

# Time Domain Approach to identify the System Properties of a Couple Structure

Nagib Mehfuz, Abu Shaid Sujon

**Abstract**— Principle method is commonly used in a time domain to identify the system properties of a vibrating source. The source is coupled to a receiving structure with a resilient mount. To solve an inverse problem it is an alternative to the existing frequency domain. Free mobility and free velocity of the source and receiver structure are determined by Least Mean Square (LMS) algorithm. In this paper, a next ended study of this time-domain approach has been introduced. By using different degrees of freedom of the connectors and changing some of the parameters like spring constant, isotropic loss factor, and damping coefficient the accuracy of the method is observed. The results suggested that in one degree and two degrees the free mobilities of the sending and receiving points can be recreated almost accurately as before. And among different parameters, the spring constant and isotropic loss factor has the most effect on the results.

**Index Terms**— time domain, free mobilities, free velocity, LMS-algorithm, degree of freedom.

## 1 INTRODUCTION

Coupled structures are widely used in the modern era. Mostly to transmit power from one part to another of a structure. For example coupling in gear, the train allows the power to be transmitted from engine to wheel to drive the vehicle [1]. To ensure desired power transmission, identifying the system properties of the coupled structures are very important. But identifying the system properties of coupled structures is a bit complicated. Generally, to identify any system or force acting on a structure, free velocities and free mobilities of the structure are required. For coupling structure, free velocities and free mobilities at the connectors between the excitation and receiving structure should be calculated. It requires the decoupling of both structures. In practice, decoupling sometimes becomes very complicated for complex structures. Properties of the connectors might change while decoupling. So measuring system properties without decoupling the structure are necessary.

Few approaches can calculate the system properties without decoupling the structure. Among them, the Principal Method (PM) is the most common [1]. It is an inverse approach where the response of the system is known and with the help of the model, the unknown excitation on the system can be calculated [2]. Free velocity and free mobility are calculated in the frequency domain. Like most other inverse approaches, this method is also very sensitive to measurement imperfections. So, the time-domain approach is proposed by Kropp and Pevic [3] that is combined with

the PM method. In this paper, a similar approach is followed to make the process more robust concerning the 'measurement noise'

In the time-domain approach, the frequency response of the system is converted into an impulse response. And rather than solving the problem by the inverse matrix method in the frequency domain, it solves the response in the time domain using an algorithm. Among different algorithms, the Least Mean Square (LMS) algorithm is used in this method. It is widely used for adaptive filter design and system identification in the field of active noise control. The main advantage of the LMS algorithm is that the effect of noise during the measurement is ignorable [4][5][6]. The algorithm is easy to implement. The application of the LMS algorithm in the field of structure-borne sound for the identification of forces on structures was introduced by Kropp and Larsson [7].

This coupled structure is attached by an elastic joint. It is assumed that the mounts between the two structures are massless [8]. According to this assumption, coupling forces become identical on both sides of the coupling mounts. In the previous work of Kropp and Pevic [3] it is shown that this assumption in many practical cases is acceptable. This method can potentially produce good results. The functioning of this method was shown for two beams, coupled with a mount.

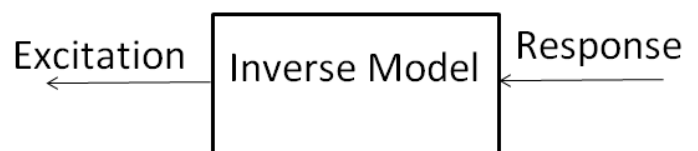


Figure 1 the inverse problem

In this paper, the method section describes the theory of

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the LMS algorithm and different parameters and how the PM method is combined with the time-domain approach. In the results and discussion section, different cases for the 2nd DOF of free mobility and error are presented.

**2. Method**

**2.1. The Least Mean Square (LMS) Algorithm**

The LMS algorithm is frequently used for designing adaptive filters and in the field of active noise control. In this case, the LMS algorithm is used to identify the unknown force in the coupling structure in the time domain [9]. Figure 2 shows a typical design condition where  $a_d$  is the output of an unknown system  $h_o$ . By using a Finite Impulse Response (FIR) filter  $h$ , having a length of  $l$  the output can be reconstructed. The error  $e$  of both outputs can be calculated by the expression below.

$$e(n) = a_d - \sum_{i=0}^{l-1} x(n-1)h(i) \tag{1}$$

Where  $x$  is the observed input into the system. The filter and the input are written in vector form as.

$$e(n) = a_d(n) - h^T x(n) \tag{2}$$

Here the transpose of the filter  $h$  is taken.

