Developing a guideline on active vibration isolation

Rolf Schirmacher[1], Roland Kappel[2]

[1] *Müller-BBM GmbH, D-82152 Planegg, Germany, Email: RSchirmacher@MuellerBBM.de*

[2] *Integrated Dynamics Engineering, D-65479 Raunheim, Germany, Email: Roland.Kappel@IDEworld.com*

Introduction

Active Vibration Isolation (AVI) moved onwards from a laboratory curiosity to state of the art technology during the last years. Today it is used mainly for demanding applications where appropriate isolation is difficult to achieve by passive means. In addition, broader applications are under investigation and a common interest in the technology from an application point of view can be found.

Whilst guidelines and standards on passive vibration isolation are available (e.g. DIN EN 1299, VDI 2062), there are currently no such documents for active systems.

In practice, it turns out that communication within the active control community and even more with (perspective) users of AVI systems is sometimes difficult. This is mainly due to a lack of common terminology (in the community) and a common understanding of the basics of the technology (at the user side).

This led to efforts to support designers, manufactureres and users of active vibration isolation systems by a VDI guideline. This guideline should give a basic understanding of active vibration isolation and define some coherent terminology. It should include practical advice for the design of active vibration isolation. To support cooperation and information exchange, it should give hints on necessary information for the specification of an active vibration isolation system and its components and also for test and measurement procedures.

This paper presents the current state of the work on the guideline and focus on the work to be done. The authors would like to start a broad and open discussion especially on the open topics, as they are decisive for the usefulness of the guideline in practical terms. Additionally, we expect this guideline to influence later discussions on other normative documents on active control of sound and vibration and therefore it should introduce an extendable framework of terminology and specification hints.

Structure of the guideline

The guideline will have the following overall structure:

Introduction This section will contain some introductory descripton of the task of the guideline.

Range of application The range of application will be limited to active vibration isolation (AVI). The guideline should supplement DIN EN 1299:1997-05 (Vibration isolation for machinery — Information for the application of source isolation), which explicitly excludes AVI.

Normative references References will include DIN EN 1299, DIN 1311, VDI 2062 and VDI 3839, reflecting vibration isolation standards. In addition they will include DIN 19226, reflecting standards on control systems.

Definition of terms First, the terms active, semi-active and passive vibration isolation will be defined (see below). As there was some special german terminology calling receiver isolation to be “active isolation”, the terms source and receiver isolation will be defined. Regarding components, the terms actuator, signal processing unit, reference sensor and error sensor will be defined.

Concept and task of AVI The guideline is not intended to be a textbook. So this section will be limited to a short description of AVI from a structural dynamics and a system theory point of view. Practical experience and advice on mechanical and control concepts relevant for AVI will be included. The intention is to give a basic understanding of concepts especially to the users.

Components of AVI systems This section will describe actuators, sensors and signal processing units as components of AVI systems and comment on the range of application of specific component designs. The main focus will be on actuators, where criteria for the selection of appropriate actuators (e.g. mechanical output, package requirements, environmental conditions) will be given and specific actuators and their typical application data will be presented. This is due to the fact that actuators often turn out to be the key element regarding the feasability of an AVI system.

Hints for the specification of AVI systems This part is currently worked on. The guideline will split up the specification to three levels, a component level, a system level and an integrated system level.

- The component level specification will ask for a complete specification of a component according to the appropriate normative documents and technical standards. As components for AVI systems are common equipment (e.g. accelerometers), no special problems are expected in this field.
- The system level specification should describe the system behaviour independent of the application environment. It will correspond to a system designer and manufacturer perspective. This topic is currently worked on, see below. this topic, see below.
- Specification on the integrated system level will be from a user perspective and describe performance in user terms. This will have to include the application environment. Work on this topic has to be done.

Test and measurement procedures Test and measurement procedures described in this guideline will be limited to system and integrated system level. They will strongly depend on the specification hints, as these will allow to define measurement quantities, for which procedures will be needed. Work in this field has to be done and is delayed until the specification hints are more clear.

Appendices In addition to more formal appendices (list of symbols, etc.), there will be two with technical contents: Appendix A will give some short technical implementation and application examples. Appendix D will give some additional references to the literature.

Open topics

As mentioned earlier, there are some open topics regarding this guideline. The comittee is working on them right now and highly appreciates any input helping us to improve the guideline and make it practicable from a designer, manufacturer and user perspective.

Definition: Active/semi-active/passive vibration isolation

Although there is some common understanding of what an active and semi-active system is, it is difficult to find a precise definition. Colloquial, an active system is one where something is done actively to counteract the disturbance while a semi-active system is a mainly passive system with some active modification to match / track a disturbance, e.g. by adapting a working point. A passive system is a system where nothing is done actively. This does not correspond to the question whether a system is purely mechanical or electro-mechanical: a piezo ceramic with a fixed shunt resistance, for example, is a passive, electro-mechanical damping system.

The current draft of the guideline focuses on the use of extra energy and the frequency of the energy supply: If the frequency is the same as that of the vibration to be isolated, it is an active system, if it is a different frequency (i.e. lower frequency, like tracking frequency variations), it is a semi-active system. The problem of this definition is that extra energy is not really necessary but reactive power is sufficient for the active modification of a mechanical impedance and even power absorption might be the physical mechanism for an active vibration isolation system. So, any energy related definition has some weakness.

System level specification hints

The system level specification should describe the AVI system behaviour independent of the application environment. It will correspond to a system designer and manufacturer perspective.

There are some terms important for the system level specification, which seem to be quite clear while other terms turn out to be difficult to describe. The difficulties typically get larger when an AVI system uses some kind of adaptive control as the control output then depends on the signals available to the AVI system. But even with fixed control systems, the overall specification might get difficult.

Some system level terms currently under discussion are

System own noise "Vibration" caused by inherent noise of the AVI system. It will depend on the system set-up, e.g. amplifier settings. "Vibration" can only be described in the intended output terms of the actuators (e.g. force) under the assumption of a mounting structure impedance (e.g. infinity). Vibration energy or acceleration levels depend on the base structure impedance and therefore are an integrated system property. System own noise should probably be given in terms of power spectral density and the data must be extended far beyond the working frequency range.

Control frequency range Frequency range, where the AVI system enhances the isolation. It might be given easily for simple feed-back loops but is more difficult to describe in generic terms for adaptive or feed-forward systems. To have a useful specification, also the amount of enhancement (to be more exact: a guaranteed minimum of this amount) has to be given as spectral data. In addition, there is always some frequency range where the AVI system has to decrease the amount of isolation. This frequency range and the level of decrease should also be described.

Convergence time and tracking properties For adaptive control schemes, the time necessary for the system to reach some specified isolation enhancement as well as the behaviour for changing signals (e.g. a changing rpm of a machinery) should be described. Doing so is quite ambitious for well known systems and signals from a theoretical point of view and even less feasable for real-world signals. Some benchmarking test cases might be given by the guideline as a practical solution.

Power consumption The overall power consumption has to be specified. This has to be done as a peak power consumption which is important for the design of the power supply network. Nevertheless, some kind of "typical value" giving a hint on later usage costs is also required, but will depend on the individual signal situation.

Integrated system level specification hints

We expect some of the topics discussed for system level specification to be too dependend on the working environment of the AVI system to be specified in a meaningful way. This might be omitted by defining simple test cases or by asking the topics to be specified for the integrated system in a specific environment. As this might be quite involved without testing in the environment, this might also not be viable for real world applications.

Contact

Comments on the outlined guideline and input on the open topics is highly appreciated. Please feel free to contact the authors, preferable by electronic mail.