

UPLIFTING SOUND QUALITY FOR CROWN EQUIPMENT CORPORATION

Today, sound is being recognized more and more as an important parameter when defining product quality. With this in focus, Crown Equipment Corporation decided to explore how improving the sound of their forklift trucks could create a better product and, in turn, a more satisfying user experience.



CHALLENGE

To explore how improving the sound of forklift trucks could create a better product and a more satisfying user experience

SOLUTION

Two Jury Studies; one in the US and another in Germany, enabling Crown to create a 'Sound Quality Preference Equation'

RESULTS

Newfound knowledge and skills leading to a more efficient and valuable development process – and the first of many new product designs



BACKGROUND

Since their entry into the material handling industry in the 1960s, Crown has become known for exceptional product design, engineering and manufacturing of an award-winning line of forklift trucks. However, in an industry facing product parity, they understand all too well how important it is for their products to have as many 'quality defining' features as possible in order to maintain their leading market position and support their sales processes.

Even though Crown's trucks have always had a reputation for delivering market-leading functionality and performance, they have also focused on maintaining the highest quality when it comes to ergonomic features, such as comfort, style and, naturally, noise – one particular area that Crown wanted to explore more deeply to augment their product development process.

CHALLENGE

The decision was therefore made to examine sound quality in detail. On one hand, this valuable knowledge would help Crown to understand the factors that influence its perception; and on the other, it would also equip them with the right skills to engineer an even higher class of product. The big question was, how?

Understanding the 'Crown sound'

"Our central aim was to find new and more efficient ways to improve our development process. This represented a perfect opportunity to adopt the latest methods and state-of-the-art tools within NVH and sound quality."

Ron Ziegler, Director – Compliance and Test Engineering

"I SEE A GROWING TREND TOWARD STRICTER MARKET REGULATION OF NOISE AND VIBRATION EXPOSURE GLOBALLY, PARTICULARLY IN THE EU AND INCREASINGLY IN THE US."

*Ron Ziegler, Director – Compliance and Test Engineering,
Crown Equipment Corporation*

In consultation with Brüel & Kjær, it quickly became clear that in order to create the 'right' forklift truck operating sound, Crown first needed to know what that sound actually was. To help clarify this, they brought on board Sound Answers, a sound and vibration consultancy company, who could help them advance their process and analysis abilities, and participate in design reviews based upon the analysis performed.

SOLUTION

Jury Study

Sound Answers introduced the concept of a 'Jury Study' as one of the most effective ways of defining sound preference. This type of exercise involves a qualitative jury of end users who rate the sound of a particular class of motorized vehicles in order of preference. These ratings are then correlated to highly

specific sound quality metrics, such as sharpness, loudness and modulation strength.

To collect the required data and generate the most conclusive results, Crown worked with Sound Answers to assemble two Jury Studies; one in the US and another in Germany. The juries consisted of managers and truck operators who were asked to rate a series of sounds from their own and their competitors' equipment, which had been carefully recorded to eliminate any weighting or bias. In addition to the recorded sounds, modified or synthesized sounds were included in the evaluation to help identify the dominant drive motor sounds that people preferred.

The Jury Study proved to be very productive and enabled Crown to understand users' sound preferences in more detail. In general,





“TOGETHER WITH SOUND ANSWERS, WE HELPED CROWN TO DETERMINE WHERE THEY WANTED TO BE AND, BY IDENTIFYING THEIR TARGETS AND EQUIPPING THEM WITH THE RIGHT KNOWLEDGE AND SKILLS, HOW TO GET THERE.”

Gary Newton,
Regional Manager, Brüel & Kjær

the results showed that people preferred forklift truck sounds to have a moderate level of low-frequency noise, and be free of both high-pitched noises and excess modulation. The results also enabled Crown to pin down a specific combination that was the ‘preferred sound’. This could then be used as a benchmark for developing other products. This enabled them to build an immediate ranking of how the recorded Crown products were judged against their competitors’, and to identify key opportunities, either for improvement or where they were already performing better.

