

## Objective/Scope

Reduce the vibration transmitted to a Hyster-Yale overhead guard by shifting the modal frequencies away from engine idle and full throttle frequencies.

## Value Proposition

- Noise from the engines of forklifts are amplified through resonance to the surrounding structure. This can be bothersome to the operator, especially when being used for prolonged periods.
- Innovative solutions to reduce resonant noise of the forklift's structure could be applied to other powered industrial trucks, resulting in a better overall experience for the operators.

## Background



**Resonance Phenomenon** – A system in resonance will vibrate at its natural frequency with maximum amplitude in response to an external force.



**Noise** – Higher vibration amplitude causes louder noise due to the excitement of sound waves in the surrounding air.



**Shifting Resonance Frequency** – Shifting the system's resonance frequency away from the motor's operating frequency decreases the likelihood that the system will amplify the noise from the motor.



**Tuning Resonance** – The system's resonant frequency can be shifted by strategically adding mass and stiffening the structure.

## Product Requirements

No modifications to the mounting interface of the OHG to the forklift shall be made.

The team will not add or remove excessive weight/mass from the OHG to compromise the strength of the part.

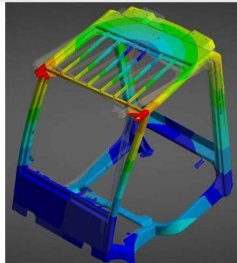
Modifications to the OHG will not interfere with the forklift operator's ability to see and drive the equipment



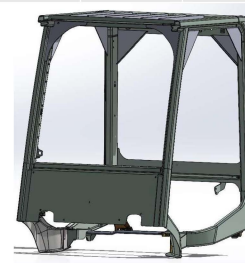
## Concept Development

- Simulated modal frequencies of unmodified Overhead Guard using Ansys, a finite element analysis software.
- Exaggerated modifications were made and simulated to iterate design concepts. Gussets were then designed in various directions to stiffen against mode shapes, which shifted frequencies.
- Aimed to shift mode frequencies away from vibrations induced by the forklift engine.

| Engine RPM                                      | 800   | 2000  | 2400  |
|-------------------------------------------------|-------|-------|-------|
| Equivalent Frequency 2 <sup>nd</sup> order (Hz) | 26.66 | 66.66 | 80    |
| Proposed Target Frequencies Range (Hz)          | 32-53 | 72-73 | 88-96 |



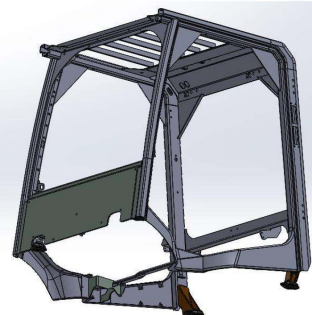
Initial Simulation – Twisting Mode Shape



Gussets in top corners to prevent twisting mode

## Final Design

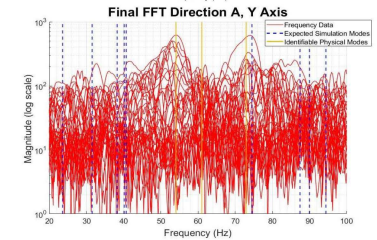
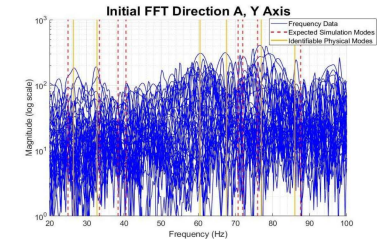
Combination of all concepts with gussets on the top corners of Overhead Guard



## Validation

- Used Arduino software and two accelerometers to record acceleration data from 38 locations around the frame.
- Transformed acceleration data into frequency spectrum using MATLAB FFT function.
- Data was collected and analyzed pre and post structural modifications.
- Comparison between initial and final frequency data revealed that structural changes affected modal frequencies.

| Initial Frequency (Hz)                    |            |          |
|-------------------------------------------|------------|----------|
| Mode                                      | Simulation | Physical |
| 1                                         | 19.097     | *        |
| 2                                         | 24.943     | 26.46    |
| 3                                         | 33.381     | 32.78    |
| 4                                         | 38.404     | *        |
| 5                                         | 40.513     | *        |
| 6                                         | 70.752     | 60.45    |
| 7                                         | 71.984     | 67.67    |
| 8                                         | 76.005     | 76.95    |
| 9                                         | 87.609     | 86.02    |
| Final Frequency (Hz)                      |            |          |
| Mode                                      | Simulation | Physical |
| 1                                         | 23.577     | *        |
| 2                                         | 31.574     | *        |
| 3                                         | 38.29      | *        |
| 4                                         | 40.175     | 54.13    |
| 5                                         | 40.7       | 61.05    |
| 6                                         | 74.523     | 73       |
| 7                                         | 87.442     | *        |
| 8                                         | 90.032     | *        |
| 9                                         | 94.456     | *        |
| *No discernable modes could be identified |            |          |



## Conclusions/Recommendations

From physical data, modes appear to shift from initial to final, showing that the modifications altered frequencies. Due to quality of accelerometers used there is low confidence in the frequencies acquired. We recommend a higher budget for more robust data acquisition equipment for future tests.

## Acknowledgements

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