NVH Design Refinement on Grader vehicle to meet Noise ISO norms.

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Abstract

Earth moving industry gaining interest in developing countries like India. Lot of OEM's are developing/modifying their product according to different application. Like Grader vehicle at Mahindra (102 hp) which don't have any benchmark or competition. Which makes it very difficult to refine in terms of design. On the other hand, governments are also coming up with stringent norms for noise and emission. ISO 6395 and 6396 are a part of noise norms that OEM's needs to meet for 2024. According to these norms noise radiation outside (Exterior noise) and incab noise both need to meet certain criteria as mentioned in regulation. NVH team taken this task to meet the regulation first time right. Step by step process is followed to achieve these targets.

To start with different baseline measurements were carried out to understand and rank different noise sources like hydraulic, fan, engine, transmission, exhaust etc. After identifying and ranking the sources different design optimizations were carried out both in CAE as well as in test. Both source level and path level optimization were carried out. Finally, a 7dB (A) reduction is achieved on sound power level which is a very significant reduction. Inside cabin noise was also reduced by 8-9 dB(A)to not only meet the target but also improve the comfort by reducing fatigue at operator.

Introduction

Government Homologation Requirements regulations CEV-BSV norms in India become more rigorous associated in vehicle noise qualities which are applicable from April 2024. Constraints of making CE product made in India to be in lined with global standards with respect to Noise and vibration norms. So, Noise level & sound quality are one of the determined factors key qualities of CE product for meeting upcoming norms and make sure product is accepted globally in shorter period at lowest cost.

Motor grader vehicle iso limits as per iso are exterior noise is 109 dB(A) 6395 and Interior Noise level 85 dB(A) ISO 6396.as NVH Engineer we bring out our motor grader vehicle below target level with desirable sound quality. Motor grader is one of the most now versatile earthmoving machines uses days for road surface leveling. The blade of Motor grader is mounted on underneath which can be lifted a lowered with a hydraulic system. Motor graders are used at considerably primarily for rough and finish grading, crowning, Motor graders are used at considerably high speeds primarily for rough and finish grading, crowning, or levelling roads, and snow or ash removal.

01 Problem Definition

Identifying the primary sources of noise in the off-road Grader during dynamic testing according to ISO 6395 and ISO 6396. Developing strategies to mitigate these noise sources and aligning them with ISO standards to ensure the noise levels are within the prescribed ISO limits. This paper describes the methodology adopted to address the issue of fan noise which was found to be major contributor for interior as well as exterior noise for motor Grader vehicle.

02 NVH Refinement process flow

Baseline dynamic test was carried out on CEV as per ISO 6395 & 6396 Measurement, Time-averaged sound pressure levels (SPL) was evaluated to calculate sound power level Critical frequencies were identified from measurements at each microphone locations Nearfield noise and vibration were measured to co-related with exterior noise. Noise Source Identification & Contribution Transfer Path Analysis, Order Analysis, Structural Analysis, Then Major Noise Source refinement Powertrain level, Fan level, Flow noise, Hydraulic Noise etc. Accessories Noise Refinement: Priority valve contribution, Rubber isolators to improve isolation. Structural and acoustic path improvements and finally we have done grader vehicle Confirmatory trials with all modifications.

03 Methodology:

The commencement of the Grader NVH development involved initiating measurements based on the proto vehicle baseline ISO. The standard test configuration comprises two in-cab microphones and six exterior microphones strategically positioned beneath a hemisphere, with its radius determined by the machine's basic length. The in-cab microphones, designated as the driver/operator ear LH & RH (see figure 1), are situated 200 mm ± 20 mm from the median plane of the operator's head, aligning with the line of sight. This positioning adheres to the specifications outlined in ISO 6394 & 6396. The final measurement considers the maximum value between the two positions. (refer figure 1). Their position is 200 mm ± 20 mm from the median plane of the head of the operator within line of the eyes, as mentioned in the ISO 6394 & 6396. The maximum value of the two positions is considered as the final measurement. For the exterior microphones, microphone & 4 will be the first approaching during vehicle forward travel to the right & left side of the vehicle. Microphone 2 & 3 will be at the end, in line with microphones 1 & 4. Microphones 5 & 6 will be at the highest points. The exact microphone location can be referred from ISO 6393 & 6395 as shown in figure.1&5.