$$h = [h(0), h(1) \dots \dots h(l-1)]^T$$

$$x = [x(n), h(n-1), \dots \dots h(n-l+1)]^T$$

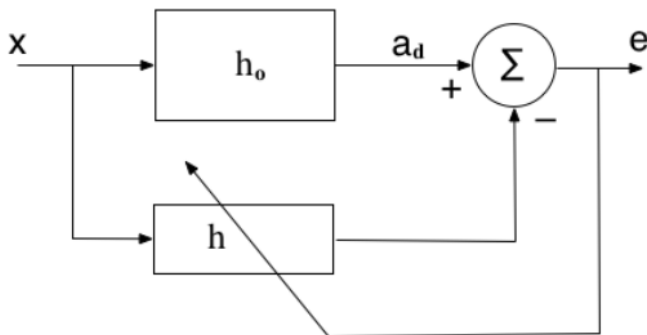
To minimize the mean value of the quadratic error the LMS algorithm is used.

$$Mean[e^2] = Mean[(a_d - h^T x(n))^2] \tag{3}$$

By taking the derivative with respect to the filter coefficients  $h_i$  the optimal filter can be found. It is known as Wiener filter.

$$h_i(new) = h_i(old) - \alpha \frac{\partial Mean[e^2(n)]}{\partial h_i} \tag{4}$$

In equation 3 is quadratic with respect to the filter coefficients and to the values of the input signal. In the beginning, one can follow the steepest gradient but this process will end up to a point of a global minimum of error [10]. From this, an iterative method can be formulated for calculating the filter coefficients by expressing a set of new (updated) coefficients  $h_i$  (new) as



**Figure 2 Block Diagram of the filter design according to LMS algorithm**

$$\frac{\partial Mean[e^2]}{\partial h_i} = 2Mean[e(n) \frac{\partial e(n)}{\partial h_i}] \tag{5}$$

Where  $\alpha$  is a weighting factor, determining the step size in the iteration process. The gradient is expressed as ensemble average which is not easy to calculate. So the method of Widrow and Hoff [11] is used to solve this problem. It estimates the gradient from the instantaneous value of the gradient for each time step  $n$ . using instantaneous gradient for each time will in average adjust the coefficients  $h_i$  in a way that reduces the mean square error. The expression is written in vector form below.

$$H(n+1) = h(n) + \alpha e(n)x(n) \tag{6}$$

This formulation of the LMS algorithm will create a filter, which converges towards the Wiener filter solution. For the convergence coefficient, one finds as a 'rule of thumb' that it has to fulfill the following condition in order to achieve convergence [12].

$$0 < \alpha < \frac{1}{l Mean[x^2(n)]} \tag{7}$$

Due to the presence of noise, there might be some error in each time gradient but because of the iteration process, the averaged gradient will still head towards the global minimum [8]. That makes the LMS algorithm robust in the presence of noise.

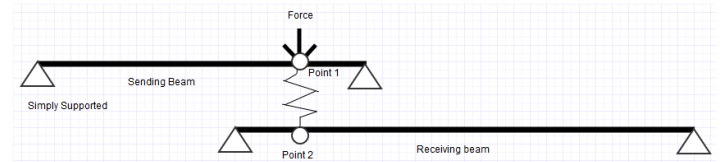
A relative mean error is defined as

$$error = \frac{\sum_{n=l}^N [e(n)]}{\sum_{n=l}^N [a_d(n)]^2} \tag{8}$$

**2.2. Two Degree of Freedom System**

Two degrees of freedom system required two independent parameters to describe their motions, i.e. displacement and bending angle. In this paper, this system is represented by two beams coupled with an elastic mount. Where excitation and response of the beams have two independent parameters. It is considered that 1st DOF excitation is a force in the y-direction (perpendicular to the beam) and 2nd DOF excitation is the moment. Similarly, the 1st DOF of response is the velocity in the y-direction and 2nd DOF is taken angular velocity in the Z direction.

In the figure 3, there are two beams: sending beam and receiving beam. Sending beam only represent point 1 and receiving beam only represents point 2.



**Figure 3 Two beam and spring when force is applied in point 1**

To understand the two-dimensional phenomenon, the whole system is divided into four cases and for each case,

there are two possibilities. Either the excitation is applied in point 1 or point 2. But the response always is taken on both points. For example, in 1st DOF, the unknown force applied to point 1 and the response is taken both in point 1 and 2 as velocity or the force is applied to point 2 and the response is taken in point 1 and 2 as velocity. In 2nd DOF, instead of unknown force, an unknown moment is applied as the excitation and the angular velocity is taken as the response.

