A ●熱-力多功能材料 1A ●複合材料疲勞與破壞 2A ●非破壞檢測及結構健康偵測 1A ●農業製造複合材料 1A ●碳-碳複合材料及發泡材料 1A 15:45 論文發表 ●奈米複合材料 CNT/CNF 排列 2B ●熱-力多功能材料 1B ●複合材料疲勞與破壞 2B ●非破壞檢測及結構健康偵測 1B ●農業製造複合材料 1B ●碳-碳複合材料及發泡材料 1B	13:15 專家講座 ●加拿大於高分子複合材料之研究 14:00 論文發表 ●奈米材料燃燒行爲 1B ●奈米工業應用 1B ●熱塑複合材料 2A ●耐高溫樹脂及複合材料 1A ●環境考量 1A 15:45 論文發表 ●奈米材料燃燒行爲 2B ●熱塑複合材料 2B ●耐高溫樹脂及複合材料 2B ●複合材料結構接頭 1B

表二　國外工作日程表

項次	日期	公差地點	交往接觸人士			工作內容
			姓名	國籍	性別	
1	0907	美國				去程(經洛杉磯轉機，於 1830 到達曼菲斯)
2	0908	美國	K.S. Raju A. Crasto	美國 美國	男 女	1.上午研討會註冊報到 2.下午參加複合材料的損傷容許分析及實驗課程(Damage Tolerance of Composites: Analysis and Testing) 3.參與複合材料的損傷容許分析及實驗之技術研討
3	0909	美國	J. F. Tarter J. Kuhn	美國 美國	男 男	1.參加多功能材料的設計、研發狀況及應用研討 2.參加奈米複合材料製程、複合材料設計與分析研討 3.多功能材料相關論文海報、展覽會參觀及蒐集多功能材料研發方向與發展趨勢資訊。
4	0910	美國	S. Itoh B. H. Lewcott	日本 美國	男 男	1.參加複合材料非破壞檢測及結構健康偵測、複合材料疲勞與破壞及奈米複合材料應用等技術專題研討會 2.奈米複合材料及複合材料科技相關論文海報、展覽會參觀及資料收集
5	0911	美國	M. Wilson B. Paul	美國 美國	男 男	1.參加奈米複合材料分析與特徵、奈米工業應用及三明治結構等技術專題研討會 2.參與學者之技術研討
6	0912					回程
7	0913					回程
8	0914					回程

参、心得

一、參加研討會心得

本次赴美國曼菲斯市公差主要任務爲參加由尖端材料科技協會舉辦之2008年秋季尖端材料科技研討會，蒐集國際最新複材相關之尖端材料發展之相關技術資料並瞭解其市場現況與未來發展趨勢。

本次研討會研討主題非常廣泛，主要探討複合材料、多功能材料及奈米複合材料等材料結構之設計、分析、製程及檢測，共有7個Keynote及Lecture、8個專業課程、62個議題論文發表，計有400餘篇論文發表。

研討會中於9月9日及10日有2天展覽會參觀，約有50個公司的展示。令人婉惜的是參展的廠商不多且大多數皆爲材料供應商、實驗/製程設備廠商、檢測實驗室/公司，且大多數皆爲傳統的老廠商像Airtech 公司、3M公司、Cytec公司及Huntsman公司等，並無較新穎的產品。展覽會中只有少數的研發、製造廠商，相關的複材成品展示並不多，亦無發現新的製程方法等可資參考之資料。

本次研討會中特別邀請歐、美、日、加著名學者7人做Keynote及Lecture，其中如美國空軍實驗室的B.L. Lee所講的” Multifunctional Materials for Adaptive & Autonomic Systems: An Overview”。說明發展更先進新世代的材料結構系統有二個準則。一爲每單位重量或體積可承載最大的負荷。二爲系統在最小的重量內結合多種功能。在傳統的認知以上二個準則應該是不相關的，例如結構最佳化一般皆尋求在能安全承載負荷時最輕的結構重量，但是這種單一考量的結構系統已無法滿足目前複雜且多功能的結構系統。他認爲未來材料結構研發的方向應該是師法大自然生物界現象，結合生態材料之開發，開創多功能化、智能化、環保化、微細化的材料，結合多種功能於一身。

在專業課程部份，職於 9 月 8 日參加“複材的容損分析及測試(Damage Tolerance of Composites: Analysis and Testing)”課程(課程簡報資料如附件二所示)， Dr. Keshavanarayana Raju 全面且詳盡的介紹複合材料及複材三明治結構的破壞型式、分析及測試並告知我們如何去面對這些問題。課程的主題有：

- 預期複合材料及複材三明治結構的破壞(What to expect in damage to laminated or sandwich composite structures)
- 斷裂、脫層及低速衝擊破壞的差異（The differences between notches, delaminations and low-velocity impact damage）
- 破壞型式的觀察（Experimental observations of typical damage）
- 破壞型式的預測方法（Prediction methods for handling and understanding damage types）
- 複材的容損（Damage tolerance – what levels might be expected in composite structures）
- 尺寸效應（Scaling approaches and effects – how they relate to strengths, failure mechanisms, and observations in the real world）
- 使用什麼分析方法及如何精確的分析（What analysis methods are available and how accurate are they）

經過此一課程，令職了解複合材料表面裂紋、斷裂、脫層及低速衝擊常是複合材料的痛處，知道何種形式及其影響。如此，將有助於在執行釋商計畫時，對於工件的設計、分析及製程安排有更深入的認知，而且在工件於製程中或使用時發生損傷，能迅速的確認破損發生的原因及尋求解決方案。未來可提昇釋商計畫參與廠商之複材設計暨製作能力，可衍生其他民生使用之複合材料工業，如高壓容器等結構件製造，將可提昇國家複材產業之發展水準。

在論文發表部份，與本單位執行計畫相關之議題包含：奈米複合材料製程、奈米複合材料分析與特徵、奈米複合材料應用、多功能材料設計能量與應用、電磁多功能材料、多功能材料非破壞檢測、複合材料設計與分析、複合材料疲勞與破壞、非破壞檢測及結構健康偵測、複合材料的測試等前瞻研究。

茲將參加本研討會論文發表所獲取之資訊與計畫執行相關議題概述如下:

1.奈米複合材料(Nano Composites)

複合材料是由兩種或兩種以上性質不同的材料組合而成，擁有單一材料無法比擬的優異性能，具有強度高、質量輕、剛度大、能耐一定的溫度等優點，並且可依條件需求進行設計與製造，以滿足各種特殊用途。

複合材料的結構是以一個相為連續相，稱為基體，而另一相是以一定的形態分佈於連續相中的分散相，稱為增強體。如果增強體是奈米級，如奈米顆粒、奈米纖維、奈米晶片、奈米晶鬚等，則稱為奈米複合材料，如圖 1 所示。

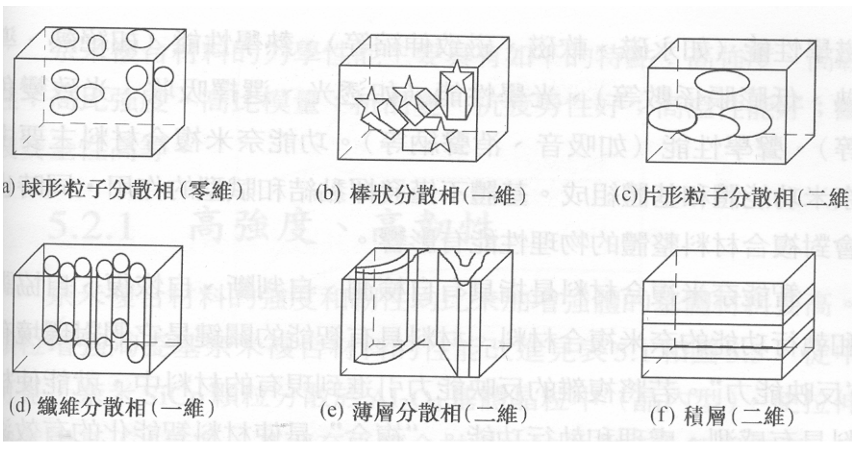

圖 1.　依增強體形狀分類的奈米複合材料示意圖

奈米複合材料依基體種類可分爲金屬基、陶瓷基、高分子基之奈米複合材料。依用途則分爲 1.結構奈米複合材料-主要用作承受負載。2.功能奈米複合材料-除用作承受負載外並具有其他物理性能，如電性、磁性、熱學等。3.智能複合材料-爲具自檢測、自判斷、自恢復、自協調和執行功能的奈米複合材料，如形狀記憶合金奈米粒子與具有相變粒子的材料複合，則具有對損傷的自預警和自修復功能。

此次奈米複材科技專題上，一共有五十二篇論文，其中最令人印像深刻的是來自美國的 Michael R. Kessler 所講的“利用奈米鋁顆粒加強高溫氰酸酯樹脂黏著劑(High-Temperature Cyanate Ester Adhesives Reinforced with Alumina Nanoparticles)”及 Gunjan Maheshwari 所講的 “智能型奈米複合材料在工業健康偵測上的應用(Smart Nanocomposites for Industrial Health Monitoring)” 。分別簡單介紹如下：

在“利用奈米鋁顆粒加強高溫氰酸酯樹脂黏著劑”這篇論文中提到，對於高分子基複合材料，基材的微小裂縫是一個長久以來就存在且無法解決的問題。複合材料當承受熱力－機械（thermo-mechanical）負荷或低能量衝擊時，這些微小的裂縫最容易造成層間脫層損傷。一旦偵測出局部脫層時最常使用樹脂注入法（resin infusion process），利用低黏度的樹脂注入損傷區域。但是，對於高溫高分子複合材料是無法利用這些低玻璃轉化溫度(Tg)的樹脂修補。

使用樹脂注入法時，一個理想的樹脂系統有以下幾個要求：

(1)低黏度（Low viscosity）

一次注射入損傷區域修理樹脂必須被引入最深入的距離。在某些情況下，爲了滲透，樹脂必須被稀釋以揮發性有機溶液達到必需的黏度。

(2)穩定在損傷區域（Stability in the damage zone）

在裂縫面，樹脂系統應該起反應結合裂縫表面，而不應該蒸發或散開。這種樹脂最好能穩定的保留在損傷區域直到熟化完全。

(3)相容膠黏劑（Compatible adhesive）

被聚合的樹脂必須同時對於基材及加強材皆是強的膠黏劑。並且有很小的收縮量以避免在熟化期間脫膠（debonding）。

(4)長的貯藏期限（Long shelf-life）

修補用樹脂系統應該被存放在暫停活動的狀態，直到需要使用時。如果保存期限不是非常長的,那麼尚未使用，就到期的材料將引起多餘的費用和有害廢料。

(5)高溫穩定（High-temperature stability）

許多複合材料被要求能穩定的處於 260℃的環境下。為了修理這些複合材料，修補用樹脂應該有更高的 Tg。低黏度樹脂通常的 Tg 都非常低，所以只能用於低溫環境下。

(6)環保問題（Environmentally benign）

環境保護是目前大家都很注重的課題，在修補過程中不應引起重大揮發性有機化合物(VOCs) 或危害空氣汙染物。

本篇論文中評估開發一種有低黏度的樹脂（bisphenol-E cyanate ester, BECy）他具有高的 Tg，可承受高溫。這種樹脂添加了鋁質的奈米顆粒於樹脂中，加強了樹脂的熱力及機械性質。這些奈米顆粒帶著甲矽烷偶合劑的功用在增加分散性及顆粒及樹脂之介面強度。經過其實驗驗證這種樹脂系統的接合強度是常用環氧樹脂（bisphenol-A type epoxy resin (EPON 828) and a cycloaliphatic (CA) epoxy）的二倍以上。

在“智能型奈米複合材料在工業健康偵測上的應用”這篇論文探索以奈米碳管 Carbon Nanotubes(CNT)及奈米碳球鏈 Carbon Nanosphere Chains(CNSC) 開發智慧型奈米複

合材料(Nanocomposite Smart Material)利用其具電化學阻抗、壓電效應和磁性等特性，作爲結構偵測與驅動用。這些敏銳的奈米複合材料可以利用應變造成導電率的改變而去預知結構損傷。由於其在結構內分佈的奈米複材傳感器可根據外加負荷而改變電子阻抗，且又有良好的比強度及比剛性，未來，這種新穎的應用，可在工業上大量的取代鋼材。而且奈米複合材料根據需求亦可將基材由環氧樹脂變更爲彈性體、水泥等材料。此文中討論這種材料的壓電效應及電化學阻抗分光學(EIS)的特性，並且利用機電關係及電化學關係作爲結構的健康監測系統。而且，由於較長的奈米碳管 CNT 可增加複合材料的層間剪強度，改進傳統複合材料的缺點，未來亦可大量應用於汽車和航太工業上。

2.多功能材料(Multifunctional Materials)

在多功能材料科技專題上，一共有廿一篇論文，其中最令人印象深刻且被此次研討會評選爲最佳論文的是 Yirong Lin 所講的“多功能複合材料用之結構壓電纖維製造及其機電特性(Fabrication and Electromechanical Characterization of a Piezoelectric Structural Fiber for Multifunctional Composites)”。

智能複合壓電元件在多功能材料結構應用發展中，同時肩負感測元件與致動元件之智能功能，是系統結構硬體最關鍵元件，未來在驅動、感測、結構阻尼等多功能材料需求之應用極具潛力。一般傳統壓電陶瓷電元件只能提供驅動、感測等壓電特性，由於有易碎之缺點，必須配合其他結構件貼附或鑲埋。雖然，目前已經發展到壓電陶瓷電纖維並配合表面指叉電極極化技術，製作高效率 d33 型複合壓電元件，可配合結構外型鋪設使用，但易碎之缺點仍舊無法徹底改善，且仍無法作爲結構件。本文發展之結構壓電纖維，以碳化矽(SiC)爲纖維核心、鈦酸鋇（barium titanate,$BaTiO_3$）爲纖維壓電外殼，製作兼具高性能之感測、致動與結構之 Active Structural Fiber (ASF)壓電元件，配合複材成形技術可製作成各式之多功能智慧型複合材料。相信此一革命性材料在不久的將來會應用於各個領域上。

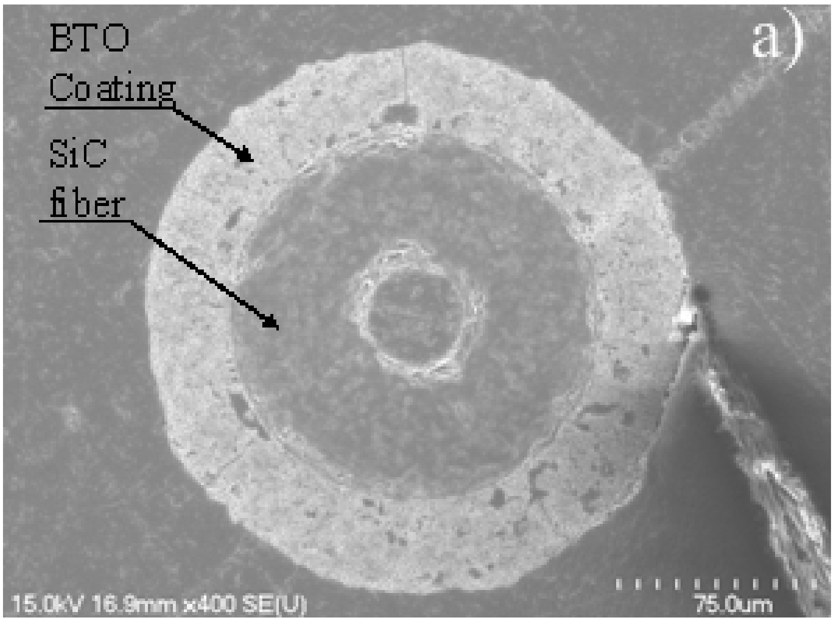

圖 2.　結構壓電纖維

在多功能材料科技專題上，另一篇論文由 K. Jason Maung 所講的“薄膜太陽能電池在環氧碳纖維複合材料的多功能集成(Multifunctional Integration and Characterization of Thin Film Silicon Solar Cells on Carbon Fiber Reinforced Epoxy Composites)”，亦值得本所發展科專計畫時參考。本文中提到太陽能板如果能與結構共構，譬如大廈、攜帶式設備或車的外殼。特別是對於重量或容量有嚴格限制的航太應用，這樣的多功能結構將減少不必要的組件及模組重量、體積，成為一輕量化的模組。雖然兩者結合模組化有很大的優點，但是其前提是必須確認，兩者中任何一個退化時將影響整體的功能。

在本篇文章裡開發一個共熟化(co-curing)的製程，來集成 Silicon 薄膜太陽板及碳纖維/環氧複材。並由實驗驗證此一製程對太陽能板光-電壓特性(photovoltaic)並無影響。且針對製成之模組施加循環負荷以瞭解其光-電壓特性能的改變。

3.複合材料(Coposite Materials)

在複合材料科技專題上，一共超過百篇論文，其中複材製造、實驗相關的有五十八

篇論文、複材設計與分析有十五篇、非破壞檢驗有七篇、破壞與疲勞有十二篇、三明治結構有六篇，其中 Lingyu Sun 所提的"鋁/PU 發泡三明治板結構在彎曲負荷下的破壞模式 (Study on Failure Mode of Aluminum/PU Foam Sandwich Plate Under Bending Loads)"。

這項研究針對邊界條件爲簡支的鋁/PU 發泡三明治樑結構於三點彎曲測試時，利用競爭機制確認結構之破壞模式。本文根據過去已發表的論文，使用簡單的分析模型去預測三明治結構的破壞模式。爲了估計簡單的分析模型在失敗形式預測的準確性，使用不同失敗形式的八個樣品，利用有限元素模擬，並與三明治結構彎曲測試比較二者力量-變形曲線，藉以確認分析模型的準確性。經過分析及實驗比較，確認本文所發展之競爭機制分析方法，確可有效的應用在破壞模式的預測。

本所所執行的『材料與化工領域軍品釋商計畫』中有許多複合材料結構件中，皆使用三明治結構設計，例如翼翅、鼻錐罩等飛彈零組件。如能精確的預測其破壞模式，可增加設計的可靠度，並且更容易達到設計最佳化，進而減輕工件的重量、降低工件的成本。

本次赴美參訪，對於國際尖端材料科技之最新市場發展趨勢已有初步掌握，其中複合奈米材料技術、多功能材料技術、複合材料技術等，均爲國內迫切需要的技術能量，而此正可規劃爲『材料與化工領域軍品釋商計畫』後續研發之重要主題，值得經濟部技術處及院內相關單位繼續支持。雖然本所在複合奈米材料、多功能材料技術研發之投入，時間上較晚，但多年來在材料配方、製程及結構上所累積之經驗，在複合材料之相關應用上，應有很好的發揮空間。

經過本次美國參訪任務後，吾人對於業界在各項技術的需求上，已能有更深入的瞭解；相關資訊的收集更可作爲研發計畫後續規劃與執行之參考。

二、效益分析

本次公差目的為參加2008年SAMPE 秋季科技研討會及展覽會(SAMPE Fall Technical Conference and Exhibition)，其重點主要在多功能材料(Multifunctional Materials)、奈米複合材料(NanoComposites)及複合材料(Composite Material)等三個領域，所獲效益相當大，敘述如下：

1、參加奈米複材技術研討後，瞭解奈米材料技術對傳統高分子塑膠之衝擊，及致使材料性能的突破及提昇，實為國內學術界及產業應積極參與開發之領域。

2、目前在奈米高分子材料開發中，黏土材料的應用佔很大比例，此與目前本組在奈米技術之研發方向相符，但如何準確的控制黏土材料的添加方式及瞭解相關之機制，在本次研討會中有許多相關學者的研究值得本組學習應用。

3、在多功能材料研究，如何整合多種材料功能為一體為目前國際上積極研究的方向之一。

4、對於多功能材料結構方面，此次研討會有許多相關研究，從材料的開發製備、結構上的應用，使職瞭解多功能材料結構方面的研究現況及未來發展趨勢。並能與此一領域之專家學者研討、諮詢與目前科專計畫有關或急欲獲得的技術資料。

5. 展望國際尖端材料科技之發展趨勢，以奈米技術為核心，師法大自然動植物界生命現象，結合生態材料之開發，開創微細化、智能化、環保化、多功能化的新興產業技術與產品，確為21世紀人類科技之發展主流。凡此種種皆是本院『材料與化工領域軍品釋商第二期計畫』科技專案後續發展規劃之重要參考依據。

肆、建議事項

1.複合材料表面裂紋、斷裂、脫層及低速衝擊常是複合材料的最碎弱且最應被避免的現象。深入瞭解何種形式缺陷及其影響，將有助於工件設計、分析及製程安排。若本院可利用現有之相關破損裕度(Damage Tolerance)分析及測試能力，並能進一步深入研究，未來可提昇釋商計畫參與廠商之複材設計、分析及製造能力，可衍生其他民生使用之複合材料工業，如高壓容器等結構件製造，將可提昇國家複材產業之發展水準。

2、目前在奈米高分子材料開發中，奈米碳管與黏土材料的應用佔很大比例，此與目前本組在奈米複合材料技術之研發方向相符，但如何準確的控制材料的添加方式及瞭解相關之機制，在本次研討會中有許多相關學者的研究值得本組學習應用。使用奈米複合材料技術能有效提昇本院及釋商計畫相關複合材料工件之熱力及機械性質，未來將相關技術技轉民間廠商能扶植複材產業技術，提昇複合材料製品之技術水準。

伍、附件

附件一、2008 年 SAMPE 秋季尖端材料科技研討會手冊

附件二、損傷容許分析及實驗課程(Damage Tolerance of Composites: Analysis and Testing)簡報資料

附件一

2008 年 SAMPE 秋季尖端材料科技研討會手冊

Multifunctional Materials: Working Smarter Together

Final Program and Exhibitor's Guide

SAMPE Fall Technical Conference and Exhibition

Cook Convention Center, Memphis, Tennessee
September 8-11, 2008

Co-located with

•American Society for Composites Annual Technical Conference
•ASTM D-30

Sponsored by the
SAMPE Great Lakes Chapter

Welcome to Memphis and the 40th SAMPE International Technical Conference COMBINED with the American Society for Composites Conference. SAMPE's Great Lakes Chapter (formerly the Michigan Chapter) and ASC have worked hard to put together for you a dual conference whereas you pay one registration and you can attend any of the SAMPE or any of the ASC Sessions. Most of the time you will have up to twelve sessions to choose from, all running simultaneously.

Our conference theme is, "Multifunctional Materials: Working Smarter Together", and a multi-faceted strategy was implemented to assemble the most up-to-date information on multifunctional and advanced material technologies. The conference features two keynote Speakers--one from SAMPE and one from ASC—and SAMPE will be hosting three Featured Speakers, five panels, and educational tutorials. On Thursday we will be hosting a day-long DoD workshop on "Structurally Integrated Energy Harvesting/Storage Capabilities" along with a Multifunctional Materials track and a Nanomaterials track. There will also be vendor exhibits and exhibit break time so you can visit with the exhibitors and not miss any of the sessions.

There will also be a Networking Outing attended by both SAMPE and ASC on the rooftop of the Historic Peabody Hotel. Afterwards, Beale Street is a block away to experience Memphis's Southern hospitality, Blues Music and fantastic BBQ.

We hope that you will enjoy the Conference, Exhibits, and Networking between two compatible societies!

Thank you for attending,
Michael T. Wilson, SAMPE General Chair
Anthony Vizzini, ASC Conference Chairman
Ronald Gibson, Nicholas Gianaris, and Brad Lucht, SAMPE Technical Program Co-Chairs

Table of Contents

Attention SAMPE Conference Attendees!

This year's SAMPE Fall Technical Conference is co-located with the ASC Conference.

All registered SAMPE Conference Attendees are free to attend ASC Conference programs on any day covered by your SAMPE registration. Simply show your badge to receive admittance to any ASC session room. The ASC Member Luncheon is not included.

ASC Final Programs are available at the SAMPE Registration area.

SAMPE Thanks Our Organizing Committee:

General Chair
Mike Wilson, Consultant

Technical Program Co-Chairs
Ron Gibson, University of Nevada-Reno
Nick Gianaris, General Dynamics Land Systems
Brad Lucht, Honeywell FM&T

Audio/Visual Co-Chairs
Kenan Wollborg, College-Park Industries

Volunteers Co-Chairs
Ralph Carson, Volunteer
German Villanueva, University of Michigan

Exhibits Co-Chairs
Brian Hull, Lewcott
Guru Kathawate, G. R. Kathawate & Associates

Publicity Chair
Megan Toscas, College-Park Industries

Finance Chair
Mike Wilson, Consultant

Sponsors Chair
Brian Paul, General Dynamics Land Systems

2008 SAMPE Fall Technical Conference At-A-Glance

Monday, September 8
Registration 7:30 AM – 5:00 PM

Tutorials 9:00 AM
- Design of Composite Aircraft Structures–*Room L3*
- Composites Fabrication Technologies–*Room L4*
- Introduction to Composite Materials–*Room L5*
- Mechanical Testing of Composite Materials–*Room L6*

*Session contains ITAR papers. ITAR

Exhibits Closed

Tutorials 2:00 PM
- Nanocomposites Technology–*Room L3*
- Thermoplastic Composites Technologies–*Room L4*
- Processing Science for Composite Structures Manufacturing–*Room L5*
- Damage Tolerance of Composites: Analysis & Testing–*Room L6*

Tutorials require a fee separate from conference registration

Tuesday, September 9
Registration 7:30 AM – 5:00 PM

SAMPE Keynote 8:00 AM
Ballroom C&D
- Multifunctional Materials for Adaptive & Autonomic Systems: An Overview

Sessions 9:15 AM
- Nanocomposites: Processing 1A*–*Room Sultana-Mississippi*
- Design for Multifunctionality: Capability vs. Application 1A–*Room L12*
- Aerospace Structures & Applications 1A*–*Room L3*
- Infrastructure Applications 1A–*Room L10*
- Manufacturing & Processing Advances 1A–*Room L5*

Panel 9:15 AM
- Defense Applications of Multifunctional Materials–*Room L14*

10:30 AM Vendor Break

Sessions 11:00 AM
- Nanocomposites: Processing 1B–*Room Sultana-Mississippi*
- Design for Multifunctionality: Capability vs. Application 1B–*Room L12*
- Aerospace Structures & Applications 1B–*Room L3*
- Infrastructure Applications 1B–*Room L10*
- Manufacturing & Processing Advances 1B–*Room L5*

Panel 11:00 AM
- Defense Applications of Multifunctional Materials–*Room L14*

Exhibits 10:00 AM – 4:00 PM

Sessions 2:00 PM
- Nanocomposites Processing 2A–*Room Sultana-Mississippi*
- Nanostructured Multifunctional Materials 1A–*Room L12*
- Design for Multifunctionality: Capability vs. Application 2A–*Room L14*
- Infrastructure Applications 2A–*Room L10*
- Manufacturing & Processing Advances 2A–*Room L5*
- Composite Design & Analysis 1A–*Room L3*

3:15 PM Vendor Break

Sessions 3:45 PM
- Nanocomposites Processing 2B–*Room Sultana-Mississippi*
- Nanostructured Multifunctional Materials 1B–*Room L12*
- Composite Design & Analysis 1B–*Room L3*
- Manufacturing & Processing Advances 2B–*Room L5*
- Environmental Considerations 1B–*Room: L10*

Committee Chairs Panel 3:45
- Reinventing Reality: The Quest for Multifunctional Material Properties–*Room: L14*

Welcome Reception 5:00 PM

Joint SAMPE/ASC Tribute to Tom Gates 6:00 PM
Memphis Room at the Marriott Hotel

Wednesday, September 10
Registration 7:30 AM – 5:00 PM

ASC Keynote 8:00 AM
Ballroom C&D

Sessions 9:15 AM
- Nanocomposites: Applications 1A–*Room Sultana-Mississippi*
- Electromagnetic Multifunctional Materials 1A–*Room L12*
- Composite Fatigue & Fracture 1A–*Room L3*
- Composites for the Automotive Industry 1A–*Room L10*
- Composites from Agricultural Products 1A–*Room L5*

Panel 9:15 AM
- Industrial Applications of Multifunctional Materials–*Room L14*

10:30 AM Vendor Break

Sessions 11:00 AM
- Nanocomposites Applications 1B–*Room Sultana-Mississippi*
- Electromagnetic Multifunctional Materials 1B–*Room L12*
- Composite Fatigue & Fracture 1B–*Room L3*
- Composites for the Automotive Industry 1B–*Room L10*
- Composites from Agricultural Products 1B–*Room L5*

Panel 11:00 AM
- Future Directions of Multifunctional Materials Research–*Room L14*

Exhibits 10:00 am – 4:00 pm

Featured Lecture 1:15 PM
- Research on Multifunctional Materials & Structural Health Monitoring in Japan–*Room 14*

Sessions 2:00 PM
- Composites for the Automotive Industry 2A–*Room Sultana-Mississippi*
- Thermo-Mechanical Multifunctional Materials 1A–*Room L12*
- Composite Fatigue & Fracture 2A–*Room L10*
- NDE & Structural Health Monitoring 1A–*Room L14*
- Composites from Agricultural Products 2A–*Room L5*
- Carbon-Carbon Composites & Foams 1A–*Room L3*

3:15 PM Vendor Break

Sessions 3:45 PM
- Nanocomposites: CNT/CNF Alignment 1B–*Room Sultana-Mississippi*
- Thermo-Mechanical Multifunctional Materials 1B–*Room L12*
- Composite Fatigue & Fracture 2B–*Room L10*
- NDE & Structural Health Monitoring 1B–*Room L14*
- Testing of Composites 1B–*Room L5*
- Carbon-Carbon Composites & Foams 1B–*Room L3*

A Night at the Peabody 6:00 PM
Joint SAMPE/ASC Networking Social Event

Thursday, September 11
Registration 7:30 AM – 1:30 PM

Featured Lecture 8:15 AM
- Ionic Polymer-Metal Composite: Soft Actuator & Sensor–*Room L14*

Sessions 9:15 AM
- Nanocomposites: Electrical & Thermal 1A–*Room Sultana-Mississippi*
- Nanocomposites: Analysis & Characterization 1A–*Room L12*
- Thermoplastic Composites 1A–*Room L5*
- Sandwich Structures 1A–*Room L10*

DoD Workshop 9:15 AM - 5:00 PM
- Structurally Integrated Energy Harvesting/Storage Capabilities–*Room L3*

Panel 9:15 AM
- Requirements for the Next Generation of Composites Engineers–*Room L14*

10:30 AM Break

Sessions 11:00 AM
- Nanocomposites: Electrical & Thermal 1B–*Room Sultana-Mississippi*
- Nanocomposites: Analysis & Characterization 1B–*Room L12*
- Thermoplastic Composites 1B–*Room L5*
- Sandwich Structures 1B–*Room L10*
- High Temperature Resins & Composites 1B–*Room L14*

*Session contains ITAR papers. ITAR

Exhibits Closed

Featured Lecture 1:15 PM
- Polymer Nanocomposites Research in Canada–*Room L14*

Sessions 2:00 PM
- Manufacturing & Processing Advances 3A*–*Room L5*
- Nano-Industrial Applications 1A–*Room Sultana-Mississippi*
- Thermoplastic Composites 2A*–*Room L14*
- High Temperature Resins & Composites 2A*–*Room L10*
- Multifunctional Materials with Integral NDE 1A*–*Room L12*

DoD Workshop 9:15 AM - 5:00 PM
- DoD Workshop-Structurally Integrated Energy Harvesting/Storage Capabilities–*Room L3*

3:15 Break

Sessions 3:45 PM
- Nanocomposites: Fire Behavior 1B–*Room Sultana-Mississippi*
- Thermoplastic Composites 2B–*Room L14*
- High Temperature Resins & Composites 2B*–*Room L10*
- Joints in Composite Structures 1B*–*Room L5*
- Resins & Adhesives 1B–*Room L12*

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Program Tracks

Nanotechnology

Monday, 2-5 PM, September 8

Nanocomposites Technology-Tutorial *(requires additional fee)*
Instructor: Drs. Jiang Zhu & Kyle Kissell, Nanoridge Materials Inc.

