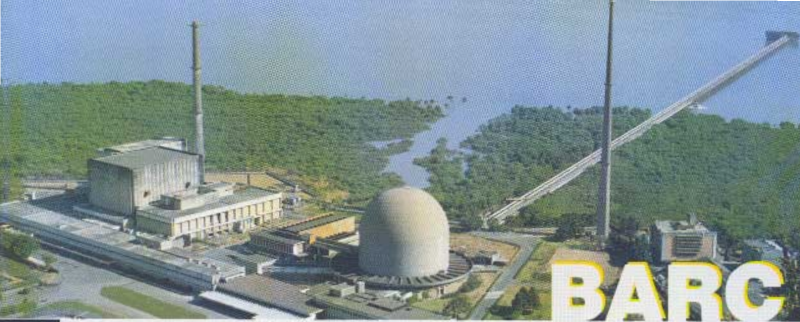

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RELIABLE FINITE ELEMENT MODELLING, DESIGN MODIFICATION AND DIAGNOSIS USING MODEL UPDATING METHOD

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Introduction

Structural design and analysis generally requires a mathematical model representing the physical behaviour of the structure so that such a model may be used to predict responses for service loads, assess structural integrity including seismic analysis and also to study the impact of suitable design modifications or system fault diagnosis. The Finite Element (FE) method is the most appropriate tool for such numerical modelling in structural engineering today. This method can handle complex structural geometry, large complex assemblies of structural components and is also able to perform different types of analysis. Even with the great advances in the field of structural modelling, an initial FE model is often a poor reflection of the actual structure, particularly in the field of structural dynamics. This inaccuracy arises because of a number of simplifying assumptions and idealizations which have to be made while constructing the FE model that generally depends on the engineering judgement. Such inaccuracy in the FE model *a priori* is well known in the scientific community and is generally brought out when compared with the experimental results. The experimental results in the structural dynamics are the modal data – natural frequencies ($\{f_{ex}\}=\left\{\sqrt{\lambda_{ex}}/2\pi\right\}$, where λ is eigenvalues), mode shapes and damping. In the modal testing, the structure is excited

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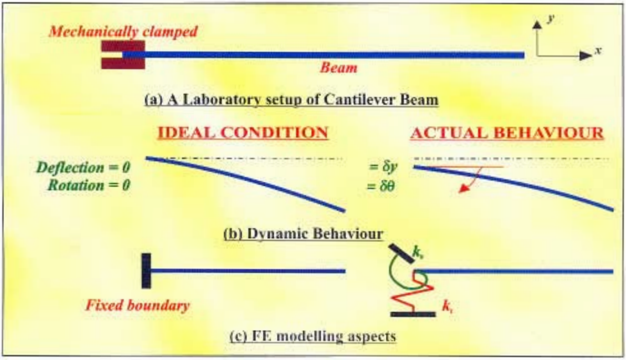


Fig.1 Cantilever beam and its behaviour and FE modelling

externally and the structural responses are processed to obtain the modal parameters. In fact, modal tests were conducted on a number of simple laboratory models of cantilever beams and most of them were not found to realize absolute fixed boundary condition at the clamp end i.e., the beam was found to have either small rotation ($\delta\theta$) or both small rotation ($\delta\theta$) and deflection (δy) at clamp end during the FE simulation. It is pictorially shown in Figure 1. If one has to construct FE model without the knowledge of the experimental modal data, the natural assumption would be ideally fixed boundary condition, which may not be true. The example of such a simple structure itself indicates the reliability of the FE model *a priori*. Based on intuition, it is difficult to find out the values of the boundary stiffnesses and, in fact, there could be many more possible potential sources for the deviation in the FE model for the large and structurally complex components. Hence, an FE model *a priori* may be useful at design stage only. However, after installation of structure, the initial FE model should be updated based on the experimental modal data obtained from in-situ modal tests so that the FE model can be used confidently for further analysis. The general practice is to update FE model by the hit and trial method so that the model comes close to the experimental modal data of the 'as installed' structure. But such practice is difficult if the number of the parameters to be adjusted is large. The resulting updated model may reduce the deviations between the initial model and experimental results to a certain extent but may not be useful for the prediction in case of any structural change in future. Recently, a formal method has been developed for the model updating eliminating all uncertainty about the updated models.

