REQUEST FOR PROPOSAL

TESTING METHODS AND MODELS FOR CONTAINERBOARD

PACKAGING TEAM

ALLIANCE FOR PULP & PAPER TECHNOLOGY INNOVATION
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1. Summary and Background

APPTI encourages the development of advanced manufacturing technologies that promise transformational impact on the paper and forest-based industries. The Alliance exists to identify industry technology needs and R&D priorities; to inform universities and government agencies about industry research needs and opportunities; and to promote collaborative R&D programs. Priority areas are next-generation chemical pulping, energy-efficient black liquor concentration, reuse of process waters, energy-efficient papermaking, cellulosic nanomaterials, and packaging testing improvement.

The newly formed APPTI Packaging Testing Team focuses on the development of more accurate physical test methods and models related to containerboard and converted packaging to enable reduction in manufacturing costs, limit customer product loss, and facilitate the development of higher performing packaging.

The team's specific aims are:

1) To improve existing test methods or to develop new ones based on developments in measurement technology and data analysis and other means

2) To improve performance models to better predict field performance

2. Project Purpose and Description

Physical test methods used to control containerboard quality often show large variations in results. Short span compression (SCT) (or STFI), ring crush (RCT), and Concora (CMT) are common tests for quality control but all lack precision. This is problematic since SCT or RCT are also used in prediction of combined board properties such as edge crush test (ECT) which is used in prediction of finished box performance e.g. box crush test (BCT). ECT is not always a good predictor of actual box performance in the field, which can result in failures leading to damaged goods because it is not a wholly indicative test of all modes of failure or environmental conditions. The easiest solution to solve packaging performance issues is to over-engineer the package by adding basis weight to cover failures from deficiencies in paperboard properties or converting. This practice is wasteful and costly for producers but is often employed as an easy solution to address consumer complaints about packaging problems. A better understanding is needed of all of the factors that impact field performance, including more accurate and precise physical tests, a greater understanding of the impact of environmental factors on box performance, and more comprehensive predictive models.

The ultimate goal is a comprehensive model of combined board behavior incorporating quasi-static, viscoelastic-plastic (e.g. creep, vibration), and hygroelastic-plastic (e.g. mechano-sorptive) behavior. A considerable amount of research has already been published that provides necessary information for a comprehensive model, but research gaps remain. Closing these gaps and developing a comprehensive model of combined board behavior is the ultimate goal of work outlined in this RFP.

3. Overall Program Objectives

We are soliciting projects that address key topics of the overall program objectives. Project submissions can cover any or all of three aspects of the program: modeling box behavior, test methods and data needed, and the effect of formation. The desired scope of the overall program includes the following topics:

Modeling Box Behavior

Develop a comprehensive model to predict box behavior - especially failure - under quasi-static testing, in varying RH environments, in dynamic load conditions, and in multiple loading conditions, including side loading and non-uniform top loading. An FEM, analytical, semi-analytical, or empirical model that describes box behavior could be acceptable. The foundation of FEM modeling is complete; development of a comprehensive model is somewhat like adding tools to the tool box. Different aspects of box behavior can be included by changing a portion of the model. For example, analysis of BCT strength at a particular constant humidity is accomplished by informing the model how the constitutive behavior changes with moisture content. By specifying the moisture content of the box, the model will proceed to solve a system of equations and provide a BCT strength for that scenario.

Additionally, a unified modeling approach for the community will help to unify research efforts, and the extensive library of experimental data will prove valuable for the development and evaluation of further modeling advancements.

An effective model should address the following needs:

(a) Incorporate and simultaneously assess multiple failure conditions, including at least bending behavior and box performance prior to failure.
(b) Identify the dominant failure mode for a particular configuration.
(c) Allow for material property variation, e.g. MD bending stiffness would be specified by mean value ±standard deviation.
(d) Determine likelihood of failure for a particular condition.

The model should use data from standard test methods, especially ECT, combined board bending, and BCT. These standard tests should initially be used to assess the validity of a particular model and provide information as to the appropriate level of structural and material homogenization. Some basic standard test methods are quite

important, especially equilibrium moisture content, for both components and combined board.

Test Methods / Data

Further develop or specify any necessary tests that exist but have not been adopted as standard test methods. For example:

(a) **Combined Board Stiffness Testing and Analysis** - FEM modeling exists, which incorporates component properties to determine ECT strength and combined board bending behavior. Shear stiffness is an important property needed for box modeling. To our knowledge, component-level modeling can only provide a reasonable estimate of combined board behavior. Therefore, new combined board tests need to be used to provide combined board stiffness information to the FEM (or other) model. Full-field plate stiffness tests exist and need only to be modified for combined board. In particular, nonlinear behavior needs to be examined and characterized. Additionally, this type of test is needed to analyze biaxial behavior. Stiffness should be understood as a function of relevant conditions (i.e. equilibrium moisture content, stress history, etc...).