Tuesday, September 9

9:15 AM Room: Sultana-Mississippi
Nanocomposites: Processing IA*
Session Chair: Holly Stretz, Tennessee Technological Univ., Cookeville, TN

11:00 AM Room: Sultana-Mississippi
Nanocomposites: Processing IB
Session Chair: Holly Stretz, Tennessee Technological Univ., Cookeville, TN

2:00 PM Room: Sultana-Mississippi
Nanocomposites: Processing 2A
Session Chair: Derrick Dean, University of Alabama, Birmingham, AL

3:45 PM Room: Sultana-Mississippi
Nanocomposites: Processing 2B
Session Chair: Derrick Dean, University of Alabama, Birmingham, AL

Wednesday, September 10

9:15 AM Room: Sultana-Mississippi
Nanocomposites: Applications 1A
Session Chair: Derrick Dean, University of Alabama, Birmingham, AL

11:00 AM Room: Sultana-Mississippi
Nanocomposites: Applications 1B
Session Chair: Derrick Dean, University of Alabama, Birmingham, AL

3:45 PM Room: Sultana-Mississippi
Nanocomposites: CNT/CNF Alignment 1B
Session Chair: Chuck Bakis, The Pennsylvania State Univ., University Park, PA

Thursday, September 11

9:15 AM Room: Sultana-Mississippi
Nanocomposites: Electrical & Thermal 1A
Session Chair: Greg Yandek, Air Force Research Lab, Edwards AFB, CA

9:15 AM Room: L12
Nanocomposites: Analysis and Characterization 1A
Session Chair: Chuck Bakis, The Pennsylvania State Univ., University Park, PA

11:00 AM Room: Sultana-Mississippi
Nanocomposites: Electrical & Thermal 1B
Session Chair: Greg Yandek, Air Force Research Lab, Edwards AFB, CA

11:00 AM Room: L12
Nanocomposites: Analysis and Characterization 1B
Session Chair: Chuck Bakis, The Pennsylvania State Univ., University Park, PA

1:15 PM - 2:00 PM Room: L10
Featured Lecture: Polymer Nanocomposites Research in Canada
Presenter: Suong V. Hoa, Concordia University, Montreal, Quebec, Canada
Moderators: Ron Gibson, University Nevada-Reno, Reno, NV and Nick Gianaris, General Dynamics Land Systems, West Bloomfield, MI

2:00 PM Room: Sultana-Mississippi
Nano-Industrial Applications 1A
Session Chair: Patrick Lake, Applied Sciences, Inc., Cedarville, OH

3:45 PM Room: Sultana-Mississippi
Nanocomposites: Fire Behavior 1B
Session Chair: Antonio Avila, Universidade Federal de Minas Gerais, Horizonte, MG, Brazil

*Session contains ITAR restricted papers. ITAR

Multifunctional Materials

Tuesday, September 9

9:15 AM Room: L12
Design for Multifunctionality: Capability vs. Application 1A
Session Chair: Gail Jefferson, University of South Alabama, Mobile, AL

9:15 AM - 12:00 PM Room: L14
Defense Applications of Multifunctional Materials-Panel
Panel Moderators: Dr. Richard Vaia, Air Force Research Lab and Dr. B.L. ("Les") Lee Air Force Office of Scientific Research

11:00 AM Room: L12
Design for Multifunctionality: Capability vs. Application 1B
Session Chair: Gail Jefferson, University of South Alabama, Mobile, AL

2:00 PM Room: L12
Nanostructured Multifunctional Materials 1A
Session Chair: Lawrence Drzal, Michigan State University, East Lansing, MI

2:00 PM Room: L14
Design for Multifunctionality: Capability vs. Application 2A
Session Chair: Seun Kahng, NASA Langley Research Center, Hampton, VA

3:45 PM Room: L12
Nanostructured Multifunctional Materials 1B
Session Chair: Lawrence Drzal, Michigan State University, East Lansing, MI

Wednesday, September 10

9:15 AM Room: L12
Electromagnetic Multifunctional Materials 1A
Session Chair: Sarah Frankland, National Institute of Aerospace, Hampton, VA

9:15 AM - 10:30 AM Room: L14
Industrial Applications of Multifunctional Materials-Panel
Panel Moderator: Guru R. Kathawate, G.R. Kathawate & Associates, Inc.

11:00 AM Room: L12
Electromagnetic Multifunctional Materials 1B
Session Chair: Sarah Frankland, National Institute of Aerospace, Hampton, VA

11:00 AM - 12:15 PM Room: L14
Future Directions of Multifunctional Materials Research-Panel
Panel Moderator: Alan Kin-tak Lau, The Hong Kong Polytechnic University

1:15 PM - 2:00 PM Room: L10
Featured Lecture: Research on Multifunctional Materials & Structural Health Monitoring in Japan
Presenter: Dr. Nobuo Takeda, The University of Tokyo, Chiba, Japan
Moderators: Ron Gibson, University Nevada-Reno, Reno, NV and Nick Gianaris, General Dynamics Land Systems, West Bloomfield, MI

2:00 PM Room: L12
Thermo-Mechanical Multifunctional Materials 1A
Session Chair: Greg Odegard, Michigan Technological Univ., Houghton, MI

3:45 PM Room: L12
Thermo-Mechanical Multifunctional Materials 1B
Session Chair: Greg Odegard, Michigan Technological Univ., Houghton, MI

Thursday, September 11

8:15 AM - 9:00 AM Room: L10
Featured Lecture: Ionic Polymer-Metal Composite as a New Actuator and Transducer Material
Presenter: Kwang Kim, University of Nevada, Reno, NV
Moderators: Ron Gibson, University Nevada-Reno, Reno, NV and Nick Gianaris, General Dynamics Land Systems, West Bloomfield, MI

9:15 AM - 5:00 PM Room: L3
DoD Workshop
Organizers: B.L. ("Les") Lee, Air Force Office of Scientific Research; James Thomas, Naval Research Lab; and Bruce LaMattina, Army Research Office

2:00 PM Room: L12
Multifunctional Materials with Integral NDE 1A
Session Chair: Soma Peroody, Proto Manufacturing Inc., Ypsilanti, MI

Cost for Tutorials: Tutorials are half-day courses that require a separate cost from the cost of registration at the conference. A printed course handout is included in the price.
Prices are: $150 with conference registration • $100 for students • $175 for other registrants

Monday, 9 AM - Noon, September 8, 2008

Design of Composite Aircraft Structures
Instructor: Prof. Doug Cairns, Montana State University

Composites Fabrication Technologies
Instructor: Dr. James C. Leslie, ACPT Inc.

Introduction to Composite Materials
Instructor: Dr. Carl H. Zweben, Composites Consultant

Mechanical Testing of Composite Materials
Instructor: Prof. Daniel O. Adams, University of Utah

Monday, 2 - 5 PM, September 8, 2008

Nanocomposites Technology
Instructor: Drs. Jiang Zhu and Kyle Kissell, Nanoridge Materials Inc.

Thermoplastic Composites Technologies
Instructor: Dr. Conchur O'Bradaigh, Eire Composites

Processing Science for Composite Structures Manufacturing
Instructor: Profs. Anoush Poursartip, Goran Fernlund, University of British Columbia

Damage Tolerance of Composites: Analysis and Testing
Instructor: Dr. Keshavanarayana Raju, Wichita State University

Important session information for all attendees.

SAMPE Restricted Papers —ITAR Regulations Session Admittance

ITAR

(REVISED PROCEDURES 6/05)

Several papers to be presented at this conference will be restricted papers governed by ITAR (International Traffic in Arms Regulations). The U.S. citizens SAMPE list used at previous conferences will not be available. If you plan to attend any presentations restricted by ITAR, you must bring proof of citizenship plus the other verification documents as shown below. Please note that only U.S. citizens and U.S. Resident Aliens can be considered for attendance at these restricted presentations.

Admittance to restricted sessions and access to restricted technical papers is implemented and controlled by U.S. International Traffic in Arms Regulations (ITAR). All restricted session attendees MUST abide by the procedures and submittal of verification documents as noted below – no exceptions:

ATTENDEE CLASSIFICATION	IDENTIFICATION & PROOF OF EMPLOYMENT REQUIREMENTS
U.S. Government Employees	**1.** Proof of Citizenship (for example, passport, birth certificate, voters registration card, naturalization papers), **and**, **2.** Personal photographic identification (passport, driver's license, corporate ID, etc.)
U.S. Citizens	**1.** Proof of Citizenship (for example, passport, birth certificate, voters registration card, naturalization papers), **and**, **2.** Personal photographic identification (passport, driver's license, corporate ID, etc.), **and**, **3.** Certification credentials based on DD Form 2345 (see below for details)
Resident Aliens (U.S.)	**1.** Resident Alien Card, **and**, **2.** Personal photographic identification (passport, driver's license, corporate ID, etc.), **and**, **3.** Certification credentials based on DD Form 2345 (see below for details)

DD Form 2345 individual certification credentials (required for U.S. & Resident Aliens) must be from one of the following:

1. Copy of an approved and active DD Form 2345 for the individual, or,
2. Copy of an approved and active DD Form 2345 for the individual's employer PLUS evidence of current employment status with that employer (corporate ID, business card, etc.), or,
3. A listing of the individual's employer in the most recent DoD quarterly Qualified U.S. Contractor Access List PLUS evidence of current employment status with that employer (corporate ID, business card, etc.).

DD Form 2345 may be downloaded and completed online in order to apply for approval to be listed on the Qualified U.S. Contractor List, www.dlis.dla.mil/jcp/. Allow at least 4 weeks prior to the SAMPE symposia or technical conference dates for this process.

How to get your ITAR Clearance:
Bring all of the above listed identification, proof of employment and certification credentials to the to the SAMPE Clearance counter at the SAMPE Registration area. Your documents will be verified and you will be provided with a stamp indicating your ITAR clearance. Photo ID will be checked against your ITAR badge before admittance is granted to any ITAR presentation.

8:00 AM - 9:00 AM Ballroom C&D

SAMPE Keynote Presentation

"Multifunctional Materials for Adaptive & Autonomic Systems: An Overview"

By: Dr. B.L. ("Les") Lee, Air Force Office of Scientific Research, Arlington, VA

The efforts to develop a newer generation of structures with more advanced performance and higher system efficiency have been guided by two criteria: (a) the achievement of maximum load-carrying capability per unit weight or volume and (b) the incorporation of specific functional properties dictated by the system requirements with minimum weight penalty. Traditionally, these two issues are addressed separately, resulting in a passive structure of optimum load-carrying capability with compartmentalized functionality often in the form of attached components. However, this approach is in stark contrast to biological systems, in which jointed frameworks and complex materials impart active functionality at multiple length scales within the materials. Our new challenge has been to learn from and mimic nature's design by developing "multifunctional" load-bearing structures with integrated functional properties, such as remediation of cracks, thermal management, vibration mitigation, detection of external threats, protection against electromagnetic radiation, built-in communication channel, self-supply of power, etc. The realization of analogous synthetic structures, which can accommodate the above-cited functions, depends on the combination of new "multifunctional" materials that inherently possess the capacity to meet the requirements for specific functionality as well as mechanical load carrying capability. It is hoped that individual material elements are simultaneously participating in distinct, beneficial physical processes thereby delivering truly dramatic improvements in system-level efficiency instead of incremental improvements encountered in mono-functional materials.

Room: Sultana-Mississippi

Nanocomposites: Processing 1A-1B

Session Chair: Holly Stretz, Tennessee Technological University, Cookeville, TN

9:15 AM

Reinforced Films Made by Crosslink Reaction Between Water-Soluble Sulfonated Carbon Nanotubes and Sulfonated Polystyrene, Y. Dai, H. Haiping, South Dakota School of Mines and Technology, Rapid City, SD; J.S. Welsh, Air Force Research Laboratory, Kirtland AFB, NM

9:40 AM

Cure Behavior of Epoxy/MWCNT Nanocomposites: The Effect of Nanotube Surface Modification, M. Abdalla, D. Dean, University of Alabama at Birmingham, Birmingham, AL; P. Robinson, Tuskegee University, Tuskegee, AL; E. Nyairo, Alabama State University, Montgomery, AL

11:00 AM

Polyimide Nanocomposite Membranes for Separation of Water and Ethanol, J.O. Iroh, W. Zhang, A. Anim-Mensah, J-P. Lee, University of Cincinnati, Cincinnati, OH

11:25 AM

The Effects of Single-Wall Carbon Nanotubes on the Shear Piezoelectricity of Biopolymers, C. Lovell, J.M. Fitz-Gerald, Department of Materials Science and Engineering, University of Virginia, Charlottesville, VA; J.S. Harrison, Advanced Materials and Processing Branch, NASA Langley Research Center, Hampton, VA; C. Park, National Institute of Aerospace, Hampton, VA

Room: L12

Design for Multifunctionality: Capability vs. Application 1A-1B

Session Chair: Gail Jefferson, University of South Alabama, Mobile AL

9:15 AM

Crosslinked Templated Mesoporous Silica Aerogels as Multifunctional Materials, H. Lu, H. Luo, G. Churu, Oklahoma State University, OK; S. Mulik, C. Sotiriou-Leventis and N. Leventis, Missouri University of Science and Technology, MO

9:40 AM

Carbon Nanotube Networks: In Situ Sensing of Damage Evolution in Fiber Composites, E.T. Thostenson, T.-W. Chou, University of Delaware, Newark, DE; L. Gao, Beijing University of Aeronautics and Astronautics, Beijing, China

10:05 AM

Strain and Temperature Sensing Properties of Multiwalled Carbon Nanotube Yarn Composites, S.K. Kahng, T.S. Gates, NASA Langley Research Center, Hampton, VA; G.D. Jefferson, National Institute of Aerospace, Hampton, VA

11:00 AM

Analyzing Interlaminar Shear Strength of Multi-Scale Composites via Combined Finite Element and Progressive Failure Analysis Approach, M. Garg, F. Abdi, Alpha Star Corporation, Long Beach, CA; S. McHugh, Lockheed Martin Corporation, Palo Alto, CA

11:25 AM

Tailoring Thermal Properties in Composite Materials and Its Interfaces for Thermo-Mechanical Applications, A.K. Roy, Air Force Research Laboratory, AFRL/RXBT, Wright-Patterson AFB, OH; S. Sihn, S. Ganguli, University of Dayton Research Institute, Dayton, OH; V. Varshney, Universal Technology Corporation, Dayton, OH

Vendor Breaks

Tuesday & Wednesday
10:30 AM - 11:00 AM
3:15 PM - 3:45 PM

Complimentary coffee will be available in the exhibition hall, sponsored by ASC.

Room: L3

Aerospace Structures and Applications 1A-1B

Session Chair: George Khawand, General Dynamics ATP, Burlington, VT

9:15 AM

Proton Exposure Tolerance of Rohacell 31 HF Foam, P. Hogue, B. Brawley, Johns Hopkins University Applied Physics Laboratory, Laurel, MD; D. Hubert, Point Magu, CA; A. Daugherty, B. Marinelli, Naval Air Weapons Center, China Lake, CA; D. Price, Raytheon Space and Airborne Systems, El Segundo, CA ITAR

9:40 AM

Safe-Life Coupon Testing of Aluminum Lined Pressure Vessels with Strain Ranges Exceeding Elastic Limits, M.B. Elliott, A.S. Hieronymus, General Dynamics Armament and Technical Products, Lincoln, NE ITAR

10:05 AM

Design and Manufacturing of Quasi-Three-Dimensional Woven Composites, D. Liu, K. Rosario, Michigan State University, East Lansing, MI; B.B. Raju, U.S. Army RDECOM/TARDEC, Warren, MI

11:00 AM

Residual Stress Modeling in the Milling Process Considering the Tribological Behavior of the Material Pair for Dry Conditions, B.M. Abraham, S.Y. Liang, J. Morehouse, Georgia Institute of Technology, Atlanta, GA

11:25 AM

Design, Characterization, Control, and Optimization of A 'Super String' Deployable Structure, M. Buckler, M. Zupan, University of Maryland Baltimore County, Baltimore, MD; M.A. Brown, TTH Research, Laurel, MD

11:50 AM

Epoxy Paint Failure in B-52 Fuel Tanks – Preliminary Development of a Model for the Process, R. Gandikota, A. Aliband, D.W. Lenz, L.E. Stevenson, T. Whitmer, R. Cash, W.T. Stevenson, Wichita State University, Wichita, KS

Room: L10

Infrastructure Applications 1A-1B

Session Chair: Hwai-Chung Wu, Wayne State University, Detroit, MI

9:15 AM

Status of Using Fiber-Reinforced Polymer Composites in U.S. Bridges, L.N. Triandafilou, P.E., Federal Highway Administration, Resource Center Structures Technical Service Team, Baltimore, MD

10:05 AM

Comparison of Composite Slab Deflections Under Blast Loads Using A Proposed Simple Practical Analytical Model and A Procedure Involving RISA-3D, M.A. Faruqi, J. Sai, P. Shah, Texas A & M University-Kingsville, Kingsville, TX; H. Estrada, The University of Pacific, Stockton, CA

11:00 AM

Damage Sensing of Bond Interface Between FRP Reinforcement and Steel Girders, S. Yamada, Y. Yoshida, S. Saito, Toyohashi University of Technology, Toyohashi, Japan; S. Yamada, Topy Industries, Ltd. Toyohashi, Japan; I. Komiya, Fukui Fibertech Co, Toyohashi, Japan

11:25 AM

Development of Fiber Reinforced Cementitious Composites, H.-C. Wu, Wayne State University, Detroit, MI

Room: L5

Manufacturing & Processing Advances 1A-1B

Session Chair: Sungho Yoon, Iowa State University, Ames, IA

9:15 AM

Foldable GFRP Boat Using Partially Flexible Composites, A. Todoroki, K. Kumagai, R. Matsuzaki, Tokyo Institute of Technology, Tokyo, Japan

9:40 AM

Thermal and Thermal Stress Analyses of the State-change Tooling, A. Vuppala, S.-Y. Luo, University of Nevada, Reno, NV; G. Calvert, J. Cao, L. Clements, 2Phase Technologies, Inc., Santa Clara, CA

10:05 AM

Block Copolymers for Epoxy Toughening, R. Barsotti, S. Schmidt, N. Macy, M. Wells, Arkema, King of Prussia, PA; R. Inoubli, St. Magnet, Arkema, Lacq, France; C. Navarro, Arkema, Cerdato, France

11:00 AM

Effect of Low Profile Additive (LPA) on the Physical and Mechanical Properties of Polyester, M.K Saraswat, K.M.B Jansen, L.J Ernst, Delft University of Technology, Delft, The Netherlands; R. Grimbergen, DSM Composites Resin, Zwolle, The Netherlands; F. Lauterwasser, DSM Composites Resin Deuschland GmbH, Ludwigshafen, Germany

11:25 AM

Impact Characterization of Core-Filled Pultruded Biocomposite Panels, R.R. Vuppalapati, K. Chandrashekhara, W.E. Showalter, Missouri University of Science and Technology, Rolla, MO

11:50 AM

A Design of Experiments (DoE) Approach to Material Properties Optimization of Electrospun Nanofibres, S.R. Coles, D. K. Jacobs, K. Kirwan, University of Warwick, Coventry, UK; J. Stanger, N. Tucker, Crop and Food Research Institute, Christchurch, New Zealand

Room: L14

Defense Applications of Multifunctional Materials - Panel

9:15 AM - 12:00 PM

Panel Moderators: Dr. Richard Vaia, Air Force Research Lab and Dr. B.L. ("Les") Lee Air Force Office of Scientific Research

Two major drivers governing the development of new Defense systems for the future Armed Forces have been the achievement of maximum load-carrying capability per unit weight/volume and the incorporation of a variety of functional properties dictated by the system requirements. Traditionally, these two issues are addressed separately, resulting in incremental improvements in mono-functional materials. However, dramatic improvements in system-level efficiency can be achieved by developing "multifunctional" materials that inherently possess the capacity to simultaneously meet the above two requirements. This panel discussion is intended to provide an overview of how the above described goals can be achieved and to assess the present needs, future possibilities and potential barriers.

Panelists:

Mr. Bill Baron (Air Force Research Lab, Air Vehicles Directorate)
Dr. Danny O'Brien (Army Research Lab)
Dr. Edward Silverman (Northrop Grumman)
Dr. Jim Thomas (Naval Research Lab)
Dr. Richard Vaia (Air Force Research Lab, Materials Directorate)

Vendor Breaks

Tuesday & Wednesday
10:30 AM - 11:00 AM
3:15 PM - 3:45 PM

Complimentary coffee will be available in the exhibition hall, sponsored by ASC.

Room: Sultana-Mississippi

Nanocomposites: Processing 2A-2B

Session Chair: Derrick Dean, University of Alabama, Birmingham, AL

2:00 PM

High-Temperature Cyanate Ester Adhesives Reinforced with Alumina Nanoparticles, M.R. Kessler, W. Liu, X. Sheng, M. Akinc, Iowa State University, Ames, IA

2:25 PM

Effect of Surface Morphology Modifications on Mechanical Properties of Fiber Reinforcements, M.S. Buckler, H.C. Malecki, M. Zupan, University of Maryland Baltimore County, Baltimore, MD

2:50 PM

A Two-Tier Approach for Addition of MWNT to Manufacture Fiber-Reinforced Polymer Nanocomposites, A. Rodriguez, C. Lim, M. Guzman, P. Kashani, B. Minaie, Wichita State University, Wichita, KS

3:45 PM

Fabrication of Ferrofluids at Controlled PH Values for Biomedical Applications, R. Asmatulu, B. Cooper, H. Misak, Wichita State University, Wichita, KS

4:10 PM

Solvent Evaporation and Agitation Time Effects on Mechanical Properties of Polymeric Nanocomposites, K.A. Shenoy, R. Asmatulu, B. Bahr, Wichita State University, Wichita, KS

Room: L12

Nanostructured Multifunctional Materials 1A-1B

Session Chair: Lawrence Drzal, Michigan State University, East Lansing, MI

2:00 PM

Enhancing the Through-Thickness Thermal Conductivity of Carbon Fiber Polymer-Matrix Composites by Nanostructuring the Interlaminar Interface, S. Han, J.T. Lin, Y. Yamada, D.D.L. Chung, University at Buffalo, State University of New York, Buffalo, NY

2:25 PM

Multiscale Fiber Reinforced Composites Using A Carbon Nanofiber/Epoxy Nanophased Matrix: Processing, Properties, and Thermomechanical Behavior, K.J. Green, D. Dean, U. Vaidya, University of Alabama at Birmingham, Birmingham, AL

2:50 PM

Dispersion Optimization of Exfoliated Graphite Nanoplatelets in Polypropylene: Extrusion vs Precoating of PP Powder, H.-M. Park, K. Kalaitzidou, H. Fukushima, L.T. Drzal, Michigan State University, East Lansing, MI

3:45 PM

The Effect of Exfoliated Graphite Nanoplatelet Size on the Mechanical and Electrical Properties of Vinyl Ester Nanocomposites, W. Liu, Inhwan Do, H. Fukushima, L.T. Drzal, Michigan State University, East Lansing, MI

4:10 PM

Nanostructured Coupling Agents for Multifunctional Composites, K. Green, M. Abdalla, N. Horton, A. Noble, D. Dean, Univ. of Alabama at Birmingham, Dept. of Materials Science & Engineering, Birmingham, AL; M.T. Universal Technology Corp., Dayton OH; J. Fielding, Air Force Research Lab., WPAFB, OH; S. Miller, Polymeric Materials Branch, Structures & Materials Division, NASA John H. Glenn Research Center, Cleveland, OH

4:35 PM

Multifunctional Polymer-Matrix and Cement-Matrix Structural Materials, D.D.L. Chung, Univ. at Buffalo, State Univ. of New York, Buffalo, NY

Room: L14

Design for Multifunctionality: Capability vs. Application 2A

Session Chair: Seun Kahng, NASA Langley Research Center, Hampton, VA

2:00 PM *1st Place Outstanding Paper*

Fabrication and Electromechanical Characterization of A Piezoelectric Structural Fiber for Multifunctional Composites, Y. Lin, H.A. Sodano, Arizona State University, Tempe, AZ

2:25 PM

Mechanical and Interface Properties of Carbon Nanofibers for Polymer Nanocomposites, T. Ozkan, Q. Chen, M. Naraghi, I. Chasiotis, University of Illinois at Urbana-Champaign, Urbana, IL

2:50 PM

Deformation and Fracture of Epoxy Nanocomposites with Silica Inclusions, Q. Chen, I. Chasiotis, Univ. of Illinois at Urbana-Champaign, Urbana, IL; C. Chen, Univ. of Dayton Research Institute, Dayton, OH; A. Roy, Air Force Research Lab., Wright-Patterson AFB, Dayton, OH

Room: L10

Infrastructure Applications 2A

Session Chair: Hwai-Chung Wu, Wayne State University, Detroit, MI

2:00 PM

Dynamic Mechanical Thermal Analyses of Polymeric Concrete Repair Materials, T.S. Rushing, US Army Engineer Research and Development Center Geotechnical and Structures Laboratory, Vicksburg, MS

2:25 PM

Lifecycle Predictions of Filament-Wound Polyurethane Utility Poles, M. Brown, M. Berksoy, RS Technologies, a Division of Resin Systems, Inc., Calgary, Alberta, Canada

Room: L5

Manufacturing & Processing Advances 2A-2B

Session Chair: Dale Brosius, Quickstep Technologies, Brighton, MI

2:00 PM

Non-Autoclave Prepreg Manufacturing Technology, G.G. Bond, J.M. Griffith, G.L. Hahn, The Boeing Company, Berkeley, MO

2:25 PM

The Creation of Ductile, Composite Prepregs, with Close to UD Properties, R. Ford, B. Griffiths, Integrated Materials Technology Ltd (IMT), Bury St. Edmunds, Suffolk, UK

2:50 PM

Tool-Shape Optimization to Minimize Warpage in Autoclave Processed L-Shaped Composite Part, A.-R Khorsand, J. Raghavan, G. Wang, University of Manitoba, Winnipeg, Canada

Manufacturing & Processing Advances 2A-2B (Continued)

3:45 PM
Development of Time-Temperature-Transformation Diagram during Cure of Polymer Composites Using Shear Rheometry and Thermal Analysis, P. Kashani, S. Alavi-Soltani, F. Ghods, B. Minaie, Wichita State University, Wichita, KS

4:10 PM
Development of a Ultra-High-Pressure RESS System for Synthesizing Nano-Sized Energetic Materials, A.C. Cortopassi, K.K. Kuo, P.J. Ferrara, T.M. Wawiernia, J.T. Essel, The Pennsylvania State University, University Park, PA

4:35 PM
Effects of High-Pressure RESS Operating Conditions on the Size of Synthesized Nano-Scale RDX Particles, T.M. Wawiernia, K.K. Kuo, P.J. Ferrara, A.C. Cortopassi, J.T. Essel, The Pennsylvania State University, University Park, PA

Room: L3

Composite Design & Analysis 1A-1B

Session Chair: Ed Semmes, NASA Marshall Space Flight Center, MSFC, AL

2:00 PM
Finite Element Analysis of Off-Axis Unidirectional Laminates with Intralaminar Damage, Y. Zhang, Institute for Aerospace Research, National Research Council Canada, Ottawa, ON, Canada

2:25 PM
A Computational Approach for Predicting A- and B-Basis Allowables for Polymer Composites, G. Abumeri, M. Garg, Alpha Star Corporation, Long Beach, CA; M. Reza Talagani, Delft University of Technology, Delft, The Netherlands

2:50 PM
Multi-Layer 2D Numerical Model for Z-Pin Composite Laminates: Compression Response and Failure, H. Huang, A.M. Waas, University of Michigan, Ann Arbor, MI

3:45 PM
Investigation of Composite Surface Effect Ship (SES) Hull Structure Under Hydrodynamic Loading Using Fluid-Structure Interaction, S. Ma, H. Mahfuz, Nanocomposites Laboratory, Ocean Engineering Department, Florida Atlantic University, Boca Raton, FL

4:10 PM
Investigation of Infusion of Ultra High Molecular Weight Polyethylene (UHMWPE) and Carbon Nanotube (CNT) into Low Density Polyethylene (LDPE) Filaments, M. Khan, H. Mahfuz, T. Leventouri, Florida Atlantic University, Boca Raton, FL

4:35 PM
Life Prediction of Carbon Fiber/PEKK Thermoplastic Composite Material for Structures Design, E. Dan-Jumbo, R. Keller, B. Westerman, The Boeing Co., Seattle, WA; A. Kuraishi, S.W. Tsai, J. Wang, Stanford University, CA

Vendor Breaks
Tuesday & Wednesday
10:30 AM - 11:00 AM
3:15 PM - 3:45 PM
Complimentary coffee will be available in the exhibition hall, sponsored by ASC.

