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Vibration Control of Cantilever Beam Using Fuzzy Logic Controller

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Abstract— The paper present to design fuzzy logic controller for identification of cracks and vibration control of cantilever beam. And identification the location and depth of creaks in beam using measured the vibration data. Fuzzy controller is applied to attenuate vibrations in a cantilever beam structure with large varying parameters. The method of detecting crack location and its intensity in beam structures by fuzzy logic techniques and using ALGOR for finite element analysis has been considered in this project. The fuzzy logic controller used here comprises of two input parameters and one output parameters. Gaussian and triangular, trapezoidal member ship functions are used for the fuzzy controller. The input parameters to the fuzzy- Gaussian controller and fuzzy- triangular controller are relative deviation of first three natural frequencies. The output parameters of the fuzzy inference system are relative crack depth and relative crack location. At the beginning theoretical analyses have been outlined for cracked cantilever beam to calculate the vibration parameters such as natural frequencies. A set of boundary conditions are considered involving the effect of crack location. A series of fuzzy rules are derived from vibration parameters which are finally used for prediction of crack location and its intensity. The comparison is made between Gaussian and triangular membership functions by calculating deviation from expected values of crack depth and crack location. He proposed approach has been verified by comparing with the results obtained from fuzzy logic technique and finite element analysis.

Index Terms— **Actuator, Cantilever Beam , Feedback System, Fuzzy logic controller, Membership functions ,Sensor**

I. Introduction

Cracks present in machine parts affect their vibration behaviour like the fundamental frequency and resonance. The amplitude of vibration increases and the occurrence of

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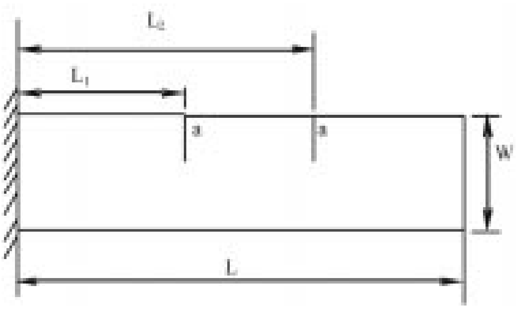

Fig: Geometry of cantilever beam with a double Edge crack

Resonance shifted as crack length increases. Structural failure refers to loss of the load carrying capacity of a component or member within a structure or of the structure itself. Structural failure is initiated when the material is stressed to its strength limit, thus causing fracture or excessive deformations. When this limit is reached, damage to the material has been done, and its load-bearing capacity is reduced permanently, significantly and quickly. In a well-designed system, a localized failure should not cause immediate or even progressive collapse of the entire structure. Ultimate failure strength is one of the limit states that must be accounted for in structural engineering and structural design. Therefore intensive research has been going on amongst the scientists and engineers to find an effective methodology to predict the location and intensity of damage beforehand.

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II. PROBLEM FORMULATION

Transfer function:

$$\frac{-472.7 s^2 - 41.1 s - 1.376e006}{139.2 s^4 + 25.88 s^3 + 4.213e006 s^2 + 3.636e005 s + 3.304e009}$$

System parameters:

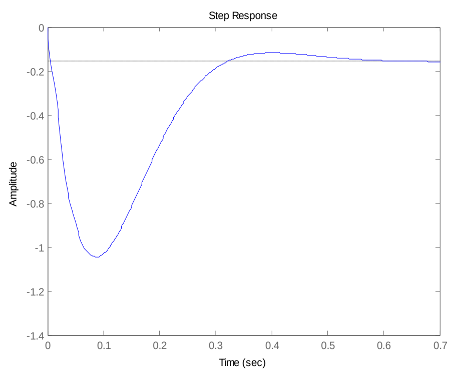
```
l= 11.8; n length of beam
t=0.05; in thickness of beam
w=0.6; in width of beam
ro=0.0975; lb/inA3
E= 1.0878E7; %lb/inA2
a=t*w; inA2
I=t*w^3/3 % Morrient of Inertia
% Properties of PZT
d31=-7.48E-9 m/volt
ha=.0105 %in height of actuator
hs=ha is height of sensor
la=l is length of actuator
ls=.5 is length of sensor
Ea=9.572E6 %lb/inA2
```

```
ba=.4 is width of actuator
bs=ba is width of sensor
Cs=.008E-6; is capacitance per unit area
xsl=3.8; is location of sensor
xs2=4.3; is location of sensor
Ca=Ea*d31*ba*(t+ha)/2; is lb*in/volt
Geometry coefficient
Ca=2*Ca is two collocated actuator
k31=.35; is coupling coefficient
g31=(-11.6E-3)*(39.368)^2
omegal=6.415E-4;
omega2=0.025;
omega3=0.198;
wl=(E*I*omegal/(ro*a))^.5; is 1st natural
freq rad
w2=(E*I*omega2/(ro*a))^.5; is 2nd natural
freq rad
w3=(E*I*omega3/(ro*a))^.5; is 3rd natural
freq rad
wla=97.5;
w2a=589.5;
z1=0.0052; is damping coefficient
z2=0.001;
z3=0.001;
Actuator and sensor constant.
ka=Ca/(ro*a) volt
ks=-bs*(hs+t/2)*(k31^2/g31) Coulomb or can
be in*lb/volt
philxa=-0.014; derivative of mode shape 1
of actuator at location 2 - location 1
phi2xa=-.074; derivative of mode shape 2 of
actuator at location 2 - location 1
phi3xa=-.173; derivative of mode shape 3 of
actuator at location 2 - location I
philxs=-5.87E-3; derivative of mode shape
1 of sensor at location 2 - location 1
phi2xs=-0.014; derivative of mode shape 2
of sensor at location 2 - location 1
phi3xs=.013; derivative of mode shape 3 of
sensor at location 2 - location 1
```

