Project Scope / Needs Assessment

Cummins Active Noise Control

EML4551

9/23/08

Group 7 Members:

Chris Schultz
Joshua Hogue
Marshall Goerg
Michael Priebe
Quennan Davis

Table of Contents

Needs Assessment 3

Project Scope 4

- **Problem Statement** 4
- **Justification / Background** 5
- **Objective** 8
- **Methodology** 9
- **Expected Results** 11
- **Constraints** 12

Works Cited 13

Needs Assessment

Thin, cost-efficient, lightweight vibration control devise utilizing both active and passive materials that is able to withstand the harsh environment of a diesel engine. The devise should compliment existing engine components in terms of mountability and space limitations despite not being extensively model specific.

Project Scope

Problem Statement

Vibrations have presented problems for engineers for many years, especially in modern times when dealing with oscillatory systems like internal combustion engines. These vibrations lead to an increase in audible noise, damage to hardware, and a reduction in performance. One area that has been considered for improvement lies in the propagation of vibrations in the valve and gear covers of mid sized diesel engines.

The design challenge is to research methods to actively and passively control radiated noise of an engine panel and to develop an effective means to reduce the acoustic emissions of the engine panels using these controls. The vibration reduction system must accommodate the existing diesel engine in terms of the operating temperature range, hi and low frequency range, engine compartment space limitations, and long lasting durability. The aim of the design is to control the propagation of the surface velocity activity and to be complimented passively.

Justification / Background

The design project for vibration and noise control was proposed by Cummins Incorporated. Cummins is a leading provider in the design and manufacture of a wide range of engines and their related components. One can find Cummins' products located in various mechanical applications ranging from large machinery and tractor-trailers to common mid-sized trucks (About Cummins…). Cummins encompasses an international market in many diverse environments.

Over the years, noise reduction has become a very popular area of interest. In diesel powered vehicles, noise vibration and harshness properties are being focused on due to cylinder and injection pressures increasing. It can be seen that one key area of improvement lies in the engine covers like the valve and gear covers. These engine covers are usually comprised of lightweight thin metal panels. The covers are connected to the main engine components on their outer edge, where inertia and impact forces are transmitted from the operating engine. The thin panel surfaces act much like a speaker cone in the way that sound is radiated due to surface vibrations.

One method currently used to dampen and lessen the radiated sound is to use a passive, rather than an active, system. A passive system can be comprised of some type of noise absorbing material such as acoustic foam. Other passive systems incorporate a double-wall shell structure for the panels instead of a single-wall design. These passive systems help to muffle the noise but do not eliminate the vibrations that cause the radiated sound. Foams and other sound absorbing materials also have very selective higher frequency ranges and cannot address lower frequencies that are major contributors to overall noise. An active system that is aimed to control and cancel surface vibrations is a better means to reduce overall noise. Current trends in vibration control research have focused on active systems utilizing active materials like piezoceramics, polyvinylindine fluoride film, and ferro-foams (Green, Edward Ray…). Active systems boast a wider range of frequency control but are more costly in terms of material cost and power requirements.

Specifically, the design proposed is based on the gear and valve covers located on Cummins' mid-sized diesel engines. The mid-sized diesel engine to be considered at this time is the Cummins ISC diesel engine. The ISC platform is very popular in the mid-size Dodge trucks. The gear cover is found vertically mounted to the front of the diesel engine, and the valve covers are located horizontally oriented on top of the engine. Diesel engine's are known for their harsh working environments. Temperatures can easily rise into the hundreds of degrees and space is always a factor when considering the internal structure of an engine bay and other engine components that neighbor space.