Figure 1. In-cab noise measurement microphone set-up. (Std 6396)

04 Grader Vehicle Homologation Requirements

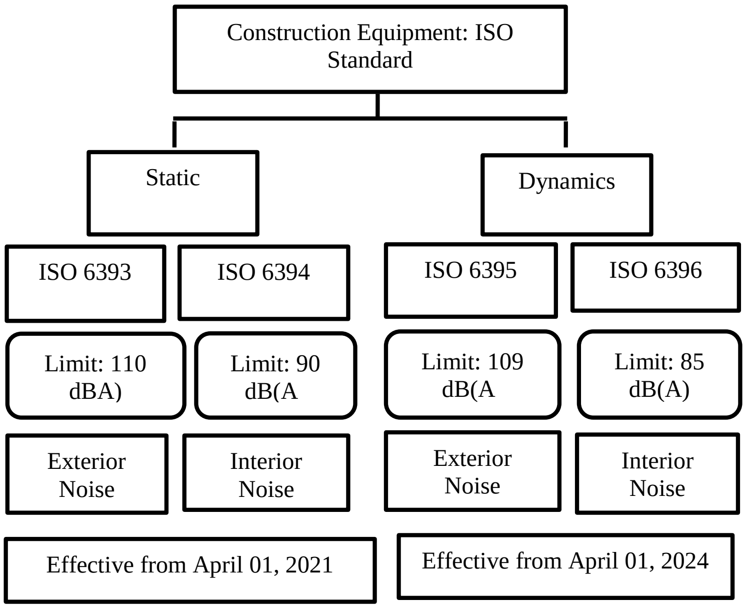

Fig: 2. Construction Equipment: ISO Standard chart

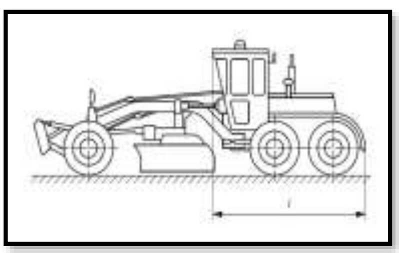

Fig:3. Grader Vehicle

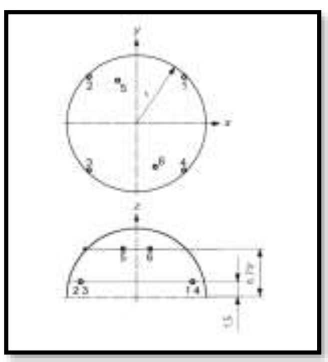

Fig: 4 Microphone array on the hemisphere (Std 6395)

Measurement surface to be used for the test shall be a hemisphere. The radius of the hemisphere. The radius of the hemisphere shall be determined by the basic length of the machine.

The Grader NVH development work started from the proto vehicle baseline ISO measurement. The typical test set up consist of 2 in-cab microphones & 6 exterior microphones. Mics. 5 & 6 will be the highest points. Refer below fig 5

