Report on the OB Stave Prototype and Tooling Design Review – 21/06/24

# Prelims

Panel: Tim Jones (Chair), Adam Lowe, James Glover

Project: Geog Viehhauser, Todd Huffman, Stephanie Yang, Adam Huddart, Eve Tse

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# Remit

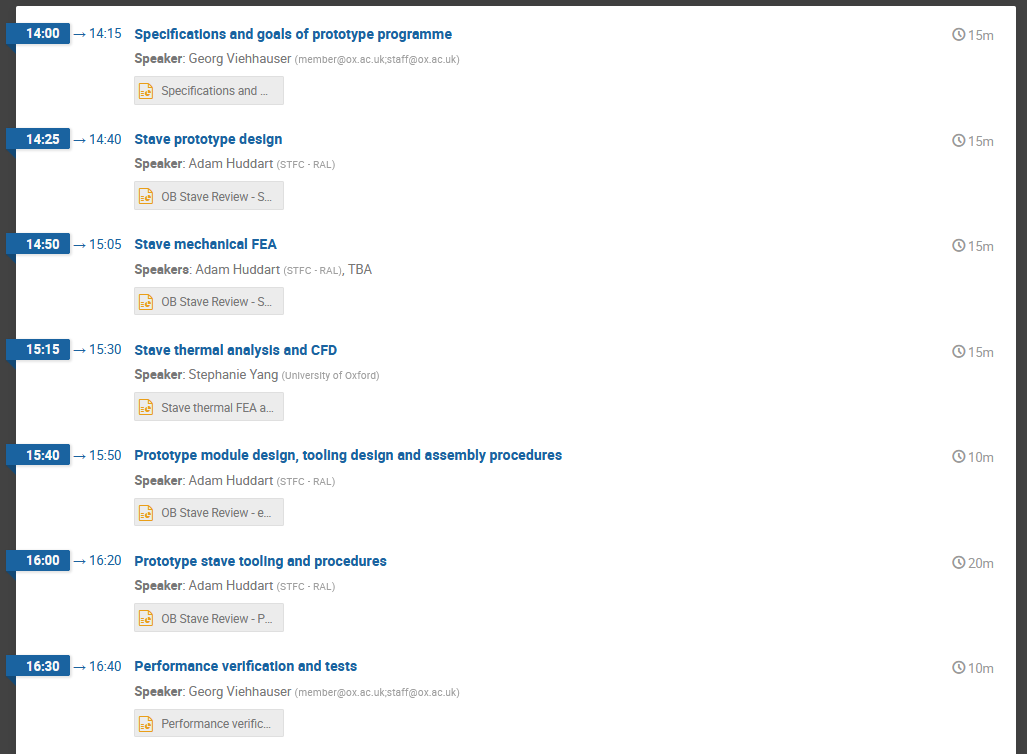
Assess the programme for OB stave prototyping, in particular

1. the requirements for the OB staves (for orientation),
2. the design for the prototype staves (incl. modules) and computational verification,
3. production tooling and procedures (stave and module),
4. proposed testing (incl. support conditions)

The basic stave design is not to be reviewed in detail at this point (although any suggestions will be gladly received and taken into consideration), as the basic stave design will be evaluated and reviewed once the results from this prototype programme are available.

The purpose of the review is to give us input for optimization of the tooling and procedures for prototype module and stave assembly and tests to be employed, and to give us confidence that we can instigate production of the tooling.

# Presentations



# Prototyping Proposal

The team wish to develop the manufacturing and integration concepts for OB staves to use as input to the production of the Technical Design Report which is needed by the end of 2024.