Research conducted in the field of active vibration control in recent years has become a keystone for design ideas in the noise reduction field. In the past decade, many new developments in the smart structures/actuators field have been made available due to smart materials such as piezocermanics, shape memory alloys, and piezoelectric patch actuators. Piezoceramic stack actuators come in various sizes, are known to be low-cost, and are lightweight. These stack actuators boast high control force properties with micron accuracy and can be directly embedded into composite structures for active control (Song, G…). Peizoelectric actuators have also been used to absorb and dissipate structural vibration energy by extracting the mechanical energy from the device structure and diffusing it into an electric voltage (Moheimani, S. O. Reza…). Piezoelectric patch actuators, also known as macro-fiber composite actuators, provide a wide range of applications due to their thin size and high strain capabilities. These patch actuators can be surface bonded to materials with little to no modifications to the original surface (Song, G…). These actuators can be easily control via electrical voltage signal provided by a signal generator or computer amplification system. These smart materials not only offer a means of dissipating mechanical energy, but also the ability to be controlled with precision control codes.

Passive systems, on the other hand, have been quite effective relative to the amount of noise reduction versus additional expense of weight, space, and material cost. Gear covers have been improved in their vibration levels in recent years due to the addition of multiple layers. Dual layer covers act as a vibration dampener and can even be combined in layer with foam for enhanced noise reduction. Innovations in acoustic dampening foams have also posed a solution. These porous materials are used to reduce sound and vibration by dissipating and converting the vibroacoustic energy into heat as the vibration and acoustic waves travel through the foam (Goransson, Peter). Sound damping foams have been used in the automotive and aerospace fields for many years mostly targeted at reducing acoustic and vibration noise. Foams such as melamine foam provide an excellent sound dampening material for high heat situations. Melamine foam can withstand heat up to 375° F and exhibits fire retardant characteristics. These passive devices tend to target higher frequencies, but they are easy to incorporate into many designs at low costs.

Both active and passive systems have been used to reduce unwanted surface vibrations and noise propagation. However, they have never been used together efficiently in combustion engine applications for vibration control of specific engine components.

Objective

The goal of the design project is to learn about and minimize the vibrations and forces coming from an engine gear or valve cover on a midsize diesel engine. As the automotive industry advances, engine size and combustion capacity has increased which is directly related to the increase in existing noise levels. The project's main aim is to successfully characterize the existing noise by pinpointing the location of the vibrations propagating the noise with the intention to either minimize or eliminate the surface velocity.

The first step of characterization is to research an existing working engine or model of an engine and measure the vibrations and forces from the gear and valve covers. Using this research and data, a theoretical model can be constructed using engineering software. From a theoretical model, a physical prototype will be constructed and tested. The prototype will be driven and tested using vibration/force feedback and control methods, which are explained in more detail in the next section. After applying these methods, the new gear or valve cover will be tested and any improvements or hindrances to the design will be recorded to make a comparison to the original unaltered system.

Ideally, eliminating all noise originating from the gear or valve cover by cancelling out any vibrations coming from the cover with active and passive noise control technologies is the main objective. Realistically, reducing the vibrations by a noticeable amount and gaining valuable knowledge and research in this area will satisfy the design problem. The end product should not only present a working solution for vibration control, but also provide data and ideas from the results and testing to supply a base for more research.