Room: L10

Environmental Considerations 1B

Session Chair: Germán Reyes, University of Michigan-Dearborn, Dearborn, MI

3:45 PM
Stochastic Modeling of Damage Evolution and Stiffness Degradation in Composites Under Environmental Ageing, R. Rahman, A. Haque, University of Alabama, Tuscaloosa, AL

4:10 PM
Particle and Fiber Exposures During Processing of Hybrid Carbon-Nanotube Advanced Composites, B.L. Wardle, N. Yamamoto, R. Guzman deVilloria, E.J. Garcia, A. John Hart, M. Hallock, Massachusetts Institute of Technology, Cambridge, MA; D. Bello, K. Ahn, University of Massachusetts, Lowell, Lowell, MA

Room: L14

Reinventing Reality: The Quest for Multifunctional Material Properties- Panel

3:45 PM - 5:00 PM
Panel Moderator: Steve Rodgers, ITT Integrated Structures, Salt Lake City, UT

The foundational enabler for any technology is discovering, developing or creating the right material to support that technology. Most often, engineering has been the fine art of compromise; the material properties may not always be perfect for the application, but they can be effectively optimized through appropriate design trades. Now, however, there is a new class of materials designed for optimization, materials in which the properties are designed for multiple, and sometimes mutually exclusive, functions.

This panel will give you an opportunity to hear from the leaders of SAMPE's Technical Communities about how they pursue the creation of Multifunctional Materials. Presentations on the development of resins, the effective use of nanotechnology, the onset of new predictive computer modeling techniques and the impact of multifunctional development on the realm of morphing materials will be followed by 30-minute question and answer period.

Panelists:
LaNetra Clayton Tate, Ph.D, Applied Technology Directorate, NASA
Joseph H. Koo, Sc. D., The University of Texas at Austin
David Rigby, Accelrys Software Inc.
Jeff Baur, Air Force Research Lab

Welcome Reception-Ballroom E

5:00 PM – 6:00 PM
On the Exhibits & Ballroom Level
Join us for the Welcoming Reception, an excellent place to network with new and existing colleagues and business partners.

Joint SAMPE/ASC Tribute to Tom Gates

8:00 PM
Memphis Room at the Marriott Hotel
This special joint ASC/SAMPE session will give the friends and colleagues of Tom Gates an opportunity to share their special memories of Tom, who passed away on April 18, 2008.

Room: Sultana-Mississippi

Nanocomposites: Applications 1A-1B

Session Chair: Derrick Dean, University of Alabama, Birmingham, AL

9:15 AM

Processing and Performance of Nanoclay Infused Low Density Polyurethane Foams, D.C. Robinson, M.V. Hosur, S. Jeelani, Tuskegee University, Tuskegee, AL

9:40 AM *3rd Place Outstanding Paper*

Stab Characterization of Ballistic Fabrics Impregnated with Shear Thickening Fluid, H.M. Rao, J. Mayo. Jr., M.V. Hosur, S. Jeelani, Tuskegee University, Tuskegee, AL

10:05 AM

Nanocomposite Mold Design and Manufacturing: Part II: Mold Manufacturing and Testing, K. Han, B. Rice, D. Johnson, J. Hartings, T. Glenchur, J. Hickey, Univ. of Dayton Research Institute, Dayton, OH

11:00 AM

Synthesis and Characterization of Nanocomposite Coatings for the Protection of Metal Surfaces, R. Asmatulu, S. Revuri, Wichita State University, Wichita, KS

11:25 AM

Effect of Surface Modification on the Rheology of Montmorillonite Clay/Polyimide Nanocomposites, J.O. Iroh, Univ. of Cincinnati, Cincinnati, OH; E. Garcia, General Electric Aircraft Engines, Cincinnati, OH

11:50 AM

Potting Compound Strength Enhancement Using Carbon Nanomaterials, J. Baalman, M. Guzman, A. Rodriguez, B. Minaie, Wichita State University, Wichita, KS

Room: L12

Electromagnetic Multifunctional Materials 1A-1B

Session Chair: Sarah Frankland, National Institute of Aerospace, Hampton, VA

9:15 AM

Measurements of Shielding Effectiveness in Polymer Coating and Composite Systems, A. Small, M. Hirsch, T. Plaisted, Luna Innovations Incorporated, Blacksburg, VA

9:40 AM

Multifunctional Integration and Characterization of Thin Film Silicon Solar Cells on Carbon Fiber Reinforced Epoxy Composites, K.J. Maung, H.T. Hahn, Y.S. Ju, Univ. of California, Los Angeles, CA

10:05 AM

Mechanical and Electromagnetic Characterization of Pultruded Polymeric Composite Materials, E. Lackey, J.G. Vaughan, R. Averill, L. Bennett, W. Elliott Hutchcraft, R.K. Gordon, Univ. of Mississippi, University, MS

11:00 AM

Three Phase Composites for Multifunctional Structural Capacitors, F. Chao, N. Bowler, X. Tan, M.R. Kessler, Iowa State University, Ames, IA; G Liang, Northwestern Polytechnical University, Xi'an, China

11:25 AM

Structure-Battery Composites for Marine Applications – Part I: Multifunctional Design and Fabrication, W.R. Pogue III, J.P. Thomas, Multifunctional Materials Branch, Naval Research Laboratory, Washington, D.C.; M.A. Siddiq Qidwai, A. Rohatgi, Science Applications International Corporation, c/o Naval Research Lab., Washington, D.C.

11:50 AM

Structure-Battery Composites for Marine Applications – Part II: Multifunctional Performance Characterization, A. Rohatgi, M.A. Siddiq Qidwai, Science Applications International Corporation, c/o Naval Research Laboratory, Washington, D.C; W.R. Pogue III, J.P. Thomas, Multifunctional Materials Branch, Naval Research Lab., Washington, D.C.

Room: L3

Composite Fatigue & Fracture 1A-1B

Session Chair: Kevin Koudela, Pennsylvania State University, State College, PA

9:15 AM

Fatigue Modeling of Marine Composites, E.C. Strauch, K.L. Koudela, Applied Research Lab., The Pennsylvania State Univ., State College, PA

9:40 AM

Influence of Time-Dependent Damage on Creep of Multidirectional Polymer Composite Laminates, A. Asadi, J. Raghavan, Composite Materials & Structures Research Group, Univ. of Manitoba, Winnipeg, Canada

10:05 AM

A Computational Investigation of Impact into Multi-Plies of Plain-Woven Fabric, M. Grujicic, W. C. Bell, T. He, G. Arakere, Clemson University, Clemson, SC; B.A. Cheeseman, Army Research Lab.-Survivability Materials Branch, Aberdeen, Proving Ground, MD; K.L. Koudela, J.F. Tarter, Applied Research Lab., The Pennsylvania State Univ., State College, PA

11:00 AM

The Bearing Strength of Titanium-Graphite Fiber Metal Laminates, J.M. Hundley, H.T. Hahn, J.-M. Yang, Univ. of California Los Angeles, Los Angeles, CA; A.B. Facciano, Raytheon Missile Systems, Tucson, AZ

11:25 AM *2nd Place Outstanding Paper*

Strain Mapping for Performance and Failure Prediction in Composites Using Digital Image Correlation, G.P. Dillon, J.F. Tarter, C. Byrne, C.L. Rachau, C.L. Muhlstein, J.G. Collins, The Pennsylvania State University, University Park, PA

11:50 AM

Mode I Failure in Z-Pinned Co-Cured Laminated Composites, S.R. Soni, J. Freels, J. Kuhn, Air Force Institute of Technology, Wright-Patterson AFB, OH

2008 SAMPE Fall Technical Conference Outstanding Paper Winners

1st Place Outstanding Paper
Fabrication and Electromechanical Characterization of a Piezoelectric Structural Fiber for Multifunctional Composites, Yirong Lin and Henry A. Sodano, Arizona State University, Tempe, AZ

2nd Place Outstanding Paper
Strain Mapping for Performance and Failure Prediction in Composites Using Digital Image Correlation, Gregory P. Dillon, James F. Tarter, Christopher Byrne, Christopher L. Rachau, Christopher L. Muhlstein, and James G. Collins, The Pennsylvania State University, University Park, PA

3rd Place Outstanding Paper
Initial Design of the Automotive Composites Consortium Structural Composite Underbody, Hannes P. Fuchs, Multimatic Engineering Services Group, Livonia, MI

SAMPE Congratulates the Authors of the Outstanding Papers!

Room: L10

Composites for the Automotive Industry 1A-1B

Session Chair: Libby Berger, General Motors, Warren, MI

9:15 AM

Interlayer Hybrid Composites of Chopped and Woven Carbon Fiber, M.A. Janney, Materials Innovation Technology LLC, Fletcher, NC

9:40 AM

Initial Design of the Automotive Composites Consortium Structural Composite Underbody, H.P. Fuchs, Multimatic Engineering Services Group, Livonia, MI

10:05 AM

Materials and Processes for a Structural Composite Underbody, L. Berger, General Motors Research and Development Center, Warren, MI; E. Banks, Polywheels Manufacturing Ltd., Livonia, MI; R. Wlosinski, USCAR, Southfield, MI

11:00 AM

Creep Characterization of Seven Automotive Composite Materials, M.C. Cook, J.M. Henshaw, The University of Tulsa, Tulsa, OK; and D.Q. Houston, Ford Motor Company, Detroit, MI

11:25 AM

Design Considerations for Energy Absorption in Automotive Sandwich Composites, J. Van Otten, S.E. Stapleton, D.O. Adams, University of Utah, Salt Lake City, UT

11:50 AM

An Integrated Approach Linking Process to Structural Modeling with Microstructural Characterization for Injection-Molded Long-Fiber Thermoplastics, B. Nghiep Nguyen, S.K. Bapanapalli, M.T. Smith, Pacific Northwest National Laboratory, Richland, WA; V. Kunc, B.J. Frame, R.E. Norris Jr., Oak Ridge National Laboratory, Oak Ridge, TN; J.H. Phelps, C.L. Tucker III, University of Illinois at Urbana-Champaign, Department of Mechanical Science and Engineering, Urbana, IL; X. Jin, J. Wang, Moldflow Ithaca, Ithaca, NY

Room: L5

Composites from Agricultural Products 1A-1B

Session Chair: Michael Kessler, Iowa State University, Ames, IA

9:15 AM

High Strength Green Composites, A.N. Netravali, Department of Fiber Science & Apparel Design, Cornell University, Ithaca, NY

9:40 AM

Plant Protein Based Plastics and Applications, D. Grewell, G. Srinivasan, M. Babol, M.R. Kessler, W. Graves, M. Helgeson, Iowa State University, Ames, IA

10:05 AM

Bio-Based Materials from Vegetable Oils, A. Campanella, R.P. Wool, University of Delaware, Newark, DE

11:00 AM

Curing and Properties of Thermoset Canola Oil Based Resins, M. Fahimian, Devi Adhikari, J. Raghavan, University of Manitoba, Winnipeg, Canada; R. P. Wool, University of Delaware, Newark, DE

11:25 AM

Thermal Analysis of Bio-based Rubber Composites from Plant Oils, S. Yoon, Iowa State University, Ames, IA and Kumoh National Institute of Technology, Gyeongbuk, Korea; W. Jeong, M. Valverde, R. Larock, M.R. Kessler, Iowa State University, Ames, IA

11:50 AM

Properties of Poly(Lactic Acid)/Polypropylene Blends, J.-F. Zhang, L. Grigorian, J. Zhu, T. Robinson, S. Ray Chaudhuri, YTC America Inc., Camarillo, CA

Room: L14

Industrial Applications of Multifunctional Materials-Panel

9:15 AM - 10:30 AM

Panel Moderator: Guru R. Kathawate, G.R. Kathawate & Associates, Inc.

Every industry is facing many challenges today due to the increase in oil prices and the global awareness on developing environmentally friendly products. These two events have triggered concerns and worry at every level from politicians and industrialists to the common man. The engineering community is being challenged in a big way. This forces materials engineers and scientists to think of ways and means to look at how multifunctional materials can be used to build high performance and efficient products in a creative way at low cost

Our team of panelists consisting of experts from global industry and academia, discuss their views on how multifunctional materials can be used to develop products to overcome some of these problems.

Panelists:

W.H. Katie Zhong, Washington State University
Jim Kuenz, E-A-R Specialty Composites, Inc.
Abhijit Gupta, Northern Illinois University
Alan K.T. Lau, The Hong Kong Polytechnic University

Room: L14

Future Directions of Multifunctional Materials Research-Panel

11:00 AM - 12:15 PM

Panel Moderator: Alan Kin-tak Lau, The Hong Kong Polytechnic University

The development of multifunctional materials has been undergoing a progressive period since the last decade, the fields of research and applications have covered a large variety of ranges which include but not limited to civil infrastructures, aerospace structures and components, domestic product design and development, micro-electro-mechanical systems (MEMs), Nano-electro-mechanical systems (NEMs), bio-medical and bio-engineering applications. In this panel session, the discussion will be focused on the future development of multifunctional materials and structures, and how to get start on creating cross-disciplinary research and collaboration between universities, research centres and the industry, in which the connection between upstream research and then downstream applications has to be effectively linked. The identification of the future trends on materials research and then narrowing down the focus to multifunctional-materials research to support the directions will be discussed.

Panelists:

Dae-Soon Lim, Korea University
Deborah D.L. Chung, University at Buffalo
Jinsong Leng, Harbin Institute of Technology
Russ Maguire, Multifunctional Mat'ls & Structures Enterprise TIG

Room: L10

Featured Lecture: Research on Multifunctional Materials & Structural Health Monitoring in Japan

1:15 PM - 2:00 PM

Presenter: Dr. Nobuo Takeda, The University of Tokyo, Chiba, Japan

Moderators: Ron Gibson, University Nevada-Reno, Reno, NV and Nick Gianaris, General Dynamics Land Systems, West Bloomfield, MI

The author has been leading a series of Japanese industry-university collaboration projects on smart materials/structures and structural health monitoring (SHM) these several years. Some representative research results are presented on multi-functional materials and SHM of composite structures developed in these projects.

Room: L14

NDE & Structural Health Monitoring 1A-1B

Session Chair: Emmanuel Ayorinde, Wayne State University, Detroit, MI

2:00 PM

Ultrasonic Nondestructive Evaluation of Composite Materials and Structures, D.K. Hsu, Iowa State University, Ames, IA

2:25 PM

Automated Portable Ultrasonic Disbond Inspection System for Ground Vehicle Metal Matrix Composite Track Shoes, X. Zhao, D. Xiang, F. Yan, Z. Ren, Intelligent Automation Inc., Rockville, MD; B.B. Raju, U.S. Army RDECOM/TARDEC, Warren, MI

2:50 PM

Acoustic Emission (AE) Monitoring of the Pulsatile Flow of Corn Oil in Water Suspension Through a Porous Medium, G. C. Chungag, E.O. Ayorinde, Wayne State University, Detroit, MI

3:45 PM

Evaluation and Detection of Bonding and Delamination in Sandwich Structures by Thin Film Thermal Sensor, M. Khairul Alam, M.S. Anghelescu, Ohio University, Athens, OH; G. Eberle, Alcan Technology & Management Ltd., Neuhausen, Switzerland

4:10 PM

Frequency and Temperature Aspects of Fatigue NDE of Some Sandwich Beams, E.O. Ayorinde, Wayne State University, Detroit, MI

Room: L12

Thermo-Mechanical Multifunctional Materials 1A-1B

Session Chair: Greg Odegard, Michigan Technological University, Houghton, MI

2:00 PM

Full Field Strain Analysis of Lightweight Aluminum Foam Hybrid Structures, G. Reyes and A. Talakola, University of Michigan-Dearborn, Dearborn, MI

2:25 PM

Damping, Tensile, and Impact Properties of Superelastic Shape Memory Alloy (SMA) Fiber Reinforced Polymer Composites, J. Raghavan, T. Bartkiewicz, S. Boyko, M. Kupriyanov, University of Manitoba, Winnipeg, Canada; N. Rajapakse, University of British Columbia, Vancouver, Canada; B. Yu, Manitoba Hydro, Winnipeg, Canada

2:50 PM

Cure Behavior of Dye-Doped Epoxy System for 2-Photon Fluorescence Imaging, R.E. Toivola, A.C. Young, B.D. Flinn, A.K. Jen, University of Washington Material Science & Engineering, Seattle, WA

3:45 PM

The Design of a Hybrid Material for Multifunctional Performance Using Advanced Analysis Techniques and Testing, E. Askari, K. Nelson, O. Weckner, J. Xu, The Boeing Company, Seattle, WA; S.A. Silling, Sandia National Laboratories, Albuquerque, NM

4:35 PM

Tensile and Interface Properties of Small Diameter Fibers Using Nano-Tensile Testing, M. Kant, D. Penumadu, University of Tennessee, Knoxville, TN

Room: L10

Composite Fatigue & Fracture 2A-2B

Session Chair: Golam Newaz, Wayne State University, Detroit, MI

2:00 PM

Mixed Mode Testing of Woven Fabric Polymer Composites, T.F. Bruce, J.T. Wood, The University of Western Ontario, London, Canada

2:25 PM

Damage Mapping of Fatigued Skin-Stringer Specimens in Three Dimensions, V. Feret, F. Hubert, McGill University, Montreal, Canada; I. Paris, Bombardier Aerospace, St-Laurent, Canada

2:50 PM

Stress Redistributions in Unit Cells of Fiber-Reinforced Composites with Interface Degradation, V. Mondragón, L.A. Godoy, M.A. Pando, F.J. Acosta, University of Puerto Rico at Mayagüez, Mayagüez, PR

3:45 PM

Tensile Failure of Fibrous Monolithic Composites, D.M. Hrobak, M. Zupan, University of Maryland Baltimore County, Baltimore, MD

4:10 PM

Strain-Life Fatigue Approach Applied to Glass Fibre Reinforced Polypropylene, J. Rehkopf, Exponent, Farmington Hills, MI; A. Conle, Ford Motor Company, Dearborn, MI

4:35 PM

Delamination Fracture Mechanisms of Continuous Fiber Polymer Composites Subjected to Mixed Mode Loading, T.F. Bruce, J.T. Wood, The University of Western Ontario, London, Ontario, Canada

Room: Sultana-Mississippi

Composites for the Automotive Industry 2A

Session Chair: Libby Berger, General Motors, Warren, MI

2:00 PM

Effect of Nanoclay Dispersion on Processing of Polyester Nanocomposite, M. Ali Bashir, F. Hubert, McGill University, Montreal, Quebec

2:25 PM

Multi-Task Research Program to Develop Commodity Grade, Lower Cost Carbon Fiber, C.D. Warren, F.L. Paulauskas, F.S. Baker, C. Cliff Eberle, A. Naskar, Oak Ridge National Laboratory, Oak Ridge, TN

Vendor Breaks

Tuesday & Wednesday

10:30 AM - 11:00 AM

3:15 PM - 3:45 PM

Complimentary coffee will be available in the exhibition hall, sponsored by ASC.

Room: L5

Composites from Agricultural Products 2A

Session Chair: Michael Kessler, Iowa State University, Ames, IA

2:00 PM

Effect of Chemical Modifications of Bamboo Fibers on BFRP Composites, R. Kumar, P.K. Kushwaha, Indian Institute of Technology Delhi, New Delhi, India

2:25 PM

Studies on Application of Under Water Shock Wave on Jute Fiber and Its Characteristics, G.M. Shafiur Rahman, H. Maehara, S. Itoh, Kumamoto University, Japan

Room: L3

Carbon-Carbon Composites & Foams 1A-1B

Session Chair: Patrick Lake, Applied Sciences, Inc., Cedarville, OH

2:00 PM

Nano-Aramid Fiber Reinforced Polyurethane Foam, E.B. Semmes, Marshall Space Flight Center, MSFC, AL; A. Frances, E.I. DuPont de Nemours and Company, Richmond, VA

2:25 PM

Preliminary Flexural Testing Results of Aluminum Foam-Polypropylene Interpenetrating Phase Composites, N. Dukhan, N. Rayess, J. Hadley, The University of Detroit Mercy, Detroit, MI

2:50 PM

Electrode Grade Composite Graphite From Coal Feedstocks, E.B. Kennel, M. Mukka, A.H. Stiller, J.W. Zondlo, West Virginia University, Morgantown, WV

3:45 PM

Structural Carbon Foams From Waste Coal, E.B. Kennel, M. Mukka, O.A. Olajide, A.H. Stiller, West Virginia University, Morgantown, WV; R.A. Wolfe, Banner Elk, NC

4:10 PM

Highly Graphitic C/C Composites for Thermal Management, A. Palmer, P. Lake, D. Burton, M. Lake, Applied Sciences, Inc., Cedarville, OH

4:35 PM

Machining, Bonding, Sealing, and Venting of Carbon Foam for Production Tooling, G.D. Shives, D.J. Miller, R.L. Shao, A.K. Francis, D.M. Kaschak, GrafTech International, Parma, OH

Room: Sultana-Mississippi

Nanocomposites: CNT/CNF Alignment 1B

Session Chair: Chuck Bakis, The Pennsylvania State Univ., University Park, PA

3:45 PM

Processing of Hybrid Advanced Composites Utilizing Capillarity-Driven Wetting of Aligned Carbon Nanotubes, H. Cebeci, R. Guzman de Villoria, B.L. Wardle, D.S. Saito, N. Yamamoto, K. Ishiguro, E.J. Garcia, A.J. Hart, S. Wicks, Massachusetts Institute of Technology, Cambridge, MA

4:10 PM

Tailored Alignment of Functionalized Multiwall Carbon Nanotubes in Epoxy, A. Sharma, C.E. Bakis, Engineering Science and Mechanics Dept., Pennsylvania State University, University Park, PA; K. Well Wang, Mechanical Engineering Dept., Univ. of Michigan, Ann Arbor, MI

4:35 PM

Electroconductive PET/SWNT Films By Solution Casting, B.W. Steinert, D.R. Dean, Univ. of Alabama at Birmingham, Birmingham, AL

Room: L5

Testing of Composites 1B

Session Chair: Don Adams, Wyoming Test Fixtures, Inc., Salt Lake City, UT

3:45 PM

Tensile Specimen Design and Experimental Procedures for Characterizing Polymeric Composites Using X-Ray Based Micro-Tomography, V. Kunc, B. Frame, Oak Ridge National Lab., Oak Ridge, TN; B.N. Nguyen, Pacific Northwest National Lab., Richland, WA; S. Case, Virginia Polytechnic Institute & State Univ., Dept. of Engineering Science and Mechanics, Blacksburg, VA; S. Young, D. Penumadu, Univ. of Tennessee, Civil & Environmental Engineering, Perkins Hall, Knoxville, TN

4:10 PM

Functionalized Surface Single Fiber Pull-Out: Experiment, S. Markkula, H. Malecki, M. Zupan, University of Maryland Baltimore County, Baltimore, MD

4:35 PM

Comparisons of Interfacial Shear Strength Measurements for Bonded Materials and Composite Materials, A. Krishnan, L.R. Xu, Vanderbilt University, Nashville, TN

A Night at the Peabody

6:00 PM – 8:00 PM

Participate in this SAMPE/ASC joint social event, a fun gathering featuring cocktails, food and great company. After this joint get-together, pursue your own plans of dinner and fun on Beale Street.

Buses will shuttle attendees to and from the Peabody Hotel. Buses will begin loading at 5:45 PM at the Memphis Marriott Hotel Lobby Level and will run continuously until 9:00 PM for the convenience of those visiting Beale Street. If you are planning to stay out on Beale Street later than 9:00 PM, trolley can return you to the Memphis Marriott Downtown Hotel until 10:30 PM. The trolley runs every 5 minutes, with a pick-up station at the Peabody Hotel and is $1 per ride.

Tickets to this event are included with full registration. Additional tickets can be purchased at the SAMPE Registration area for $55.

Room: L10

Featured Lecture: Ionic Polymer-Metal Composite as a New Actuator and Transducer Material
8:15 AM - 9:00 AM
Presenter: Kwang Kim, University of Nevada, Reno, NV
Moderators: Ron Gibson, University Nevada-Reno, Reno, NV and Nick Glanaris, General Dynamics Land Systems, West Bloomfield, MI

Ionic Polymer-Metal Composites (IPMCs) are a unique polymer transducer that when subjected to an imposed bending stress, exhibits a measurable charge across the chemically and/or physically placed effective electrodes. The current state-of-the-art IPMC manufacturing technique incorporates two distinct preparation processes: initial compositing process and subsequent surface electroding process. Due to different preparation processes, morphologies of precipitated platinum are significantly different. In this presentation, the basic principles of IPMC actuator/transducer and its manufacturing techniques will be discussed.

