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This document highlights items of interest on 5052 aluminum honeycomb (HC) material. This material is commonly used as the core of composite sandwich panels for lightweight structures. The mechanical properties of the core are typically not considered since the loads are carried primarily through the composite facesheets. However, there are cases where the core plays a more important role and its mechanical behavior would need to be resolved in more detail, particularly if its mechanical properties were not what were expected. This becomes more critical for manned spaceflight programs in which material documentation and pedigree are important. As part of a quality program, the HC core should be specified properly when ordered and quality checks should be made on received material to ensure its correctness. To this end, this report presents some simple data, which can be used for benchmarking HC properties.

Manufacturing of the sandwich panels is usually performed by a process involving layup of the composite prepreg facesheets, sheets of adhesive for bonding the facesheets to the core, and the HC core. This layup is bagged, evacuated, and co-cured according to recommended schedules to ensure complete consolidation of the sandwich structure. The core is expected to be completely bonded to the facesheets with adequate wetting of the core with the adhesive. The facesheets are to be fully consolidated with minimal voids. As one can imagine, each of these elements has its individual response to the heat/time schedule used in manufacturing, and this often leads to multistep heating and pressurization schedules. As the individual components in the panel are changed due to the need to minimize consolidation times, improve properties, or provide materials, which can withstand higher service temperatures, higher heating temperatures and times may be of interest. This report, therefore, provides results of simple aging studies on the 5052 HC and its resulting mechanical properties.

Finally, design and analysis of sandwich panel structures requires material properties for input to the models. Many models treat the HC as a homogeneous structure using smeared properties, often taken from either HC supplier datasheets, or bulk 5052 properties. With more sophisticated models, explicit modeling of the HC cell structure is employed, where the individual cells are modeled and properties for the aluminum foil used to make the HC are utilized. These properties are not readily available. This report provides some room temperature (RT) tensile properties of the aluminum foil, which can be used in these models.

The 5052 aluminum is hardened by magnesium and often coupled with cold work of the material to gain strength. The compositional specification calls for 2.2 to 2.8 wt% Mg. The yield strength is a function of magnesium content and, in the annealed condition, can range from 11 to 15 ksi as the magnesium content increases within this specification range. Elongation, modulus, and corrosion resistance are invariant over this range of magnesium content. This is general information taken presumably from bulk material, that is, bars, plates, and sheet. Chemical analysis was performed on samples extracted from two 5052 HC panels procured as a part of the Composite Exploration Upper Stage (CEUS) program. Results are given in Table I for HC purchased from two different vendors, and a piece of 5052 foil used as starting stock for HC manufacturing. All three analyses show standard 5052 chemistry as indicated in AMS4004D. However, multiple measurements of magnesium, the prime

TABLE I.—CHEMISTRY OF 5052 HONEYCOMB (HC)

Element, wt%	AMS4004D	HC 1	HC 2	Foil
Mg	2.2 to 2.8	2.18 2.16 2.29	2.16 2.29	2.18 2.21
Cr	0.15 to 0.35	0.18	0.17	0.18
Si	0.25 max.	0.08	0.05	0.13
Fe	0.40 max.	0.27	0.27	0.24
Cu	0.1 max.	0.04	0.04	0.04
(ppm)				
Ba		21	18	
Ca		28	18	10
Ga		140	140	100
K		40	30	30
Mn	1,000 max.	225	220	380
Na		250	210	200
Ni		70	70	60
Sr		210	170	
Ti		290	200	230
V		120	120	100
Zn	1,000 max.	90	90	70
Zr		10	10	10
Al		Remainder		

strengthening element, indicate that these are sometimes low and slightly out of specification. Alloy manufacturers claim these are within rounding errors. It is not believed that these small out-of-specification values affect the properties.