In the gradient based sensitivity methods of the model updating, the most important aspect is to define an error function between the computed and experimental modal data. This error is generally minimized by the optimisation of the error function, which is usually a highly non-linear function with respect to the updating parameters. In defining the error function, as well as in the construction of the sensitivity matrix (derivative of the natural frequencies with respect to the updating parameters), the correct pairing of computed modal data with the experimental modal data is essential. This is important because the pairing of computed and experimental modal data based on the sequential order of mode numbers may not always be correct. This correlation between the computed and the experimental data is generally established using the Modal Assurance Criterion (MAC). Another important task in model updating is the selection of the parameters (such as boundary stiffnesses, joint off-set, physical dimensions, material properties, etc.) to be updated. The parameters should be chosen with the aim of correcting the recognized uncertainty in the model. Moreover, the computed natural frequencies, mode shapes and response of the FE model should be sensitive to the updating parameters. The flow diagram of this model updating is shown in Figure 2.

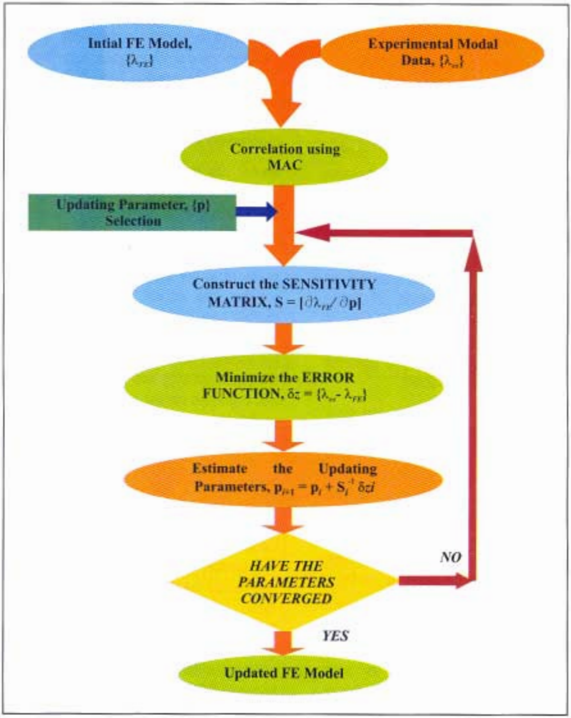


Fig. 2 Simplified flow diagram for the model updating method

The objective of the article is to summarise the usefulness of model updating as a tool for reliable modelling and non-destructive diagnosis through several examples. The advantage of the model updating method over the hit and trial method is also brought out through an example.

Examples of Model Updating

The following examples have been chosen to highlight the need for the sensitivity method of the model updating process and to emphasise that the physical insight is vital to produce a better model of a structure, that may be used to test design modifications and fault diagnosis.

Hit and Trial Method: Three examples of the structural components used in the nuclear plants are discussed here. First one is a full scale *shut-off rod guide tube* assembly at RCnD. Second is a *moderator sparger tube* proposed to be used in MAPS and third example is the *horizontal long waste storage tank* (25m long, 4m outer dia) of KARP, Kalpakkam. The schematic of these components are shown in Figures 3 to 5. The modal tests were conducted to extract natural frequencies, mode shapes and modal damping. The identified natural frequencies are listed in Table-1.

FE models were also developed using two node Euler-Bernoulli beam elements. In the initial FE model, ideal boundary conditions (i.e., clamped conditions for the sparger tube ends) were assumed. The computed natural frequencies are also listed in Table-1 for comparison with modal test frequencies. It can be seen from the table, that the computed frequencies deviate significantly from the experimental values hence the initial FE model is not reliable and needs to be updated.

Since the material and geometrical properties of the examples were exactly known the boundary conditions may be the main reason for such deviations. Based on the physical understanding of the problems, the boundary stiffnesses were adjusted by the hit and trial method to bring the FE model close to the experimental results. For the first example of the shut-off rod guide tube, value of only one rotational spring at the support of the outer tank was adjusted. The computed frequencies from the updated FE model are almost same as the measured ones and are listed in Table-1. However, for other two examples, the parameter to be adjusted were large (3 boundary stiffnesses for the sparger tube and 8 boundary stiffnesses for the tank in one direction) and the updated models are also not so close to the experimental results. The predicted natural frequencies from the updated models are also listed in Table-1. These examples only realise that the updated FE models by the hit and trial method may not be very accurate if number of parameter to be adjusted is large.