(b) **Failure Criteria Parameters** - The appropriate parameters for failure criteria need to be determined. Tsai-Wu failure theory appears to be the most commonly used, but multi-axial tests are needed to characterize this failure theory. These also need to be determined for different equilibrium moisture contents.

(c) **Component Hygroexpansivity** - Component hygroexpansivity for in-plane and out-plane behavior needs to be determined. Strip hygroexpansivity measurements are influenced by weight and do not provide simultaneous MD/CD determinations. Data on hygroexpansivity as related to equilibrium moisture content is needed.

(d) **Moisture Transport -** Standards exist for water vapor transmission rate, but these standards do not provide the necessary data for FEM modeling, which needs moisture diffusion coefficients. Some identification of diffusion coefficients has been performed in the literature but more are needed for box behavior modeling, especially moisture-gradient creep.

(e) **Viscoelastic-Plastic Behavior** - No standards exist for identifying viscoelastic-plastic behavior. Admittedly, this behavior is challenging to model for many materials and is an active area of research. Viscoelastic-plastic characterization requires several tests and different test geometries, given that both in-plane and out-of plane parameters are needed. Work by Nygårds and co-workers have made excellent progress in this area for out-of-plane behavior.

(f) **An updated BCT**: At a minimum, the complete load-displacement data should be recorded and compared to FEM (or other) modeling. Analysis of crease crushing, especially when that behavior ceases, and progression of panel bulge are needed as a

minimum to evaluate models. Best case scenario is comparing full-field displacements of box panels with models.

(g) **STFI** – Conduct a detailed study with the fundamental understanding of STFI clamp width and the relationship to board formation and floc sizes and STFI variability. Can modifications to the classic STFI standard reduce the overall testing variation?

(h) **Other Tests / Data Needed** - Identify and develop any necessary tests that do not exist or improve existing standards. For example, extensional and compressive behavior of combined board: are not challenging to perform, but nonlinear behavior needs to be characterized. This information is needed for FEM modeling and the characterization of failure/yield surfaces.

Effect of Formation and Strength Variation in a Sheet

Improve prediction and measurement of structural formation (variation of strength in paper.) A significant amount of work has been completed on optical formation; however limited progress has been made on structural formation. Creating a measurement technique and/or predicting structural formation will help the industry understand variation in testing better and offer more accurate inputs for models.

4. Request for Proposal and Project Timeline

The time line for receipt of proposals and selection of projects is provided below. Project work is expected to commence by April 1, 2020. Projects should not exceed two years in duration and $200,000 total ($100,000 per year). A large project proposal would need to address several testing and data gaps as well as incorporate model development or enhancement. Smaller targeted projects that address a particular gap will also be considered.

The proposal is not to exceed 10 pages, single-spaced, 11-point font or larger. The proposal is to include the following information and sections:

- Project Title
- Project Objective
- Principle Investigator (PI) including title, organization, address, e-mail and phone
- List of senior researchers (Co-PI) assisting on the project; include title and affiliation
- Proposed cost to APPTI; identify any institutional contribution as a separate line
- Summary
- Expected project duration
- Introduction with sufficient detail to assess the reasonableness of the proposed research
- Experimental approach—this is not required in detail, but should provide a list of methods, equipment and analysis; references to literature are helpful
- A list of deliverables

- A time line: list of project milestones
- Budget and senior staff qualifications
- List of institutional equipment/capabilities relevant to the proposed project
- Endnotes, budget and senior staff qualifications and institutional capabilities are not included in the proposal page count

Note: A proposal template is included at the end of the RFP

Request for Proposal Timeline:

All proposals in response to this RFP are due no later than 8:00 am EST, January 13, 2020. Submitting proposals before the deadline is strongly encouraged. Review of the proposal is expected to commence as soon as the proposal is received.

Evaluation of proposals is expected to be completed by January 28, 2020. If additional information or discussions are needed during this time, the PI(s) will be notified.

The selection decision for the winning proposal is expected to be made no later than January 31, 2020. Notifications to respondents who were not selected will be completed within three days of the decision.

Upon notification, APPTI will promptly begin contract negotiation with the selected PI. Contract negotiations are expected to be completed by February 21, 2020.