There are a large number of tempers for aluminum alloys. The 5052 can be strengthened by cold work and given the “H” temper. Subsequent digits indicates the amount of cold work and the thermal treatments that follow. The thermal treatments are used to stabilize the microstructure such that it cannot age (soften) with time. The 5052 can come in a variety of tempers. The softest is in the annealed (0) state. Other tempering states are also available that indicate varying levels of strain hardening. The most common tempers are H32, H34, H36, and H38. The increasing number indicates an increase in strength and a simultaneous decrease in ductility. Tensile values for bulk 5052 as a function of temper are listed in Table II. It is generally assumed and desired that 5052 HC is supplied in the H38 or H39 (fully hardened and stabilized) condition. However, this requirement is rarely, if ever, stated in the ordering specifications, nor is it part of the standard designation code for the HC. Typically, only the alloy type (e.g., 5052) is designated. Often, the temper is not shown in the HC manufacturer’s datasheets. Hexcel (Ref. 1) does indicate that their 5052 version has an H39 temper.

The temper H19 or H191 is not recommended for use in sandwich composites as this temper, while fully hardened (similar to the H39 temper), is not stabilized and the alloy will soften with panel curing. Note that H191 is the only recommended temper for 5052 in AMSA81596 (Ref. 2) and AMS4004D (Ref. 3). Meanwhile, AMSC7438 (Ref. 4) does not mention tempering at all. Data in AMSQQ250/8

(Ref. 5) are for bulk materials and give a variety of tempers. Hence, citing a given AMS specification does not guarantee a specific temper.

To summarize the previous discussion on tempering, HC properties and stability are controlled by the tempering condition. These properties, therefore, dictate the HC effective properties. The condition that the HC is ordered to, or received in, is usually an unknown, and there is a potential risk associated with this practice. The remaining discussion will address 5052 HC material properties and their response to aging.

Two small tensile samples were sectioned from a piece of 5052 HC core of unknown temper (presumably H38). The samples were rectangular in shape having a width of approximately 0.05 by 1 in. in length. The thickness of the samples was 0.0015 in. This was a double foil thickness since the nominal single foil thickness was only 0.0007 in. The room temperature (RT) tensile results are shown in Figure 1 and indicate an ultimate tensile strength (UTS) of approximately 34 ksi. This may imply a lower temper than H38, which reportedly (AMSQQA250/8, Ref. 5) cites a UTS value of 39 ksi.

TABLE II.—DATASHEET VALUES (REFS. 6 AND 7) FOR 5052 BULK MATERIAL

Temper	Ultimate tensile strength, ksi	Yield, ksi	Elongation, percent
O (annealed)	28	13	25
H32	33	28	12
H34	38	31	10
H36	40	35	8
H38	42	37	7