Model Updating Method: Considering such limitations, now a formal method is developed for the model updating. Using the updating method, a study of a reliable FE modelling was carried out. The example of the *sparger tube* was considered again. Now, the gradient based sensitivity model updating was applied to the FE model of the sparger tube setup. Three boundary stiffnesses - k_1, k_2 and k_3 as shown in Figure 4 were chosen as the updating parameters. The iterative process of the model updating was carried out using first five well correlated natural frequencies of the initial FE model with the experimental natural frequencies. It was observed that the updated FE model further reduces the error in the computed natural frequencies compared to the updated model by the hit and trial method. The computed frequencies by the updated FE model along with the experimentally identified natural frequencies are listed in Table-2. The natural frequencies computed by the model obtained by the hit and trial method is also listed in Table-2 for comparison. As can be seen from Table-2 that the system (the sparger tube together with extensions) natural frequencies computed by the updated model is more close to the measured frequencies. This indicates an overall improvement in correlation between the FE model and the 'as installed' system. Thus, the model updating, if applied correctly, may produce much better model compared to the hit and trial approach.

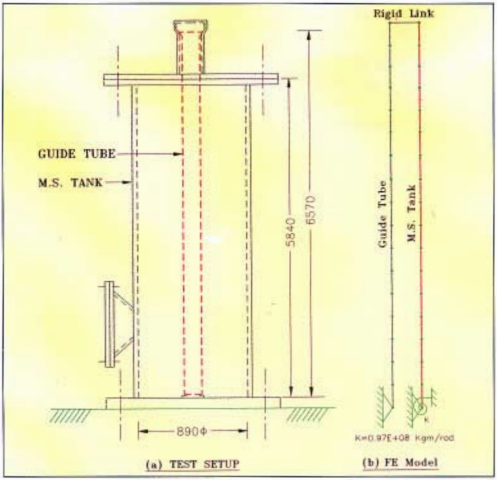
The most important thing to emerge out from the model updating method is that the estimated updated parameters deviate significantly from the values by the hit and trail method though there is not much difference in the frequency estimation.

Table 1 : Natural frequencies (Hz) of structural components

Mode No	Experi-mental Data	Initial FE model	Final FE model	Error Initial (%)	Error Final (%)	Description
Shut-off Rod Guide Tube Setup at RCnD						
1	6.510	6.977	6.545	+7.174	+0.538	Tube : 1st flexural beam mode
2	11.920	12.960	11.923	+8.725	+0.025	Tank : 1st cantilever beam mode
3	20.997	22.62	21.222	+7.730	+1.071	Tube : 2nd flexural beam mode
Sparger Tube Setup at Hall-7						
1	17.24	21.46	18.93	+24.48	+9.803	1st flexural beam mode of the tube
2	46.56	62.42	50.61	+34.06	+9.698	2nd flexural beam mode of the tube
3	58.25	---	55.87	---	-4.086	Flexural beam mode of the complete system (tube with both extensions).
4	64.00	---	60.22	---	-5.906	
5	103.9	117.70	101.3	+13.28	-2.502	3rd flexural beam mode of the tube
Horizontal Long Tank, KARP, Kalpakkam – in Lateral Direction						
1	5.625	3.724	5.617	-33.79	-0.142	Rigid body mode of the tank on its central and outer supports
2	19.00	0.733	17.59	-96.14	-7.421	Rigid body rotation of the tank due to twisting of the central support
3	25.25	15.01	20.09	-40.55	-20.436	Flexural beam mode-1 of the tank

