Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader: Alex Tang Grade: 12

   Email: alextang12421@gmail.com Phone: (516) 425-5679

   b. Team Member: ______ c. Team Member: ______

2. Title of Project:

   Validation of High-Order Theories for Sandwich Beam Behavior Using DirectImage Correlation (DIC) Techniques

3. School: George W. Hewlett High School School Phone: (516) 792-4002

   School Address: 60 Everit Avenue, Hewlett, NY, 11557

4. Adult Sponsor: Terrence Bissoondial Phone/Email: tbissoondial@hewlett-woodmere.net

5. Does this project need SRC/IRB/IACUC or other pre-approval? ☐ Yes ☑ No Tentative start date: 06/28/2019

6. Is this a continuation/progression from a previous year? ☐ Yes ☑ No

   If Yes:

   a. Attach the previous year's ☐ Abstract **and** ☐ Research Plan/Project Summary

   b. Explain how this project is new and different from previous years on

   ☐☐ Continuation/Research Progression Form (7)

7. This year's laboratory experiment/data collection:

   06/28/2019 — Actual Start Date: (mm/dd/yy)

   08/22/2019 — End Date: (mm/dd/yy)

8. Where will you conduct your experimentation? (check all that apply)

   ☑ Research Institution ☐ School ☐ Field ☐ Home ☐ Other: ______

9. List name and address of all non-home and non-school work site(s):

   Name: SUNY Stony Brook University

   Address: 100 Nicolls Rd, Stony Brook, NY 11794

   Phone/email: (631) 632-6000

10. **Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions and attach to this form.**

11. **An abstract is required for all projects after experimentation.**

Research Plan/Project Summary Instructions

A complete Research Plan/Project Summary is required for ALL projects and must accompany Student Checklist (1A).

1. All projects must have a Research Plan/Project Summary
   a. Written prior to experimentation following the instructions below to detail the rationale, research question(s), methodology, and risk assessment of the proposed research.
   b. If changes are made during the research, such changes can be added to the original research plan as an addendum, recognizing that some changes may require returning to the IRB or SRC for appropriate review and approvals. If no additional approvals are required, this addendum serves as a project summary to explain research that was conducted.
   c. If no changes are made from the original research plan, no project summary is required.

2. Some studies, such as an engineering design or mathematics projects, will be less detailed in the initial project plan and will change through the course of research. If such changes occur, a project summary that explains what was done is required and can be appended to the original research plan.

3. The Research Plan/Project Summary should include the following:
   a. **RATIONALE:** Include a brief synopsis of the background that supports your research problem and explain why this research is important and if applicable, explain any societal impact of your research.
   b. **RESEARCH QUESTION(S), HYPOTHESIS(ES), ENGINEERING GOAL(S), EXPECTED OUTCOMES:** How is this based on the rationale described above?
   c. Describe the following in detail:
      - **Procedures:** Detail all procedures and experimental design including methods for data collection. Describe only your project. Do not include work done by mentor or others.
      - **Risk and Safety:** Identify any potential risks and safety precautions needed.
      - **Data Analysis:** Describe the procedures you will use to analyze the data/results.
   d. **BIBLIOGRAPHY:** List major references (e.g. science journal articles, books, internet sites) from your literature review. If you plan to use vertebrate animals, one of these references must be an animal care reference.

Items 1–4 below are subject-specific guidelines for additional items to be included in your research plan/project summary as applicable.

1. **Human participants research:**
   a. **Participants:** Describe age range, gender, racial/ethnic composition of participants. Identify vulnerable populations (minors, pregnant women, prisoners, mentally disabled or economically disadvantaged).
   b. **Recruitment:** Where will you find your participants? How will they be invited to participate?
   c. **Methods:** What will participants be asked to do? Will you use any surveys, questionnaires or tests? If yes and not your own, how did you obtain? Did it require permissions? If so, explain. What is the frequency and length of time involved for each subject?
   d. **Risk Assessment:** What are the risks or potential discomforts (physical, psychological, time involved, social, legal, etc.) to participants? How will you minimize risks? List any benefits to society or participants.
   e. **Protection of Privacy:** Will identifiable information (e.g., names, telephone numbers, birth dates, email addresses) be collected? Will data be confidential/anonymous? If anonymous, describe how the data will be collected. If not anonymous, what procedures are in place for safeguarding confidentiality? Where will data be stored? Who will have access to the data? What will you do with the data after the study?
   f. **Informed Consent Process:** Describe how you will inform participants about the purpose of the study, what they will be asked to do, that their participation is voluntary and they have the right to stop at any time.