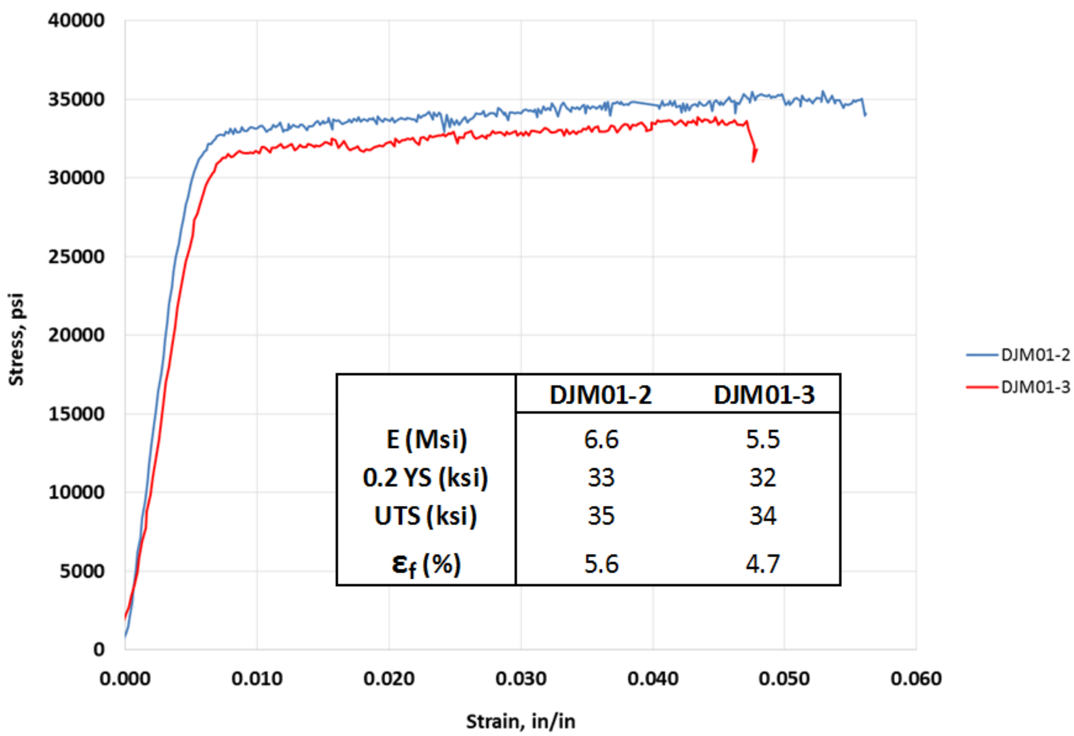


Figure 1.—Room temperature tensile results from samples excised from honeycomb core.

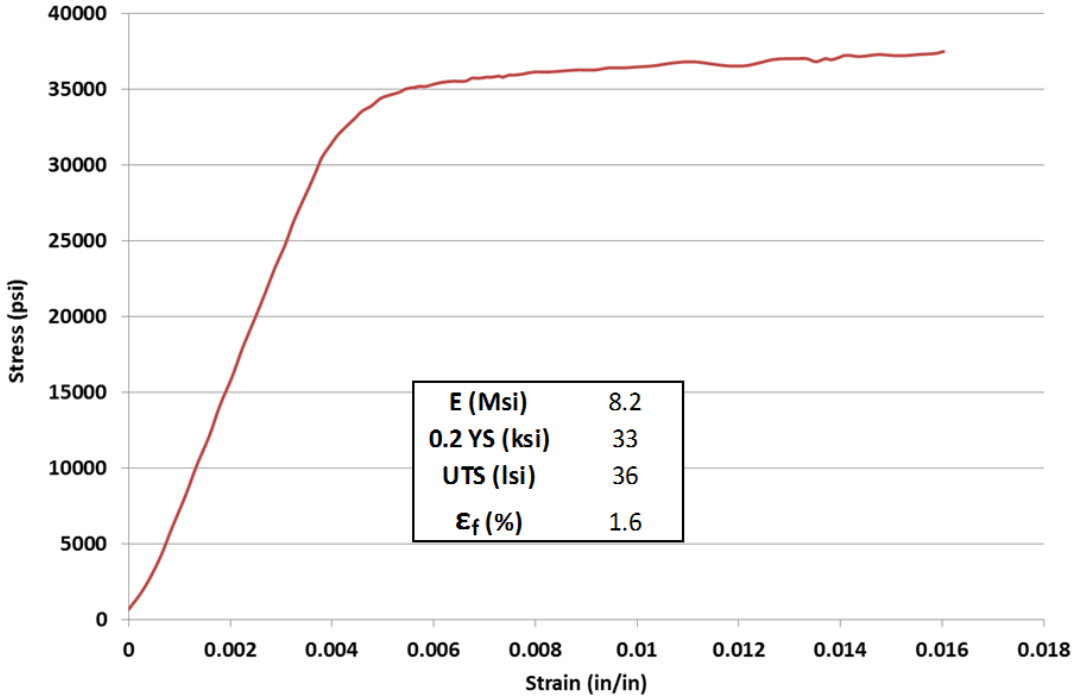


Figure 2.—Room temperature tensile result from 5052 H39 foil sample.

