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Evaluation of Optimum Pattern of Blow Holes to enhance Damping in Casting Structures

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***Abstract* - Damping is a measure of rate at which vibration energy dissipates in any structure. In order to protect any structure from vibration damping needs to be enhanced. Damping exists in many forms like material damping, dry friction damping, etc. Damping is even influenced by the manufacturing process. Out of two manufacturing types that are casting and forging it is found that casting imparts more damping than forging. The reason for which is attributed to the casting defects like blowholes. But for a casting of given shape, geometry, dimensions and volume allowable number of blow holes for the desired strength are not specified anywhere. The outcome of the paper would be bringing out the relation between number of blowholes and their orientation with respect to strength and damping characteristics in a controlled casting environment.**

Key Words: Damping, Vibration, Blow holes, Strength, etc

1. INTRODUCTION

1.1 PROBLEM DEFINITION

Damping is a measure of rate at which vibration energy dissipates in any structure. In order to protect any structure from vibration damping needs to be enhanced. Damping exists in many forms like material damping, dry friction damping, etc. Damping is even influenced by the manufacturing process. Out of two manufacturing types that are casting and forging it is found that casting imparts more damping than forging. The reason for which is attributed to the casting defects like porosity i.e. blowholes [1]. A blowhole is basically a discontinuity, which enhances the rate of dissipation of vibration energy. But a common belief is blowhole deteriorates the strength of any structure. However formation of blowholes in any casting is unavoidable and thereby few blow holes are permitted to maintain the strength within allowable tolerances. But for a casting of given shape, geometry, dimensions and volume allowable number of blow holes for the desired strength are not specified anywhere. Arriving at a compromising platform for number of blowholes for maintaining desired strength and damping enhancement through experimental simulation is taken up in this project. Series of experiments are planned through casting with intentionally induced blowholes in different numbers. The cast object will be subjected to mechanical tests and damping measurement tests. The outcome of the project would be bringing out the relation between number of blowholes and their orientation with respect to strength and damping characteristics in a controlled casting environment.

1.2 *PRESENT RESEARCH WORK*

L. I. Tuchinskii, et.al [1], worked in this area that has brought out that the vibration-absorbing capacity of titanium increases with an increase in porosity, which is the result of the higher stress concentration at the surface of pores causing a higher level of micro plastic deformation in the local areas of the skeleton. The size of the titanium powder fraction has a significant influence on the vibration-absorbing properties of the investigated materials. An increase in the titanium powder size causes easing of the conditions for occurrence of local deformations in the larger micro volumes. The basic mechanisms of dissipation of energy in the investigated pseudo alloys are micro plastic deformation caused by stress concentration close to the pores filled with the low-melting constituent, micro plastic deformation of the low-melting soft phase, and friction between the titanium skeleton and the low-melting constituent. The investigation of the damping capacity of porous titanium and pseudo alloys based on it showed the possibility of their use as constructional materials for the production of machine parts subjected to dynamic action.

A.I. Beltzer [2] investigated the influence of porosity on vibrations of elastic solids and stated that wave scattering due to in homogeneities in a solid leads to damping of wave motion in a random mixture of elastic materials. In particular, the phenomenon is observed in a material containing random porosity. A general dissipative model is presented to evaluate the influence of small randomly distributed pores on the dynamic response of elastic structures. The numerical results are given for transverse wave propagation and for vibrations of a beam. It is shown that analysis of vibrations of elastic solids containing random porosity can be carried out by the methods of viscoelasticity.

Wilfred John Funk and Arthur Stimson Draper [3] have mentioned in their book that a defect in weld will tend to cause rapid damping of the sound.

1.3 SCOPE OF WORK

Based on the summary of outcome of literature review stated in previous section, scope of work is framed.

Researcher 1 [1] has brought out the direct dependence of damping on porosity nothing but blow holes. But he did not highlight the experimental characterization methodology and he has limited his research work more to the theoretical aspects.

Researcher 2 [2] has also almost reiterated the same fact but of course the case study considered was different. He has presented a theoretical model to support his research.

It is felt that both the researchers discarded the fact that with porosity strength of a casting gets diminishes. For a selected porosity one has to carefully estimate the strength and doubly ensure that it is as per the desired value. In addition to this both have not touched up on experimental characterization methodology.

Hence the scope of the work framed for the present project is to establish an experimental methodology to characterize the influence of porosity on damping and estimation of strength.