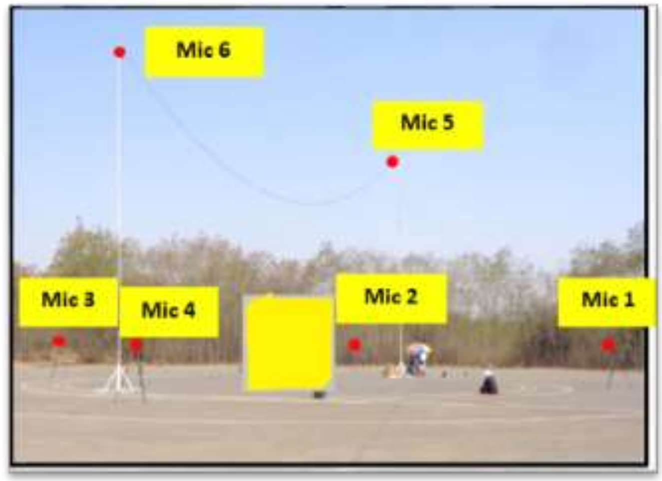

Fig:5. Grader vehicle iso measurement test setup

For the first phase of the Grader vehicle, the engine rated RPM and vehicle stationary measurements must be made. Phase II measurement requires the vehicle to be moving forward at its maximum engine fly-up RPM, but not faster than eight kilometres per hour. The measurements of outside noise will be expressed as Sound Power Level (dB(A)) and inside noise as Sound Pressure Level (dB(A)). Measurements were taken in accordance with the standards, and the outcomes were not very encouraging. They were departing from the goal by 2–7%. Because to the fan noise, the in-cab noise level was extremely high and unpleasant. The driver found this situation to be extremely unpleasant. In order to identify the noise source, this required detailed study. Prioritising the development for high-ranked noise sources will be simpler when the contributions from each noise source have been assessed. The noises from the engine, fan, exhaust, intake, hydraulic system, and engine accessories are among these sources. The noise was then recorded from every source in accordance with established protocol and compared to the objective. Each source's % contribution is displayed in the below figure. Significant contribution was discovered from the cooling fan in addition to the engine hydraulic system. The noise inside the vehicle is less from the exhaust, intake, and engine accessories.

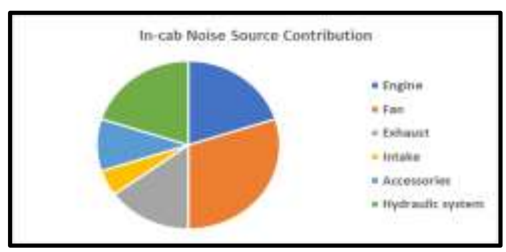

Fig: 6. Contribution of different noise sources in In cab noise

Following iterations were carried out on Grader to identify probable noise sources.

1. Baseline measurements
2. Fan Removed from Vehicle
3. Exhaust Bypass
4. Turbocharger Clad

5. Transmission Clad

6. Engine Clad (Top, Bottom, LH, RH)

7. Intake Bypass

Iteration 1: Fan removed.

Fig:7 Without Fan

Fig: 8 With Fan

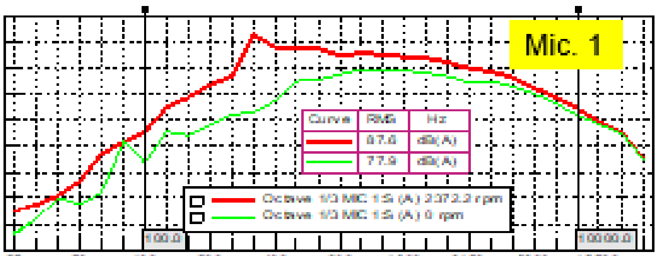

Fig:9 Without Fan result

Following the test, a noticeable reduction in noise was detected across the frequency range. Fan is therefore one of the main causes of the rise in noise levels generally. Now, the development trials were focused on the fan noise.

Iteration 2: Exhaust Bypass

Fig:10 Exhaust Bypass

After analyzing the fan noise trails, we conducted an exhaust bypass to check for any contribution to exhaust noise. We utilized a universal exhaust for these trails However, there is no significant noise reduction has been observed due to exhaust bypass.

Iteration 3: Turbo Clad contribution analysis

Fig: 11Turbo Clad contribution analysis

In turbo cladding we use lead sheet for cladding for turbo and the analysis of Turbo Clad's contribution reveals that there hasn't been a notable reduction in noise observed.

Iteration 4: Transmission Clad

Fig:12. Transmission Clad contribution

Transmission cladding, we use same lead sheet for masking, and we observed There is no significant noise reduction observed by transmission cladding.