A roll of 0.0016-in.-thick foil was received from a HC manufacturer. The 5052 foil was in the H39 (similar properties to the H38 temper) condition. Seven samples were taken in both the rolling direction and the transverse direction. Samples were 2 in. long, 0.19 in. wide, and 0.0016 in. thick. Three of these samples were 2-in.-long dogbones, which had a 0.25 in. gage width. All samples were tested at RT and employed photogrammetry for measuring strain. There were no observable trends within the samples tested. A typical stress-strain curve is shown in Figure 2. Tensile properties are shown in the inset table representing an average of all 14 tests. The properties appear to agree with 5052 H38 values, although values given in various datasheets and specifications vary greatly. The cited modulus is usually 10 Msi whereas the measured values were somewhat lower at 8.2 Msi. Likewise, the measured strain to failure was lower (1.6 percent) and ranged from 0.5 to 3.4 percent. Some references cited a 2 percent minimum on failure strain and as high as 7 percent. The low value of failure strain in the current tests could be a result of the small sample size or the fact that these tests were on foils and not bulk material.

Aging studies were performed on the 5052 H39 foil. Sections of foil were aged at temperatures of 350 and 400 °F for times of 1, 3, and 8 hr. The 350 °F temperature represents a common co-cure temperature for sandwich panels. The higher temperature (400 °F) was chosen as a possible extension for future curing, or for higher service applications. The RT tensile curves are shown in Figure 3 for the 350 °F aged material. There is no difference in tensile properties until after an 8 hr age. The longer aging results in a very slight reduction (6 percent) in strength. The failure strain remains unchanged.

Aging at 400 °F (Figure 4) shows an immediate drop in tensile strength after just 1 hr of aging. The 1 and 3 hr ages yield similar properties, but both are 10 percent less than the unaged material. After an 8 hr age a further drop in strength occurred being 15 percent below the unaged state. It appears as if the failure strains for the 400 °F aged material are also slightly larger, although these may fall within the normal variation of values for strain to failure.