Transfer function of the system

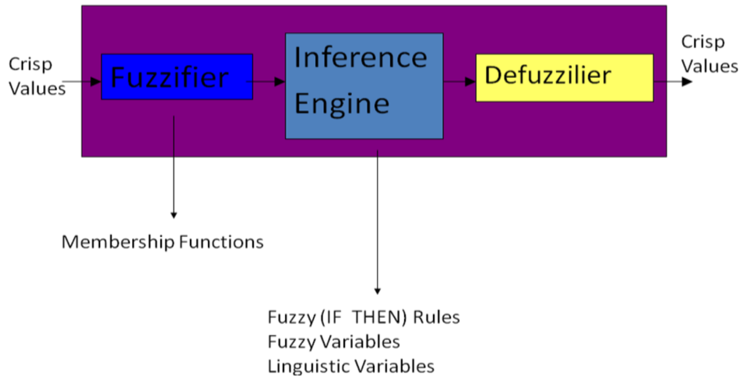
$$\frac{-472.7\, s^2 - 41.1\, s - 1.376e006}{139.2\, s^4 + 25.88\, s^3 + 4.213e006\, s^2 + 3.636e005\, s + 3.304e009}$$

Step Response Of Cantilever Beam



III. FUZZY LOGIC CONTROLLER

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise.



In contrast with binary sets having binary logic, also known as crisp logic, the fuzzy logic variables may have a membership value of only 0 or 1. Just as in fuzzy set theory with fuzzy logic the set membership values can range (inclusively) between 0 and 1, in fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {true (1), false (0)} as in classic predicate logic. And when linguistic variables are used, these degrees may be managed by specific functions, as discussed below. Fuzzy logic has been applied to diverse fields, from control theory to artificial intelligence, yet still remains controversial among most statisticians, who prefer Bayesian logic, and some control engineers, who prefer traditional two-valued logic Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in. Vibration analysis is used to test a material against random vibrations, shock, and impact. each of these incidences may act on the natural vibration frequency of the material which, in turn, may cause resonance and subsequent failure. Fatigue analysis helps designers to predict the life of material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material

IV FUZZY RULES

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Fuzzy Rules based on fuzzy premises and fuzzy consequences eg if height is short and weight is light than feet are small short (height) and light (weight) => small (feet)

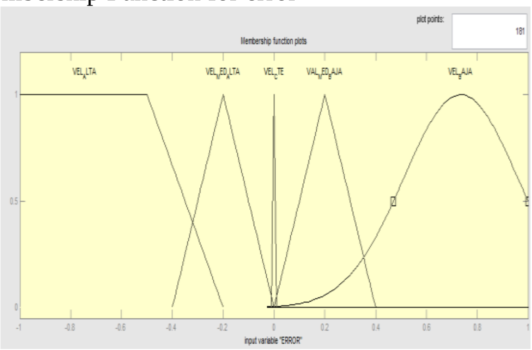
IV. MEMBERSHIP FUNCTION

A Fuzzy set is defined by a function that maps objects in a domain of concern to their membership value in the set. Such a function is known as Membership Function. It is usually denoted by the Greek symbol for ease of the recognition and consistency. In other words membership function can be defined as a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. Fuzzify the data or create membership values for the data and put them into fuzzy sets .Put simply, we have to divide each set of data into ranges .The Y value will always be on a range of 0 to 1 (theoretically 0 to 100%).