2. **Vertebrate animal research:**
   a. Discuss potential ALTERNATIVES to vertebrate animal use and present justification for use of vertebrates.
   b. Explain potential impact or contribution of this research.
   c. Detail all procedures to be used, including methods used to minimize potential discomfort, distress, pain and injury to the animals and detailed chemical concentrations and drug dosages.
   d. Detail animal numbers, species, strain, sex, age, source, etc., include justification of the numbers planned.
   e. Describe housing and oversight of daily care
   f. Discuss disposition of the animals at the termination of the study.

3. **Potentially hazardous biological agents research:**
   a. Give source of the organism and describe BSL assessment process and BSL determination.
   b. Detail safety precautions and discuss methods of disposal.

4. **Hazardous chemicals, activities & devices:**
   - Describe Risk Assessment process, supervision, safety precautions and methods of disposal.
   - Material Safety Data Sheets are not necessary to submit with paperwork.

Validation of High-Order Theories for Sandwich Beam Behavior Using Direct Image Correlation (DIC) Techniques

RESEARCH PLAN

A.

Rationale

As engineering technology advances, a demand for new, innovative materials have arisen to support and realize new concepts. Many of these technologies demand material properties that no natural substance possesses. Therefore, to achieve these goals, new material breakthroughs, mainly in the form of composite materials, must be explored. One type of composite material currently being intensely studied and developed for these purposes is the sandwich panel composite.

Sandwich composites are layered structures that consist of two thin, high-strength, and stiff face plates, typically fashioned from metal or carbon composites, attached to a thick core of light but low-strength material, usually a honeycomb structure or foam. Sandwich structures are characterized by their low density and light weight, high stiffness and strength, and high energy-absorption capability, especially in the case of high velocity impacts. (Yuan, et al.) Due to these unique properties, sandwich structures have become more widely used in aerospace, nautical, and civil applications where strength and light weight are of great importance. The increased use of sandwich structures in industry has necessitated the development of new sandwich theories that would be able to better model the real-life performance of sandwich composites.

The conventional theory used in analysis of sandwich composite panels is the Classical theory. This theory is based on the general Timoshenko beam theory with the Euler-Bernoulli assumptions that cross sections of the face sheets do not deform significantly under load and that there is no rotation of the cross section as a result of the load. This model does, however, not factor into consideration the compression of the sandwich beam core, modelling the compressible core of the sandwich structure if it were completely rigid. This model could reasonably accurately model the behavior of older metal honeycomb-cored sandwich panels, which were much less susceptible to in-plane deformation as a response to stress than newer foam and non-metallic honeycomb cores. (Forstig et al.) Therefore, the Classical model has serious limitations when it comes to modeling modern sandwich construction methods (Phan et al.). This study investigates various theories to determine which is best to fully model the real-world behavior of the compressible core. More specifically, this study seeks to use a model sandwich beam structure to investigate the accuracy of predictions by the EHSAPT, HSAPT, and Elasticity theories for sandwich structures.

B.

Research Question

How do different beam theories – Classical, First-Order Shear, Elasticity, HSAPT (High-Order Sandwich Panel Theory), and EHSAPT (Extended-HSAPT) – predict the normalized deflection response of a sandwich beam under loading stress?

Hypothesis

The Classical Theory will not be able to accurately predict the normalized deflection response of the sandwich beam under loading stress due to its assumption of rigidity in the entire structure, which causes it to be unable to properly model the compressible core of the sandwich beam. The First-Order Shear Theory will be a better model than the Classical Theory but suffers from limitations in modeling the response of stiff face sheets characteristic of sandwich beams. The Elasticity, HSAPT, and EHSAPT theories will be the best models of sandwich beam loading stress, as these higher order theories are able to more properly model the properties of compressible sandwich beam core and face sheets.

Engineering Goal and Expected Outcome

A model sandwich beam will be fabricated and loaded in a three-point loading press. The normalized deflection of the sandwich beam under loading stress will be derived and compared to predictions made by the five theories being investigated.

C.

Procedures:

The sandwich sample will be constructed of a core of glass-embedded foam and two face sheets of woven carbon fiber. Glass-embedded foam has the advantage of having randomly dispersed reflective particles within its structure that will allow Direct Image Correlation (DIC) techniques to be applied in the analysis of the sandwich panel under stress without the need to apply a speckle pattern using paint, which would likely affect the mechanical properties of the sandwich panel.