Table 1: Different Case Conditions

Cases	Excitation		Response	
	Position	Degree of freedom	Position	Degree of freedom
Case 1	Point 1(1st Beam)	1 <sup>st</sup> (Force)	Point 1 & 2	1 <sup>st</sup> (Velocity)
	Point 2(2 <sup>nd</sup> Beam)	1 <sup>st</sup> (Force)	Point 1 & 2	1 <sup>st</sup> (Velocity)
Case 2	Point 1(1st Beam)	2 <sup>nd</sup> (Moment)	Point 1 & 2	1 <sup>st</sup> (Velocity)
	Point 2(2 <sup>nd</sup> Beam)	2 <sup>nd</sup> (Moment)	Point 1 & 2	1 <sup>st</sup> (Velocity)
Case 3	Point 1(1st Beam)	1 <sup>st</sup> (Force)	Point 1 & 2	2 <sup>nd</sup> (Angular Velocity)
	Point 2(2 <sup>nd</sup> Beam)	1 <sup>st</sup> (Force)	Point 1 & 2	2 <sup>nd</sup> (Angular Velocity)
Case 4	Point 1(1st Beam)	2 <sup>nd</sup> (Moment)	Point 1 & 2	2 <sup>nd</sup> (Angular Velocity)
	Point 2(2 <sup>nd</sup> Beam)	2 <sup>nd</sup> (Moment)	Point 1 & 2	2 <sup>nd</sup> (Angular Velocity)

For each case, there are four velocities. In total for four cases, there are 16 velocities. The new variables were defined as  $V_{snm}$  and  $V_{rmm}$  where,  $n=1, 2$  and  $m=1... 4$ . For the velocities describing the coupled structures, the first index concerns the receiving point the second index indicates the excitation case.

- $n=1$ : refers to sending beam  $n=2$ : refers to receiving Beam
- $m=1$ : excitation on the sending structure (point 1) in DOF 1-force
- $m=2$ : excitation on the sending structure (point 1) in DOF 2-moment
- $m=3$ : excitation on the receiving structure (point 2) in DOF 1-force
- $m=4$ : excitation on the receiving structure (point 2) in DOF 2-moment

Again, for each case, two free mobilities can be calculated. One for the sending beam in point 1 and another is the receiving beam in point 2. In total, for four cases eight free mobilities were found.  $Y_{sab}, Y_{rab}$  where 's' denoted the sending beam, 'r' denoted receiving beam. Then, the first index 'a' determines the DOF of the excitation, the second index 'b' indicates the DOF of the response.  $a=1$ : 1st degree of excitation  $a=2$ : 2nd degree of excitation  $b=1$ : 1st degree of response  $b=2$ : 2nd degree of response.  $Z$  is the impedance of the mounting.

$Y_{s11}, Y_{s12}, Y_{s21}, Y_{s22}$  and  $Y_{r11}, Y_{r12}, Y_{r21}, Y_{r22}$  are the four sending free mobilities and four receiving free mobilities are needed for describing the whole structure. There are also eight unknowns ( $ZY_{s11}, ZY_{s12}, ZY_{s2}, ZY_{s22}$  and  $ZY_{r11}, ZY_{r12}, ZY_{r21}, ZY_{r22}$ ) due to the unknown coupling forces.

In total, there are sixteen unknowns to deal with, but the equation system can be easily divided into successive steps where first the terms related to the coupling forces are calculated and then the free mobilities as it was shown in the previous section.

For each case, force is motioned either  $F_{sp}$  or  $F_{rp}$  where 's' denoted the sending beam, 'r' denoted receiving beam,  $p=1$  means the 1st degree of freedom or  $p=2$  for the 2nd degree

of freedom. Coupling forces are denoted by  $F_{c;sq}$  and  $F_{c;rq}$ . Where 's' denoted the sending beam, 'r' denoted receiving beam,  $q=1$  means the 1st degree of freedom or  $q=2$  for the 2nd degree of freedom.

The equations for the four cases are mentioned below and solved by a network of filter processes to get the free mobilities that are desired.

**2.2.1. Case 1**

In case 1, as stated in table 1 for each excitation response is taken into two points. 1st DOF excitation in point 1 leads to three equations below.

$$F_{s1}Y_{s11}+F_{c;s1}Y_{s11}=V_{s11} \tag{9}$$

$$F_{c;s1}Y_{r11}=V_{r11} \tag{10}$$

$$F_{c;s1}=-Z(V_{s11}+V_{r11}) \tag{11}$$

For the excitation in the receiving structure at point 2, the equations can be constructed as follows

$$F_{r1}Y_{r11}+F_{c;r1}Y_{r11}=V_{r13} \tag{12}$$

$$F_{c;r1}Y_{s11}=V_{s13} \tag{13}$$

$$F_{c;r1}=-Z(V_{r13}+V_{s13}) \tag{14}$$

From the equations 9, 11, 13 and 14 two equations can be determined.

$$-ZY_{s11}(V_{r13}+V_{s13})=V_{s13} \tag{15}$$

$$F_{s1}Y_{s11}-ZY_{s11}(V_{s11}+V_{r11})=V_{s11} \tag{16}$$

By solving these two equations 15 and 16 by filter network system the free mobility of the sending structure  $Y_{s11}$  for 1st DOF of excitation and response can be determined. First, the equation 15 is represented by the filter below. Where  $(V_{r13} + V_{s13})$  is the input of the filter.  $V_{s13}$  is the desired output from the filter. As the input and output are known, the unknown filter coefficient  $ZY_{s11}$  can be determined by using LMS algorithm where the optimal goal is to minimize the error  $e_r$ .