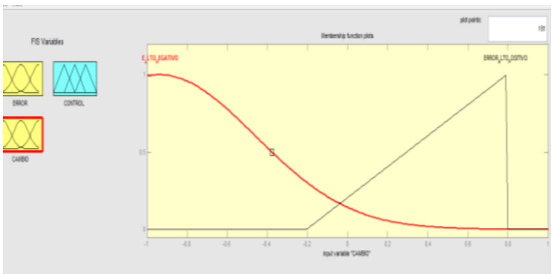
$$\text{Relative crack location}=rcl=\frac{\int location.\mu_{rcl}(location).d(location)}{\int \mu_{rcl}(location).d(location)}$$

$$\text{Relative crack depth}=rcd=\frac{\int depth\mu_{rcd}(depth).d(depth)}{\int \mu_{rcd}(depth).d(depth)}$$

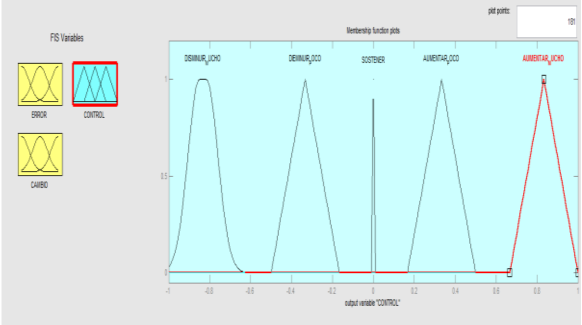
a. Membership Function for error



b. Membership Function for two inputs



c. Membership Function for one output

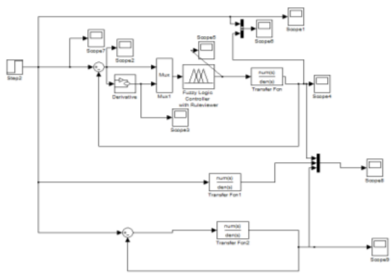


V. SIMULATION AND RESULTS

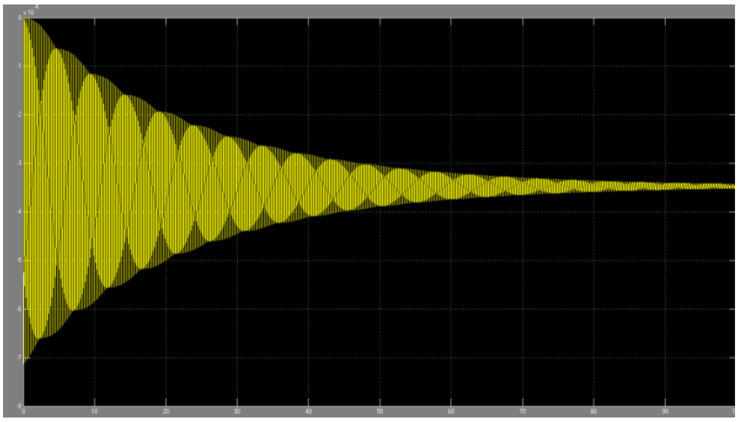
Transfer function of cantilever beam:

$$\frac{-472.7\ s^2 - 41.1\ s - 1.376e006}{139.2\ s^4 + 25.88\ s^3 + 4.213e006\ s^2 + 3.636e005\ s + 3.304e009}$$

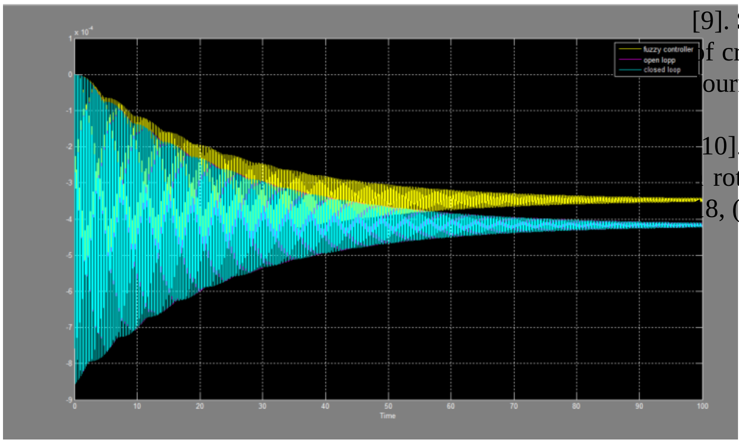
A. SIMULINK MODAL



B. Step Response of fuzzy controller



C. Step Response of between open loop, close loop and fuzzy controller



VI. Conclusion

By the Membership Function, We have been detecting the crack depth and crack location, here, the fuzzy logic controller is used for vibration control of cracks through the fuzzy parameters. So we identify the damage cracks in cantilever beam.

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