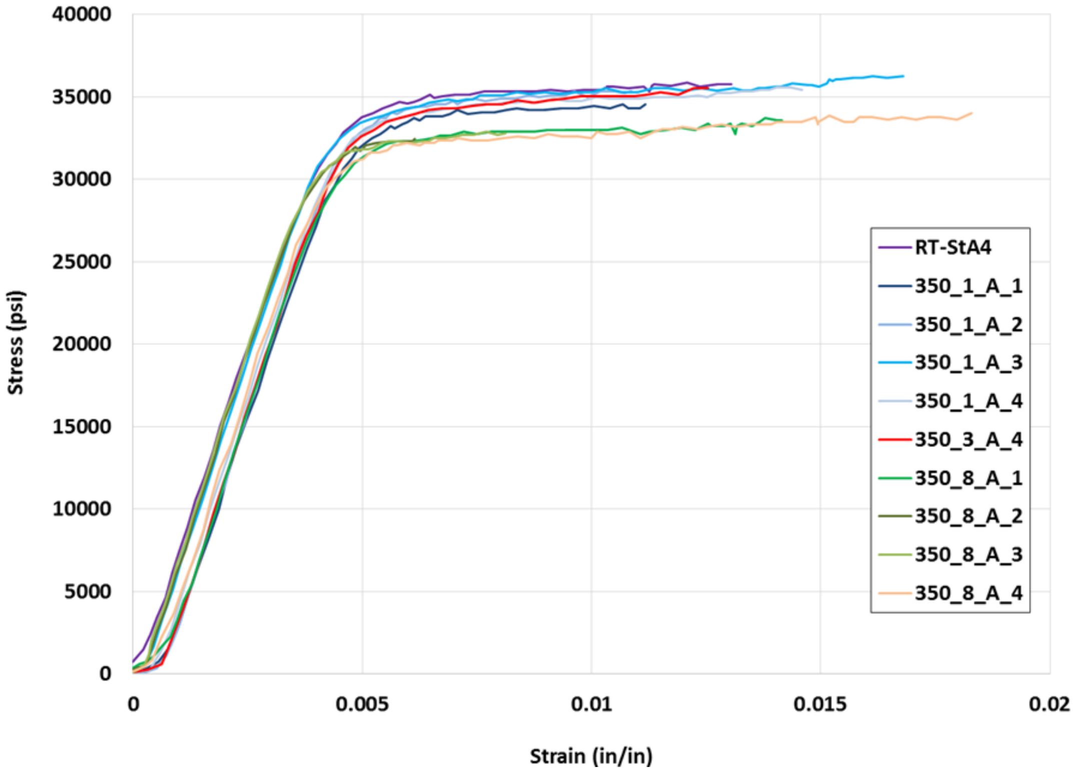


Figure 3.—Aging response of 5052 H39 foil at 350 °F.

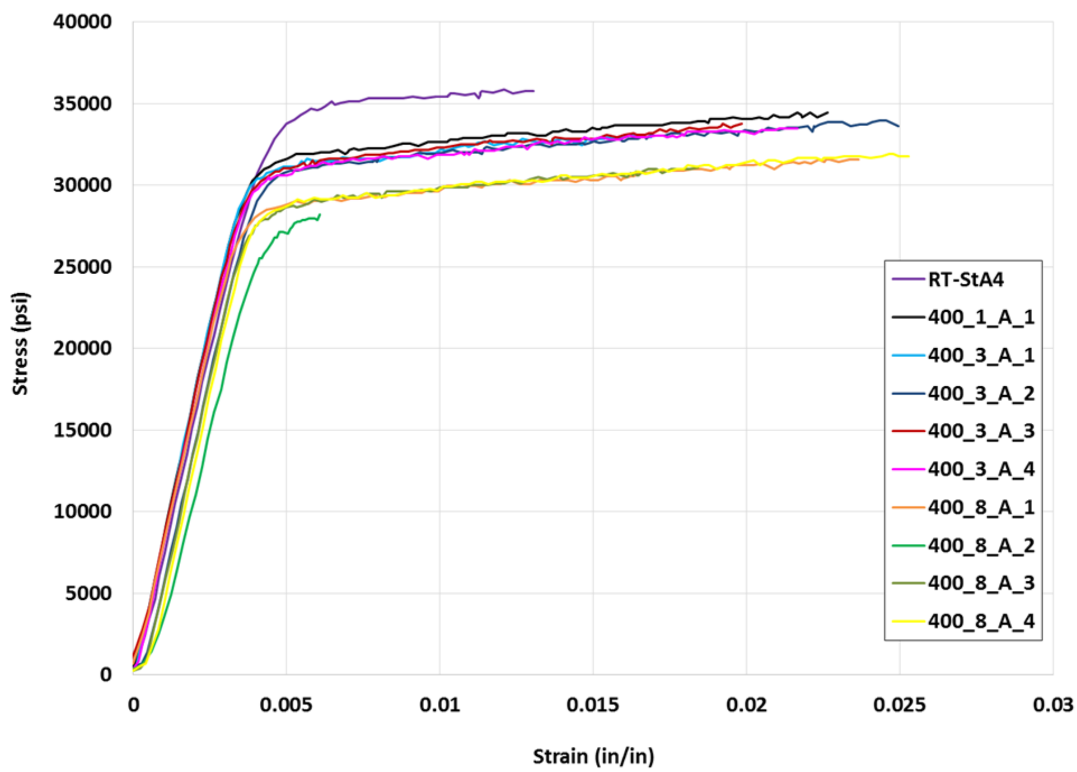


Figure 4.—Aging response of 5052 H39 foil at 400 °F.