1.4 CONSTRUCTION DETAILS

A circular plate of 200 mm diameter and 20 mm thickness made of aluminium is chosen for the present project. The idea behind choosing small size plate is to have high frequency. This is because if the plate is chosen larger in size its frequency will be low and it is obvious that at low frequency damping will be low. As the primary objective of this project is to compare the damping for two castings of same plate with different porosities, it is decided to choose the plate dimensions in such a way that the frequency will be high as at high frequency damping also will be more. If the damping is low comparison for two configurations will be a complex task to quantify the improvement in damping with porosity.

2. RADIOGRAPHY TESTING

2.1 INTRODUCTION

The objective of this part of the project is to identify the degree of porosity by locating number of blow holes for plates with different values of porosity. The idea is to bring out difference in porosity by identification of blow holes using radiography testing technique. This chapter brings out the details of radiography testing of plates with different values of porosity.

2.2 RADIOGRAPHY TESTING

Radiography testing is carried out to identify the order of porosity by locating the number of blow holes in the castings of the plates. This plate is realized by casting process one with less porosity and one with more porosity. It is well known fact that the strength of a cast structure comes down with number of internal defects associated with casting. However the type of defect which is of concern in this project is porosity. Porosity of a casting will be visible in form of blow holes. A number blow hole is an indication of order of porosity. One plate is realized with normal procedure of casing which consists of blowholes as resulted naturally. Second plate is realized with more number of blow holes which have been obtained artificially by adjusting melting temperature and solidification process.

The objective is to bring out the porosity of plates with different values of porosity. Radiography test is carried out on both the plates on a radiography testing machine separately to evaluate the porosity.

Two different samples are prepared one of which is from plate with less number of blow holes and other is from plate with more number of blow holes. However dimensions and shape of the specimen are identical for both the samples.

2.3 RESULTS

Radiography tests are carried out on both the specimens and the results are enclosed as Appendices to this thesis.

2.4 OBSERVATIONS

- Sample 1 got less number of blow holes.
- Sample 2 got more number of blow holes.

3. TENSILE TESTING

3.1 INTRODUCTION

The objective of this part of the project is to evaluate the strength of plates with different values of porosity. The idea is to bring out the quantitative decrement of strength with porosity and to show that decreased strength of plate with more porosity is acceptable to be used as a structure. This chapter brings out the details of tensile testing of plates with different values of porosity.

3.2 TENSILE TESTING

Tensile testing is carried out to evaluate the strength of the plate. This plate is realized by casting process one with less porosity and one with more porosity. It is well known fact that the strength of a cast structure comes down with number of internal defects associated with casting. However the type of defect which is of concern in this project is porosity. Porosity of a casting will be visible in form of blow holes. A number blow hole is an indication of order of porosity. One plate is realized with normal procedure of casing which consists of blowholes as resulted naturally. Second plate is realized with more number of blow holes which have been obtained artificially by adjusting melting temperature and solidification process.

The objective is to bring out the tensile strength of plates with different values of porosity. Tensile test is carried out on both the plates on a universal testing machine separately to evaluate the tensile strength.

Two different samples are prepared one of which is from plate with less number of blow holes and other is from plate with more number of blow holes. The dimensions and shape of the specimen are chosen as per the tensile test requirements. However dimensions and shape of the specimen are identical for both the samples.

Sl. No.	Dimension	Value
1.	Gage length	88 mm
2.	Width	16 mm
3.	Thickness	3 mm
4.	Fillet radius (min.)	11 mm
5.	Overall length (min.)	200 mm
6.	Length of reduced section (min.)	100 mm
7.	Length of grip section (min.)	33 mm
8.	Width of grip section (approx.)	22 mm

Table 3.1 Dimensions of the specimen

3.3 *RESULTS*

Tensile tests are carried out on both the specimens and yield strength values are obtained as the yield strength will be considered for ductile materials.