Iteration 5: Engine Clad (Top, Bottom, LH, RH)

Fig:13 Engine Clad

Engine cladding, we did first engine top, and downside masked with lead sheet and took the measurements and saw there is any improvements then next activity we did RH &LH side covered with some acoustic materials and again we did measurements, However, there is Significant noise reduction observed in the high frequency range due to engine cladding. Refer below plot

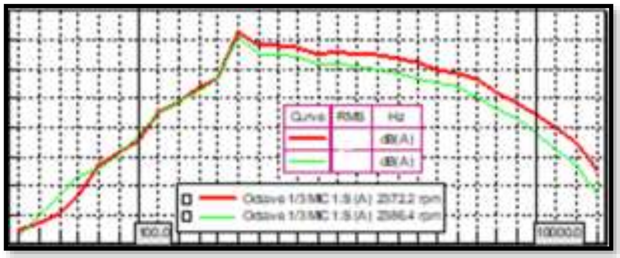

Fig: 14 Engine Clad (Top, Engine Clad (Top, Bottom, LH, RH) results

04 Baseline fan Vs Modified Fan

Fig:15 Baseline fan

Fig:16 Modified fan.

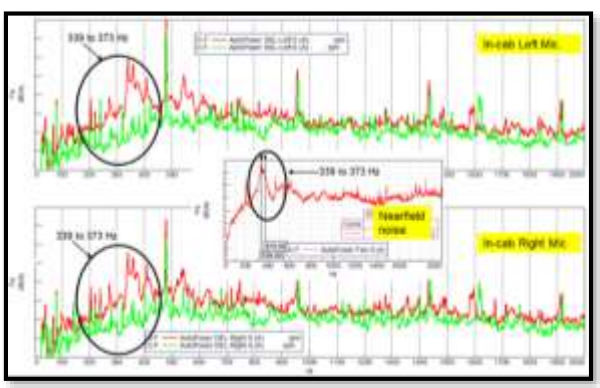

Fig:17 Fan contribution analysis results

At the crucial frequency, a significant reduction in noise has been noticed. When measuring fan noise, the same dominant frequency is seen. Thus, one of the main causes of the rise in noise levels overall is the fan.

We measured the newly modified fan, and the results showed a considerable reduction in noise under stationary test conditions. Additionally, as confirmed by nearfield noise and vibration data, this corresponds to the fan contribution analysis's operating frequency. Therefore, it is assumed that during dynamic trials, there will be a similar trend of noise reduction. After the modified fan we find out fan tip having vibration on high speed. Since we fix it fan blade blex for avoiding such vibration due to this vibration are converting in air borne noise those noise is impacting in In cab noise.

05 Fan blade Blex contribution analysis

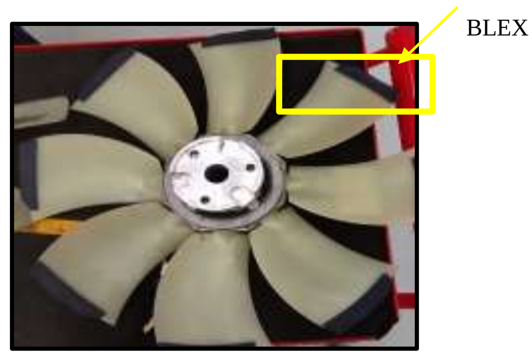

Fig:18 Fan Blade Blex

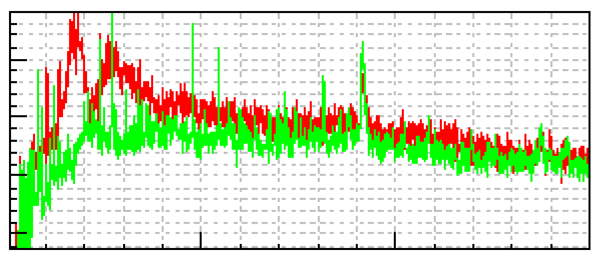

Fig: 19 Exterior Mic no 1 Fan blade Noise spectrum analysis for fan contribution contribution analysis