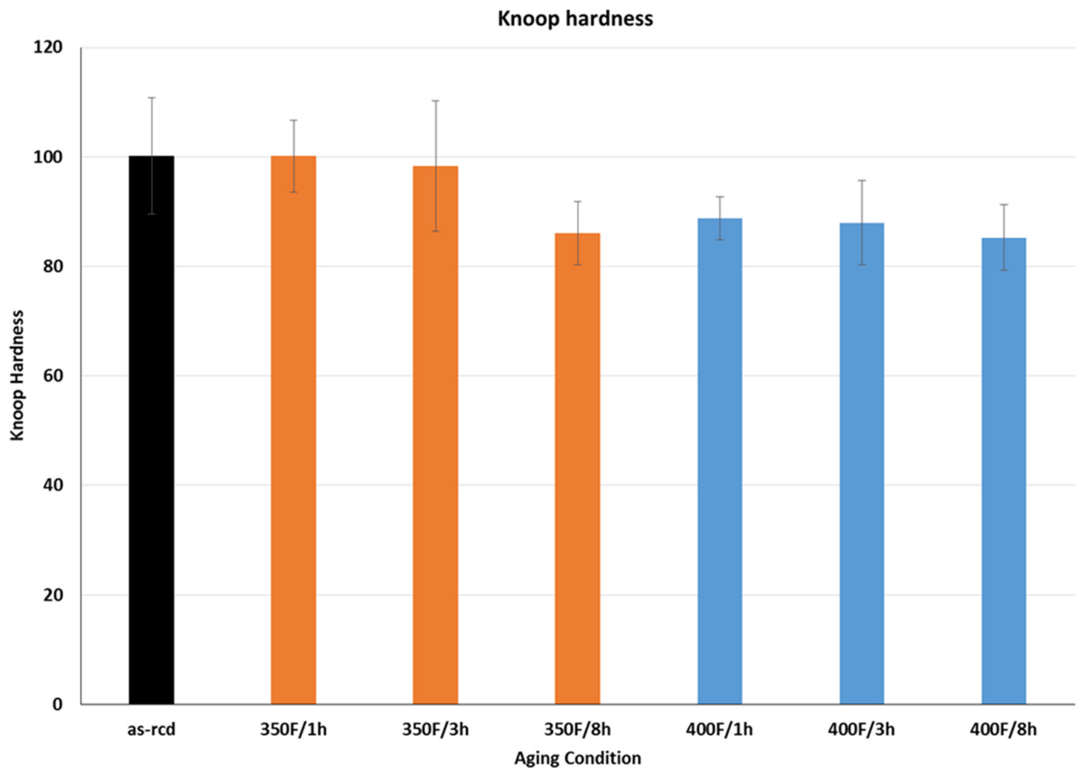


Figure 5.—Hardness of 5052 H39 foil as a function of aging.

Elastic modulus was calculated for all samples and pooled since there was no apparent trend as a function of aging. The average modulus was 8.3±0.3 Msi.

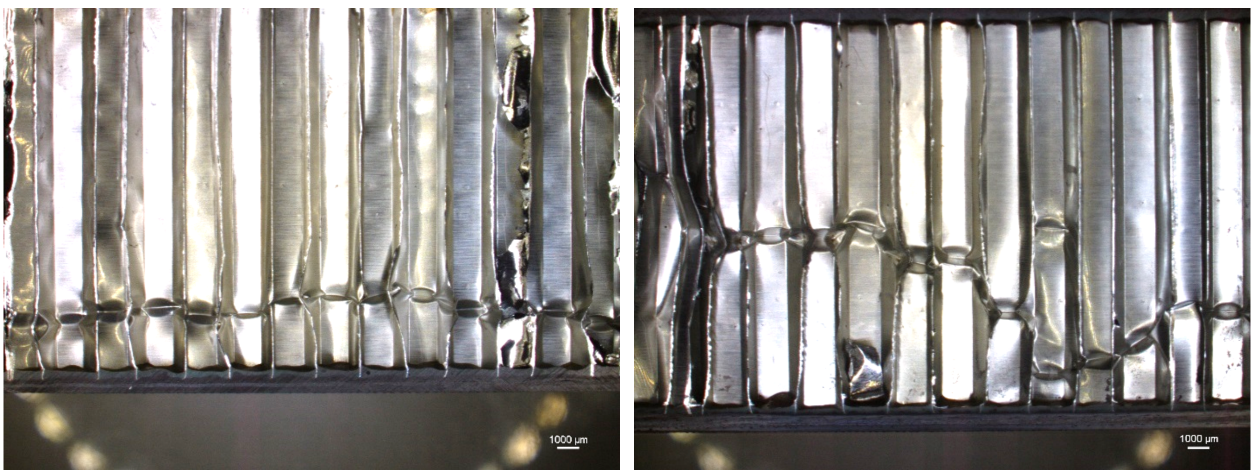
Sections of the foil were also metallographically mounted to allow Knoop hardness tests. Approximately 10 indents were taken per sample. Knoop hardness is shown in Figure 5 as a function of aging condition.