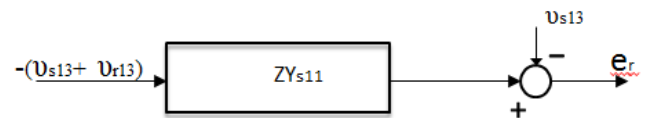


Figure 4 Formation of equation as network of filter suitable for the LMS algorithm for  $ZY_{s11}$

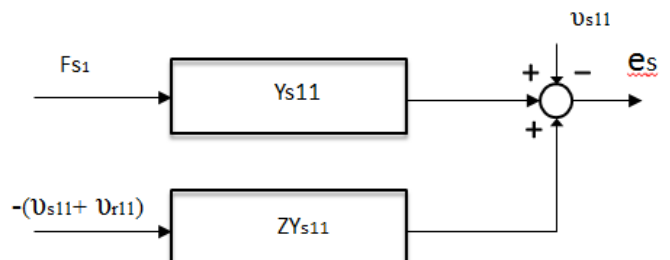


Figure 5 Formation of equation as network of filter suitable for the LMS algorithm for  $ZY_{s11}$

**ble for the LMS algorithm for  $Y_{s11}$**

Using the information  $Z Y_{s11}$ , the free mobility  $Y_{s11}$  is calculated by forming another filter network mentioned below. The desired output is  $v_{s11} + Z Y_{s11} (v_{s11} + v_{r11})$  and the input  $F_{s1}$  is taken as one. So the unknown filter coefficient, which represents the free mobility  $Y_{s11}$  can be determined by LMS algorithm.

Similarly,  $Y_{r11}$  can be determined by solving the equations 9, 10, 11 and 12.

Other cases also follow the same procedure. So equations those are needed to identify the free mobility in sending beam point 1 are mentioned only for the rest of the cases. Then they are represented in a filter network diagram. Free mobility of the receiving beam at point 2 can also be calculated in a similar way.

**2.2.2. Case 2**

For the excitation in the sending structure, the equations can be constructed as follows

$$F_{s2} Y_{s21} + F_{c;s2} Y_{s21} = v_{s12} \tag{17}$$

$$F_{c;s2} Y_{r21} = v_{r12} \tag{18}$$

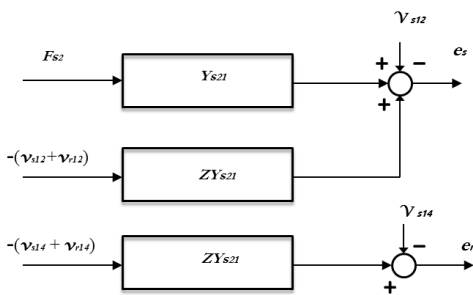
$$F_{c;s2} = -Z(v_{s12} + v_{r12}) \tag{19}$$

For the excitation in the receiving structure, the equations can be constructed as follows

$$F_{r2} Y_{r21} + F_{c;r2} Y_{r21} = v_{r14} \tag{20}$$

$$F_{c;r2} Y_{s21} = v_{s14} \tag{21}$$

$$F_{c;r2} = -Z(v_{r14} + v_{s14}) \tag{22}$$



**Figure 6 Formation of equation as network of filters suitable for the LMS algorithm for  $Y_{s21}$**

From the equations 17, 19, 21 and 22 the free mobility of the sending structure  $Y_{s21}$  for 2nd DOF of excitation and 1st DOF of response can be determined following the filter network mentioned above.

$$-Z Y_{s21} (v_{r14} + v_{s14}) = v_{s14} \tag{23}$$

$$F_{s2} Y_{s21} - Z Y_{s21} (v_{s12} + v_{r12}) = v_{s12} \tag{24}$$

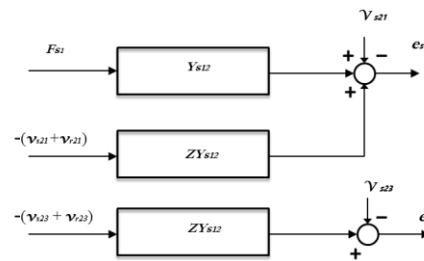
**2.2.3. Case 3**

For the excitation in the sending structure, the equations can be constructed as follows