3.3.1 Plate with less number of blow holes

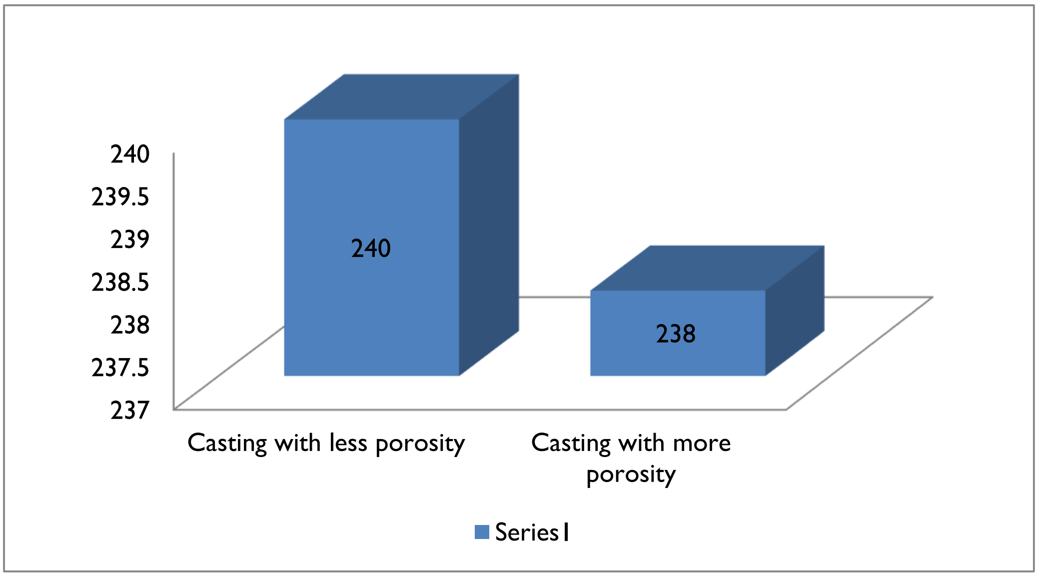
From the tensile test results ultimate tensile strength (UTS) of the plate with less number of blow holes is 240 MPa.

3.3.2 Plate with more number of blow holes

From the tensile test results ultimate tensile strength (UTS) of the plate with less number of blow holes is 238 MPa.

3.4 *OBSERVATIONS*

- With more porosity strength of casting got reduced from 240 MPa to 238 MPa.
- Strength got reduced by 2 MPa.
- Any structure that will be realized with this casting with more porosity needs to be designed keeping a note about its ultimate tensile strength i.e. 225 MPa.
- Design with this casting is to be done choosing the factor of safety accordingly.



EXPERIMENTAL EVALUATION OF DAMPING

4.1 *INTRODUCTION*

The primary objective of this project is to bring out the influence of porosity of a casting on damping. As mentioned in previous chapters a circular plate is chozen for experimental evaluation of damping. This chapter brings out the experimental evaluation followed by results.

4.2 EXPERIMENTAL SET UP

For evaluating the damping the plate needs to be artificially vibrated and the input excitation force and the acceleration response are to be measured. From the transfer function of ratio of response acceleration and input force damping can be extracted. Plate was held in such a way that none of its degree of freedom is constrained during vibration which is known as free vibration. This test is known as modal test.

For a Multi DOF system the equations of motion for free vibration conditions can be expressed as follows [4]

$$[M]\{\ddot{X}\}+[C]\{\dot{X}\}+[K]\{X\}=0$$

Where [M]: the mass matrix
[C]: the damping matrix
[K]: the stiffness matrix
{X}: the response vector

Transforming the above time domain matrix equation into the Laplace domain (variable p), assuming the initial displacements and velocities are zero, yields:

$(p^2[M]+p[C]+[K]).\{X(p)\} = 0$
i.e.
$[Z(p)].\{X(p)\} = 0$
where [Z(p)] is the dynamic stiffness matrix

inverting the above equation results in the definition of the transfer function matrix, [H(p)]:

$\{X(p)\} = [H(p)]$
where $[H(p)] = [Z(p)]^{-1} = adj([Z(p)])/(|Z(p)|$
adj([Z(p)]: the adjoint matrix of [Z(p)]
|[Z(p)]|: the determinant of matrix [Z(p)]

The determinant of matrix [Z(p)] is the system characteristic equation. The roots of this equation defines the resonance frequencies of the system. This equation generates complex valued eigen values. The real part is the damping factor and the imaginary part gives the damped natural frequency. The frequencies obtained from FEM are undamped natural frequencies. These eigen values corresponds a set of eigen vectors which are nothing but mode shapes.

The subsystems required for conducting modal test are [5]

- Suspension mechanism
- Excitation system
- Force Transducer
- Accelerometer
- Data acquisition system & Data analyzer

4.2.6 Results

Damping test is carried out on both the plates (One plate with less porosity and other plate with higher porosity) and from the measured FRFs damping is extracted using half power point method.