They are basing their programme on the current design for staves suitable for Layer 4 (R=420mm, L=840mm). The stave consists of a low-mass carbon-fibre, Kapton and foam structure which, when populated with adhesively-bonded sensors, forms a sealed conduit through which air can flow. Heat is transferred from the modules into the air stream via convective cooling from the surface of the silicon sensors. Where regions of the sensors have higher power densities low density thermally-conductive foam is placed in the air-path to increase the local heat transfer coefficient. They assume a heat-load of 37.5W and estimate that air flowing with a stream velocity of 12ms-1 is needed to remove the heat whilst limiting the temperature rise of the sensors to ~ 10°C.

The prototyping programme aims to study;

* Demonstrate the proof-of-principle that the construction of such a stave is possible; the key features are the use of the co-curing of CFRP pre-preg to the thermally-conductive foam, CFRP I-beam and longerons AND the placement and adhesive bonding of pre-curved sensors onto the stave to form a gas-tight conduit
* The experimental determination of the mechanical rigidity and vibrational response of the stave (supported at its ends) and comparison with FEA models.
* The experimental determination of the thermal gradient along the length of the stave and perform comparisons with FEA models.

The team intend to make use of existing stocks of “K9” thermally conductive foam (Lockheed-Martin), K13C2U/EX-1515 pre-preg (Toray), and thermo-mechanical sensors supplied by others.

The panel were impressed by the amount of work carried out by the relatively small team over a short period of time.  However, the panel also have concerns around the scope of work needed to deliver the programme as presented given the limited size of the team. As such the comments below should be considered in that light and result from the reviewers’ desire to see the this initial phase of the project reach a successful conclusion in a timely manner.

# Comments

Much of our discussion focused on the manufacture of the passive part of the stave. We believe that the manufacture of such a structure is probably attainable but we felt that the project was challenging, particularly given the short timescales and our general feeling that the team has limited effort available to it.

In particular we were concerned that the use of 2-ply (inherently asymmetric) facings could be difficult to consolidate fully and would be likely to create geometrical deformations in the regions that will eventually be glued to the sensors and make the attainment of a gas-tight seal too challenging. During the meeting the team did mention their intention to look at alternative pre-preg systems, with reduced cured-ply-thickness (CPT), in the longer term. With that in mind the reviewers felt it would be better to adopt a symmetric 3-ply laminate that should be better controlled and have less geometric distortion to facilitate the sealing of the conduit for the prototyping programme. Once the proof-of-principle has been demonstrated, and with radiation-length in mind, final staves could be developed with an alternative pre-preg with thinner CPT (25-30µm) with which the laminate lay-up could be further optimised to achieve the best results.

As discussed during the meeting, there were concerns expressed about the geometrical precision of the mould tools and internal components of the stave (eg I-beams, K9 foam, etc) that would be required for a 2-part mould to function correctly and achieve full consolidation. The reviewers suggest the team evaluate using an “open-mould” technique with a suitable intensifier as a back-up.

The reviewers feel that the gluing of sensor modules onto the bare stave and the necessity to control of the bond-lines to achieve a gas-tight seal is a major challenge. We believe there are actually 2 glued interfaces to worry about; the first is between the silicon sensor and the Kapton carrier and the second is between the Kapton carrier and the CFRP laminate. Whilst the former can be inspected and re-worked (eg glue fillet) once the assembled sensor module has been bonded together, the joint between the Kapton and the CFRP cannot be re-worked if there are leaks. The team should think about the likely machining tolerances of the assembly tooling and the internal components of the stave (eg foam, I-beam, longerons) and define target bond-line thickness for the sensor-to-stave gluing. A conservative bond-line thickness, that would ensure any local variations can be accommodated without risk of glue squash-out, should be chosen to facilitate the manufacture of staves with good gas-tightness for the prototyping programme. Once the proof-of-principle has been demonstrated, and the geometrical requirements have been fully understood, efforts should then be made to reduce the amount of adhesive if needed.

Finally, the reviewers thought other aspects of the project, eg FPC and TAB bonding development work, would benefit from having reasonable mechanical mock-ups (perhaps ¼ length staves) to work with and the stave development team should seek to make these available for as an output of their programme.