$$F_{s1} Y_{s12} + F_{c;s1} Y_{s12} = v_{s21} \tag{25}$$

$$F_{c;s1} Y_{r12} = v_{r21} \tag{26}$$

$$F_{c;s1} = -Z(v_{s21} + v_{r21}) \tag{27}$$



**Figure 7 Formation of equation as network of filters suitable for the LMS algorithm for  $Y_{s12}$**

For the excitation in the receiving structure, the equations can be constructed as follows

$$F_{r1} Y_{r12} + F_{c;r1} Y_{r12} = v_{r23} \tag{28}$$

$$F_{c;r1} Y_{s12} = v_{s23} \tag{29}$$

$$F_{c;r1} = -Z(v_{r23} + v_{s23}) \tag{30}$$

From the equation 25, 27, 29, and 30 the free mobility of the sending structure  $Y_{s12}$  for 1st DOF excitation and 2<sup>nd</sup> DOF response can be determined following the filter network mentioned above.

$$-Z Y_{s12} (v_{r23} + v_{s23}) = v_{s23} \tag{31}$$

$$F_{s1} Y_{s12} - Z Y_{s12} (v_{s21} + v_{r21}) = v_{s21} \tag{32}$$

**2.2.4. Case 4**

For the excitation in the sending structure, the equations can be constructed as follows

$$F_{s2} Y_{s22} + F_{c;s2} Y_{s22} = v_{s22} \tag{33}$$

$$F_{c;s2} Y_{r22} = v_{r22} \tag{34}$$

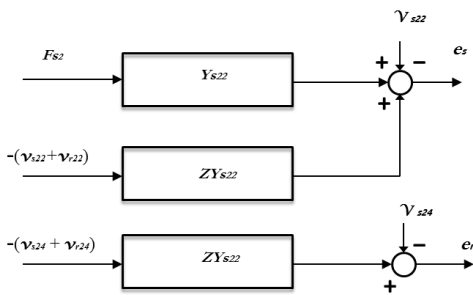
$$F_{c;s2} = -Z(v_{s22} + v_{r22}) \tag{35}$$

For the excitation in the receiving structure, the equations can be constructed as follows

$$F_{r2} Y_{r22} + F_{c;r2} Y_{r22} = v_{r24} \tag{36}$$

$$F_{c;r2} Y_{s22} = v_{s24} \tag{37}$$

$$F_{c;r2} = -Z(v_{r24} + v_{s24}) \tag{38}$$



**Figure 8 Formation of equation as network of filters suitable for the LMS algorithm for Ys22**

From the equations 33, 35, 37 and 38 the free mobility of the sending structure  $Y_{s22}$  for 2nd DOF of excitation and 2nd DOF of response can be determined following the filter network mentioned above.

$$-ZY_{s22}(V_{r24} + V_{s24}) = V_{s24} \tag{39}$$

$$F_{s2} Y_{s22} - ZY_{s22}(V_{s22} + V_{r22}) = V_{s22} \tag{40}$$

**1.3. Comsol Simulation for finding velocities**

In Comsol initially, 2D space dimension is selected. Then two types of physics are selected 'Beam (beam)' and 'Multibody Dynamics (mbd)'. 'Frequency Domain' study has been done. Parameters are set as mentioned in table 2 and 3.

Table 2

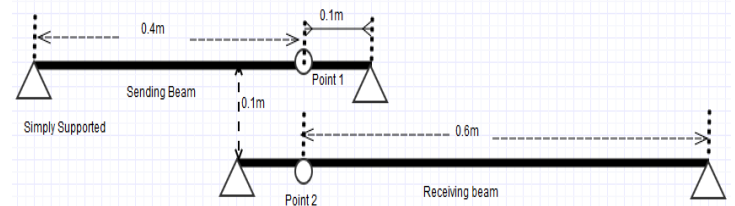
Parameters of the Beam	Values
Young's Modulus	7200 Pa
Isotropic Loss Factor	0.4
Density	2700 kg/m <sup>2</sup>
Poison's Ratio	0.34

Table 3

Parameters of the Connector	Values
Spring Constant	100 N/m
Damping Coefficient	0.02 Ns/m

The drawing of the coupled system is done in comsol. 'Bezier Polygon' is created which resemble the beams in the system. The upper one is considered as the sending beam and the lower one as receiving beam. The length of those beams is 0.5m and 0.7m respectively. Two beams are 0.1m apart. Two points are created on the both beams exactly in the same point which is 0.4m from the origin. And depending on the condition the force or the moment is added in the point 1 and point 2 respectively. To make the beams simply supported the prescribed displacement in the

y-direction is taken as '0' at the two end of the beams.