The hardness on the as-received, H39 condition measured 100 and is in agreement with that shown in the ASM Materials Data Sheet (Ref. 8) for the H38 temper. In trend with the tensile properties, there is no change in hardness after a 1 or 3 hr aging treatment at 350 °F. There was a noticeable drop in hardness following 8 hr of aging. There was an equivalent reduction in hardness for samples aged at 400 °F with the largest drop identified with the 8 hr age. The hardness follows the trends identified in the tensile results as a function of aging.

Flatwise compression (FWC) tests were performed to study the effects of aging on core crushing. Two samples were taken from the CEUS panel. Four additional samples (two each) were also given the above-mentioned aging treatments for 8 hr and then compressed. The samples were 2 by 2 by 1.1 in. in size. The maximum buckling stress is given in Table III and indicates a fair amount of scatter in the data. One of each treatment has a high and a low stress associated with it, believed to be associated with the failure mode. The specimens with the lower buckling stress failed on the same buckling plane (Fig. 6(a)), whereas those samples with the higher buckling stress failed in a much more tortuous manner (Fig. 6(b)).

TABLE III.—MAXIMUM STRESS FOR FLATWISE COMPRESSION (FWC) SAMPLES WITH DIFFERENT AGING TREATMENTS

Specimen	Maximum stress, psi
No aging	
FWC–9	210
FWC–5	187
350 °F/8 hr	
FWC–6	190
FWC–10	212
400 °F/8 hr	
FWC–8	219
FWC–11	165



(a) (b)

Figure 6.—Buckled core of untreated samples. (a) Flatwise compression (FWC)–5. (b) FWC–9.

There is no apparent difference for the samples with the high buckling stresses as a function of treatment. However, it appears that for the samples with the low buckling stresses, there may be some aging effect since specimen FWC–11, which was treated at 400 °F, has a slightly lower buckling stress. There would need to be more detailed studies to confirm the influence of aging on buckling strength.

Summary

This work explains that the properties of aluminum 5052 material used commonly for honeycomb (HC) cores in sandwich panels are highly dependent on the tempering condition. It has not been common to specify the temper when ordering HC material nor is it common for the supplier to state what the temper is. For aerospace uses, a temper of H38 or H39 is probably recommended. This temper should be stated in the bill of material and should be verified upon receipt of the core. To this end some properties provided herein can aid as benchmark values.

Behavior of the sandwich panel may be affected by the strength and stiffness of the core. While the primary loads may be carried predominantly by the composite facesheets, off-axis loads could create critical stresses in the core resulting in, for example, core crushing. Studies on damage tolerance of sandwich panels may model the core explicitly, which requires the input of properties for the core foil material. For this purpose there are some properties given in this paper that can be used for the 5052 H38 or H39 conditions.

Finally, results are presented from an aging study on 5052 H39, which can be used as guidance for both the use of higher cure temperatures for the sandwich panels or applications of the HC at higher service temperatures. If the small drop in strength can be tolerated by the design, 5052 H39 aged for 8 hr exposure at 400 °F could be possible, facesheet and core adhesive permitting.

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