4.2.6.1 Plate with less porosity

Frequency Response Function (FRF) of the plate with less porosity is shown in figure 4.5.

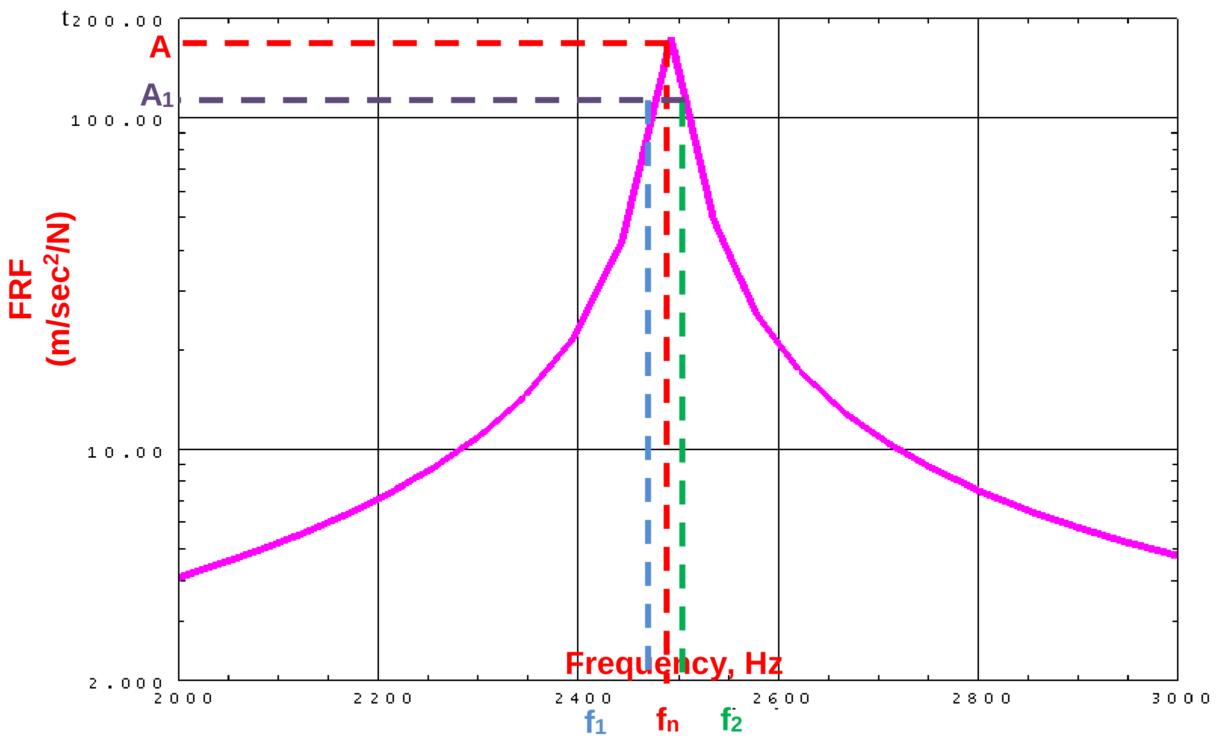


Figure 4.5 FRF of plate (Less porous)

In the above figure the peak represents the natural frequency of the plate with less porosity. Further

f_n: Natural frequency of the plate

A: Amplitude corresponding to natural frequency, f_n

$A_1 = 0.707$ x A

f_1 & f_2: Frequencies projected on X – axis corresponding to amplitude A1

From half power point method [6] damping can be expresses as

$$\frac{f_n}{f_2 - f_1} = \frac{1}{2\xi}$$

ξ: Damping factor

From the above plot A = 174 $m/sec^{2,}$ A1 = 0.707 x 174 = 123 m/sec^2

$f_1 = 2480$ Hz, $f_n = 2493$ Hz, $f_2 = 2505$ Hz

Substituting these values in the above formula

$$\frac{2493}{2505 - 2480} = \frac{1}{2\xi}$$

From above

ξ: Damping factor = 0.005 = 0.5 %

4.2.6.2 Plate with more porosity

Frequency Response Function (FRF) of the plate with more porosity is shown in figure 4.6.