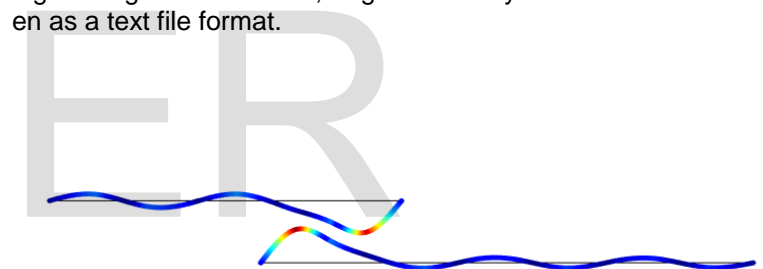


**Figure 9 Two beams Geometry**

Material properties like Young's Modulus, Isotropic Loss Factor, Poison's Ratio and Density which are chosen as the close to Aluminum. The values are mention in table 2. The beam section damping is added as Loss factor model type and Isotropic loss factor value is taken 0.02.

Under Multibody Dynamics spring-damper is added into the system. After spring constant and damping coefficient are set as 7, meshing is carried out.

The study is performed within low to mid-range frequency (1-2000Hz). In result section, the data of velocity is taken for point 1 and point 2 for the 1st degree of freedom. For a higher degree of freedom, angular velocity data is also taken as a text file format.



**Figure 10 Two beams after simulation in Comsol**

**3. Results and Discussions**

**3.1. Effect of different Spring Constant**

The spring constant is a very important parameter that affects the free mobility of the coupled structure. Initially, the spring constant, k is taken 100Nm and the velocity of the structure is calculated due to the force applied. As the spring constant increases, the force being transmitted through the spring also increases. It increases the velocity of the structure.

Finally, very high spring constant is used to see its effect on the structure. After a number of simulations, it is found that the deviation in free mobility from Comsol and LMS algorithm is considerably large when the spring constant is above 5000 Nm. In 20000 Nm spring constant, the deviation is very prominent. In this paper, the two spring con-



starts are studied which are presented below.

Table 4

Different Spring Constant	Values
1st condition	20000 N/m
2nd condition	50000 N/m

To understand the effect of spring constant on free mobility, two extreme conditions are considered: One mobility of the sending beam for case 1 (section 2.2.1) where all the excitations and responses are taken in 1st DOF and the other mobility of the sending beam for case 4 (section 2.2) where all the excitations and responses are taken in 2nd DOF.

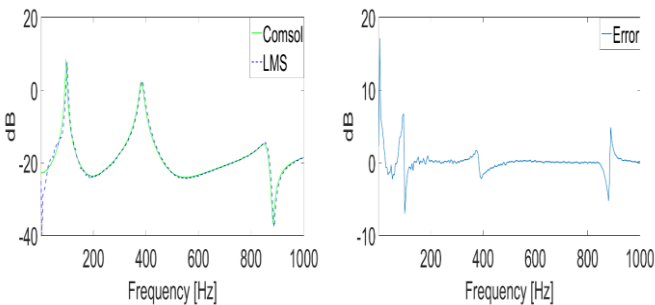


Figure 11 Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation

For the first condition, at  $k=20000$  Nm, the difference between both methods is up to 5 dB in lower frequencies (100 Hz) found in figure 11. But for higher spring constant at  $k=50000$  Nm the deviation is increased up to 10 dB in lower frequencies and even higher frequencies like 400 Hz and 850 Hz some deviations occurred (figure 12).