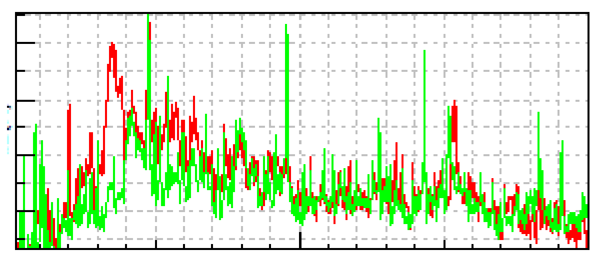

Fig: 20 DE In cab noise Fan blade Noise spectrum analysis for fan contribution

The spectral analysis plots unmistakably depict a discernible reduction in noise levels, showcasing noteworthy advancements in both exterior microphone recordings and the in-cab driver ear levels, as exemplified in Figure 20. Belx technology helped reducing fan tip vibrations and turbulence at the tip as gap between blade and shroud is reduced. After the various trails we went for Structural and acoustic path improvements, and we have work on that and improved those area. We have significant has been observed while testing.

06 Structural and acoustic path improvements

Fig: 21 Steering pump bypasse

Fig: 22 Floor Acoustic Pack

Enhanced acoustic packaging has proven effective in reducing high-frequency noise, while modifications to the hydraulic pipes of the steering pump have contributed to the reduction of structure-borne noise.

Airborne Noise is emanating from the fan engine cavity, and cabin, while structural borne noise is originating from fan vibrations and chassis brackets through mounts affecting the vehicle cabin driver ear level

Cabin mounts will bring all the structural vibration that is being transmitted through the chassis from: Fan, Hydraulic Pump, Valve Box,

NVH Improvements on grader vehicle level

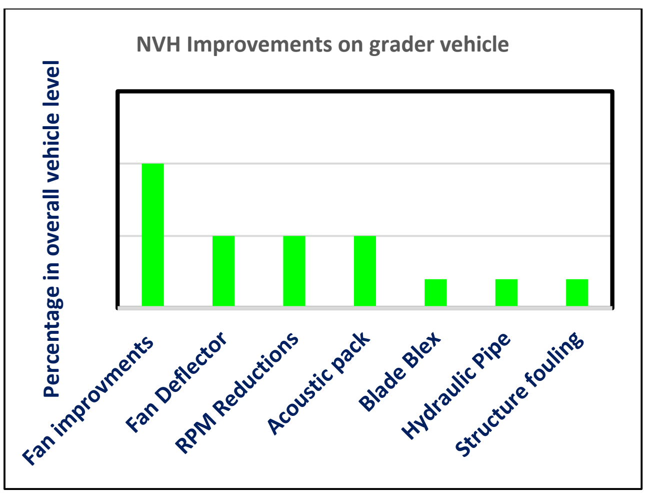

Fig: 23 Overall NVH improvements on grader vehicle

Following numerous iterations, we have pinpointed fan noise as the culprit affecting our grader vehicle. Consequently, the development trials have been specifically geared towards addressing and mitigating the issues related to fan noise. After the fan noise developments, we did some others iteration's for reducing grader vehicle level In cab noise as well as exterior noise level to bring it out in ISO std limits. Ones we achieved the iso target we did some trails mention on fig :23 for refer however we received some significant improvements on In cab noise as well as exterior noise level.

Conclusion: The journey of refining NVH in the grader vehicle underscores the effectiveness of a systematic approach in resolving any issues at the vehicle level. The identification of noise sources and meticulous data analysis stands out as crucial tools for effective problem-solving. Ultimately, our efforts have resulted in achieving ISO norms at a level that places us within the best-in-class category.

Reference:

1. ISO 6393, "Earth moving machinery – Determination of sound power level – Stationary Test Conditions", Third edition, 2008.
2. ISO 6394, "Earth moving machinery – Determination of emission sound pressure level at operator's position – Stationary Test Conditions", Third edition, 2008.
3. ISO 6395, "Earth moving machinery – Determination of sound power level – Dynamic Test Conditions", Second edition, 2008.
4. ISO 6396, "Earth moving machinery – Determination of emission sound pressure level at operator's position – Dynamic Test Conditions", Second edition, 2008.
5. The Gazette of India, PART II - Section 3 - Sub-section (i), Ministry of Road Transport and Highways Notification, 2020.