Table 2 : Measured and computed natural frequencies (Hz) of the sparger tube

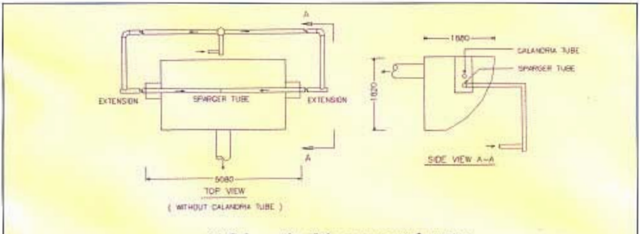
Parameters		Experimental Data (a)	Updated FE model		Error (%)		
			Hit and trial method (b)	Sensitivity model updating (c)	(a & b)	(a & c)	(b & c)
Updating	k_1, N/m	UNKNOWN	$1.570 \times 10^{+7}$	$2.163 \times 10^{+7}$	---	---	+37.77
	k_2, N-m/rad.		$9.810 \times 10^{+3}$	4.029×10^{-22}	---	---	-100.0
	k_3, N/m		$1.962 \times 10^{+7}$	$2.208 \times 10^{+7}$	---	---	+12.54
Modes	1st, Hz	17.24	18.93	18.24	+9.803	+5.800	-3.645
	2nd, Hz	46.56	50.61	49.95	+9.698	+7.281	-1.304
	3rd, Hz	58.25	55.87	58.09	-4.086	-0.275	+3.973
	4th, Hz	64.00	60.22	62.89	-5.906	-1.734	+4.434
	5th, Hz	103.9	101.3	103.8	-2.502	-0.096	+2.468



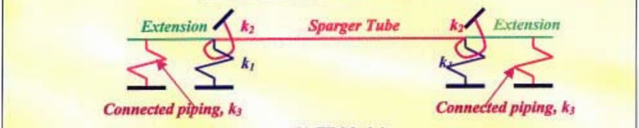
(a) TEST SETUP

(b) FE Model

Fig. 3 Schematic of Guide Tube setup and its FE model



(a) Schematic of the sparger tube setup



(b) FE Model

Fig. 4 The test setup and its FE Model

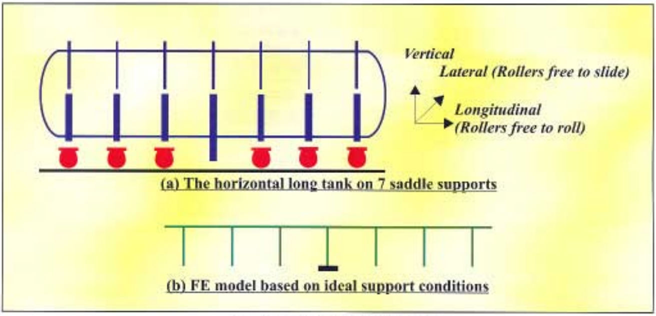


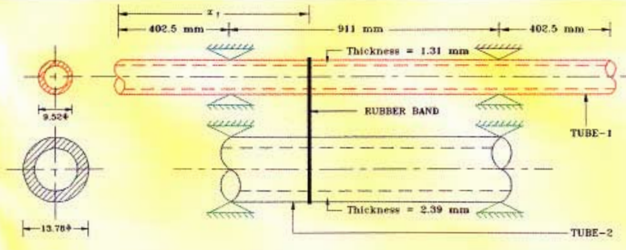
Fig. 5 Schematic of the tank and its FE model

The rotational boundary stiffness (k_2) becomes close to zero indicating that the outer tank supporting the sparger tube is not providing any rotational constraint to the sparger tube. Since the tube was not rolled to the tube sheet of the tank, the tube may be expected to have free rotation at support. This is a very important conclusion that could not be arrived at by the hit and trial approach. This example brings out the limitation of the hit and trial approach that the adjustment of few natural frequencies could be possible but the updated model may not be reliable. Hence, the model updating method should be used. Once the reliable model is obtained, the model can be confidently used for the design qualification and the design modification of the structure.

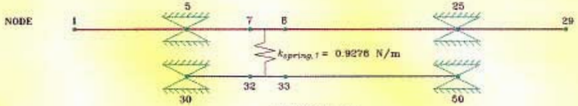
Model Updating as a Diagnostic Tool

Non-intrusive and non-destructive fault detection for mechanical structures using experimentally measured modal data has been an area of active research for decades. The basic principle of most of the research studies is to use experimental modal data of structures before any fault such as crack has formed as base-line data, and all subsequent tests are compared to it. Deviation in the experimental results from the base-line data is then used to estimate fault. The methods of model updating may also be used as *non-destructive and non-intrusive tools* for the diagnosis of various faults in structural systems. Once again the correct choice of updating parameters is vital to ensure a meaningful diagnosis. Few such examples are below.

