Development of 6aω Coplanar Fixture for Hybrid III 50th Percentile Anthropomorphic Test Device (ATD)

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INTRODUCTION

- Numerous data acquisition methods are available, but testing of coplanar intracranial scheme is limited.
- Two leading causes of Traumatic Brain Injuries are motor vehicle accidents and sport-related injuries.[1].
- Mild Traumatic Brain Injuries account for 82.7% of youth hospital admissions, 15% of which are moderate to severe. [1]
- Existing spatial scheme allows for cranial deformation during impact, resulting in the failure of rigid body kinematics and kinetics.
- Acquired data currently requires numerical differentiation to determine angular acceleration, leading to estimation errors. Errors avoided with Coplanar scheme.
- To investigate 6aω Coplanar Fixture optimization, Finite Element Method will be implemented using Modal Analysis to reduce structural vibration.
- The intent of this study is to optimize data acquisition by moving sensors off the cranial lining and studying the natural frequencies of the fixture through modal analysis.

METHODS

Optimal Design

- Compare Material Properties of Steel and 6061 Aluminum
- Initial FE modal analysis to finalize material
- Modal analysis outputs frequency response and period
- Develop multiple designs with variable masses and structures
- Machine optimal design
- Perform impact tests, analyze data

Distance Testing

- Create separate fixture to test variable distancing of sensors from center of gravity
- Perform FE modal analysis to ensure feasibility
- Machine distance testing fixture
- Perform impact tests, analyze data
- Finalize acceptable distancing of sensors

KEY: COMPLETE; IN PROCESS; FUTURE

REFERENCES CITED

1. Imhof, H.-G., and P. Lenzlinger. “Head, Thoracic, Abdominal, and Vascular Injuries." (2011).

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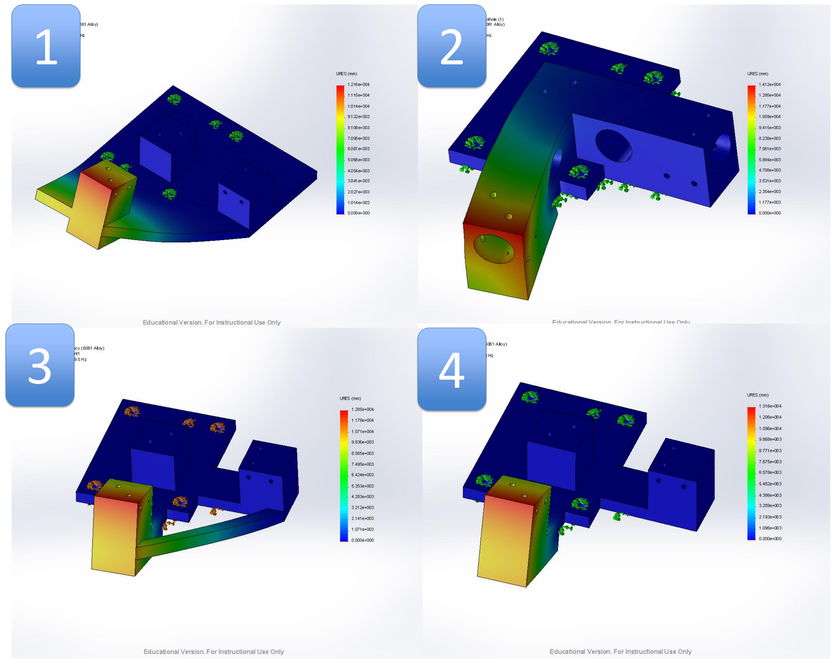
RESULTS & DISCUSSION

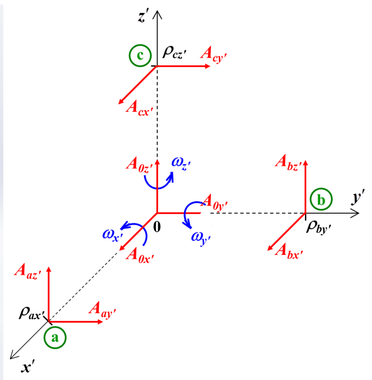


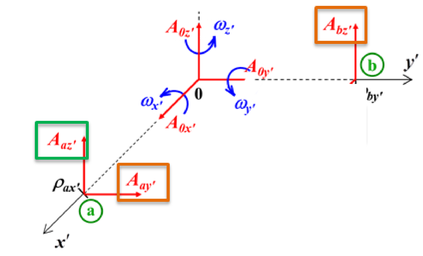
Design #	Mass(kg)	Frequency (rad/s)	Period (sec)
Design 1	0.08	21698	0.00029
Design 2	0.07	57258	0.00011
Design 3	0.06	16710	0.000376
Design 4	0.06	16843	0.000373

- Constraints required period (T) be smaller than 0.001 seconds. A period larger than 0.001 seconds causes noise to develop in the data.
- A higher natural frequency correlates to a smaller period (T) for each design. The optimal design holds the highest frequency.
- Natural Frequency (w_n) can be derived from the equation below. A balance between the mass and stiffness (k) is essential.
- Design 4 clearly attains an optimal design frequency, while limiting weight.

$$w_n = \sqrt{\frac{k}{m}} = \frac{1}{T}$$

w_n – Natural Frequency
m – Mass
k – Stiffness
T – Period



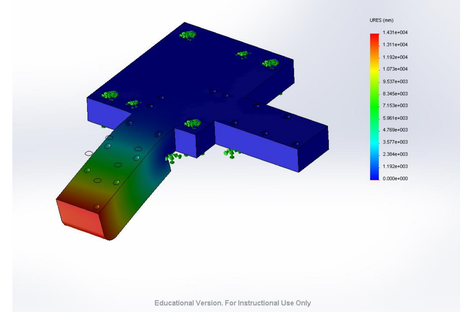


$$\dot{\omega}_{x'} = -(A_{0z'} - A_{bz'}) / \rho_{by'} - \omega_{x'}\omega_{z'}$$
$$\dot{\omega}_{y'} = (A_{0z'} - A_{az'}) / \rho_{ax'} + \omega_{x'}\omega_{z'}$$
$$\dot{\omega}_{z'} = -(A_{0y'} - A_{ay'}) / \rho_{ax'} - \omega_{x'}\omega_{y'}$$

Spatial | Coplanar

Distance Testing Device

- Accelerometers placed at variable distances (0.75 cm spacing)
- Impact testing will determine ideal sensor distance from center of gravity.
- Smaller distance between sensors will produce less vibration due to cantilever beam vibration principles
- Distance testing will reaffirm modal analysis of initial designs.



CONCLUSIONS & FUTURE

- Balance between heightening the natural frequency of the designs and the inertial properties is crucial. Ex.: A heavy design will have an ideal frequency but will alter the center of gravity of the head due to inertial differences.
- Design 2, a design similar to the THOR ATD head fixture, possesses the ideal inertial and frequency balance. The hollow cuts allow for optimal stress concentration levels, while decreasing the overall mass.
- Moving forward, impact testing and data analysis will provide quantitative measurements to reaffirm the feasibility of the 6aω Coplanar data acquisition method, in addition to possible optimizations in design.
- Optimizations in data acquisition, especially in impact testing, will result in safer vehicles and athletic equipment. Brain injuries will decrease, saving lives.

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