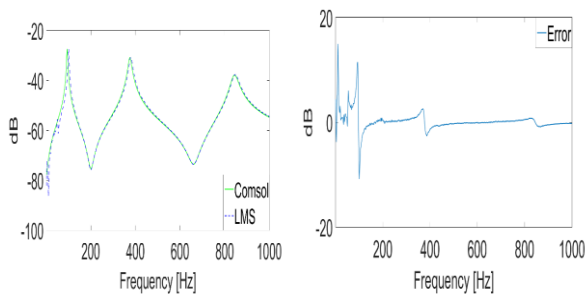


Figure 12 Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation

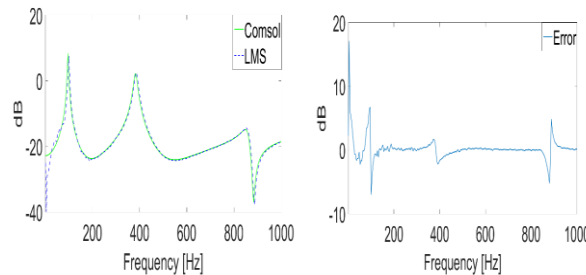


Figure 13 Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation

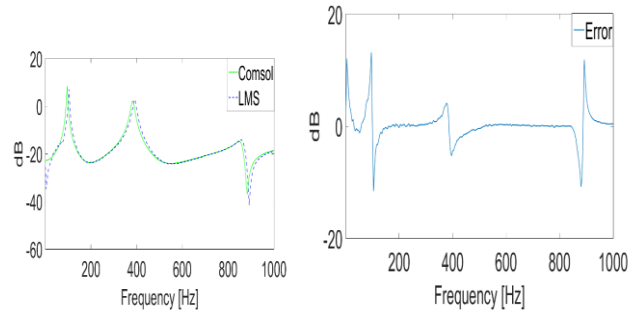


Figure 14 Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation

For the second condition at  $k=50000$  Nm, the absolute error is around 10 dB in the pick frequencies (150 Hz, 450 Hz, and 900 Hz) in figure 13. And for higher spring constant the error goes up to 20 dB that shown in the figure 14. For different cases, the same results are found. So it can be concluded that as the spring constant increases it is difficult to predict the free mobility from LMS and it deviated from the simulation data. By increasing the iteration steps the absolute error might be mitigated.

### 3.2. Effect of different Isotropic loss factor

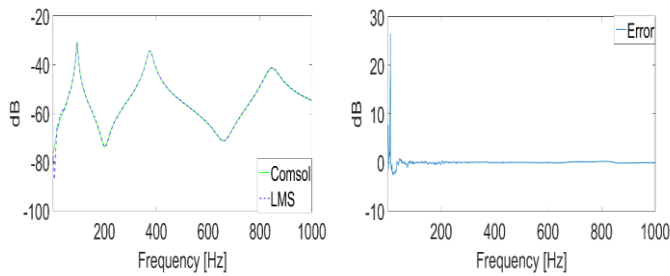
The isotropic loss factor is a parameter that affects the material damping. In this paper, it is the parameter of the beam. Material damping transforms the vibration energy of the structure into another form of energy such as heat. As the loss factor goes higher the vibration in the structure will be reduced that also reduced the velocity. Eventually, the amplitude of the free mobility will be decreased.

Table 5

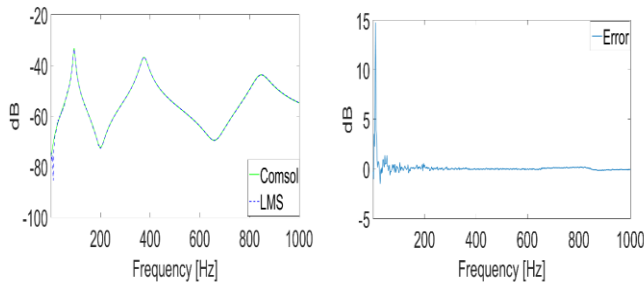
Different Isotropic loss factor	Values
1st condition	0.06
2nd condition	0.08
3rd condition	0.1

Here mobility of the sending beam for case 1 (section 2.2.1) where all the excitations and responses are taken in 1<sup>st</sup> DOF, is chosen to analyze the effect of different isotropic loss factors. Initially, the loss factor is chosen 0.06. When the isotropic loss factor is 0.06, in figure 15 shows that the absolute error in lower frequencies is 30 dB. Then the error is reduced and become less than 1 dB in higher frequencies. At isotropic loss factor 0.08, in figure 16 shows the reduction of the absolute error in lower frequencies up to 15 dB.

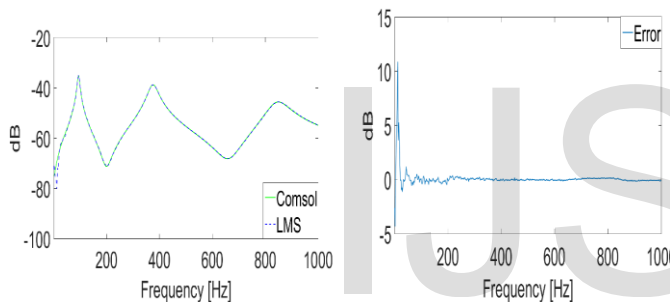
Figure 17 shows the reduction of the absolute error in lower frequencies up to 10 dB at isotropic loss factor 0.1.



**Figure 15** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation



**Figure 16** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation



**Figure 17** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation

So it can be concluded that in higher isotropic loss factor the absolute error in lower frequencies reduced considerably. For higher frequency, there is no significant effect.