The estimation of support locations: Many flexible mechanical systems such as fuel pins, heat exchanger tubes, control rods and various instrumented and shrouded tubes used in nuclear power plants and other engineering industries are beam-like components with a number of intermediate supports along their length. In many cases, these intermediate supports are firmly fixed. However, in some cases, they may be loosely coupled and may move from their original locations during operation, for example because of flow induced vibration. Undetected, such dislocated supports may deteriorate the system performance and consequently jeopardise the safety of the structure or plant. Visual inspection of such support locations in the structural system is not always possible if the structural configuration is complex. One such example is a *Coolant channel of PHWR.* The coolant channel consists of two co-axial tubes, and two loosely held spacers maintain the annular



(a) Schematic of the setup assembly



(b) FE Model

Fig. 6 Laboratory experimental setup

gap between them. It is known from the in-service inspection that these spacers move from their design locations during plant operation. Hence, an identification technique based on model updating using deviation in only natural frequencies is explored on a simple laboratory setup.

The example is a laboratory scale experiment comprising of two tubes made of steel, which are inter-connected by a rubber band. Figure 6(a) shows a schematic of the setup and gives details of the dimensions and the boundary conditions of both of the tubes. Modal tests were conducted for two different locations of the rubber band (656.5 and 746.5 mm from one end). Figure 6(b) shows the FE model of the setup that was developed using lumped mass Euler-Bernoulli beam elements for both of the tubes and a spring element for the rubber band. The spring element was modelled such that it can be placed within the beam element (i.e., spring can be placed other than node also) and the position (x_1) of the spring explicitly appears in the stiffness matrix of the system.

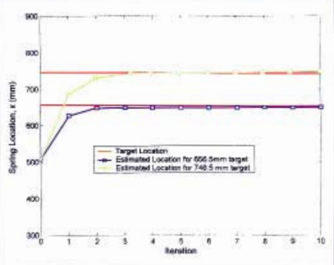
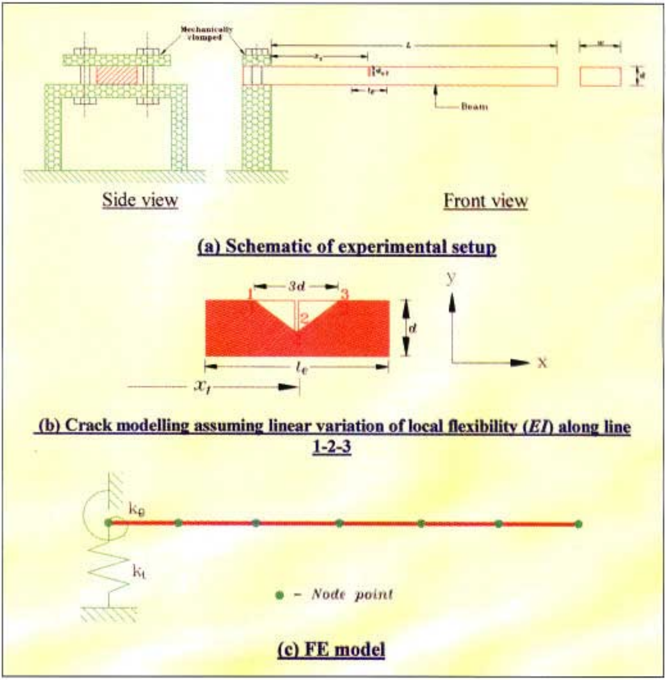


Fig.7 Convergence of the estimated support location for both cases

The estimation of the spring location has been carried out using the position (x_1) of the spring as the updating parameter. The first three natural frequencies were used to define the error function. An iterative process of the model updating was carried out with an initial guess of the spring location, $x_1 = 508.44$ mm. The position of the spring for both cases was identified within an error of -0.69% and –0.19% from the target locations of 656.5 mm and 746.5 mm respectively. Figure 7 gives the convergence history for detection of the spring location for both cases.

The estimation of crack size and location: Shafts are common beam type structures generally used to carry and transfer high loads in machines. Cracks are potential cause of structural failures, so early detection of cracks is important. The presence of a crack in structure reduces the stiffness in the region of crack. The reduction in stiffness is associated with decrease in natural frequencies. Hence, a method is developed for FE modeling of the shaft type structures using Euler-Bernoulli beam elements with some modification in the vicinity of crack. The detection of crack using model updating was also demonstrated.