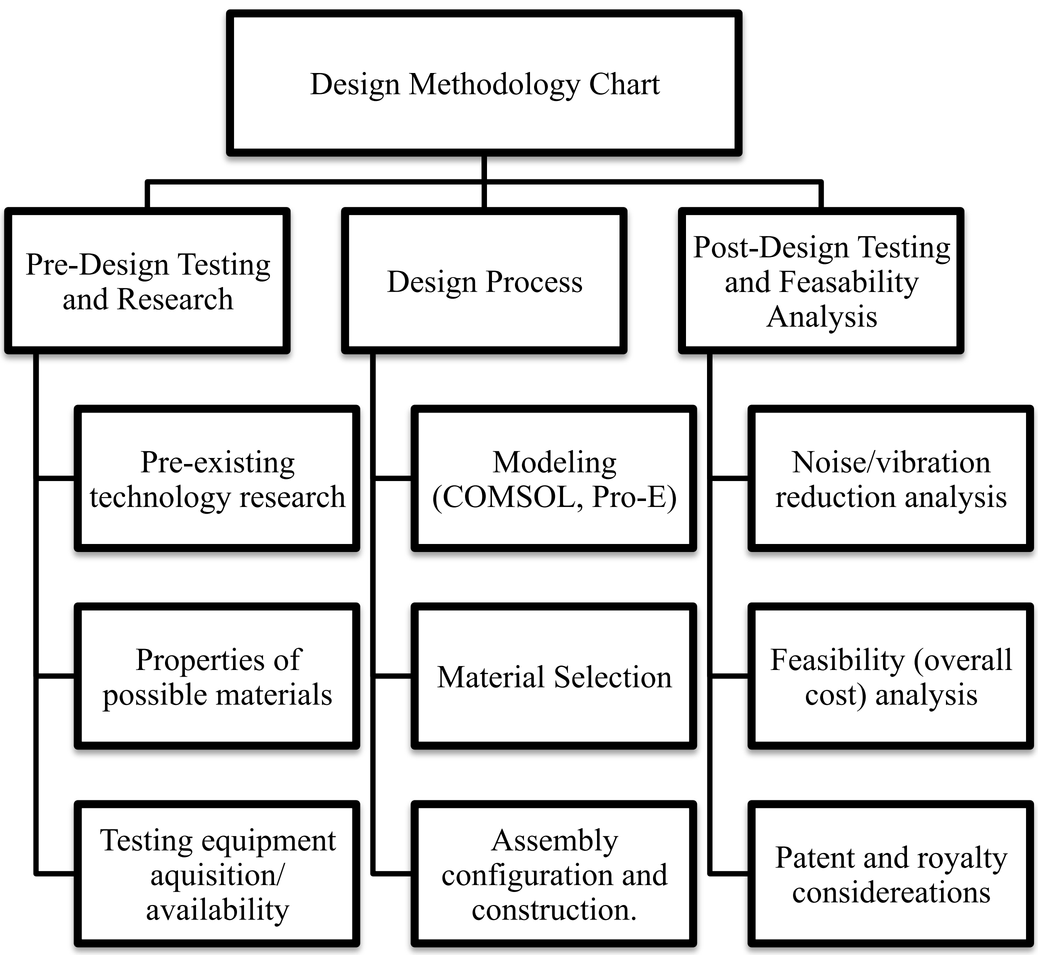
The first semester will be used primarily to research existing or new methods for active and passive noise control as well as modeling the gear or valve cover in different software programs for additional testing and planning. A theoretical model of the active and passive system will be constructed so that a working prototype can be machined, tested, and edited. The second semester's goal is to build a physical working solution to the design problem and project description. Once the working model has been tested and optimized, a concise comparison between the prototype and unaltered system will be conducted.

Methodology

In order to cancel or reduce sound emission a very clear picture of the origin of that sound must be obtained. As stated in our project description the gear cover to be tested acts as a speaker rapidly vibrating and emitting sound through very small oscillatory displacements. When characterizing the cover it will be important to identify several characteristics including the locations of maximum displacements, the forces involved in aforementioned displacements, as well as the range of frequencies. This data will be used to determine the material selection and the arrangement of the active and passive components. A comparison of the noise reduction from the designed system and other strictly passive systems will be done towards the end in order to determine the value and efficiency of the finished product.

The displacement along the surface of the cover will not be constant, and the locations at which it is the highest will need to be determined. Cummins may be providing this information. If however this data is not provided or not sufficient it will have to be obtained through experimentation. In order to find the displacement operating conditions will have to be simulated. Since an entire engine is unlikely to be provided other testing equipment (possibly provided FAMU/FSU College of Engineering) will be needed. The displacement and frequency measurements will likely be taken with either a capacitor probe or some type of piezoelectric set-up (converting the mechanical motion to electrical signal translating to displacement values). The forces exerted by this movement will need to be obtained more indirectly. A simple estimation of the force could be obtained using a defined element of the cover, measuring the average displacement over that element, then using the material properties calculate the force required for the measured motion. A more accurate measure of the force can be obtained using computer software such as COMSOL by setting the measured displacement and frequency as the boundary conditions.