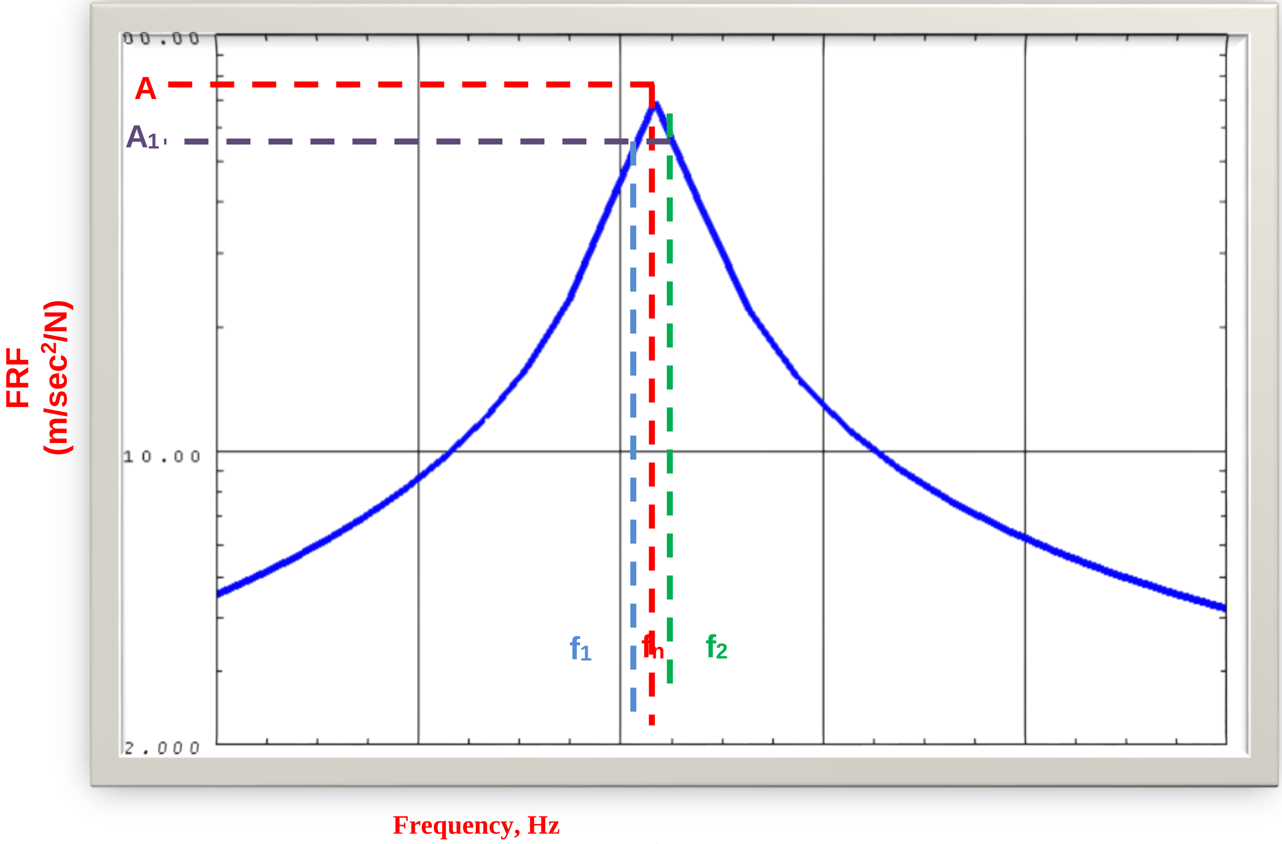


Figure 4.6 FRF of plate (More porous)

In the above figure the peak represents the natural frequency of the plate with more porosity. Further

f_n: Natural frequency of the plate

A: Amplitude corresponding to natural freqeuncy, f_n

$A_1 = 0.707 \times A$

f_1 & f_2: Frequencies projected on X – axis corresponding to amplitude A1

From half power point method damping can be expresses as

$$\frac{f_n}{f_2 - f_1} = \frac{1}{2\xi}$$

ξ: Damping factor

From the above plot

$A = 70\ \text{m/sec}^2$

$A1 = 0.707 \times 70 = 50\ \text{m/sec}^2$

$f_1 = 2402$ Hz

$f_n = 2433$ Hz

$f_2 = 2463$ Hz

Substituting these values in the above formula

$$\frac{2433}{2463 - 2402} = \frac{1}{2\xi}$$

From above

ξ: Damping factor = 0.0125 = 1.25 %

4.2 OBSERVATIONS

- It is clearly evident that the damping for the plate with more porosity is 2.5 times higher than that of with less porosity.