Sound quality equation

Most interestingly – and usefully – these results enabled Crown to create a ‘Sound Quality Preference Equation’, a mathematical formula that could be used to accurately define the objective metrics of Crown’s ideal forklift truck sound (known as the Sound Target). This formula would help them to evaluate any of their trucks’ sound against their competitors’, reliably predict the impact of alternate designs, and communicate these clearly to their internal engineering teams.

In short, the equation would enable them to predict, measure and make precise adjustments to the sound of all future product de-

signs much earlier in the development phase and, crucially, based on actual user preference.

RESULTS

With this initial goal reached, Crown were then able to leverage what they had learned about defining, measuring and analyzing sound quality and use it to support the development of a new sound quality model design; specifically, the exhaust system of their new line of LP Gas forklift trucks.

Setting clear parameters

At this stage, Crown was confident in their ability to put these new techniques into practice, with Brüel & Kjær and Sound Answers standing by to help them optimize the final design. Immediately, they were able to make full use of their new knowledge and tools; by running data through their Sound Quality Preference Equation, they could rank and analyze competitor products and set clear parameters for their own product’s sound quality target and design.

3D CAE model

Then, in order to correlate, visualize and audition the test data, a 3D CAE model of the new exhaust system design was built using MSC Actran® acoustics software. In combina-

tion with Brüel & Kjær’s NVH post-processing software, Actran was able to simulate a working 3D model of their exhaust system that could display the mechanical, acoustic and aeroacoustic characteristics of the system, along with its internal gas flow. This enabled Crown to accurately predict and listen to how the final product would sound and behave under a wide variety of conditions.

Physical prototype

Once Crown was satisfied with the CAE model design, they were able to move forward with a physical prototype. This allowed them to correlate the test results from the virtual and physical model and refine the design to bring the exhaust noise even closer to their Target Sound. As an important part of this, Brüel &

Virtual prototypes

3D CAE models, like those created by Actran, enable engineers to validate and optimize designs using virtual prototypes. They are exceptionally valuable to reduce development time and cost by helping engineers to define and apply more precise results earlier in the design cycle.



Both indoors and out, sound can be an important customer consideration

Kjær's Low Frequency Sound Source tool was used to measure the transmission loss, which revealed how close Crown's virtual model was to its physical counterpart. All this data could be correlated back to the Actran model to continue improving and optimizing the sound and, each time the model was updated, the results could be run through the Sound Quality Preference Equation to determine their impact.

A final prototype was then built using the improved design from the updated Actran CAE model. Once it had been installed on a forklift truck, the entire project team, including those from Crown, Brüel & Kjær, Sound Answers and MSC Software, each reviewed its performance in person for any final refinements. The unanimous decision was that the new exhaust system was a significant improvement over the previous design; an opinion that has since been widely affirmed across all their engineering teams.

CONCLUSION

Everyone at Crown has greatly valued Brüel & Kjær's and Sound Answers' roles in helping them to gain a firm understanding of how sound quality plays a vital part in product development – and how best to achieve it.

The entire exercise has had a major influence on how Crown conducts their development processes and now they are continuing to further develop their strong capabilities in acoustic modelling (along with other CAE tools). Previously, much of the important testing, evaluation and refinement phases were weighted to the end of project. Now, these can be conducted far more upstream, greatly shortening the development time, reducing the need for additional design build test iterations and thereby significantly lowering development costs.

More importantly, this has enabled Crown to move from what was primarily a knowledge-based approach to one built on actual

metrics. The data captured and results generated enable a far more efficient and effective development process where new learning can be transferred from one project to the next. As a result, they are now well on their way to a point where sound quality methods and acoustic modelling will be the principal means used to specify and validate noise requirements.

These methods and tools also have broad application in many areas. Crown is conducting several projects aimed at reducing overall vehicle noise and vibration, which will ultimately reduce operator exposure to noise and greatly enhance comfort and usability.

Crown's vertically integrated processes provide a level of control and consistency that brings unsurpassed results for their customers. And today, with this invaluable new understanding, they are now equipped to lift those results even higher.

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