Room: Sultana-Mississippi

Nanocomposites: Electrical and Thermal 1A-1B
Session Chair: Greg Yandek, Air Force Research Lab, Edwards AFB, CA

9:15 AM
Nanostructured Thermal Interface Pastes for Microelectronic Cooling, C. Lin, D.D.L. Chung, University at Buffalo, State University of New York, Buffalo, NY

9:40 AM
Adherent Carbon-Based Films Exhibiting High Electrical Conductivity, Y. Yamada, D.D.L. Chung, University at Buffalo, State University of New York, Buffalo, NY

10:05 AM
Dielectric Properties of ZnO/PVDF Flexible Composites, C. Dagdeviren, M. Papila, Sabanci University, Istanbul, Turkey

11:00 AM
Polyimide Nanocomposites for Tunable Coefficient of Thermal Expansion, G.R Sharma, M.R. Coleman, Cora Lind, The University of Toledo, Toledo, OH

11:25 AM
Carbon Nanotube Reinforced Polymers for Multifunctional Composite Structures, S. Chung, R. Foedinger, Materials Sciences Corporation, Horsham, PA; M. Weisenberger, M. Meier, University of Kentucky Center for Applied Energy Research, Lexington, KY; J.K. Roberts, U.S. Army Aviation and Missile Research Development and Engineering Center Redstone Arsenal, AL

11:50 AM
Electrical Conductivity Measurements and Lightning Strike Results of Nano/Macromaterials Enhanced Polymeric Composites, T. Gibson, University of Dayton Research Institute, Dayton, OH; J. Chase Fielding, Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright-Patterson AFB, OH

Room: L12

Nanocomposites: Analysis and Characterization 1A-1B
Session Chair: Chuck Bakis, The Pennsylvania State Univ., University Park, PA

9:15 AM
Mechanical Characterization of Multi-Wall Carbon Nanotube/Poly(Methyl Methacrylate) Nanocomposites: A Metrology Comparison Study, E.U. Onyegam, J.H. Koo, J.H. Im, P.S. Ho, Austin, TX

9:40 AM
A Scaling Parameter for Determining Exfoliation Efficiency in Nanocomposites, H.A. Stretz, V.D.N. Palla, Tennessee Technological University, Cookeville, TN

10:05 AM
Chemistry of Mechanical Performance: Memory, Self-Healing Behavior, and High Impact Resistance in Nanocomposites, C.E. Powell, G.W. Beall, C. Booth, Texas State University-San Marcos, San Marcos, TX

11:00 AM
Multi-scale Modeling of Bending Behavior of Carbon Nanotube-Reinforced Composites, L. Cui, L. Sun, Beijing University of Aeronautics and Astronautics, Beijing, China

11:25 AM
Dynamic Mechanical Analysis of Graphite Platelet and Nanoclay Reinforced Vinyl Ester, and MWCNT Reinforced Nylon 6,6 Nanocomposites, A. Almagableh, S. Gupta, P. Raju Mantena, A. Al-Ostaz, Composite Structures and Nano-Engineering Research, The University of Mississippi, University, MS

11:50 AM
Uncertain Mechanical Properties of Nanocomposite Materials, L.R. Xu, A. Krishnan, C.M. Lukehart, Vanderbilt University, Nashville, TN

Room: L5

Thermoplastic Composites 1A-1B
Session Chair: Uday Vaidya, The University of Alabama at Birmingham, Birmingham, AL

9:15 AM
Manufacturing Study of Unidirectional AS4D/PEKK Tape, C.Ó. Brádaigh, R. Canavan, J. Lee, J-M. Bocquel, P. Mallon, ÉireComposites Teoranta, An Choill Rua, Indreabhán, Co. Galway, Ireland

9:40 AM
Processing and Mechanical Characterization of Thermoplastic Nanocomposites, S. Roy, K. Narasimhan, University of Alabama, Tuscaloosa, AL

10:05 AM
The Effect of Forming Processes on the Environmental Resistance of Carbon/PPS, S. Wijskamp, A. Leusink, R. Lenferink, W. Kok, Ten Cate Advanced Composites, The Netherlands

11:00 AM
Continuous Reinforced Thermoplastic Composites for Aircraft Applications, M. Favaloro, Ticona Engineering Polymers, Amesbury, MA

11:25 AM
A Comparison of Maximum Use Temperatures for High Performance Thermoplastic Composites, H. Ramathal, M. Favaloro, Ticona Engineering Polymers, Amesbury, MA

11:50 AM
Full Field Strain Analysis of Thermoplastic Woven Composites, G. Reyes and S.T. Mane, University of Michigan-Dearborn, Dearborn, MI

Breaks
10:30 AM - 11:00 AM
3:15 PM - 3:45 PM

Room: L10

Sandwich Structures 1A-1B

Session Chair: Alan Nettles, NASA Marshall Space Flight Center, MSFC, AL

9:15 AM

Study on Failure Mode of Aluminum/PU Foam Sandwich Plate Under Bending Loads, L. Sun, W. Chen, Beijing University of Aeronautics and Astronautics, Beijing, P.R. China

9:40 AM

Assessment of Extruded Polystyrene Foam for Sandwich Composite Applications, C.C. Wellnitz, I. Miskioglu, ME-EM Department, Michigan Technological University, Houghton, MI; J.D. Zawisza, The Dow Chemical Company, Dow Chemical U.S.A., Midland, MI

10:05 AM

Cyclic Response of Pin-Reinforced Foam Core Sandwich Panels, S.M. Storch, M. Zupan, University of Maryland Baltimore County, Baltimore, MD; D.D.R. Cartie, Cranfield University, Cranfield, UK

11:00 AM

A Fastener-Free Primary Structural Joint Between Sandwich Panels, J.H. Fogarty, The Boeing Company, St. Louis, MO

11:25 AM

Modeling High Velocity Impact of Fire Exposed Sandwich Composites, J. Mosbrucker, M. Hanson, L. Gibbon, and C.A. Ulven, North Dakota State University, Fargo, ND

11:50 AM

Compression After Impact Testing of Sandwich Structures Using a Four Point Bend Test, A.T. Nettles, J.R. Jackson, NASA Marshall Space Flight Center, Huntsville, AL; T.S. Gates, NASA Langley Research Center, Hampton, VA

Room: L14

Requirements for the Next Generation of Composites Engineers - Panel

9:15 AM - 10:30 AM

Panel Moderator: Brad Lucht, Honeywell FM&T, Kansas City, MO

What should engineering education be like in the future to prepare the next generation of composites engineers?

Modifying the engineering education system will require the continuous and ongoing interaction between engineers in industry and educators in academe.

What role can SAMPE play to facilitate the exchange of ideas and information between these groups?

The panelists will discuss their views on what academia can do to provide the composites engineers that industry needs, and what industry can do to support the development of academic programs that will produce these engineers.

Panelists:

Ben Wang, Florida State University

Les Kramer, Lockheed Martin Missiles and Fire Control

Shridhar Yarlagadda, University of Delaware

Gail Hahn, Boeing Phantom Works

Becky Abdel-Magid, Winona State University

Peter Wu, Spirit AeroSystems

Breaks

10:30 AM - 11:00 AM

3:15 PM - 3:45 PM

Room: L3

Structurally Integrated Energy Harvesting/Storage Capabilities - DoD Workshop

9:15 AM - 5:00 PM

Organizers: B.L. ("Les") Lee, Air Force Office of Scientific Research; James Thomas, Naval Research Lab; and Bruce LaMattina, Army Research Office

Usable electrical energy can be harvested from ambient solar radiation, waste heat, and mechanical vibrations relying on photovoltaic, thermoelectric/thermionic, and piezo/magneto-electric means respectively. Harvested electricity can, in turn, undergo immediate in-situ usage (e.g. self-powered sensors), or be stored in capacitors or batteries for in- or ex-situ usage. Batteries, capacitors or other micro-devices for energy storage as well those elements used for energy harvesting can be embedded or integrated into load-bearing structures in various forms such as thin film laminates or surface coating layers.

Speakers and Presentations:

Minoru Taya, University of Washington - Keynote: "Energy Harvesting and Storage Systems and Their Integration to Aero Vehicles"

Bruce Lanning, ITN Energy Systems: "Multifunctional Power Systems Using Flexible Thin Film Solid State Lithium Batteries and Polycrystalline CIGS Solar Cells"

Jerry Fleming, Luna Innovation: "Development of High Power Density Thermoelectric Modules for a Miniaturized Thermal Energy Harvesting System"

Greg Carman, UCLA: "An Overview of Mechanical and Thermal Energy Harvesting Systems Developed at UCLA"

Max Shtein, University of Michigan: "Fiber-Based Devices for Solar and Thermal Energy Harvesting Composites for Aerospace Applications"

Tom Hahn, UCLA: "Multifunctional Energy Harvesting & Storage Structural Composites"

Marty Dunn, University of Colorado: "Design Methods for Multifunctional Composites with Energy Harvesting and Storage Functionalities"

Ann Marie Sastry, University of Michigan: "Intercalation of Li in Structural Materials: Toward Structural Batteries for Compact Power"

Brian Sanders and Greg Reich, Air Force Research Lab: "Structurally Integrated Thermal Energy Harvesting System"

Eric Wetzel, Army Research Lab: "Structural Batteries and Capacitors for Army Applications"

Siddiq Qidwai, Naval Research Lab: "Structurally Integrated Energy Storage Composites for Unmanned Underwater Vehicles"

Room: L14

High Temperature Resins & Composites 1B

Session Chair: Stan Prybyla, Breakthrough Technology Development, Brecksville, OH

11:00 AM

Evaluation of Toughness and Hot/Wet Performance of Epsilon Resin System, W.H. Li, S. Lehmann, Henkel Corporation, Bay Point, CA

11:25 AM

Improved Matrix for Carbon Fiber Composites for Aircraft, S.E. Bender, J. Economy, University of Illinois at Urbana-Champaign, Urbana, IL

Room: L10

Featured Lecture: Polymer Nanocomposites Research in Canada

1:15 PM - 2:00 PM

Presenter: Suong V. Hoa, Concordia University, Montreal, Quebec, Canada

Moderators: Ron Gibson, University Nevada-Reno, Reno, NV and Nick Gianaris, General Dynamics Land Systems, West Bloomfield, MI

Research on polymer nanocomposites in Canada has been focused mainly on the incorporation of nanoparticles such as nanoclays, carbon nanotubes, carbon nanofibers into polymeric systems including thermoplastics such as epoxies, polystyrene, polylactic acid (PLA), and polyethylene terephthalate (PET). Apart from industrial uses, significant applications are for aerospace. Significant advances have been made for the incorporation of clays into epoxies. Different models have been developed:

- Model for the effects of different mixing parameters (temperature and speed of mixing) for the high speed mixing process.
- Model for the absorption of water into polymer nanocomposites
- Model for the increase in fracture toughness due to fine dispersion of particles.

Incorporation of carbon nanotubes into epoxies have been shown to form a sensor network that can provide more consistent detection of occurrence of cracks in composite laminates as compared to strain gauges.

Room: L5

Manufacturing & Processing Advances 3A

Session Chair: Dale Brosius, Quickstep Technologies, Brighton, MI

2:00 PM

RSRM Nozzle Flex Boot Material Replacement, C.J. Jordan, D.E. Gorringe, ATK Launch Systems, Promontory, UT ITAR

2:25 PM

PBI-NBR Closed Mold Fabrication Process Development, D. Gorringe, C. Jordan, ATK Launch Systems, Promontory, UT ITAR

2:50 PM

Fabrication of Silicon Carbide and Refractory Metal Based Composites for Nuclear Applications Using Polymer Infiltration and Pyrolysis, A.K. Singh, R.P. Singh, School of Mechanical and Aerospace Engineering, Oklahoma State University, OK

Room: Sultana-Mississippi

Nano-Industrial Applications 1A

Session Chair: Patrick Lake, Applied Sciences, Inc., Cedarville, OH

2:00 PM

Industrial Applications for Carbon Nanofiber Reinforced Polymer Composites, C. Leer, P. Lake, D. Burton, M. Lake, Applied Sciences, Inc., Cedarville, OH

2:25 PM

Metal-Free Thermal Conductive Polymers, E. Hammel, X. Tang, A. Eder, Electrovac AG, Klosterneuburg, Austria

2:50 PM

Smart Nanocomposites for Industrial Health Monitoring, G. Maheshwari, N. Mallik, S. Narayanan Sundaramurthy, M.Dadhania, W. Li, D. Hurd, Y.H. Yun, M.J. Schulz, J. Abot, Wondong, E. Head, V. Shanov, C. Jayasinghe, P. Salunke, L. Lee, University of Cincinnati, Cincinnati, OH; S. Yarmolenko, J. Sankar, North Carolina A&T State Univ., Greensboro, NC

Room: L14

Thermoplastic Composites 2A-2B

Session Chair: Selvum Pillay, The University of Alabama at Birmingham, Birmingham, AL

2:00 PM

Prestressed Carbon/Fiber Thermoplastic Electromagnetic Railgun, A. Littlefield, J. Root, R. Mysliwiec, K. Olsen, US Army RDECOM-ARDEC Benét Laboratories, Watervliet, NY ITAR

2:25 PM

Processing and Characterization of Thin-Walled Long Fiber Reinforced Thermoplastic (LFT) Composites, H. Ning, S. Pillay, U. Vaidya, J.B. Andrews, The University of Alabama at Birmingham, Birmingham, AL

2:50 PM

Development of a Thermoplastic Prepreg Manufacturing Process by Continuous Resin Infusion, J.C. Ragone, K. Mallick, University of Michigan–Dearborn, Dearborn, MI

3:45 PM

Influence of Nanoclay Addition on Properties of Unsaturated-Polyester Nanocomposite Gel Coat System, P. Jawahar, K. Kanny, Durban University of Technology, Durban, South Africa; M. Balasubramanian, Indian Institute of Technology Madras, Chennai, India

4:10 PM

Damping Behavior of Long Fiber Reinforced Thermoplastic (LFT) Composites, A. Goel, Pennsylvania State University, University Park, PA; K.K. Chawla, U.K. Vaidya, University of Alabama at Birmingham, Birmingham, AL

4:35 PM

Preparation and Characterization of Commodity Thermoplastics Reinforced with Natural Fiber Byproduct, M.A. Fuqua, S. Huo, and C.A. Ulven, North Dakota State University, Fargo, ND

Room: L12

Multifunctional Materials with Integral NDE 1A

Session Chair: Soma Perooly, Proto Manufacturing Inc., Ypsilanti, MI

2:00 PM

Direct Laser Fabrication of Conical Si Tips With Nanoscale Sharpness, J.P. Moening, D.G. Georgiev, The University of Toledo, Toledo, OH

2:25 PM

Effect of Ion Bombardment on the Properties of Magnetron Sputtered Samarium Cobalt Films on Chromium Underlayers, M.K. Ghantasala, Western Michigan University, Kalamazoo, MI; J. Wang, Swinburne University of Technology, Hawthorn, VIC, Australia; S. Perooly, Proto Manufacturing Inc., Ypsilanti, MI

Room: L10

High Temperature Resins & Composites 2A-2B

Session Chair: Stan Prybyla, Breakthrough Technology Development, Brecksville, OH

2:00 PM

Influence of Ply Stacking Sequence on Anisotropic Oxidation Growth in Laminated Composites, G.P. Tandon, W.R. Ragland, University of Dayton Research Institute, Dayton, OH; G.A. Schoeppner, Air Force Research Laboratory/RXBC, WPAFB, OH ITAR

2:25 PM

Thermal Oxidative Barrier Coating for Polymer Matrix Composites, W.R. Ronk, T.A. Bullions, GE Aviation, Cincinnati, OH ITAR

2:50 PM

High-Temperature Finishes for Silicon Carbide-Reinforced Composites, R.E. Allred, J.-M. Gosau, J.P. Barlow, Adherent Technologies, Inc., Albuquerque, NM ITAR

3:45 PM

Comparison of Physical and Mechanical Properties of High-Temperature Resin Transfer Molding (PETI-330, PETI-375, AFR-RTM, and AFR-RTM Modified), T. Storage, Materials & Manufacturing Directorate, WPAFB, OH; T. Gibson, University of Dayton Research Institute, Dayton, OH ITAR

4:10 PM

Thermo-Oxidative Characterization of BMI Subjected to Service Environment, S. Putthanarat, G.P. Tandon, University of Dayton Research Institute, Dayton, OH; G.A. Schoeppner, AFRL/RXBC, WPAFB, OH ITAR

Room: Sultana-Mississippi

Nanocomposites: Fire Behavior 1B

Session Chair: Antonio Avila, Universidade Federal de Minas Gerais, Horizonte, MG, Brazil

3:45 PM

Residual Impact Strength of Nanocomposites after Intense Heat Exposure, A.F. Ávila, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil; J.H. Koo, The University of Texas at Austin, Austin, TX; A.Q. Bracarense, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

4:10 PM

Kinetics of Thermal Degradation of Thermoplastic Polyurethane Elastomer Nanocomposites, D.W.K. Ho, J.H. Koo, J.C. Lee, O.A. Ezekoye, The University of Texas at Austin, Austin, TX

4:35 PM

Enhancement of Flame Retardancy in Epoxy and Bismaleimide/Carbon Fiber Composites by the Incorporation of Buckypaper on the Composite Surface, Q. Wu, J. Bao, C. Zhang, Z. Liang, B. Wang, Florida State University, Tallahassee, FL

Room: L5

Joints in Composite Structures 1B

Session Chair: Guru Kathawate, G.R. Kathawate & Associates, Inc., Lake Orion, MI

3:45 PM

Hybrid Composite Joining Techniques, F. Thomas, E. Semmes, Marshall Space Flight Center, MSFC, AL ITAR

4:10 PM

Bearing Strength and Failure Behavior of Bolted Stitched CFRP Laminates, A. Yoshimura, Y. Iwahori, Advanced Materials Group, Aerospace Research and Development Directorate, JAXA, Tokyo, Japan

4:35 PM

Joining Thick Composite Panels with the Use of Unitary 3-D Woven Couplers and Patches, A. Bogdanovich, D. Mungalov, 3TEX, Inc., Cary, NC; O.O. Ochoa, S.M. Lee, Texas A&M University College Station, TX

Room: L12

Resins & Adhesives 1B

Session Chair: Terry Tsuchiyama, The Boeing Company, Seattle, WA

3:45 PM

Advanced Epoxy System for Large Scale Composite Ship Component Manufacturing Using the VARTM Process, J. Pacanovsky, Triangle Polymer Technologies, Inc., Triangle Park, NC; A. Kelkar, R. Bolick, North Carolina A&T State University, Greensboro, NC

4:10 PM

Results of an Out Time Study of a New 350°F Cure Structural Adhesive Film, P.E. Rajtar, D. Salnikov, 3M Aerospace and Aircraft Maintenance Division, St. Paul, MN

Registration Hours

Monday, September 8	7:30 AM – 5:00 PM
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Wednesday, September 10	7:30 AM – 5:00 PM
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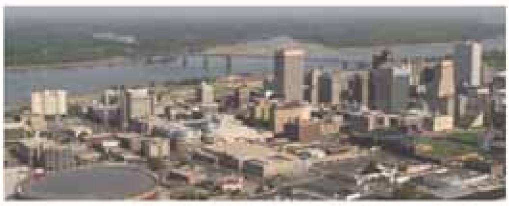

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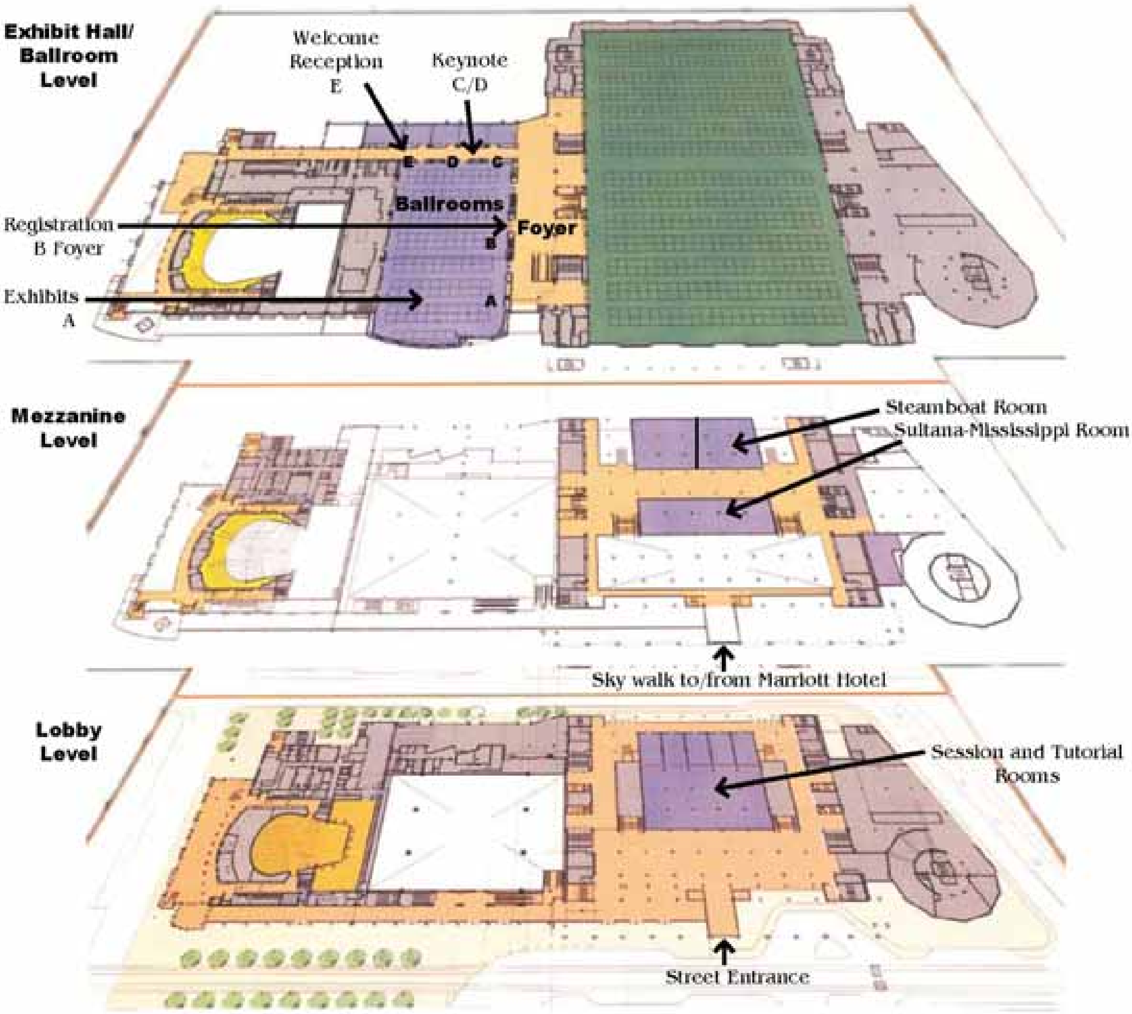

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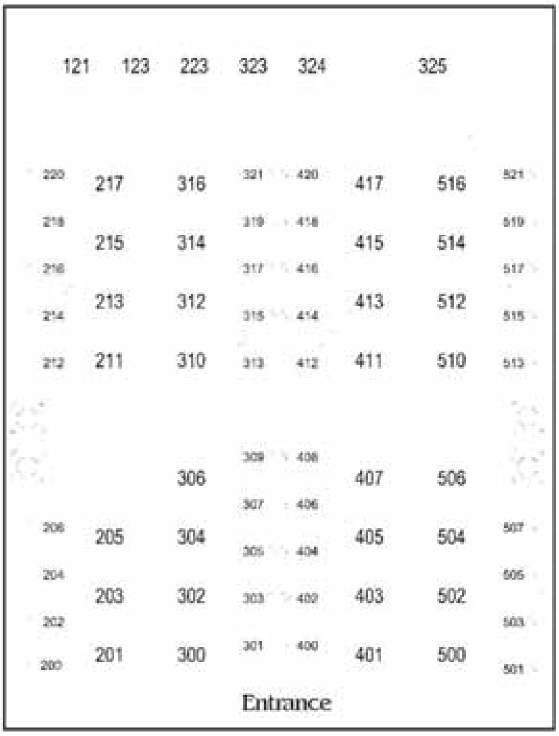

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附件二

損傷容許分析及實驗課程(Damage Tolerance of Composites: Analysis and Testing)簡報資料

DAMAGE TOLERANCE OF COMPOSITES : Analysis and Testing

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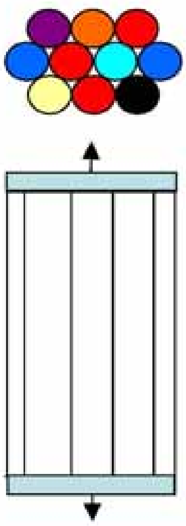
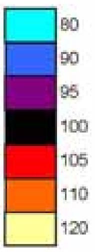
Department of Aerospace Engineering
Wichita State University

In constructing wings, one should make one cord to bear the strain and a lower one in the same position so that if one breaks under strain, the other is in position to serve the same function – Leonardo Da Vinci (on design of flying machines)

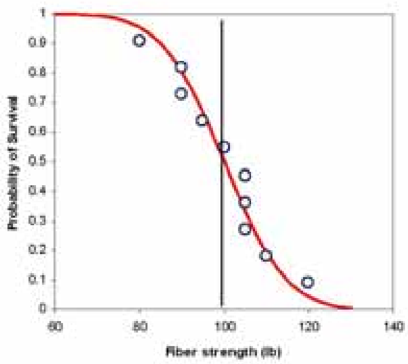
The Composite Action….

- Consider a fiber bundle (no resin or matrix)..
  - All fibers have same geometry & stiffness
  - Strengths are different





Fiber no.	Strength (lbf)
1	80
2	90
3	105
4	105
5	110
6	105
7	100
8	90
9	95
10	120
Average	100
Stdev	11.55



What is the strength of the fiber bundle ?

Progressive failure of fibers in bundle….

Increasing load →

Fiber no.	Strength (lbf)	step (1) 100	step (2) 500	step (3) 700	step (4) 800	step (4) 800	step (5) 805	step(6) 810	step(6) 810	step(6) 810
1	80	10	50	70	80 (- fails)	0	0	0	0	0
2	90	10	50	70	80	88.89	89.44	90 (- fails)	0	0
3	105	10	50	70	80	88.89	89.44	90	115.7(-fails)	0
4	105	10	50	70	80	88.89	89.44	90	115.7(-fails)	0
5	110	10	50	70	80	88.89	89.44	90	115.7(-fails)	0
6	105	10	50	70	80	88.89	89.44	90	115.7(-fails)	0
7	100	10	50	70	80	88.89	89.44	90	115.7(-fails)	0
8	90	10	50	70	80	88.89	89.44	90 (-fails)	0	0
9	95	10	50	70	80	88.89	89.44	90	115.7(-fails)	0
10	120	10	50	70	80	88.89	89.44	90	115.7	810 (-fails)
Average	100									

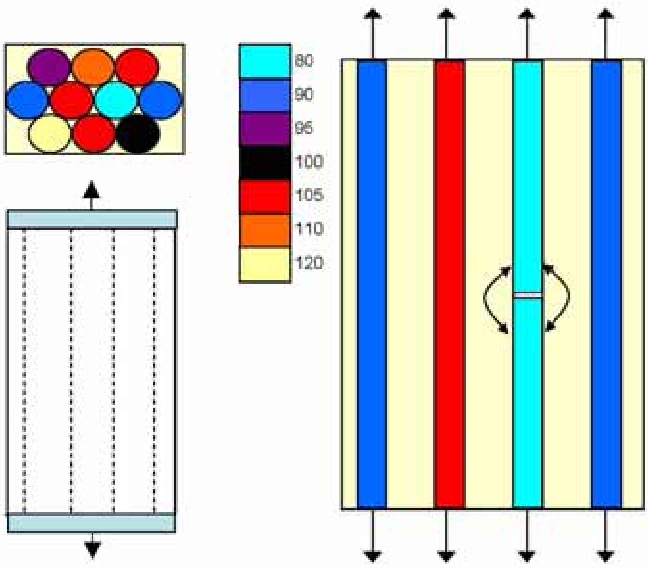
Load redistribution (step (4) 800)

Load redistribution (step(6) 810)

→ *Fibers can break only once*

Bundle fails at 810 lbs ⇒ **81 lbs/fiber < Average fiber strength**

Fiber bundle embedded in resin (matrix)



Broken fibers carry load !