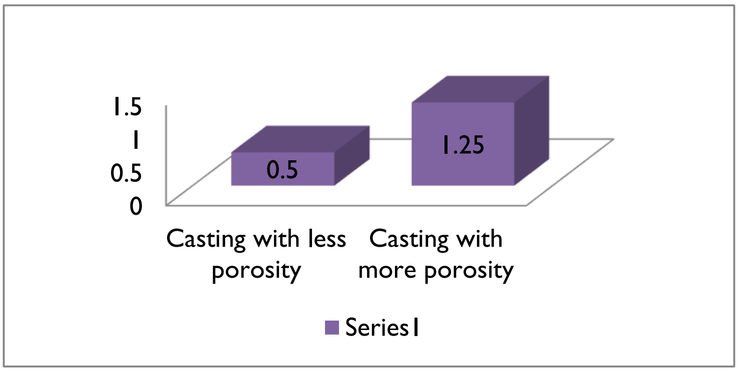
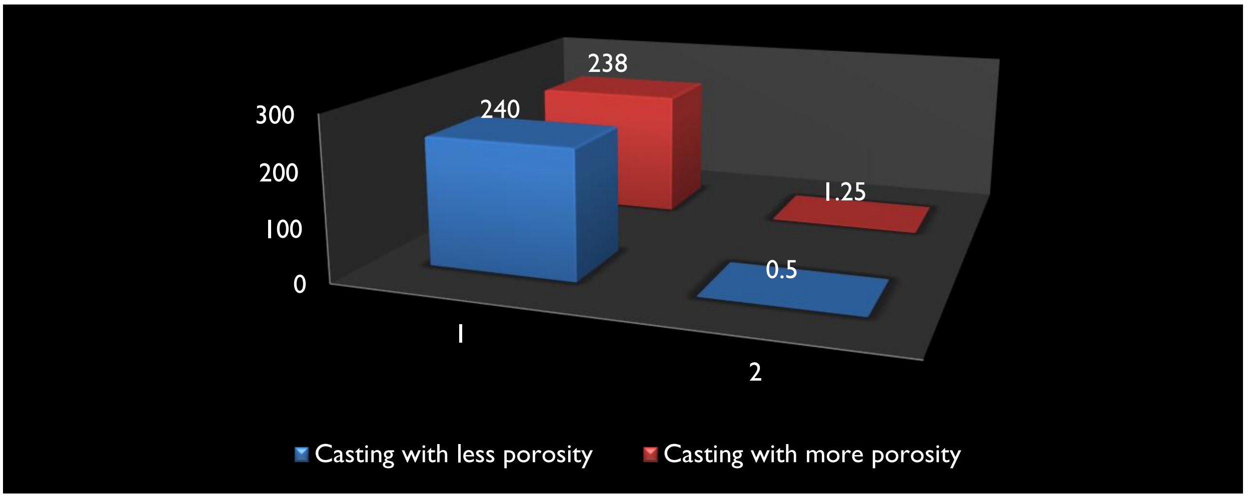


Fig 4.7

CONCLUSIONS

- Literature review carried out before commencing the project conveyed a message that so far no research has been done to experimentally establish that porosity in a casting enhances the damping. Rather many researchers are attempting to bring out new class of materials like foam.
- The main drawback associated with foam is very low strength which inhibits to use foam alone as structure rather it needs to be used as insert in main structure made with different material.
- This project established experimentally the benefit of porosity of a casting in sense of damping.
- As far as the material presently considered in the present project i.e. aluminium is concerned, the limit of having more porosity is not to have strength less than its allowable strength i.e. 225 MPa.
- 2.5 times damping is gained with the reduction in strength just by 2 MPa achieving which otherwise is not that easy.
- If same order of increment in damping is to be achieved by use of foam, complex manufacturing process is involved like making aluminium casting first with holes and then pour foam to fill those holes which is a costlier process.
- Where as for implementing the proposed idea no special manufacturing technique is necessary.
- The final outcome of this project is proposal of an innovative concept to gain damping with ease of implementation and aided by experimental characterization.
- This concept is very well suitable to any kind of structural applications as it can by implemented to any structural material like aluminium or steel, etc.



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