(a) Schematic of experimental setup

(b) Crack modelling assuming linear variation of local flexibility (*EI*) along line 1-2-3

(c) FE model

Fig. 8 Cracked cantilever beam and its FE Model

Emphasis was again on producing a model of the damaged structure that is suitable for model updating. For illustration, a problem of a cantilever beam with a crack is considered. The beam is made of aluminium of length 1832 mm and cross-section 25 x 50 mm. Figure 8(a) shows a schematic of the test setup. The modal tests were conducted on the beam with a crack at x_l = 275 mm and the crack depth (d_{cl}) of 4mm, 8mm and 12mm. The Euler-Bernoulli beam element is used to model the beam. The crack is modelled such that it can be placed within the beam elements of the FE model as shown in Figure 8(b). This modelling approach is once again such that the system stiffness matrix is a continuous function of the crack depth and its location, similar to the spring support model discussed earlier. The typical FE model is shown in Figure 8(c). The estimated boundary stiffnesses, k_t and k_θ, are 26.5 MN/m and 150 kNm/rad. respectively.

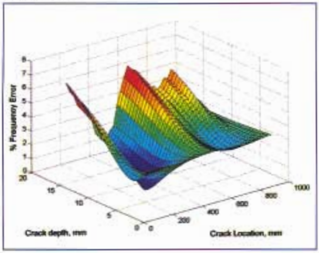


Fig. 9 Surface plots for % frequency error versus crack depth and location for the experimental case of 8 mm crack depth

Once again using this FE model, the crack identification is performed using two updating parameters, namely the crack location (x_l) and depth (d_{cl}). The first four measured natural frequencies were used to define the error function. An initial guess of the crack location, x_l = 400mm and depth, d_{cl} = 2mm were made to start the iterative process of model updating till convergence. It was observed that the crack detection is quite effective and the error in the detection is small. The crack location estimation is more accurate (error less than 5%) compared to the crack depth estimation (error within 30%). The inaccuracy in the crack depth estimates may be due to the difficulties in measuring the crack depth, or possibly because the natural frequencies are more sensitive to the location. Surface plot for %Frequency Error versus crack location and depth is also shown in Figure 9 for the case of the crack depth, d_{cl} = 8mm. Only one minima seen in Figure 9 indicates the uniqueness of the suggested identification technique.

Concluding Remarks

The dynamic qualification of structures requires an FE model. The reliability of the qualification is totally dependent on the quality of the FE model of the structure. In general, an FE model *a priori* is not reliable in structural dynamics. Such a model needs validation by comparing with the experimental modal data. The adjustment of the FE model by the hit and trial method using the experimental modal data may not always produce a reliable FE model. The FE model updating is the most appropriate tool for such requirements. The most important aspect is the choice of updating parameters. Choosing a good set of updating parameters means the updated model has physical meaning and can be used with confidence for design modifications and structural optimisation. This was shown dramatically for the *sparger tube* example. The advantage of the model updating over the initial FE model and the model obtained by the hit and trial method is brought out clearly. Hence, it should be made mandatory to qualify most of the safety related components including the reactor building of Nuclear Power Plants using an updated FE model. Once the updated model is obtained, an impact of the suitable design modification and fault diagnosis could be possible. This will enhance the confidence level in the overall safety of the plant.

The use of model updating method as a non-intrusive and non-destructive diagnostic technique was also demonstrated by the detection of cracks and support locations. Presently, only two areas of the NDT have been explored. The method has much more capability and potential. The model updating, when applied correctly, can be profitably exploited in modelling, design modification and fault diagnosis.

DEVELOPMENT OF SENSOR FOR REMOTE DETECTION OF ECCENTRICITY BETWEEN COAXIAL METALLIC TUBES

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Introduction

Eddy current sensor system along with associated signal conditioning electronic circuits for qualitative and quantitative detection of eccentricity between coaxial metallic tubes made of non-ferrous and low electrical conducting material has been designed and developed in Reactor Engineering Division, BARC. This miniature sensor can be kept in close proximity of metallic objects and is insensitive to the lift-off errors. The system can be used with 100 metres cable length and is capable to detect eccentricity between coaxial metallic tubes within overall accuracy of 0.5 mm. The design and developmental work involving design of sensor and associated signal conditioning hardware and software has been completed. This sensor will be used as embedded sensing element in hydraulically actuated devices, that are subjected to heavy mechanical stresses, for detection of eccentricity between metallic tubes under operating conditions. This report highlights general design and developmental aspects of the sensor along with associated hardware.