- Load is redistributed /retransmitted to the broken fiber by the resin
  - Single fiber can be broken multiple-times /at multiple locations
- Neighboring fibers "pick-up" load locally --stress concentration

Agenda

- Damage Tolerance, Durability and Resistance
- Typical defects in Laminated & Sandwich Composites
- Sources of defects
- Damage Resistance & Tolerance – Experimental Observations
  - Solid Laminates
  - Sandwich Construction (WSU/NIAR)
- Analysis methods & guidelines
  - Damage Tolerance
    - Discrete damage
    - Distributed damage

Damage Tolerance

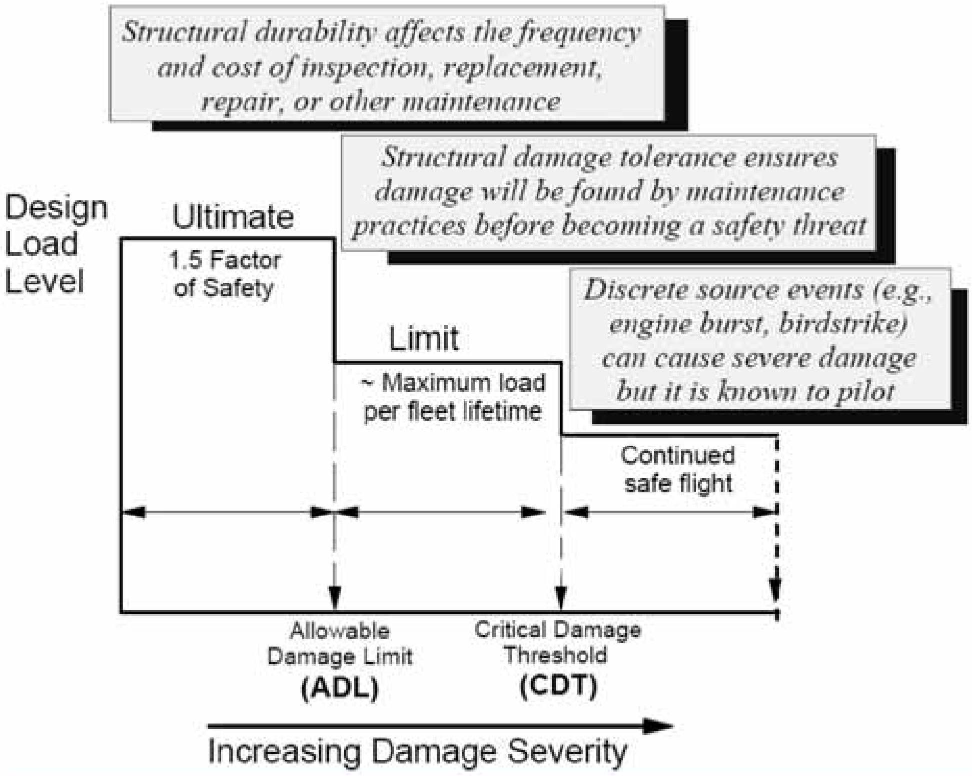
- The ability of the airframe (end product) to resist failure due to the presence of flaws, cracks, or other damage for a specified period of time (or until such damage is detected, through inspections or malfunctions, and repaired)
  - Addresses safety
  - Assumes presence of certain flaws/defects
    - Methods of damage detection/quantification
    - Growth of damage under service loads
    - Degradation of strength & stiffness with damage growth

References:
R.L. Seirakowski and G.M. Newaz, Damage Tolerance in Advanced Composites, Technomic Publishing Co.
MIL-HNDBK-17-3F

Durability

- The amount of abuse or energy a structure/material can absorb without resulting in damage[1]
- The ability of a structural application to retain adequate properties (strength, stiffness, and environmental resistance) throughout its life to the extent that any deterioration can be controlled and repaired, if there is a need, by economically acceptable maintenance practices[2].
  - Addresses economic issues

References:
[1]*R.L. Seirakowski and G.M. Newaz, Damage Tolerance in Advanced Composites, Technomic Publishing Co.*
[2]*MIL-HNDBK-17-3F*



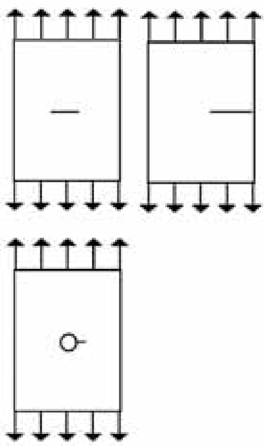
Damage Resistance

- measure of the relationship between parameters which define an event, or envelope of events (e.g., impacts using a specified impactor and range of impact energies or forces), and the resulting damage size and type[1]

References:
[1]MIL-HNDBK-17-3F

Damage/flaws in Metallic Structures

- CRACKS
  - Through thickness / part through (corner cracks)
  - Modes : I, II and III
  - Toughness
  - Growth Rate
- DENTS
- SCRATCHES
- Etc..

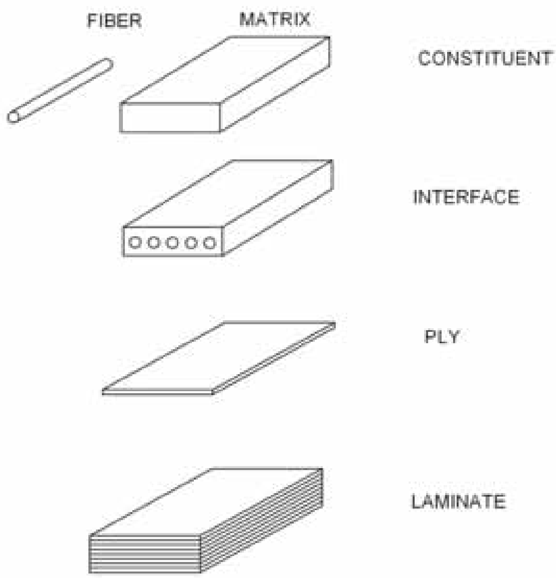


Damage/flaws in Laminated Composites

The damage/flaws in fiber reinforced composites can be classified based on their length scales and the properties they affect.The diffreent levels at which damage can occur are

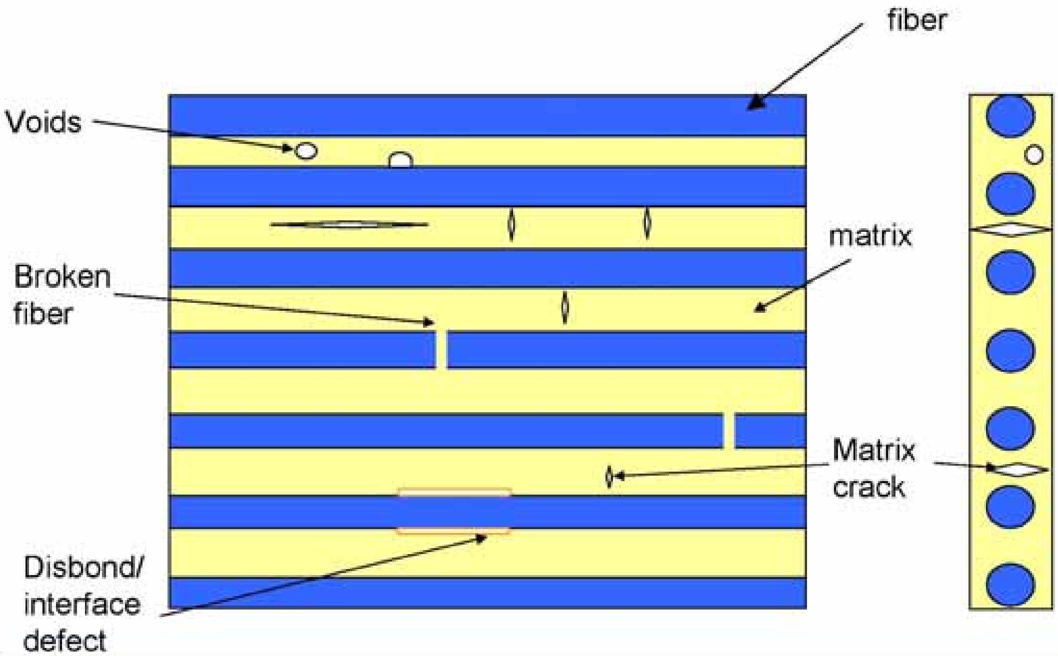
1. Constituent & Interface level
2. Ply level
3. Laminate level

The damage state in laminated composites will be a combination of the various damages states occurring at different length scales. The relative proportion/occurrences of each of these damage states will depend on the material type, stacking sequence and most importantly – the nature of the damage causing event.



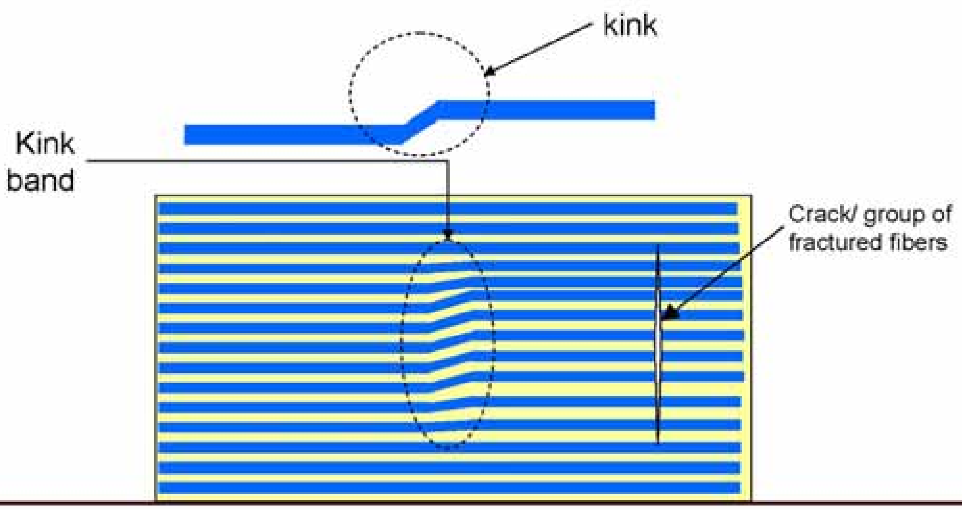
Damage/flaws in Laminated Composites

- Constituent and Interface level



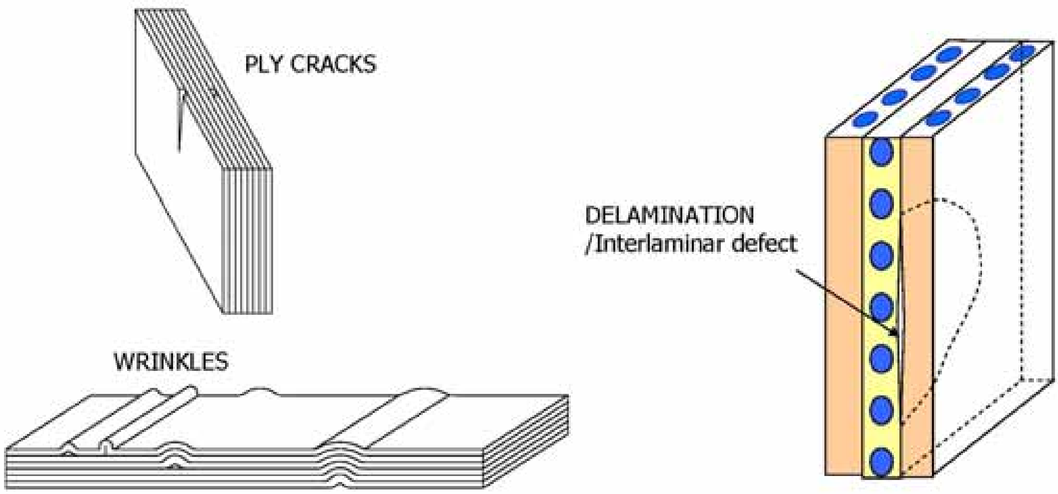
Damage/flaws in Laminated Composites

- Ply level-
  - Kink bands
    - reduces compression load capability
  - Fractured fibers



Damage/flaws in Laminated Composites

- Laminate level



Typical defects in Composites[Ref]

- Debonds
- Delaminations
- Inclusions (release film, bugs, etc.)
- Voids, blisters
- Impact damage
- Fiber misalignment
- Cut or broken fibers
- Abrasion, scratches
- Wrinkles
- Resin cracks, crazing
- Density variations
- Improper cure (soft resin)
- Machining defects (improper hole size, etc)

Ref: R.L. Seirakowski and G.M. Newaz, Damage Tolerance in Advanced Composites, Technomic Publishing Co.

Fabrication/processing induced damage (defects)[Ref]..

- Abrasions, scratches, dents, punctures
- Cut fibers
- Knots, kinks
- Voids
- Resin rich/lean areas
- Sub quality materials
- Uncured resin
- Inclusions (bugs/release film,tape, blade)
- Tool installation and removal
- Mandrel removal problems
- Tool drop (impact damage)
- Proof testing

Ref: R.L. Seirakowski and G.M. Newaz, Damage Tolerance in Advanced Composites, Technomic Publishing Co.

In-field/Service problems^Ref^…

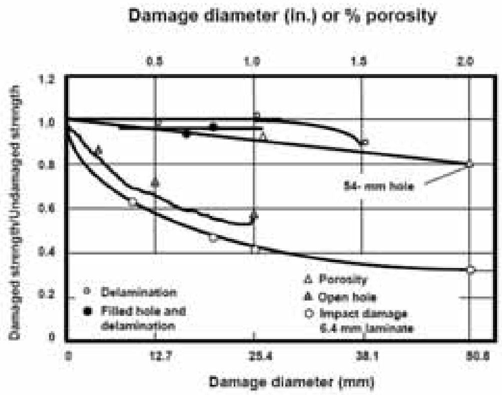
- Vibration
- Shock
- Lightning damage
- Environment cycling
- Flight loads
- Improper repair/maintenance
- Pebble impact ◀
- Scratches, dents, punctures
- Corrosion
- Erosion, dust, sand
- Bacterial degradation

Ref: R.L. Seirakowski and G.M. Newaz, Damage Tolerance in Advanced Composites, Technomic Publishing Co.

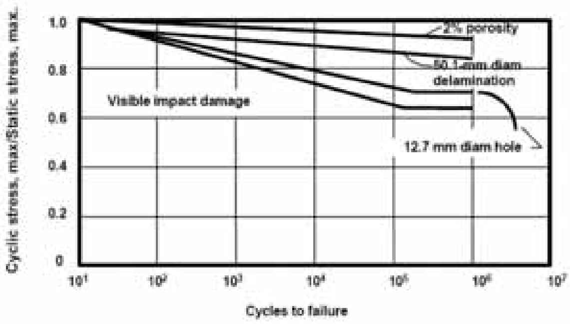
COMBINATION OF DAMAGES[1].

In general, impact events cause combinations of damages. High-energy impacts by large objects (i.e., turbine blades) may lead to broken elements and failed attachments. The resulting damage may include significant fiber failure, matrix cracking, delamination, broken fasteners, and debonded elements. Damage caused by low-energy impact is more contained, but may also include a combination of broken fibers, matrix cracks and multiple delaminations. There is some experimental evidence that, for relatively small damage sizes, impact damage is more critical than other defects (see figures). Note that all of the data shown in these figures are for damage sizes less than 2 inches (50 mm). Some results for damages greater than 2 inches (50 mm) suggest large holes or penetrations are at least as severe as equivalent sizes of impact damage.

- **Impact damage has been observed to be a severe form of damage**
  - **Residual strength**
  - **Fatigue life**



Relative severity of defect damage on static compression strength.

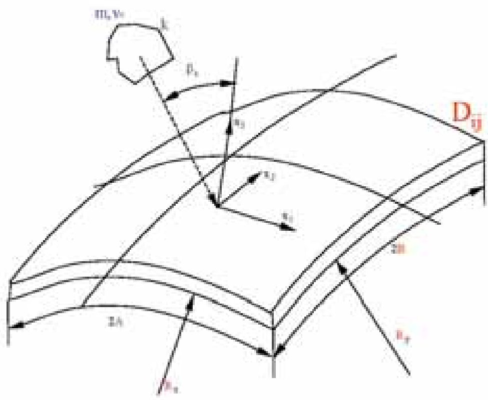


Relative severity of defect damage on compression fatigue strength, R=10.

References: [1]MIL-HNDBK-17-3F

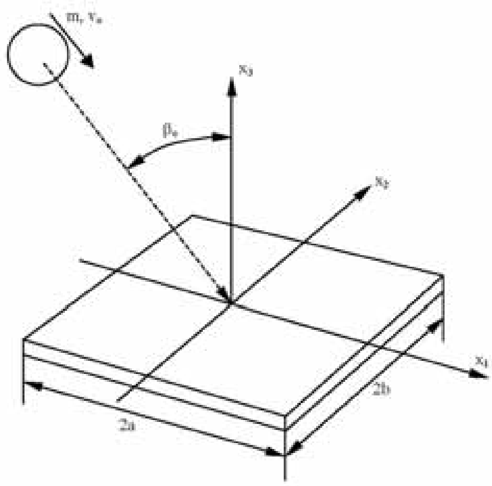
Impact Damage Resistance…

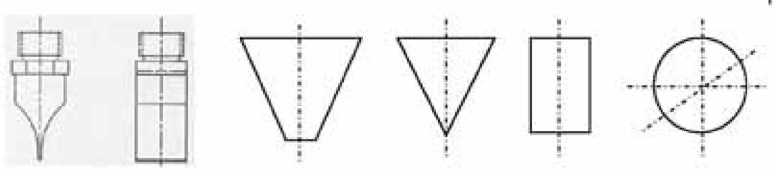
- VARIABLES
  - EXTRINSIC
    - Impactor geometry
    - Impactor mass
    - Impactor material
    - Impact energy,velocity, angle
    - Boundary conditions
  - INTRINSIC
    - Structure type
      - Laminated, sandwich , stiffened etc
    - Material(s)
    - Layup Schedule
    - Structure Geometry



Impact Damage Resistance…

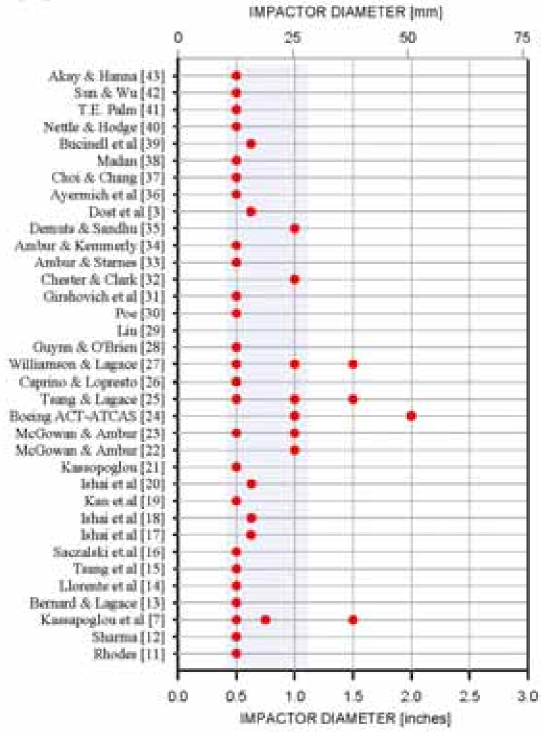
- IDEALIZED CONDITIONS
  - Flat structures
  - Spherical/hemispherical, cylindrical, conical impactors
  - Normal Impacts
  - Clamped, simply-supported or rigid base boundary conditions
  - Test sections – rectangular, circular





Impact Damage Resistance...

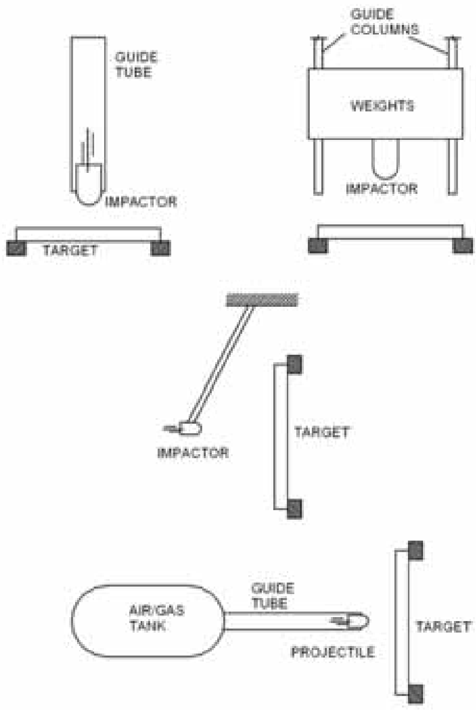
- Impactor types
  - Spherical
  - Steel, Aluminum, plastic
  - Impactor diameters
    - 0.5" to 3"



The impactor shapes, sizes and materials are representative of the geometry and material of the actual object/projectile that causes damage in service. The objects/projectile (e.g., gravel, hail stone, hand tools, baggage, etc) may not necessarily have a well defined geometry and stiffness. The shapes used in experimental investigations are chosen due to the simplifications they facilitate during analysis. Further using a regular geometry can help characterize the effects of geometric features such as radius, etc., in a systematic manner.

Damage Resistance...

- Test Methods
  - ASTM D7136
  - various...
- Test Apparatus/ Methods
  - Static indentation
  - Drop-weight impact tests
    - Gravity assisted
    - Spring loaded
  - Impact Pendulums
  - Gas guns
- Test Objectives
  - Time history of force, velocity, displacement, energy, strain (if instrumented), etc.
  - Energy absorption
  - Impact damage characterization



Damage Resistance…

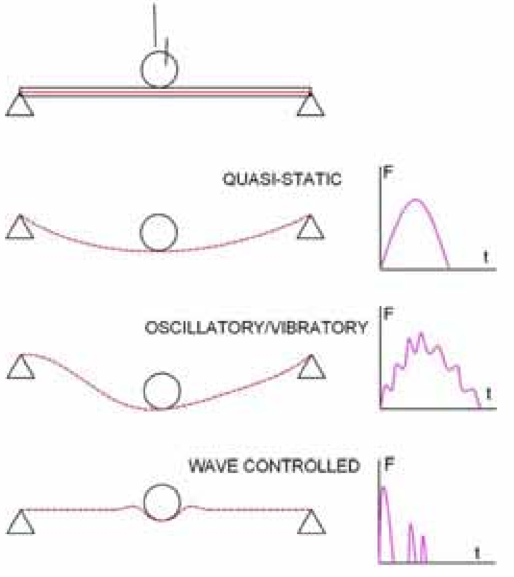
Types of impact events

Depending on the relative properties (stiffness, strength mass, velocity) of the projectile and the target, the target undergoes different deformation modes. These deformation modes result in different damage states. The damage causing events may be classified as quasi-static, vibratory and wave propagation phenomena depending on the various combinations of the above mentioned variables.

Quasi-static events are those when the global deformation of the target is established through out the impact event (or for the duration of contact between the projectile and target). This situation prevails when the fundamental frequency of the projectile is vary large in comparison to that of the target. The force-time history for such impact is characterized by smooth sinusoid type curves.

Vibratory impact represents the case in which the different vibration modes of the target are involved in the impact process. Depending on the combination of impactor and target properties, certain vibrational modes will be dominant. The force-time history for such impacts is characterized by the presence of higher frequency oscillations which indicates the presence of different vibratory modes.

When the duration of impact is much smaller than the time required by a flexural wave to reach the boundary(ies), such events are known as wave controlled impacts.

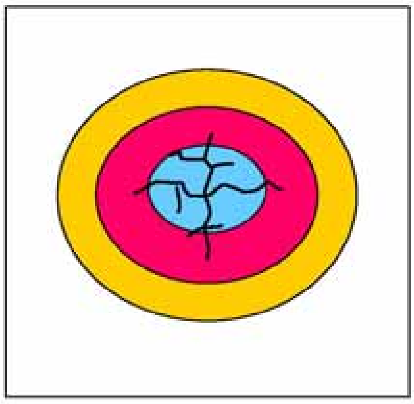


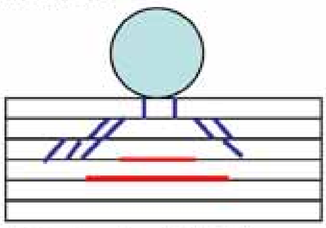
Ref. R.L. Serakowski and G.M. Newaz,

$\left(T_{PULSE}/T_{target}\right)$	Response
$< \frac{1}{4}$	Wave Controlled
$\frac{1}{4} < \frac{T_{PULSE}}{T_{target}} < 4$	Osciallatory
> 4	Quasi - Static

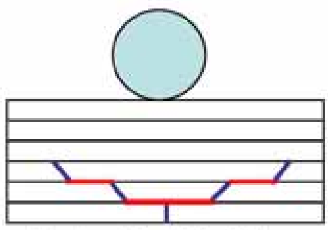
Damage Resistance – Impact Damage…

- IMPACT DAMAGE STATES
  - Distributed, asymmetric damage
    - Ply / laminate fractures
    - Distributed matrix cracks
    - Delaminations
    - Disbonds
    - Punctures
    - dent
    - Combination of the above in varying proportions
  - Laminated vs. sandwich structures
    - Core damage





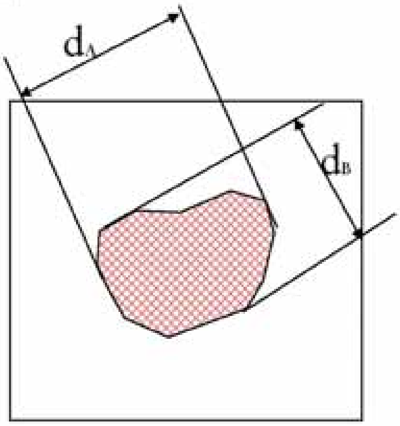
Hard striker/Stiff Target

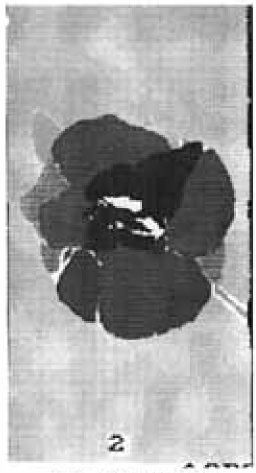


Hard striker/Flexible Target

IMPACT DAMAGE...

- DAMAGE CHARACTERIZATION
  - Destructive methods
    - Sectioning
    - Thermal deplying
    - Non-destructive methods (NDI)
      - TTU
      - Pulse-echo
      - X-ray
      - Tap testing
      - Non-contact strain mapping
      - etc
  - DAMAGE METRICS
    - Planar damage size
      - Diameters, areas
        - »Projection of all damage states
      - Damage depth
      - Dent depth distribution



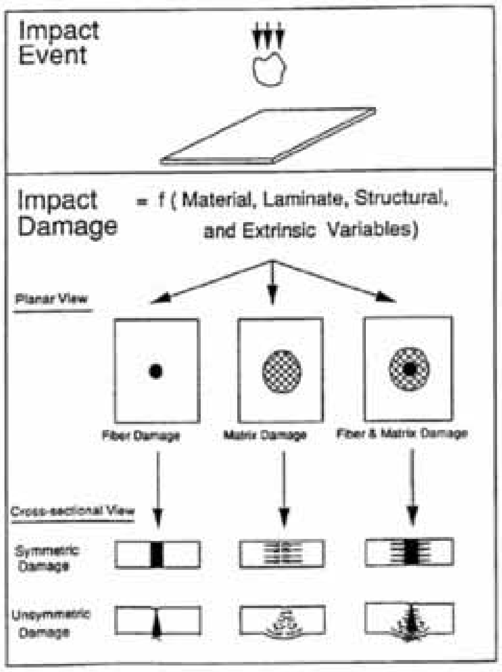


16-ply

Ref: NASA/Boeing ATCAS,

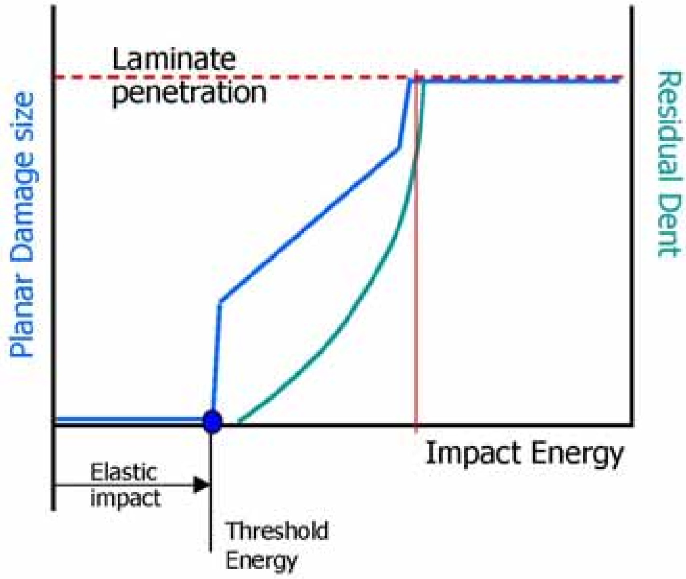
IMPACT DAMAGE IN LAMINATES...