The actual arrangement of the individual materials in the design will depend heavily on the data collected during testing. The overall idea however should remain relatively constant. The points of maximum displacement will contribute most of the overall noise emanating from the cover. The active material will most likely be used at these points to eliminate or at least limit the motion of the cover; when the cover pushes up the active material will push down. The actual choice of active material as previously stated will depend on several factors already discussed as well as operating temperature and longevity. This/These active materials will be combined with preexisting passive materials to optimize overall noise reduction. Automotive acoustic foam and paneling already in use are the probable choices for the passive component. The overall system will then be tested against a non-modified cover as well as preexisting methods of noise reduction. From these comparisons the value and feasibility of the project will then be determined.



Expected Results

As stated earlier, the design's objective is to minimize vibrations and forces causing noise from a gear or valve cover of a midsize diesel engine. Characterization of the model system and covers are to be done before and after any adjustments or modifications are made. Active noise control methods are expected to produce a more effective and reliable means to reduce vibration than passive methods. Both will be applied if space is available as well as resources. With the data and research completed, the design solution that we propose will be applied to the gear or valve cover. The working solution will then be tested and presented to the faculty, staff, and Cummins representatives. Reducing the vibrations will lead to reduced wear on the engine thus resulting in increased engine life and user maintenance. A decrease in audible noise coming from the engine might prove to be more appealing to the buyer market. From research conducted, there are no adverse results expected from reducing vibrations on the valve or gear covers. After our results have been recorded and presented, a cost analysis as a solution to this problem will also be presented to show if this would be a practical application to overall engine quality.

Constraints

- Budget
  - A $1500 budget is provided by Cummins

- Design
  - Project description prohibits use of microphone and sound source for control feedback
  - Vibration/force feedback and control will be used instead
  - Frequency range of panel vibration is to be measured
  - Active control designs to be considered rather than just passive
  - Structurally transmitted vibrations are only considered, and direct acoustic transmission will be excluded

- Working with a Cummins Midrange Engine
  - A specific geometry is required to be fit
  - Activation may be applied anywhere on the cover or its connection to the engine structure, however it cannot compromise potential joint sealing
  - Design must not increase effective thickness of the cover by more than 15mm, nor extend beyond its outline

- Temperature
  - The materials used for this project must be able to withstand extremely high temperatures from a working diesel engine

- Materials
  - Layer materials such as isolation gaskets must be accounted for in design

- Other constraints
  - Potential for noise reduction relative to a plain cover may be assessed
  - A working prototype utilizing an active control solution is preferred, however the design itself may not be a complete working model

Works Cited

About Cummins. 12 July 2007. Cummins Inc. 21 Sept. 2008 <http://www.cummins.com/cmi/content.jsp?siteId=1&langId=1033&menuId=1&overviewId=0&menuIndex=none>.

Goransson, Peter. "Tailored acoustic and vibrational damping in porous solids – Engineering performance in aerospace applications." Aerospace Science and Technology 12 (2008): 26-41.

Green, Edward Ray. "A Examination of "smart" Foams for Active Noise Control." Purdue University. Dissertation Abstracts International 56 (1995): 4372.

Moheimani, S. O. Reza. "A Survey of Recent Innovations in Vibration Damping and Control Using Shunted Piezoeletric Transducers." IEEE Transactions on Control Systems Technology 11, No. 4 (July 2008): 482-494.

Song, G., V. Sethi, H.-H. Li. "Vibration control of civil structures using peizoceramic smart materials: A review." Engineering Structures 28 (2006): 1513-1524.

Additional Note: Reference to the product description provided for the Senior Design course and documentation provided by Cummins representative Richard Varo is to be acknowledged.