To bond the face sheets with the core, epoxy glue will be applied to the bottom face sheet and then evenly spread. The foam core will then be placed on top of the bottom plate. Epoxy will then be applied to the top face sheet and evenly spread. The top face sheet will then be stacked on top of the core. Weights will be placed evenly on top of the completed sandwich panel and then left for 24 hours in order to remove as many air gaps as possible, and to completely cure the epoxy binder before experimentation. After the 24-hour setting period, the sides of the sandwich composite structure will be removed using a band saw and then sanded to remove any epoxy residue that spilled over the side of the sandwich panel during the setting process.

The completed sandwich panel is to be placed in a three-point loading machine that will be operated by the mentor. Cylindrical bottom supports will be placed at each end of the sandwich composite structure. Cylindrical supports are preferred due the fact that a cylinder with its side tangent to the sandwich panel theoretically will contact the sandwich composite panel along one infinitesimally thin line, and therefore will minimize the influence of the bottom supports on the shear and bending response of the sandwich panel under stress.

Once placed in the loading machine, a downward force will be applied by lowering a load arm upon the sandwich panel. A load cell with force readings being fed to the control software of loading machine will be attached to the loading arm. At set intervals, loading will be stopped and an image will be taken until the proportionality limit, where the structure reaches the plastic state and undergoes irreversible structural changes, is reached. The proportionality limit will be determined to have been reached by monitoring the stress-strain graph output in the loading machine control software. After the proportionality limit is reached, data collection will be stopped, and the loading machine returned to its zero position.

Risk and Safety

Carbon fiber – dust may cause temporary respiratory and eye irritation – goggles, gloves, and masks will be worn when working with carbon fiber.

Glass-particle embedded foam – respiratory and eye irritation caused by dust may occur – goggles, gloves, and masks will be worn when working with foam.

Epoxy binder – contact with the resin part of the epoxy glue may cause skin and eye irritation – goggles, gloves, and masks will be worn when working with epoxy.

Bending press – may cause mechanical injury to appendages – will be operated by trained adult mentor.

Data Analysis

The loading machine control software exports a data set that correlates compression force to the displacement of deflection. The data set will then be correlated with the stress-strain curve created by the control software in order to find the domain of the elastic portion of the stress-strain curve. This data will used to derive the Young's Modulus and distributed load of the sandwich beam.

The calculation of Young's Modulus and distributed load will be necessary in order to calculate the variable of comparison between the theories under investigation – normalized deflection. The calculation of normalized deflection for the model sandwich beam allows comparison with the normalized deflection presented by the theoretical prediction of the theories under consideration. Graphs will then be created presenting the relationship between normalized deflection and the percentage distance along the beam to compare the performance of the five theories.

Direct Image Correlation (DIC) techniques will be used to compare the response of the sandwich beam between loading cases. DIC is a technique that allows correlation between two different loading cases based on a speckle pattern present on the cross-section of the sandwich beam being analyzed. As the sandwich beam deforms under stress, the speckle patterns will deform with the beam. Digital photos are taken at given intervals of displacement. A software solution will then be used to correlate between different images using the speckle pattern within the sandwich beam.

D.

References

Kardomateas, G. A., & Phan, C. N. (2011). Three-dimensional elasticity solution for sandwich beams/wide plates with orthotropic phases: The negative discriminant case. Journal of Sandwich Structures & Materials, 13(6), 641–661. https://doi.org/10.1177/1099636211419127

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Amir Fathi, Jan-Hendrik Keller, Volker Altstaedt, Full-field shear analyses of sandwich core materials using Digital Image Correlation (DIC), Composites Part B: Engineering, Volume 70, 2015, Pages 156-166, ISSN 1359-8368, https://doi.org/10.1016/j.compositesb.2014.10.045.

Gdoutos, E.E., Daniel, I.M., Wang, KA. et al. Experimental Mechanics (2001) 41: 182. https://doi.org/10.1007/BF02323195

Frostig, Y., Baruch, M.,Vilnay, O., and Sheinman, I., 1992, "High-Order Theory for Sandwich-Beam Behavior With Transversely Flexible Core," J. Eng. Mech., 118(5), pp. 1026–1043.

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ADDENDUM

No changes were made to the research plan