- Damage (metrics) depend on
  - Material
    - Toughness
    - Weave style
  - Thickness
  - Layup sequence
  - Impactor



Ref: L.B. Ilcewicz & E.F. Dost NASA/Boeing ATCAS, NASA-CP-10075, 1991

Impact Damage in Laminates…



The planar damage size and damage depth have been observed to follow a characteristic trend as illustrated in the accompanying figure. At low impact energy levels which result in low enough impact forces, the impact behavior will be elastic in nature. Some amount of the impact energy will be transferred to the target structure as kinetic (vibration energy) and the remainder returned back to the impactor.

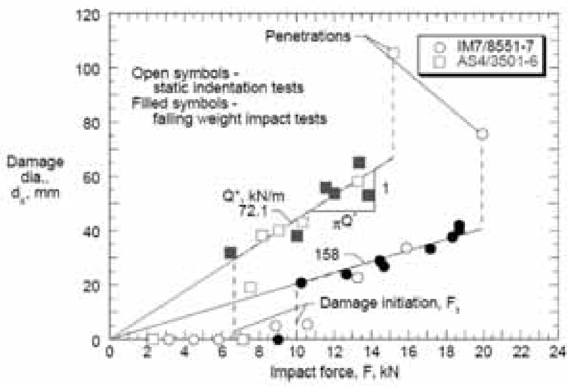
At a certain impact energy level, damage is initiated in the target structure. This energy level is called as threshold energy level. The threshold energy level is dependent on several factors which include the impactor geometry and stiffness, target properties (e.g., material, layup, size, boundary conditions, etc.)

The planar damage size and damage depth increase proportional to the impact energy past the threshold level. The rate of increase is again a function of the impactor and target properties. With increasing energy levels, the amount of fiber fracture will increase resulting in tearing of the laminate. The plies in the damaged region have less stiffness and

Ref : MIL-HDBK-17-3F

Impact Damage …Laminate material effects

- The ability of composite structures to resist or tolerate damage is strongly dependent on the constituent resin and fiber material properties and the material form. The properties of the resin matrix are most significant and include its ability to elongate and to deform plastically. The area under a resin's stress-strain curve indicates the material's energy absorption capability. Damage resistance or tolerance is also related to the material's interlaminar fracture toughness, G, as indicated by energy release rate properties. Depending on the application G_I, G_{II}, or G_{III} may dominate the total G calculation. These parameters represent the ability of the resin to resist delamination, and hence damage, in the three modes of fracture. The beneficial influence of resin toughness on impact damage resistance has been demonstrated by tests on newer toughened thermoset laminates and with the tougher thermoplastic material systems.

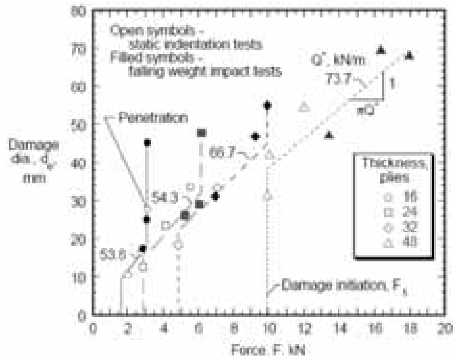


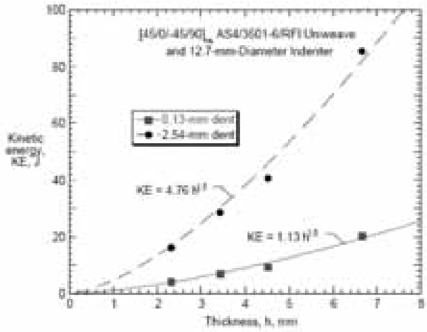
Investigations have been conducted on the effect of fiber properties on impact resistance. In general, laminates made with fabric reinforcement have better resistance to damage than laminates with unidirectional tape construction. Differences among the carbon fiber tape laminates, however, are small. Some studies have been made of composites with hybrid fiber construction, that is, composites in which two or more types of fibers are mixed in the lay-up. For example, a percentage of the carbon fibers are replaced with fibers with higher elongation capability, such as fiberglass

Ref : MIL-HDBK-17-3F

Impact Damage …Laminate thickness effects

The damage (planar size and dent depth) formed in laminates has been shown to be dependent on the laminate thickness. The maximum planar damage that can be inflicted on a laminate prior to penetration, is dependent on the thickness of the laminate. The thicker laminates accommodate more planar damage prior to penetration, thus absorbing more energy in the process. In addition, the impact forces associated with planar damage initiation has been observed to be proportional to the laminate thickness.

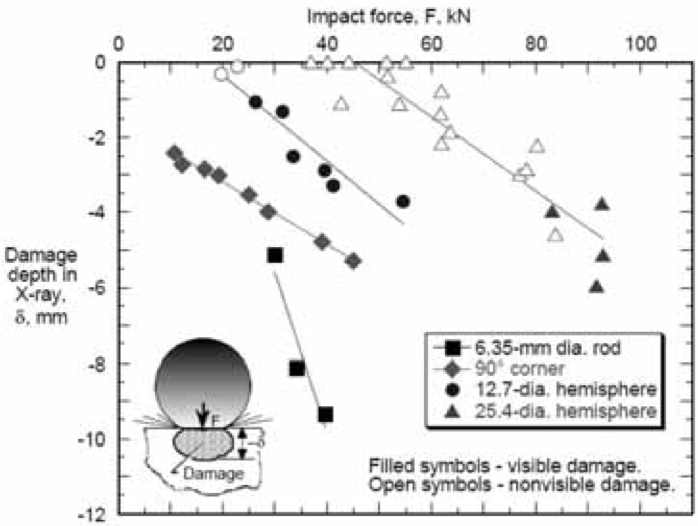




Damage resistance of [45/0/-45/90]$_{ns}$ AS4/3501-6/RFI uniweave using 0.5 in. (12.7 mm) diameter indenter.

Ref : MIL-HDBK-17-3F

Impact Damage …Impactor size/shape effects

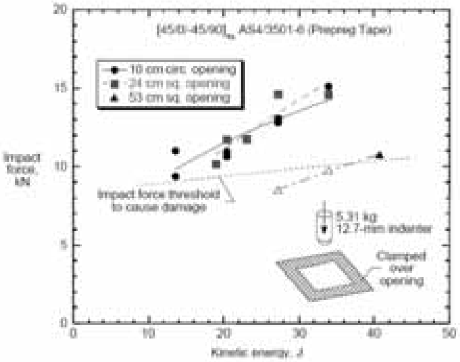


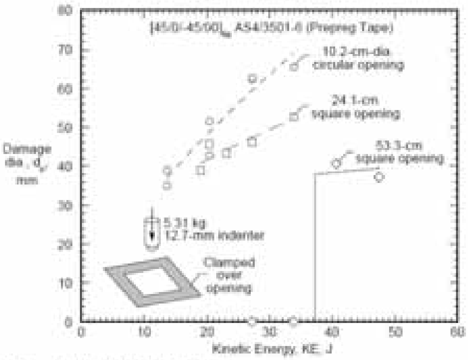
Impact damage for 1.4 in. (36 mm) thick AS4/epoxy filament wound case (FWC) with impactors of various shapes (Reference 7.5.1.4).

Impact damage depth governed by the contact load distribution between the projectile & target. With stiffer and smaller/sharper projectiles, the contact force is distributed over a smaller area. Since the transverse properties of laminates are typically lower than in-plane properties by order(s) of magnitude, high contact stresses will initiate damage in the laminate. With blunt (large diameter) impactors, the laminate (target) tends to wrap around the impactor as it deforms (bends). This increases the contact area between the target and the impactor. Thus with blunt impactors, it takes higher force to initiate damage in the laminate/target.

Ref : MIL-HDBK-17-3F

Impact Damage ...Size effects





Energy Balance....

$$E_{TOTAL} - E_{REB} = E_{DMG} + E_{VIB} + E_{RES}$$

E_{TOTAL} : Impact/kinetic energy of projectile

E_{REB} : kinetic energy returned to projectile (rebound)

E_{DMG} : Energy dissipated due to damage formation

E_{VIB} : Energy transferred to structure as vibrational energy (+ damping)

E_{RES} : Energy associated with residual elastic field

The bending stiffness of the test specimen decreases with increasing test section (distance between supports). The reduced bending stiffness results in lower impact forces, lower local contact stresses due to increased contact area, and the energy transferred to the specimen as vibrational energy increases. Thus the threshold energy increases with the size/compliance of the structure. This is true for low-velocity impacts where the global deformation is established during the impact process. However, under high speed impacts, the interaction of target and impactor will be independent of the boundary conditions on the target.

Ref : MIL-HDBK-17-3F

Damage Tolerance Tests..

- Tension Tests
  - Dominated by fiber properties
- Compression (Compression-After-Impact*) tests
  - In-plane loading
  - most severe loading mode (based on strength degradation)
  - Failure modes – delamination, local fiber buckling (kinking), fracture across net-section, global buckling, etc.
  - ASTM D7137
- Shear Tests
- Flexure Tests
- Fatigue

* This test is typically conducted to obtain a measure of the tolerance to impact damage and hence the name.

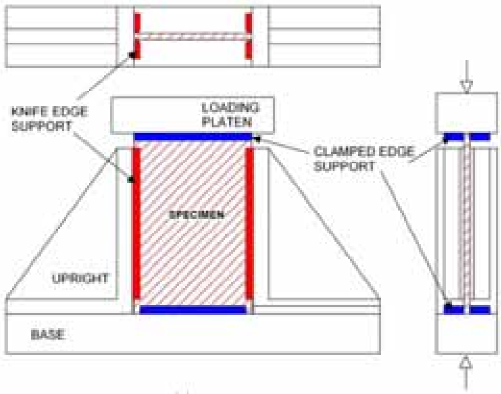
Damage Tolerance Tests..

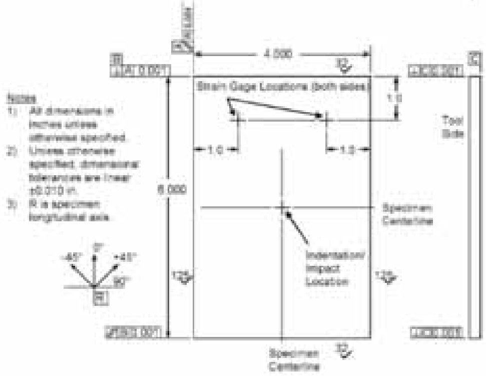
Compression (CAI) tests

The CAI tests are conducted to obtain a measure of the tolerance of a laminate to a damage caused by a specific impact event. This test method is often used for screening material systems.

The test method involves the in-plane compressive loading of a rectangular laminated specimen. The loading is introduced along the edges (top & bottom) of the specimen as illustrated in the accompanying figure. The stability of the specimen is always a concern during this test. Thus, appropriate supports along the lateral (vertical) edges and loading edges must be provided to avoid buckling problem.

The compressive loading is very sensitive to the specimen geometry and alignment of the text fixture. The loading edges have to be parallel and the loading surfaces have to be perpendicular to the plane of the specimen. In addition, the two loading surfaces of the fixture must be parallel to ensure uniform load distribution along the width and across the thickness of the specimen. To facilitate a measure of the uniformity of load introduction along the edges, back to back strain gages are bonded to the test specimen as shown in the figure. The specimens are typically preloaded to about 100lbf to obtain a measure of the bending introduced due to misalignment of specimen and non-parallelism of loading edges. Remedial measures are taken if necessary





Ref: ASTM D7137

Compression (CAI) tests...

The bending due to aforementioned reasons may be alleviated by using an alignment platen and/or shimming. As a rule of thumb, the load distribution is considered to be uniform if the differences between strain gage readings are less than 5%. If the impact damage in the specimen is severe enough (i.e., significant dent and fiber fracture), the bending deformation cannot be avoided.

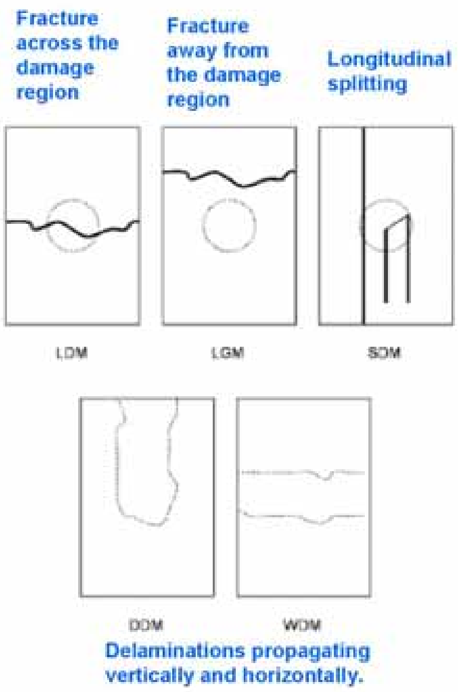
The compression test is conducted by loading the test fixture using an electromechanical or servo hydraulic test stand. The test is conducted under stroke or displacement control at a constant speed of 0.05 in/min (Ref. ASTM D7137). The crosshead or actuator displacement, force and strains are recorded continuously during the test. The maximum load supported by the specimen prior to failure is used to compute the CAI strength.

The CAI strength is given by

$$F^{CAI} = \frac{P_{MAX}}{A}$$

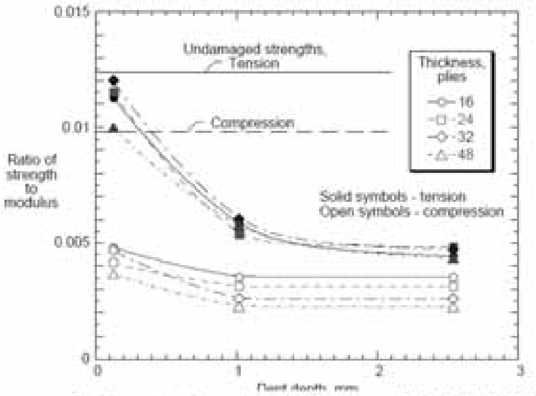
Where, P_{MAX} is the maximum load prior to failure and A is the cross sectional area of the specimen.

Depending on the material type, stacking sequeqnce and nature of impact damage, different failure modes may be observed under compressive loading. Some of the acceptable modes (per ASTM D7137) are illustrated in the figure

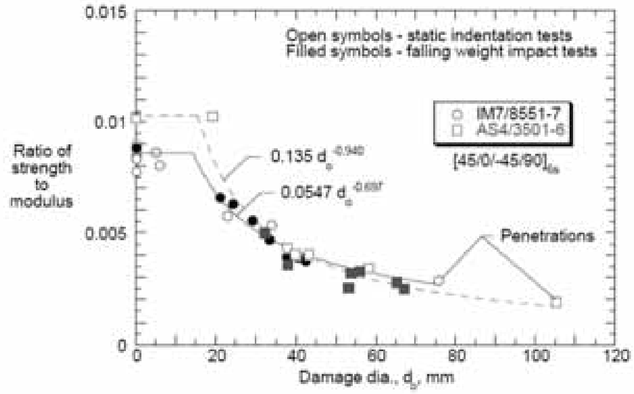


Ref: ASTM D7137

Residual Strengths of Laminates..



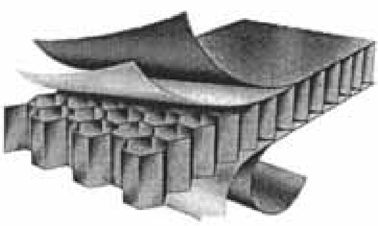
Post-impact tension and compression strengths for [45/0/-45/90]$_{ns}$ AS4/3501-6/RFI uniweave (0.5 in. (12.7 mm-diameter tup))

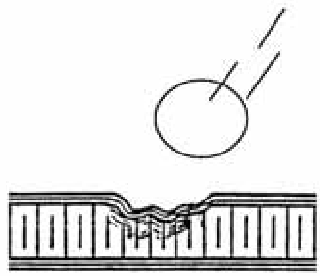


In general, for a given laminate type and damage state, the residual strength will be dependent on the loading mode. For example, if the damage state consists of small dent and negligible fiber fracture, the tensile strength degradation will not be as high as the compression strength. This is due to the stabilizing effect of the tensile loading (it tends to straighten the dent). Both tensile and compressive strengths have been observed to approach a plateau with increasing damage size and severity. While the residual compressive strength may be lower in magnitude relative to the tensile strength, the percentage degradation relative to the undamaged strength may be the same in both cases. The choice of loading mode used to evaluate the damage tolerance of a certain laminate should be driven by the loading mode associated with the end application. A wrong choice of loading mode may lead to weight penalties and/or an unsafe structure.

Sandwich Damage Resistance & Tolerance investigations at WSU/NIAR

- Funding Agency : FAA William J. Hughes Technical Center, Atlantic City, NJ
- Program monitor : P. Shyprykevich, C. Davies
- P.I. : J.S. Tomblin
  - Co-P.I : K.S. Raju B.L. Smith (1999 – 2001)

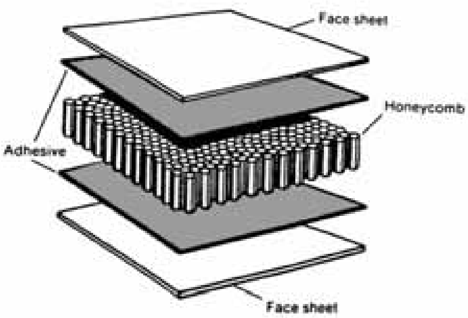




Issues addressed

- Sandwich structures with thin-facesheets (2 to 6 plies) : representative of most General Aviation airframes
- Damage resistance – typical damage states
  - Effects of facesheet, core (thickness) and impactor diameter on damage size and type
  - NDI methods for damage detection
- Damage tolerance – CAI
  - Failure mechanisms
- Curvature effects
- Scaling effects
- Fatigue
- Comparison with open-hole configuration
- Full-scale testing under combined loading
  - Longitudinal, pressurization induced hoop loading

MATERIAL SYSTEMS & SANDWICH CONFIGURATIONS...



SKINS

- NB321/3K70P PLAIN WEAVE CARBON FABRIC
- NB321/7781 SATIN WEAVE GLASS FABRIC

CORE

- PLASCORE PN2-3/16-3.0 HONEYCOMB [3/8" & 3/4" thick]
- DIVINYCELL HT-50 FOAM [3/8" & 3/4" thick]

ADHESIVE

- Hysol 9628.060 PSF NW film adhesive

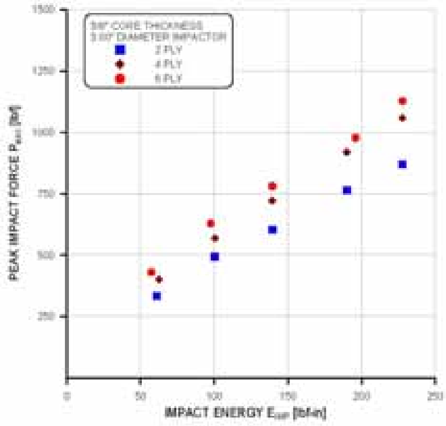
- Quasi-isotropic, thin skins [0.016" to 0.048"]
- Similar to current GA practices

[(90/45)/CORE/(45/90)]

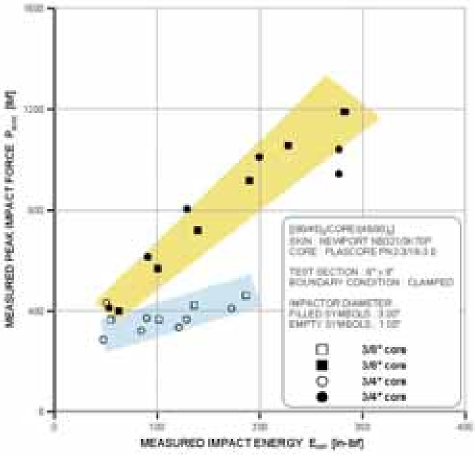
$[(90/45)_2/CORE/(45/90)_2]$

$[(90/45)_3/CORE/(45/90)_3]$

LOW-VELOCITY IMPACT TESTING…



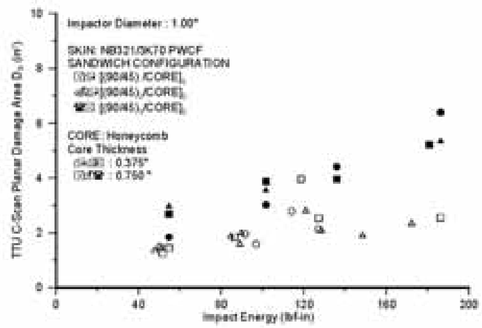
- TEST CONFIGURATION
  - CLAMPED EDGES
  - 8″x 8″ TEST SECTION
  - IMPACTOR DIAMETERS
    - 1.00″ AND 3.00″
  - IMPACT VELOCITY
    - 96 in/sec



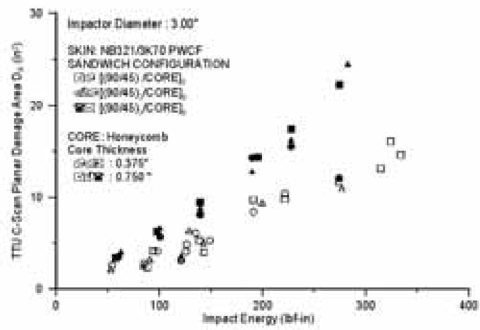
- PEAK IMPACT FORCE
  - PANELS SUSTAIN HIGHER IMPACT LOADS WITH LARGER DIAMETER IMPACTORS
  - DIFFERENCES TEND TO DIMINISH AT LOWER ENERGY LEVELS
  - PROPORTIONAL TO SKIN STIFFNESS

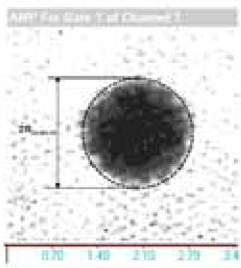
c.f. DOT/FAA/AR-00/44 January 2001

NON-DESTRUCTIVE IMPACT DAMAGE CHARACTERIZATION…



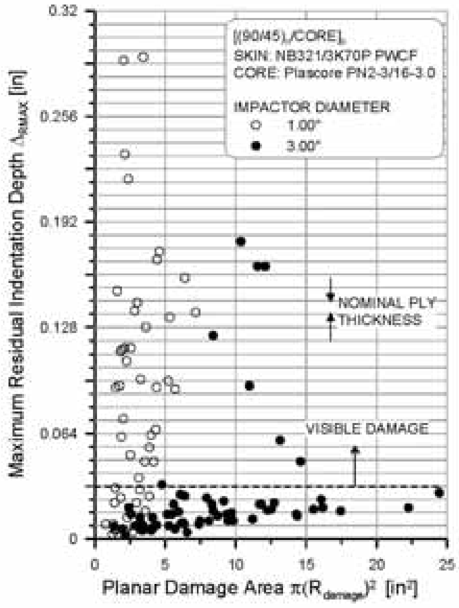
- TTU C-SCAN DAMAGE SIZE
  - PROPORTIONAL TO IMPACTOR DIAMETER
  - LARGER DAMAGE SIZE FOR THINNER CORE
    - CORE PROPERTIES
  - DIFFERENCES TEND TO DIMINISH AT LOWER ENERGY LEVELS
  - DAMAGE SIZE SATURATES UPON INITIATION OF SKIN DAMAGE
  - VISIBLE SKIN DAMAGE PREVALENT IN PANELS IMPACTED WITH 1.00" IMPACTOR





NON-DESTRUCTIVE IMPACT DAMAGE CHARACTERIZATION...

- Impact damage state governed by impactor size
  - 1″ diameter impactor
    - Significant indentation depth
    - Small planar damage size
    - Visible skin damage/fractures
  - 3″ diameter impactor
    - Large planar damage size
    - Indentation depth less than facesheet thickness due to springback
    - No visible skin damage



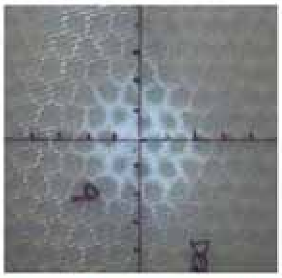
DESTRUCTIVE DAMAGE EVALUATION

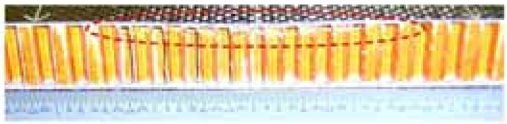
- **1″ IMPACTOR**
  - SKIN FRACTURE
  - CORE CRUSH
  - DAMAGE SIZE ∝ IMPACTOR SIZE
  - CORE DAMAGE PROPAGATES ACROSS THICKNESS

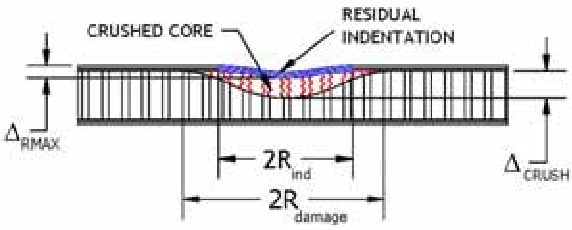
- **3″ IMPACTOR**
  - NO VISIBLE SURFACE SKIN DAMAGE
  - CORE FRACTURE
  - CORE DAMAGE PROPAGATES ACROSS WIDTH

IMPACT DAMAGE IN SANDWICH PANELS & DAMAGE METRICS

- **FACESHEET DAMAGE**
  - Delaminations
  - Fractures
  - METRICS
    - Facesheet Damage Diameter
    - Fracture Length
- **CORE DAMAGE**
  - Core crushing
  - Cell wall fractures
  - METRICS
    - Core crush Depth Δ_{CRUSH}
    - Core Damage Diameter $2R_{damage}$
- **RESIDUAL INDENTATION**
  - METRICS
    - Diameter of Indentation region $2R_{ind}$
    - Maximum Indentation Depth Δ_{RMAX}

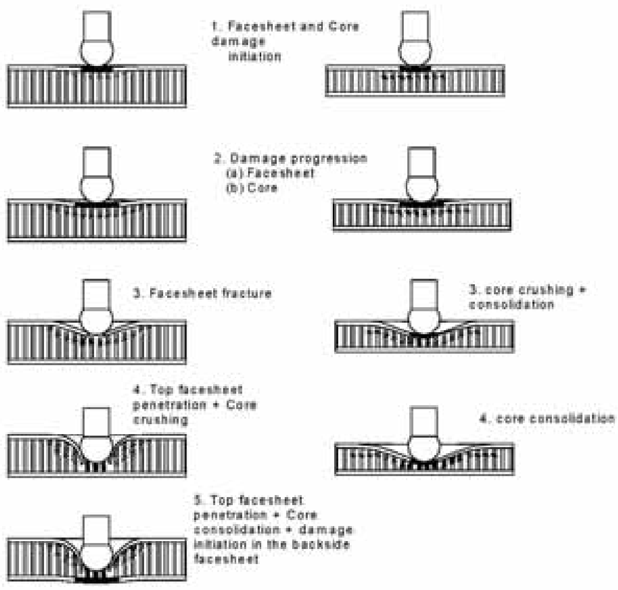




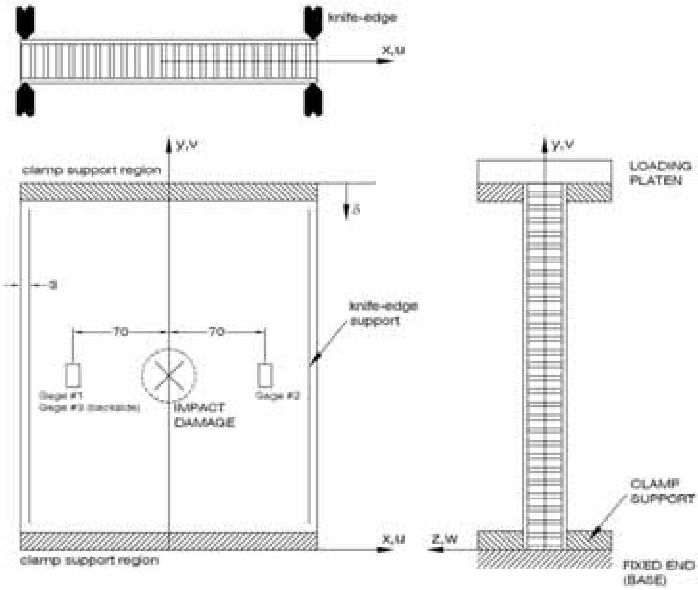


Damage evolution in sandwich panels

The core thickness and impactor diameter influence the planar damage size significantly. The sandwich panels with thicker cores produce damage sizes which are consistently smaller than those of panels with thinner core. This can be attributed to the two contrasting damage progression mechanisms in these panels, which are based on destructive sectioning of impact damaged panels, as illustrated in the figure. The amount of core compression that can be achieved prior to core compaction is limited by the core thickness. The initiation of facesheet fracture is further governed by the amount of localized bending that can be accommodated due to the indentation deformation. Thus, a thicker core, where core crush depth can be larger, thus accommodating more facesheet bending, results in smaller damage regions and facesheet fracture initiation at relatively lower energy levels. Further, the core cell damage tends to propagate across the width of the panel for thinner cores and thicker facesheets, while the cell walls collapse in an accordion manner in sandwich panels with thicker cores, over a smaller area.