Project Timeline:

Project work is expected to commence by April 1, 2020, and conclude either 12-months, but not more than 24-months following initiation.

Projects exceeding 1 year in duration are required to submit an interim report 13 months after the project contract is signed. All projects are expected to provide a final report within 30 days of project completion. If there are unavoidable delays, a no-cost extension not to exceed 6 months can be negotiated.

5. Budget

Proposals must include a budget identifying key personnel and estimated costs. APPTI is a non-profit corporation organized for scientific and educational purposes, within the meaning of Section 501(c)(3) of the Internal Revenue Code of 1986. The payment of indirect costs (overhead) is limited to 20% of total costs. Equipment and supplies are not to exceed 10% of total costs. Travel is not to exceed 10% of total costs. For projects where there is a significant institutional contribution, these limits can be waived at the discretion of APPTI and the funding companies.

6. Qualifications

A biographical sketch of each senior participant in the project should be included. This should include a publication list with an emphasis on publications most relevant to the project. The bio and publication list are not to exceed 2 pages for each senior staff

person listed. In the biographical sketch, be sure to identify any specific prior experience and skills of relevance to the proposed project.

7. Proposal Evaluation Criteria

APPTI Packaging member companies will evaluate all proposals based on the following criteria. To ensure consideration for this Request for Proposal, your submission should be complete and include all of the following criteria:

- Overall proposal suitability: proposed solution(s) must address the needs and challenges included herein and be presented in a clear and organized manner
- Impact: The likelihood the proposed approach will address the technical challenge.
- Innovation: The extent to which the proposed work is novel and innovative.
- Proposed Work
- Team Organization, Capabilities and Qualifications: Respondents will be evaluated on their experience and capability as they pertain to the scope of this project. Respondents will be evaluated on examples of their work in similar areas.

APPTI will evaluate proposals based on the above criteria. The highest rated proposals will be considered for funding. Provided a sufficient number of supporting member companies are interested in funding the effort, negotiation of a formal agreement to carry out the work will commence. It is possible that no proposals will meet the criteria and therefore none will be funded. This RFP should not be interpreted as a guarantee that funds will be provided.

8. Proposal Guidelines

The proposal shall contain the following information as described more fully in the Proposal Guidelines section beginning on page 13:

- Total Project Cost
- Concept Summary – A description of the proposed project and how it will address the goals as described in this RFP
- Project Duration/Timeline/Milestones
- Innovation: why the proposed work represents an innovative approach to address the challenge
- Impact – Information on the specific technical challenge that will be addressed
- Proposed Work – A description of the approach and the work that will be undertaken; scientific and technical data supporting the approach; alternative approaches considered
- Team Organization, Capabilities and Qualifications – Roles, responsibilities, capabilities, experience of the project team
- Resources that will be accessed (experimental and analytical laboratories, computing capabilities, etc.)
- Project Budget

9. Submission

Respondents must submit their proposals by 8:00 am EST, January 13, 2020 to david.turpin@appti.org

Attachment:
PROPOSAL PREPARATION GUIDELINES

RFP – Insert Project Title

GUIDELINES FOR PROPOSAL PREPARATION

PROJECT TITLE _____
Project Team _____

Total Project Cost _____
Project Duration _____

1. **Concept Summary**
   - *Describe the proposed concept with minimal jargon, and explain how it addresses the project purpose.*
2. **Innovation and Impact**
   - *Describe how the concept will meet the RFP purpose.*
   - *Clearly identify the technical challenge that will be solved and how the project will address the challenge.*
   - *Identify the benefit that would be realized through successful development of the proposed technology.*
   - *Describe how the proposed effort represents an innovative and potentially transformational solution to the identified technical challenge.*
   - *Explain the concept's potential to be disruptive compared to existing or emerging technologies.*
   - *Clearly identify quantitative technical performance and cost targets for the proposed technology. If applicable, compare the targets to current and emerging technologies.*
3. **Proposed Work**
   - *Describe the planned technical approach to achieve project objectives.*
   - *Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach.*
   - *Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.*
   - *Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?*
   - *Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.*
   - *Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.*
   - *Define the final deliverable(s) for the project*

4. **Project Timeline**
    - The proposal should include a project timeline with key milestones
5. **Team Organization, Capabilities and Qualifications**
    - *Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.*
    - *Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.*
    - *Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.*
    - *Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.*
6. **Project Budget**
    - *Include information on the funding level required to complete the project, itemized by type of funding (personnel, supplies, overhead, etc.) and project phase.*