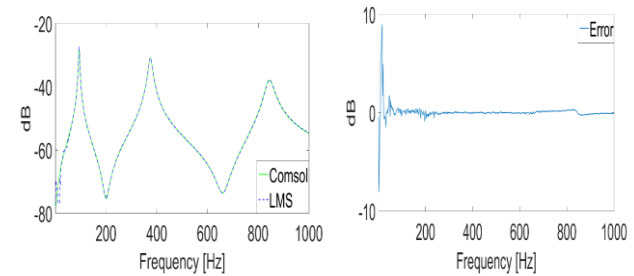
**3.3. Effect of different Damping Coefficient**

Table 6

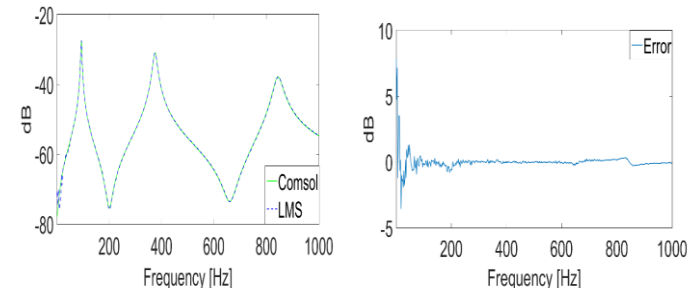
Different Damping Coefficient	Values
1st condition	0.04
2nd condition	0.06
3rd condition	0.08
3rd condition	1.00

Damping coefficient is the parameter of the connector that might affect the results. Four different damping coefficients are applied here. And the excitation and response conditions remain same the previous section. For 1st condition, 0.04 damping coefficient is applied. Figure 18 shows the same pattern as before some deviation of absolute error in lower frequencies and not much error in higher frequencies. For 2nd condition, the damping coefficient is applied 0.06. For this, the absolute error is presented in figure 19. For 3rd condition, the damping coefficient is applied

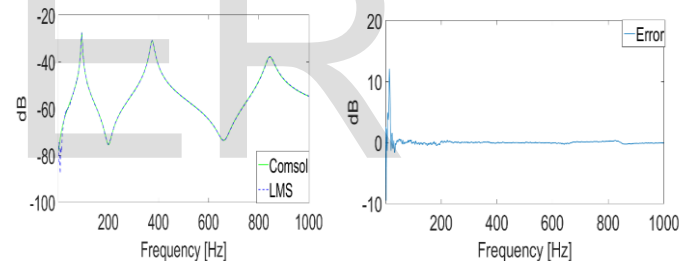
0.08. For this, the absolute error is presented in figure 20. For 4th condition, the damping coefficient is applied 0.1. For this, the absolute error is presented in figure 21.



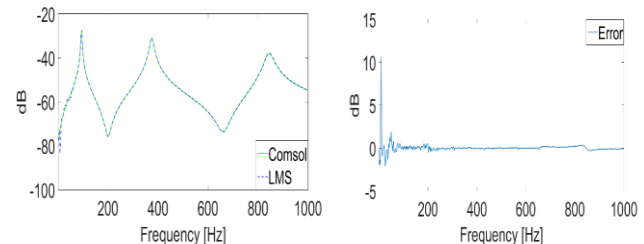
**Figure 18** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation



**Figure 19** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation



**Figure 20** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation



**Figure 21** Free Mobility predicted from LMS Algorithm and Simulation and Error of the estimation

It is found that all the graphs show the almost same results. At the end, it can be concluded that due to very low damping coefficient there is not much effect on the results.

**4. Conclusion**

The LMS algorithm is a common and well-known tool in adaptive design filters. In this paper, the LMS algorithm is used in the time domain and combined with the frequency domain Principle Method to investigate the free mobilities of a coupled structure. Two beams coupled in one degree

of freedom and two beams coupled in two degrees of freedom by an elastic mount are the two cases mentioned here. In both cases, the LMS algorithm shows good results. Some important parameters of the structure and elastic mount that might affect the dynamic system of the structures are also investigated. Among them, structural damping parameter: isotropic loss factor and mounting parameter: spring constant has the most effect. High loss factor and high spring constant increases the error between the simulation data and LMS prediction in low frequencies. The equation system is programmed as a filter network to identify the solution. The shortcoming of the method is a huge calculation time due to the iteration process. If the iteration process increases it can increase the calculation time up to a few hours. Another important issue for the LMS algorithm is the step size, Small step size gives more accurate results. If the step size is very small it might take a long time to calculate. So an optimal step size should be used to reduce the calculation time without affecting the accuracy of the results [13] [14].

Further work can be done by increasing the number of DOF of the mounting. Investigate its effect in predicting free mobility using the LMS algorithm. In this paper, the classical LMS algorithm is used which can be improved to get a better prediction in the higher degree of freedom. For solving the equation system another approach was showed by Wolfgang and Paviç [3]. Direct solving with a symbolic toolbox, it might be interesting to analyze the effect of this different solving method. Using the LMS algorithm in structure-borne sound and system and source identification rather than the conventional inverse method is a quite new approach. System properties can be easily identified through this method. Due to the robustness of the solution, it can be a very efficient alternative to understanding the coupled structure without decoupling them.

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