Compression After Impact Testing



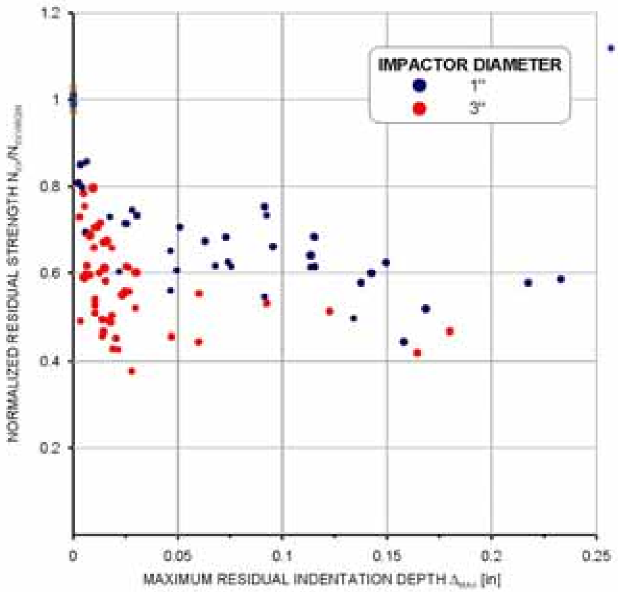
SPECIMEN CONFIGURATION

- CLAMPED END CONDITIONS ALONG LOADING EDGES
- KNIFE EDGE SUPPORT ALONG VERTICAL EDGES
- LOCAL BUCKLING OF SKIN NOT CONSTRAINED ALONG VERTICAL EDGES
- FAR-FIELD STRAIN GAGES
  - ALIGNMENT CHECK
  - FAILURE STRAINS

TEST CONTROL

- DISPLACEMENT CONTROL
- 0.05 in/min

Residual Strength Characterization

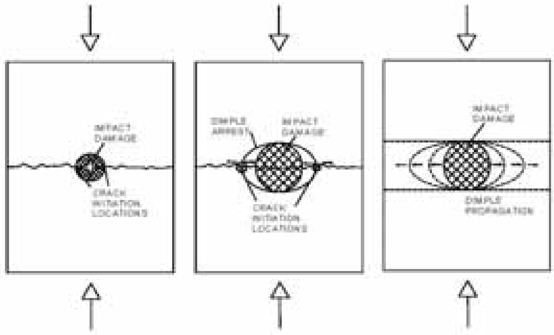


- MAXIMUM RESIDUAL INDENTATION
  - RESIDUAL STRENGTH REDUCED BY ABOUT 60% IN PANELS IMPACTED WITH 3″ IMPACTOR
    - INDENTATION LEVELS < SKIN THICKNESS
  - RESIDUAL STRENGTH REDUCED BY ABOUT 50% IN PANELS IMPACTED WITH 1″ IMPACTOR
    - INDENTATION LEVELS > SKIN THICKNESS
  - MAXIMUM RESIDUAL INDENTATION IS NOT SUITABLE FOR BVID DEFINITION !

BEHAVIOR OF DAMAGED SANDWICH PANELS UNDER IN-PLANE COMPRESSIVE LOADS & FINAL FAILURE MODES

Depending on the state of impact damage and the sandwich configuration (thin/thick facesheet , thin/thick core), three contrasting failure mechanisms and resulting final failure modes can be observed in sandwich panels under in-plane compression loads.

The first mechanism involves a net-section compression facesheet fracture. This occurs in specimens with facesheet fractures and excessive dents such as those occurring when the impacted facesheet has been penetrated.



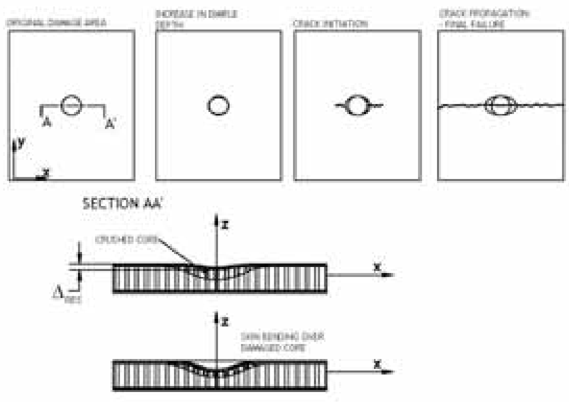
The second mechanism involves the formation of a dimple which is nothing but the facesheet bending locally over the damaged core. Under certain circumstances (e.g., thin facesheets), the dimple will only grow in depth (i.e., bending of facesheet) but not in its planar size or will be arrested after a limited growth. This local bending leads to formation of cracks at the edges of the dimple resulting in facesheet fracture

In the third mechanism, similar to the previous mechanism, the dimple forms and grows in depth and width. At a certain load level, the planar size of the dimple is arrested by the healthy core and thus the dimple depth alone increases. If the facesheet is thick enough, the bending energy accumulated in the facesheet locally is released by initiating new core crush and propagating the dimple in a unstable manner.

Mechanism-II

Impact damage states & Sandwich Configurations

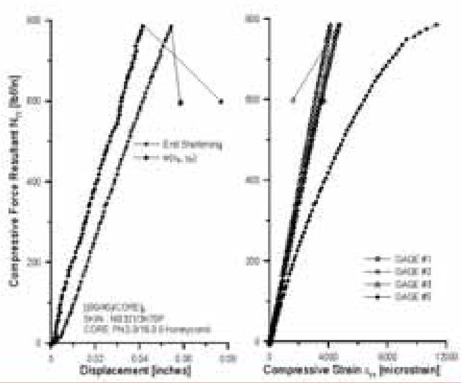
- **Facesheet with deep dents due to impact (e.g., 1" impactor)**
- **Thin facesheets impacted with large diameter impactors(e.g., 3" impactor)**
- **Thick cores**



Failure mechanism & Final Failure Mode

Here, the impact damage is effective as a stress raiser. The bending of the facesheet over the core results in a region that is less stiffer than the surrounding region under in-plane compression. This results in a situation similar to an "open hole", i.e., a stress concentration. A crack initiates at the edge of the dimple and propagates width wise resulting in COMPRESSIVE SKIN FRACTURE

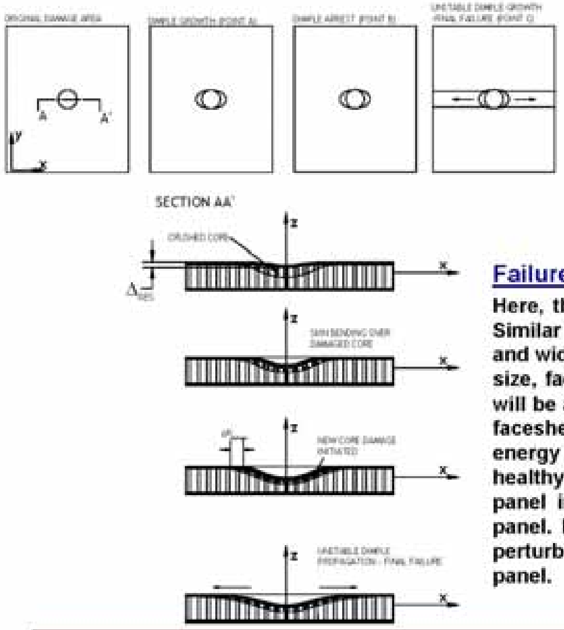
The above mechanism is captured by measuring the surface strains (along loading direction) and out-of-plane displacement at the center of the dimple (damage region). The variation of displacement and strain with applied loading is shown in the accompanying plots. The out-of-plane displacement and strain at the center of simple increase monotonically indicating facesheet bending over damaged core. If the core is thin, the dimple will perturb the back side facesheet resulting in global buckling

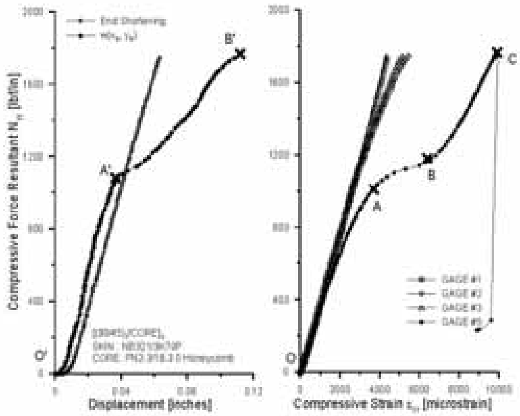


Mechanism-III

Impact damage states & Sandwich Configurations

- Facesheets impacted with large diameter (e.g., 3" impactor) and no visible facesheet damage
- Thick facesheets, Thin facesheets and thin core



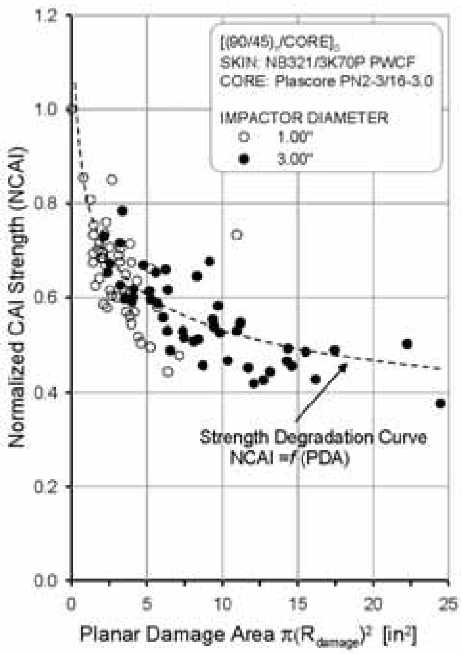


Failure mechanism & Final Failure Mode

Here, the impact damage is effective as a geometric imperfection. Similar to the previous case, the dimple forms and grows in depth and width and at a certain load level (which is a function of damage size, facesheet & core properties), the planar growth of the dimple will be arrested (point B). With increasing load, the local bending of facesheet will lead to accumulation of strain energy locally. This energy will be released by initiating the crushing of the surrounding healthy core. The dimple will propagate across the width of the panel in an unstable manner resulting in buckling failure of the panel. If the core is thin, the initial bending of the facesheet will perturb the backside facesheet and trigger a global buckling of the panel.

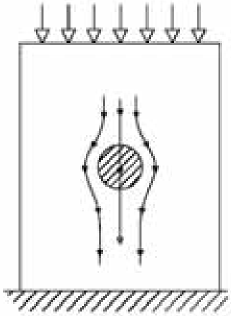
Compressive Residual Strength of Sandwich Panels

- Compression Strength (CAI) governed by planar damage size
  - Panels impacted with smaller (≤1") impactor or with facesheet fractures (high energy levels)
    - Compressive skin fracture propagating from the impact damage site to the outer edges
  - Panels impacted with larger impactors (>1")
    - Formation of dimple around the impact site
    - Failure initiation due to stress concentration at edge of dimple (thin facesheets)
    - Propagation of dimple across the width of panel (thick facesheets)

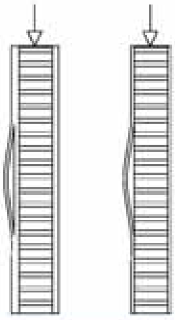


Comparison of Impact Damage severity with other Damage states (Sandwich panels)

- Impact Damage
  - Distributed damage which includes material damage (facesheet and core damage) and geometric imperfection (residual dent)
  - Since the facesheet in the damage region retains some fraction (depends on energy level) of the initial stiffness, some amount of load is carried by it. Thus, the damaged region supports some of the applied loading.



- Delaminations & Disbonds [facesheet/core]
  - Manufacturing induced.
  - Load transmitted through the delaminated/disbond region causes outward buckling of the facesheet. Fracture toughness of the facesheet (or faceheet & core interface) will govern the propagation of delamination (or disbond)
  - These damage states seldom occur due to impact loading. Core damage is always present!



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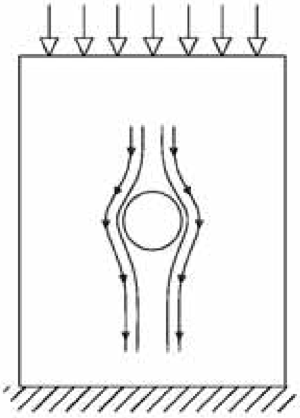
Comparison of Impact Damage severity with other Damage states (Sandwich panels) ...

- Discrete Damage
  - Open-hole, notches, etc. (idealizations?)
  - Since no material is present in the damage region, the load has to go around this region thus generating the stress concentration effect
  - These damage states are easier to simulate and quantify



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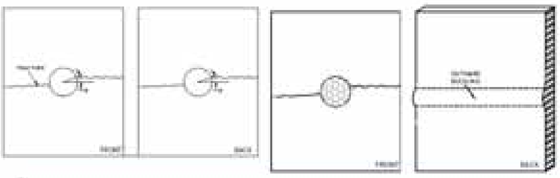
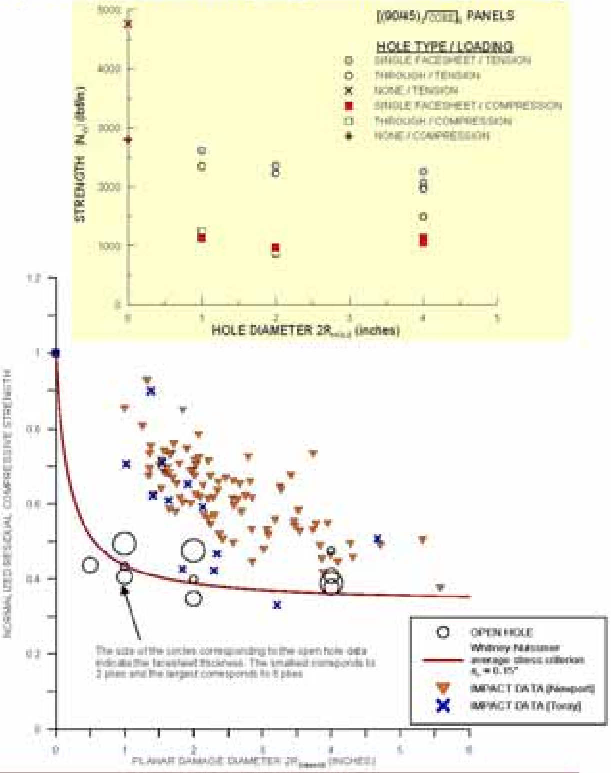
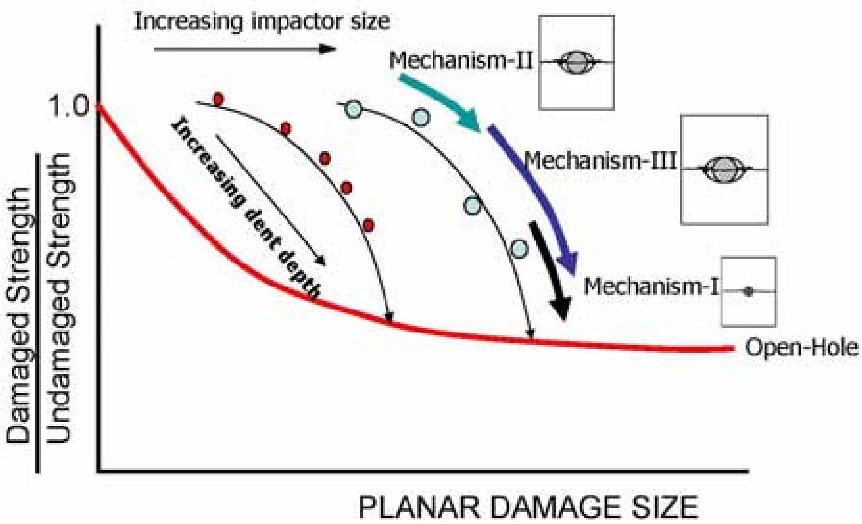
Comparison of Impact Damage with Open-Hole Damage (Sandwich panels)

In an effort to understand the relative severity of impact damage and open-holes in sandwich panels, an experimental investigation. It is interesting to know that the open-hole may represent the situation when a repair patch peeling off due to inferior bonding. Thus, open-hole damage is also a plausible damage state for sandwich structures. The compressive residual strength of open-holes were observed to form the lower bound for impact damage states possessing the same planar damage size. With increasing levels of residual sent depth and facesheet fractures, the residual strength of impact damaged panels approach the open-hole strength. Thus open-hole strength may be used for a conservative design.



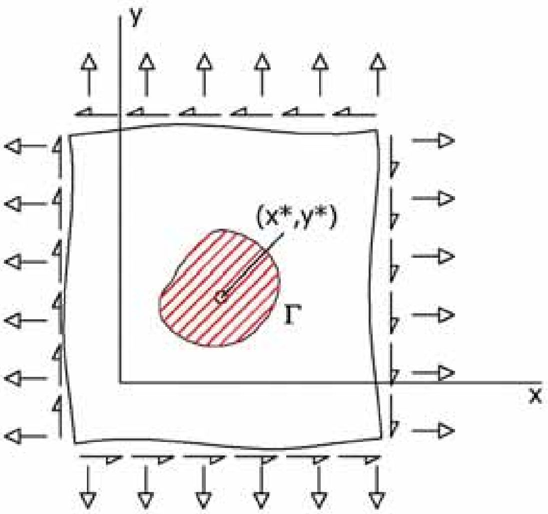


Comparison of Impact Damage with Open-Hole Damage (Sandwich panels)…



Damage Tolerance - Analysis

Problem statement



Given a structure subjected to far-field stress (load) σ_{ij}. The structure contains damage at a location (x*,y*,z*) contained within some region Γ, which was inflicted prior to the application of load.

Required- critical value of σ_{ij} or value of σ_{ij} at/beyond which the structure loses its load carrying capability

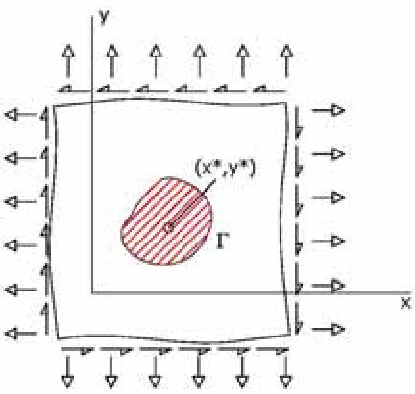
OR

What is the degradation or reduction in the load carrying capability of the structure in the presence of damage?

Damage Tolerance - Analysis

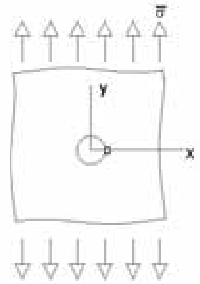
Requirements for satisfactory(?) analytical prediction

- Good description of the problem
  1. Geometry of problem
     - Structure under analysis
     - Damage metrics
       - Planar size, location across the thickness of laminate, dent depth, etc.
  2. Constitutive properties (stiffness & strength)
     - Undamaged region
     - Damaged region
       - Spatial description of degraded material properties
  3. Loads and constraints/boundary conditions
- Tools for prediction of stress & strain fields
- Failure criteria and property degradation rules



Strength of Notched Laminates

Lay-up	Stress Concentration k_σ	Strength Ratio based on stress concentration $R_k = 1/k_\sigma$	Measured Strength Ratio R_m
$[0/90/0/90]_S$	5.80	0.172	0.314
$[0_2/\pm 45/\bar{0}]_S$	3.68	0.271	0.617
$[\pm 45/0_2/\bar{0}]_S$	3.68	0.271	0.529
$[0/\pm 45/0/\overline{90}]_S$	3.45	0.289	0.435
$[0_2/\pm 45/\overline{90}]_S$	3.45	0.289	0.435
$[0/\pm 45/90]_S$	3.00	0.33	0.394
$[+45/90/0/-45]_S$	3.00	0.33	0.465
$[\pm 45/0/\pm 45]_S$	2.45	0.408	0.546
$[\pm 45/\pm 45]_S$	1.84	0.543	0.909
$[+45_2/-45_2]_S$	1.84	0.543	0.833

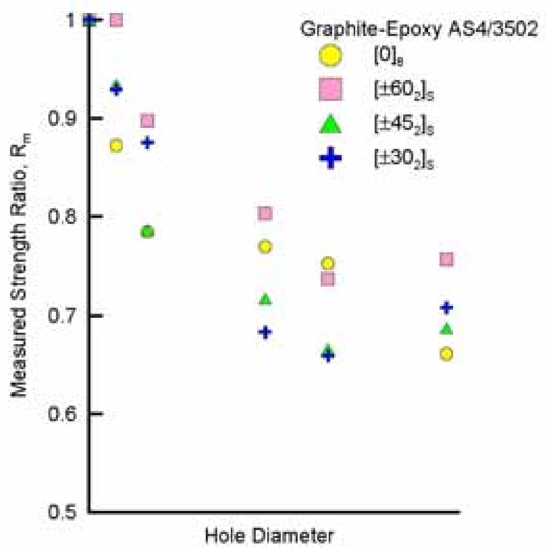


$$k_\sigma = \frac{\sigma_y(R,0)}{\bar{\sigma}}$$

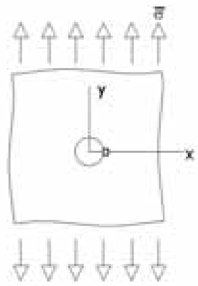
$$R_m = \frac{\text{Notched Strength}}{\text{Unnotched Strength}}$$

Ref: I.M. Daniel, R.E. Rowlands, and J. B. Whiteside, " Effects of Material and Stacking Sequence on Behavior of Composite Plates with Holes," Exp. Mech., Vol. 14, 1974.

Strength of Notched Laminates



S.C. Tan, Stress Concentrations in Laminated Composites, Technomic Publishing Co.

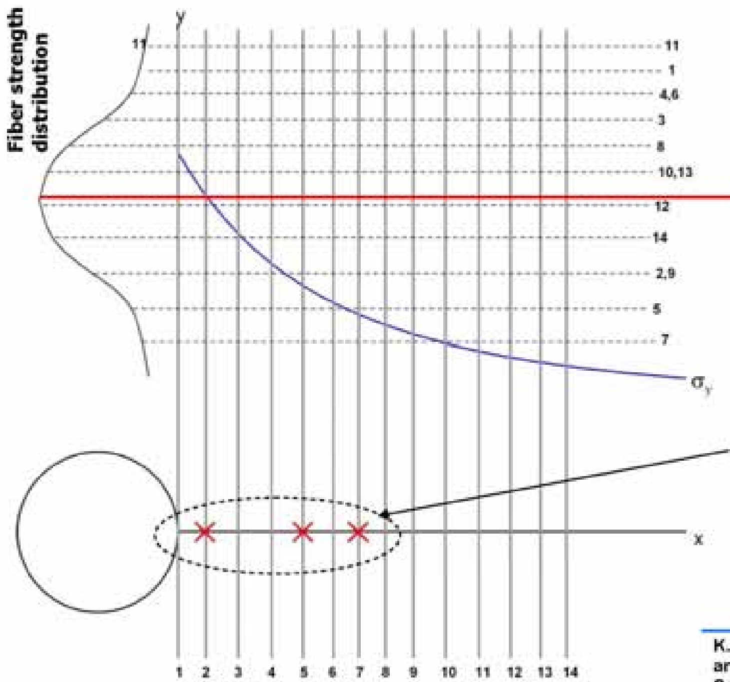


Observations

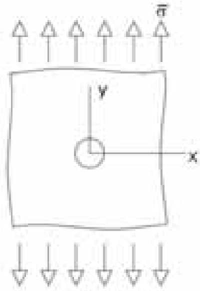
Notched strength of composite laminates is a function of stacking sequence, notch geometry and notch radius

Notched strength can be different even though the stress concentration factors are the same!

Strength of Notched Laminates



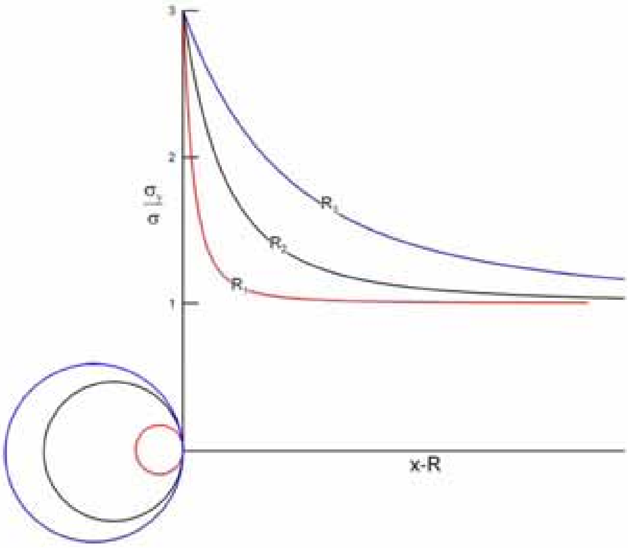
~ Average fiber strength



Process zone – redistribution of load occurs. Stress distribution will be altered.

K.L. Reifsnider and S.C. Case, Damage Tolerance and Durability of Material Systems, John Wiley & Sons, Inc.

Strength of Notched Laminates

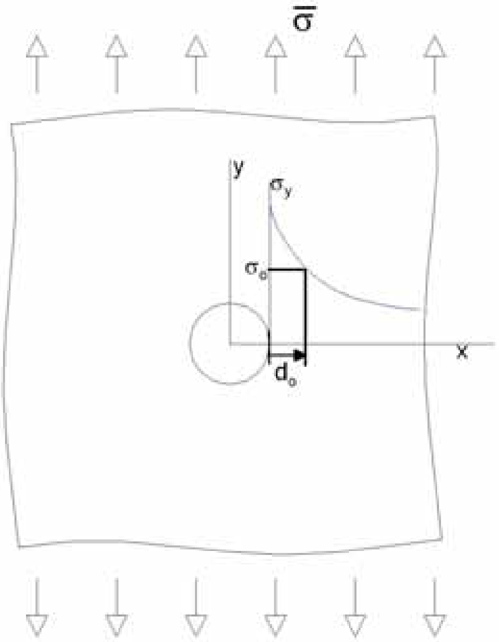


For a general laminate, the process zone may include delaminations between adjacent plies, matrix cracking, etc., all of which cause stress redistribution – across the width of the laminate and between the plies. Thus, once some failure is initiated, the theoretical stress distribution is not valid.

With increasing notch radius, more material adjacent to the notch is subjected to intense stress. Thus a larger notch will produce more reduction in strength

Thus, any failure criteria/model to predict notched strength must account for the process zone and the notch size effect.

