Additive Manufactured Function Integrated Damping Structures

Mechanical vibrations occur in almost all industrial applications. They are usually undesired and make damping necessary. The additive manufacturing processes offer a huge amount of design freedom given by the layer wise manufacturing. Further, they possess unique process specific properties. Utilizing this, it is possible to design and manufacture parts that already imply an integrated damping function. The process characteristics can be used to directly manufacture particle damper inside the parts with additive manufacturing by integrating special shaped cavities that are filled with the powder material during manufacturing.

1. Objectives

The goal of the Additive Manufactured Function Integrated Damping Structures (AMFIDS) project is to research how additive manufacturing processes can be used to integrate damping functions into existing structures of technical systems. In addition, it has to be analyzed how the damping effect can be specifically adjusted to different occurring vibrations, in order to achieve an optimal damping value. Based on the empirically developed results a simulation model will be conceived, that can simulate the damping function for different vibrations and for different part structures. The conceived simulation model should support the design of parts with integrated damping functions for different occurring vibrations.

2. Procedure

In order to fulfil the objectives of the AMFIDS project, the required test technology has been developed and manufactured first. The test technology is able to create free and forced vibration under bending or torsional load. Furthermore test specimens with different integrated damping functions have been developed. Subsequently to the development of the test technology and the test specimens, experimental tests were conducted. For this purpose, the test specimens have been manufactured using laser beam melting (LBM), laser sintering (LS) and fused deposition modeling (FDM) processes. The goal is to determine optimal variations for the influencing factors, so that vibrations can be specifically minimized, changed or eliminated. By comparing the results to the results of a reference test specimen, which does not have an integrated damping effect, the degree of minimization, change or elimination of the vibration will be determined. Based on the experimental examinations' results a simulation model will be conceived. Finally, the results will be validated using a technical sample part. For this purpose, a damping function is integrated into a vibrating part and simulated. By means of an application test, it will be shown that the damping effect was specifically included.

3. Latest results

In the experimental investigations, free bending tests have been focused first. Therefore, test specimen with different cavity the test specimen was excited by a defined distance. After releasing the exciting force, the test specimen is able to vibrate freely. The damping behavior is evaluated by calculating the logarithmic decrement, which characterizes the decay of one displacement amplitude to the following one. Due to the non-linear behavior of particle dampers the decrement is calculated for each cycle and related to the corresponding time mean value. This proceeding allows to evaluate the logarithmic decrement as a function of time. In the charts the logarithmic decrement is plotted as a function of the maximum amplitude with a mirrored x-axis to show the time trend. By comparing the logarithmic decrement of the different test specimen the damping behavior is characterized. It is not possible to calculate the damping factor because of the non-linear behavior. By varying the different geometrical attributes of the dampers cavity, the damping effect can be significantly changed. The attribute "cavity volume" for the laser melting process as an example will show this:

Therefore, test specimen with cavities of different cross sectional area in direction of vibration are manufactured with respect to established design rules (see DMDR-projects). The material used is the stainless steel 316L. Within the tests the specimen are excited by 5mm from the neutral position. The calculated logarithmic decrements are shown in figure 6.

The highest damping appears for the biggest cavity (45 cm³). The smaller cavities show less damping. The starting point of the curves displaying the initial damping of the first amplitude also emphasizes this behavior. With similar start excitation of 5 mm the highest cavity volume shows the smallest start amplitude of 1.7 mm. For the other test specimen the initial damping is lower. The higher damping is a result of the higher amount of particles inside the cavity for higher cavity volumes leading to more impacts and by that to a higher energy dissipation. The laser sintering process does not enable such a high damping because of the reduced flowability of the particles due to higher thermal damage of the powder in the manufacturing process.

Since the FDM process does not use powder as raw material, the integration of particle dampers is not possible. Never the less, this manufacturing technology offers other approaches for the direct integration of damping structures. Using only the design freedom dynamic vibration absorbers known for skyscrapers to build earthquake-proof buildings can be manufactured. Experimental tests have shown the feasibility of this approach to reduce undesired vibrations using the FDM process. Since the material damping of additive manufactured structures is yet not known, the dynamic vibration absorber cannot be design properly.

4. Outlook

In further investigations, other vibration forms and loads will be tested. Further, the concept for a simulation model will be developed. Finally, design guidelines are derived from the experimental data to achieve a proper design for vibration damping.

Project Manager	*Prof. Dr. -Ing. Detmar Zimmer*
Scientific Associate/s	*Thomas Künneke, M.Sc.*

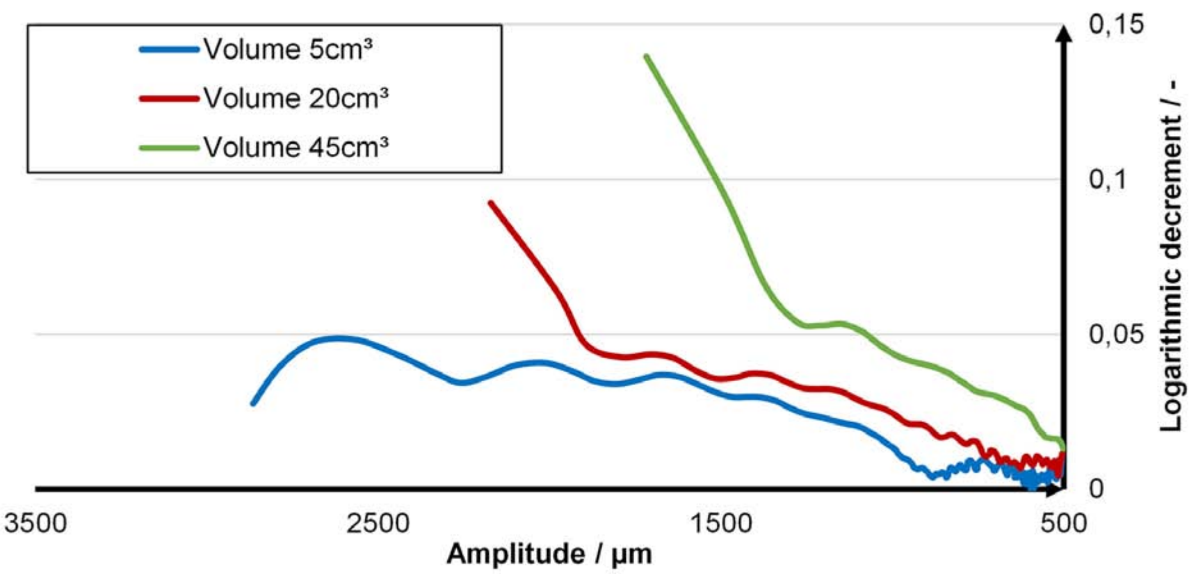

Figure 6: Damping behavior of different cavity volumes (LBM)