Failure Criteria for Notched Laminates



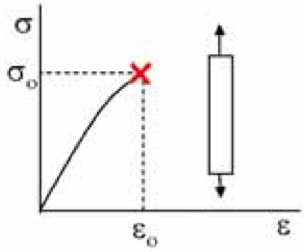
WHITNEY-NUISMER CRITERIA

- Point Stress Criterion

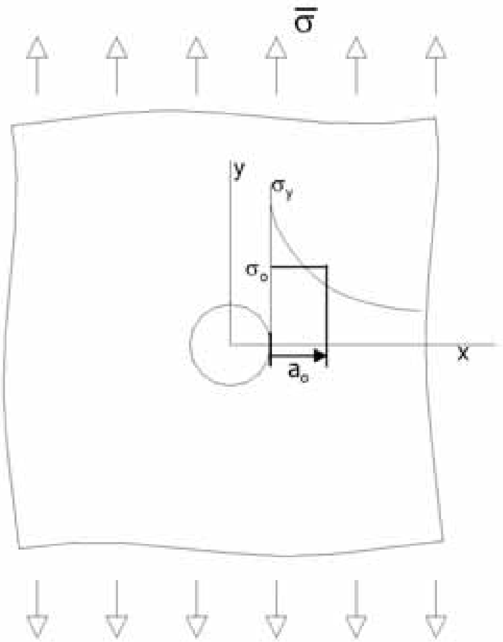
Failure occurs when the stress, σ_y, at some distance d_o from the notch equals or exceeds the strength, σ_o, of the unnotched laminate.

i.e., at failure $\sigma_y(R+d_o,0)=\sigma_o$

d_o ~ characteristic length



Failure Criteria for Notched Laminates



WHITNEY-NUISMER CRITERIA

- Average Stress Criterion

Failure occurs when the average stress, σ_y, over some distance a_o from the notch equals or exceeds the strength, σ_o, of the unnotched laminate.

i.e., at failure $$\frac{1}{a_o}\int_R^{R+a_o}\sigma_y(x,0)dx=\sigma_o$$

a_o ~ characteristic length

Failure Criteria for Notched Laminates

WHITNEY-NUISMER CRITERIA

Characteristic lengths a_o and d_o

Consider the stress distribution along y=0 in an infinite orthotropic plate containing a circular hole

$$\sigma_y(x,0) = \frac{\bar{\sigma}}{2}\left[\underbrace{2+\left(\frac{R}{x}\right)^2+3\left(\frac{R}{x}\right)^4}_{\text{ISOTROPIC Soln}} - \left(K_T^{\infty}-3\right)\left\{5\left(\frac{R}{x}\right)^6 - 7\left(\frac{R}{x}\right)^8\right\}\right]$$

NOTE : this is an approximation

where

$$K_T^{\infty} = 1+\sqrt{\frac{2}{A_{22}}\left[\sqrt{A_{11}A_{22}} - A_{12} + \frac{A_{11}A_{22}-A_{12}^2}{2A_{66}}\right]}$$

Stress concentration factor at the edge of the hole in an infinite orthotropic plate

$$= 1+\sqrt{2\left[\frac{E_y}{E_x} - \upsilon_{xy}\right] + \frac{E_y}{G_{xy}}}$$

in terms of Engg. constants

WHITNEY-NUISMER CRITERIA....

Characteristic length d_o

Point stress criterion... at failure $\sigma_y(R+d_o,0)=\sigma_o$

Let σ_N^{∞} be the strength of notched plate

At failure...

$$\sigma_y(R+d_o,0) = \frac{\overset{=\sigma_N^{\infty}}{\bar{\sigma}}}{2}\left[2+\left(\frac{R}{R+d_o}\right)^2 + 3\left(\frac{R}{R+d_o}\right)^3 - \left(K_T^{\infty}-3\right)\left\{5\left(\frac{R}{R+d_o}\right)^6 - 7\left(\frac{R}{R+d_o}\right)^8\right\}\right] = \sigma_o$$

if we let $\xi_P = \dfrac{R}{R+d_o}$

$$\frac{\sigma_N^{\infty}}{\sigma_o} = \frac{2}{2+\xi_P^2+3\xi_P^4 - \left(K_T^{\infty}-3\right)\left(5\xi_P^6 - 7\xi_P^8\right)}$$

WHITNEY-NUISMER CRITERIA....

Characteristic length a_o

Average stress criterion... at failure $\frac{1}{a_o}\int_R^{R+a_o}\sigma_y(x,0)dx=\sigma_o$

Let σ_N^∞ be the strength of notched plate

At failure...

$$\frac{1}{a_o}\int_R^{R+a_o}\frac{\overset{=\sigma_N^\infty}{\overline{\overline{\sigma}}}}{2}\left[2+\left(\frac{R}{R+d_o}\right)^2+3\left(\frac{R}{R+d_o}\right)^3-\left(K_T^\infty-3\right)\left\{5\left(\frac{R}{R+d_o}\right)^6-7\left(\frac{R}{R+d_o}\right)^8\right\}\right]dx=\sigma_o$$

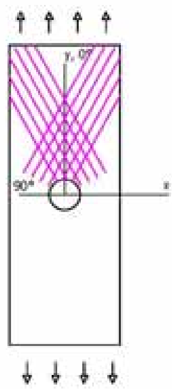
$$\text{if we let } \xi_A=\frac{R}{R+a_o}$$

$$\frac{\sigma_N^\infty}{\sigma_o}=\frac{2(1-\xi_A)}{2-\xi_A^2-\xi_A^4-\left(K_T^\infty-3\right)\left(\xi_A^6-\xi_A^8\right)}$$

WHITNEY-NUISMER CRITERIA....

Determination of Characteristic lengths a_o and d_o

Consider laminates fabricated using AS4/3502 material. The lamina properties for the material are*



Longitudinal Modulus E_{11}= 20.8 x 10^6 psi
Transverse Modulus E_{22}=1.5 x 10^6 psi
In-plane Shear Modulus G_{12} = 0.88 x 10^6 psi
In-plane major Poisson's ratio ν_{12} = 0.29
Ply thickness T_{ply}=0.005in

Consider the following laminate configurations for which the characteristic lengths are required
$[0]_8$, $[\pm30]_{2S}$,$[\pm45]_{2S}$,$[\pm60]_{2S}$

* S.C. Tan, Stress Concentrations in Laminated Composites, Technomic Publishing Co.

Using the Lamina properties and Classical Laminated Plate Theory, determine the stress concentration factor for an infinite plate with a hole

$$K_T^{\infty} = 1 + \sqrt{\frac{2}{A_{22}}\left[\sqrt{A_{11}A_{22}} - A_{12} + \frac{A_{11}A_{22} - A_{12}^2}{2A_{66}}\right]}$$

Lay-up	K_T^{∞}
$[0]_8$	6.519
$[\pm 30]_{2S}$	2.842
$[\pm 45]_{2S}$	2.045
$[\pm 60]_{2S}$	1.892

* S.C. Tan, Stress Concentrations in Laminated Composites, Technomic Publishing Co.

Let the experimental data* for unnotched and some notched data be available for the laminates being discussed

Lay-up	Hole diameter (inches)				
	0	0.046	0.1	0.3	0.6
$[0]_8$	1	0.87	0.78	0.77	0.66
$[\pm 30]_{2S}$	1	1	0.90	0.80	0.76
$[\pm 45]_{2S}$	1	0.93	0.79	0.72	0.69
$[\pm 60]_{2S}$	1	0.93	0.88	0.68	0.71

$$= \frac{\text{Notched Strength}}{\text{Unnotched Strength}}$$

* S.C. Tan, Stress Concentrations in Laminated Composites, Technomic Publishing Co.

The characteristic lengths can be determined in two ways. In the first method, use one notched strength value (along with the corresponding notch size) for a given lay-up and substitute into the following equation(s).

$$\frac{\sigma_N^\infty}{\sigma_o} = \frac{2}{2+\xi_P^2+3\xi_P^4-(K_T^\infty-3)(5\xi_P^6-7\xi_P^8)}$$ ~ point stress criterion

$$\frac{\sigma_N^\infty}{\sigma_o} = \frac{2(1-\xi_A)}{2-\xi_A^2-\xi_A^4-(K_T^\infty-3)(\xi_A^6-\xi_A^8)}$$ ~ average stress criterion

Solve the equations for ξ_P & ξ_A

$$\text{Obtain } d_o = \left(\frac{1}{\xi_P}-1\right)R \text{ and } a_o = \left(\frac{1}{\xi_A}-1\right)R$$

Use the characteristic lengths for predicting strength for other notch sizes.

<u>NOTE:</u> correlation with experimental data (other notch sizes) will be dependent on the choice of notch size used for obtaining the characteristic lengths

In the second method, use more than one notched strength value (along with the corresponding notch sizes) for a given lay-up and curve fit the following equations

$$\frac{\sigma_N^\infty}{\sigma_o} = \frac{2}{2+\left(\frac{R}{R+d_o}\right)^2+3\left(\frac{R}{R+d_o}\right)^4-(K_T^\infty-3)\left[5\left(\frac{R}{R+d_o}\right)^6-7\left(\frac{R}{R+d_o}\right)^8\right]}$$ ~ point stress criterion

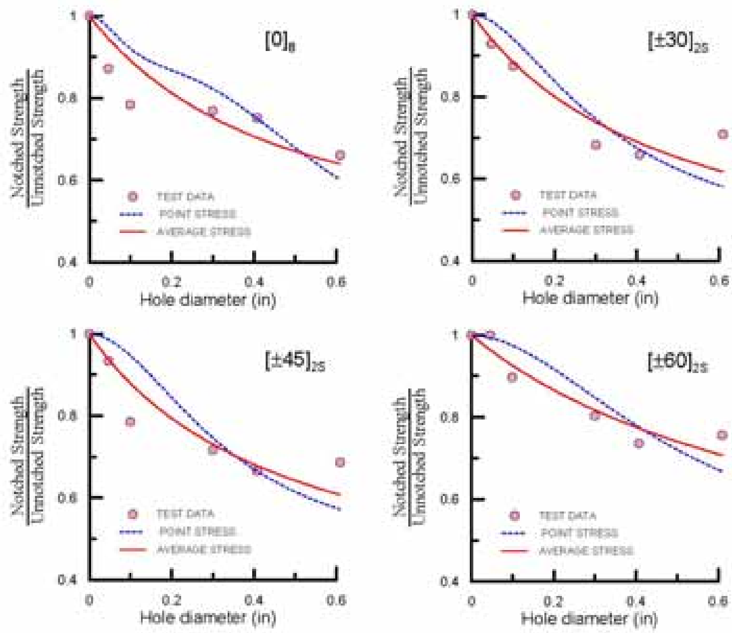
$$\frac{\sigma_N^\infty}{\sigma_o} = \frac{2\left(1-\frac{R}{R+a_o}\right)}{2-\left(\frac{R}{R+a_o}\right)^2-\left(\frac{R}{R+a_o}\right)^4-(K_T^\infty-3)\left[\left(\frac{R}{R+a_o}\right)^6-\left(\frac{R}{R+a_o}\right)^8\right]}$$ ~ average stress criterion

Using least square curve-fit to obtain characteristic lengths d_o and a_o.

Use the characteristic lengths for predicting strength for other notch sizes.

<u>NOTE:</u> correlation with experimental data (other notch sizes) will be dependent on the choice of notch sizes used during the curve fit process.

Point Stress & Average Stress Criteria



Characteristic lengths based on best-fit curve

Lay-up	d_o(in)	a_o (in)
$[0]_8$	0.16	0.77
$[\pm30]_{2S}$	0.22	0.71
$[\pm45]_{2S}$	0.24	0.69
$[\pm60]_{2S}$	0.37	1.20

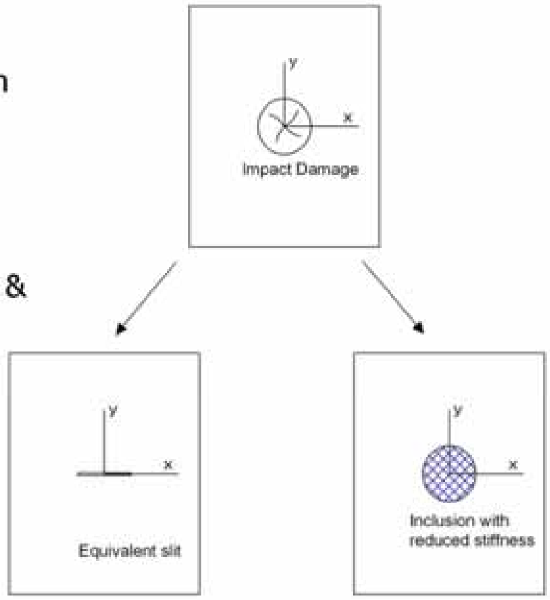
WHITNEY-NUISMER Point & Average stress CRITERIA....

Observations

1. Require elastic properties of the material (A_{ij})
2. Strength of unnotched laminate (from experiments /analysis)
3. Strength of at least 'one' notched configuration (from experiments)
4. Uses elastic solutions for stress distributions
   - K_T for infinite plate is used. Could use *correction factors* for finite width
5. Does not say anything about the micro failure mechanisms and resulting stress distributions in the *process* zone
6. Used for predicting failure loads (complete loss of load carrying capability). Cannot be used for predicting loss in stiffness prior to failure or the load-displacement behavior
7. Characteristic lengths are NOT material property. They depend on stacking sequence.
8. Characteristic lengths are NOT independent of notch geometry

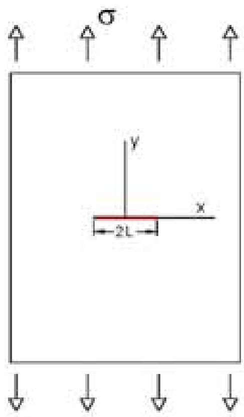
Residual Strength Prediction of Impact Damaged Laminates

- Fracture Mechanics Approach
  - The impact damage is reduced to an equivalent slit (Caprino; Husman, Whitey & Halpin; Lal)
- Plate with inclusion
  - The impact damage is reduced to a region of reduced stiffness (El-Zein & Reifsnider)



The above methods do not explicitly represent the damage states present in the laminates nor do they capture the failure mechanisms under in-plane loading. However, the above approaches provide a simple alternatives which use limited experimental results. The exact representation of the damage states existing in a laminate and the failure mechanisms under in-plane loading is not a simple task.

Equivalent Slit Model– Caprino



Critical stress based on LEFM

$\sigma_c = K_{IC}(\pi L)^{\frac{1}{2}}$

K_{IC} ~ Fracture toughness of material

Since a process zone (psuedo plastic zone) is present at the notch tip in composites, the exponent 1/2 is replaced by 'm'

$\therefore$ The critical stress $\sigma_c = K_{IC}(\pi L)^m$

Let σ_o be the strength of unnotched material

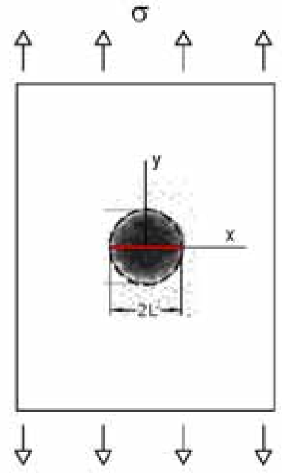
we may write $\sigma_o = K_{IC}(\pi L_o)^m$ ....where L_o is the size of an intrinsic flaw

Therefore, $\frac{\sigma_c}{\sigma_o} = \left(\frac{L_o}{L}\right)^m$

The above eqn can be used to predict strength of notched laminates. The value of 'm' is determined using experiments.

Equivalent Slit Model– Caprino

Application of model to impact damaged laminates



Assume that the notch length $2L_o$ is the same as that of the planar impact damage size. Based on experimental observations, the impact damage size is expressed as a function of kinetic energy U

i.e., we may write $L = kU^n$

Let U_o be the maximum impact energy level which the material can withstand without any degradation of strength. The intrinsic flaw size may be experssed as $L_o = kU_o^n$

The residual strength may be expressed as

$$\frac{\sigma_R}{\sigma_o} = \left(\frac{U_o}{U}\right)^{m \times n}$$

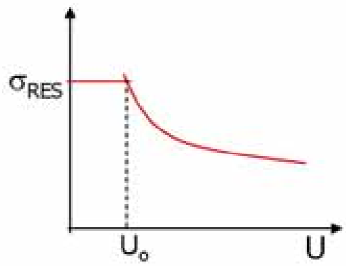
since U_o is typically unknown, the residual strength is written as

$\sigma_R = CU^{-\alpha}$

where $\alpha = m \times n$

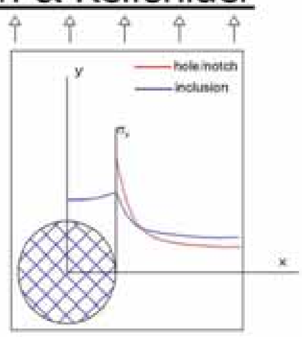
C and α are determined by curve fitting the experimental data

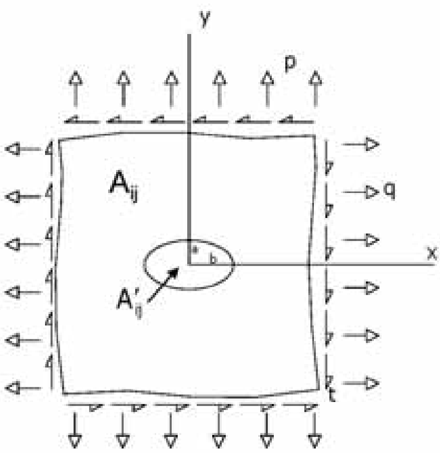
These values are dependent on material system and lay - up.



Equivalent Inclusion Model– El-Zein & Reifsnider

This model addresses the fact that the impact damage region does possess some residual stiffness and strength. As a result of this, some of the load is supported by the damage region resulting in a reduction of the stress concentration effect.





Impact damage region is modeled as an elliptical inclusion with reduced stiffness properties

$$A'_{ij} = mA_{ij} \quad m \le 1$$

The stresses are obtained using complex functions approach

$$\sigma_x = p + 2\mathrm{Re}\left[\mu_1^2\phi_1'(z_1) + \mu_2^2\phi_2'(z_2)\right]$$

$$\sigma_y = q + 2\mathrm{Re}\left[\phi_1'(z_1) + \phi_2'(z_2)\right]$$

$$\tau_{xy} = t - 2\mathrm{Re}\left[\mu_1\phi_1'(z_1) + \mu_2\phi_2'(z_2)\right]$$

Equivalent Inclusion Model– El-Zein & Reifsnider

The global stresses obtained are then used to obtain the local stresses in each ply
The residual strength of composite laminate is determined by averaging a failure criterion over a characteristic length Do

$$\frac{1}{D_o}\int_{b}^{b+D_o}\frac{\sigma_{ip}(x,0)}{X_T}dx = 1$$

X_T ~ Unidirectional tensile strength

To determine the stiffness ratio 'm', it is assumed that the ratio is the same as the ratio of the damaged area to some reference area

$$m = \frac{A'_{ij}}{A_{ij}} = \frac{A_{Reference}}{A_{Damage}}$$

The reference area $A_{Reference}$ is a characteristic flaw size up to which no significant reduction in strength occurs. It is associated with a specific energy level

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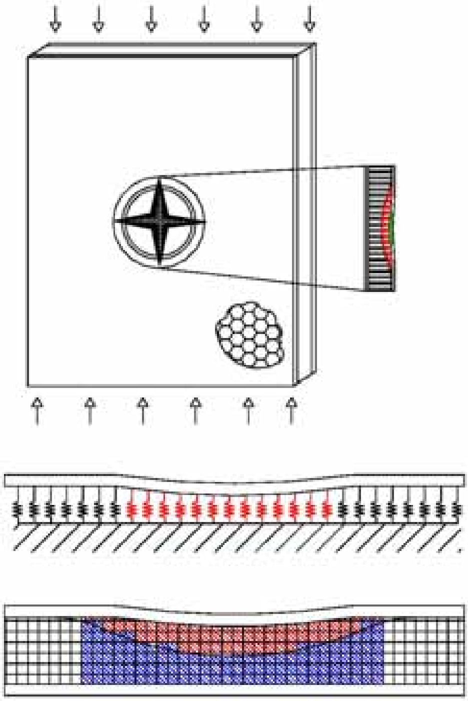
Damage Tolerance analysis of Sandwich Panels



Damage tolerance of sandwich composites with low-velocity impact damage has been shown to be critical under in-plane compressive loading. Under tensile loading, in the absence of facesheet damage, the residual dents tend to *flatten out* resulting in minimal strength degradation.

The damage in sandwich panels consists of material damage states (core and facesheet) and a geometric damage state which is the residual dent distribution. Both damage states have to be included in analysis methods for residual strength prediction.

Two popular methods used for strength preidction are

1. Foundation model (Ref: Moody & Vizzini) - here the sandwich is modeled as a sheet on a foundation representing the core. Different foundation behaviors are used for core in the damaged region and undamaged region. The foundation can only support normal loads. Interaction with backside facesheet is neglected

2. Finite Element Models (e.g., Hwang & Lacy)

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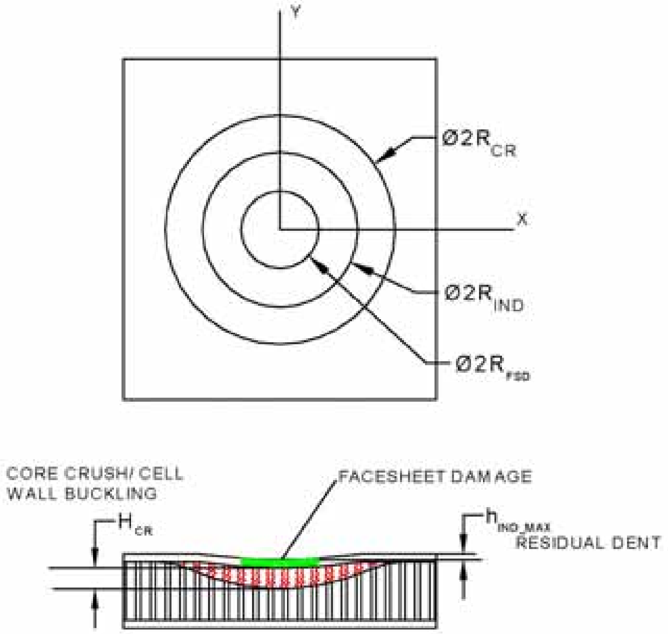
Inputs for FE model



DAMAGE METRICS

Residual dent depth distribution
$h_{RES} = h_{RES}(h_{IND\_MAX}, x, y)$

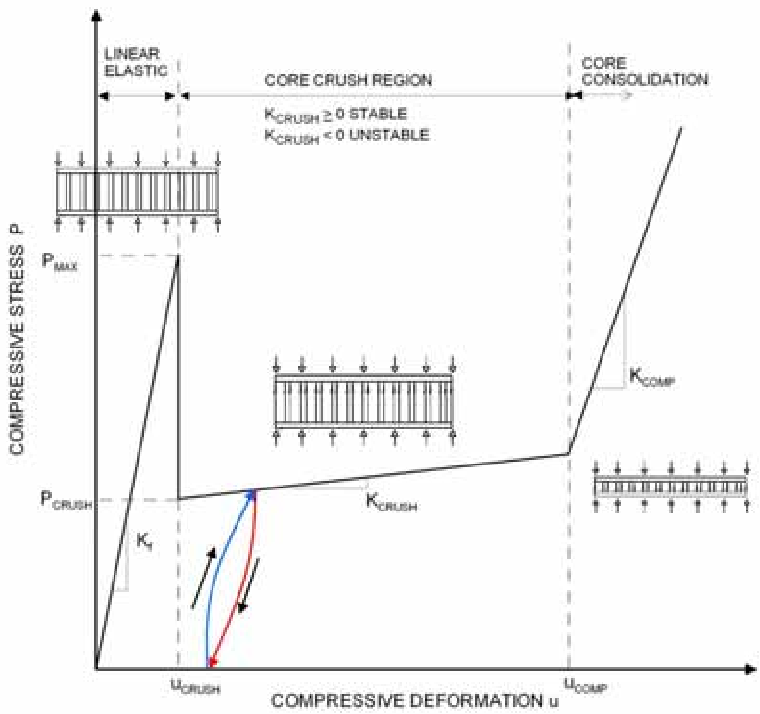
Core crush depth distribution
$H_{CR} = H_{CR}(x, y)$

Extent of Facesheet damage region ~ $2R_{FSD}$

Residual Stress Field $\sigma_{ij}^{RES} = \sigma_{ij}^{RES}(x, y)$

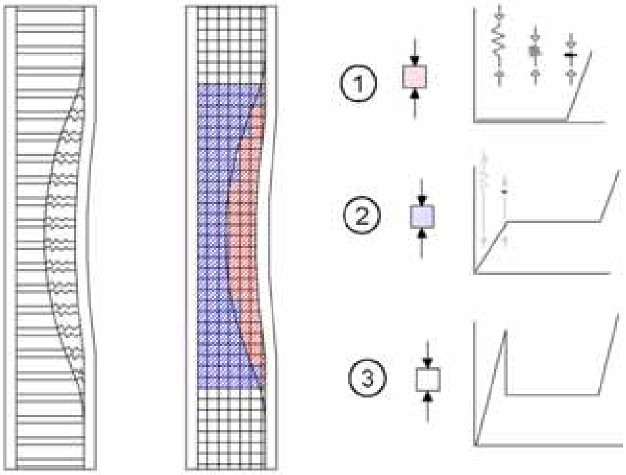
c.f. Y. Hwang and T. E. Lacy., "Numerical Estimates of the Compressive Strength of Impact-damaged Sandwich Composites," J. Composite Materials, Vol.41, No.3, 2006

Honeycomb core behavior under Transverse Compression



The typical load displacement behavior of honeycomb cores under out of plane compressive loads is illustrated in figure. The honeycomb core response is linear within a given deformation limit. Within this limit the core behaves elastically and has a relatively high stiffness. At the end of this region, some failure mechanism is initiated in the core. The failure mode is dictated by the core cell wall properties and geometry. The failure mechanism can be a cell wall fracture at one extreme or a cell wall buckling/wrinkling at the other extreme. Most practical honeycomb cores undergo a combination of the above failure modes. These failure mechanisms lead to a stable crushing region where the failure propagates across the thickness of the core. The buckling initiated failure leads to a progressive folding of the honeycomb core cell walls as illustrated in figure. The load corresponding to the stable crushing regions is a fraction (less than 50% typical) of the peak load in the elastic range. The crushing of the core proceeds until a deformation limit is reached whence the load increases rapidly owing to the compaction of the core material.

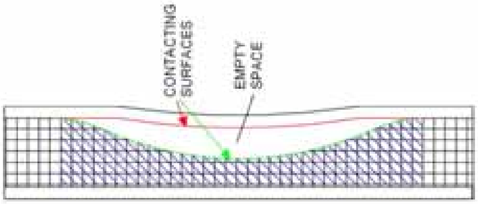
Modeling of core damage region



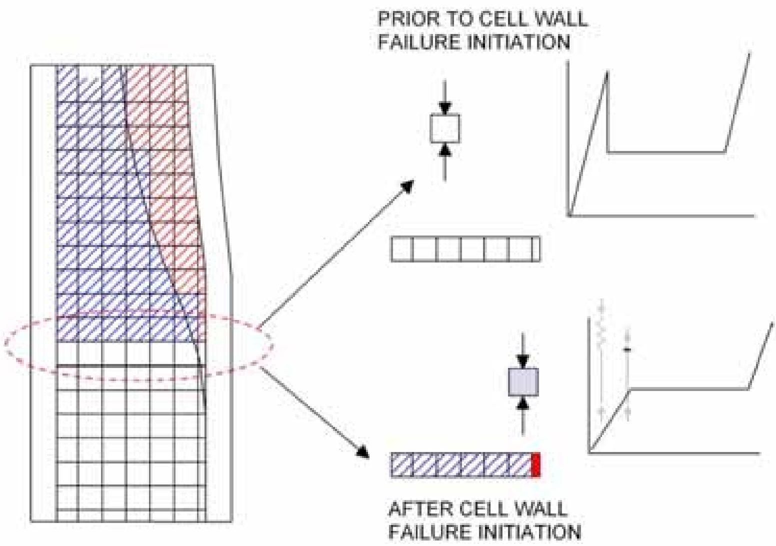
The modeling of the dimple arrest and propagation process requires that the damaged core behavior be modeled appropriately. The damaged core adjacent to the facesheet consists of core cell walls that have been folded and unfolded during the impact loading. Upon the application of in-plane compressive loads to the sandwich panel, the facesheet in the dent region will bend over the damaged cell walls. These damaged cell walls (red in color) will not resist the bending deformation of the facesheet until the cell walls are compacted. Upon compaction, the adjacent cell walls (blue in color) will resist further bending of the facesheet.

However, the resistance of these cell walls are lower than that of the healthy cell walls and will begin to crush when the compressive stress in the core reaches the crush stress level.

Another approach to model the different regions of the damaged core is to eliminate the region representing the folded cell walls and define contacts between the facesheet and the underlying core region.



Modeling of core damage region



Upon sufficient loading of the sandwich panel, the local bending of the facesheet will initiate failure in the healthy core adjacent to the core damage region. This failure initiation in the core occurs adjacent to the facesheet. Even though the analysis does not indicate failure in the core elements away from the facesheet, their behavior will change as illustrated in the figure. This change in behavior of a cell element due to failure of a neighboring element must be included in the modeling process. This can be accomplished by using material model "switching" option.

NOTE: The cell wall buckling and crushing process is a structural problem involving thin walled honeycomb structure. During the FE analysis, the honeycomb structure is idealized as a continuum to reduce the number of elements required to represent the core and thus decrease the computational effort. The definition of different core material behaviors and their switching during the analysis is an approximation of observed structural behavior using idealized material behavior.

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