Background

Precise measurement and correction of eccentricity between the two co-axial metallic tubes is essential in many industrial fields. One of such requirements in Indian nuclear reactors is the need to measure and correct the eccentricity between highly radioactive non-ferrous low electrical conductivity metallic tubes viz. Pressurized Heavy Water Reactor (PHWR) coolant channel Pressure Tube and Calandria Tube. An eddy current sensor based transducer and its associated hardware has been designed in order to check the eccentricity between metallic tubes in vertical axis ('Y' direction). These tubes are initially eccentric which needs to be corrected by using a Tube Flexing Tool (TFT). The sensor needs to be mounted in one of the bearings of TFT as an integral part of the tool, which will be inserted in the bore of inner tube. The TFT is hydraulically actuated in 'Y' direction, generating vertical thrust to correct the eccentricity between the metallic tubes based on the eccentricity information feed back received from the transducer. This transducer needs to be operated from 100 metres cable distance and should be fairly insensitive to the lift-off errors. Further, since the TFT is subjected to very high mechanical stresses during eccentricity correction operation, the sensor needs to be protected against the damages. Also, since the stresses developed in the metallic tubes affects the eddy current generation (due to change in metallic conductivity), it is required to have suitable compensation provision in the system to nullify the stress induced signal variation of the transducer. The transducer dimensions should be fairly small enough to fit in the bearing housing of TFT. The design constraints, constructional features and performance evaluation of the transducer system has been described in the following sections .

Design Constraints and Salient Features

a) Mounting : The sensor, being the integral part of the eccentricity correction tool TFT, needs to be mounted in the bearing housing of the tool. The transducer should be designed such that the magnetic flux emerging out of the sensor should link the coaxial metallic tubes. The metallic body of TFT should not divert the magnetic flux. In order to achieve this, 'C'-clamp type pancake probes have been designed to ensure the flux linkage to both the tubes, in spite of sensors being embedded in the tool bearing.

b) Size : The sensor size should be small enough to fit in the bearing of TFT.

c) Sensitivity : The sensor should be enough sensitive to detect precisely the eccentricity between the metallic tubes. In order to improve the sensitivity of the sensor, the $\omega L/R$ ratio of the coil should be high. Mumetal has been used as the sensor material. One can also use ferrite core to improve the sensitivity; however, mumetal has been used for higher sensitivity and better strength.

d) Tool bearings: In order to reduce the diversion of flux generated in the sensor which is embedded in the bearing housing, the metallic bearings cannot be used for TFT. Non-metallic high crushing strength phenolic bearings have been used to serve the purpose. The sensor is embedded in one of the phenolic bearings and is protected by suitable potting.

e) Operating environment : The sensor system should be capable to work in RFI and EMI noisy environment.

Constructional Features and System Configuration

The schematic of the eccentricity measurement transducer is shown in Fig.1. The transducer works on eddy current principle. The parameters such as conductivity, permeability, dimensions of the test object, spacing between the test object and test coil, spacing between the test objects and test frequency affecting eddy current are phase sensitive. It has been seen that the parameter like lift-off is less phase sensitive as compared to parameters like thickness variation and spacing between the components. In order to nullify the lift-off error, the phase measurement technique has been used in the system instead of amplitude measurement technique, since the latter is more sensitive to lift-off errors.

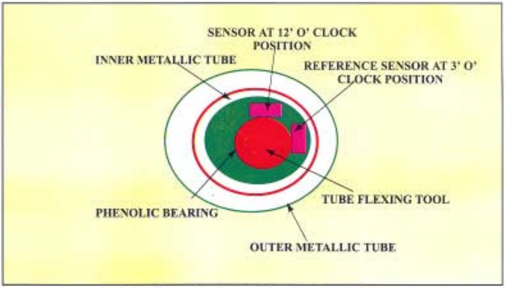

Fig. 1 Schematic of eccentricity detection transducer

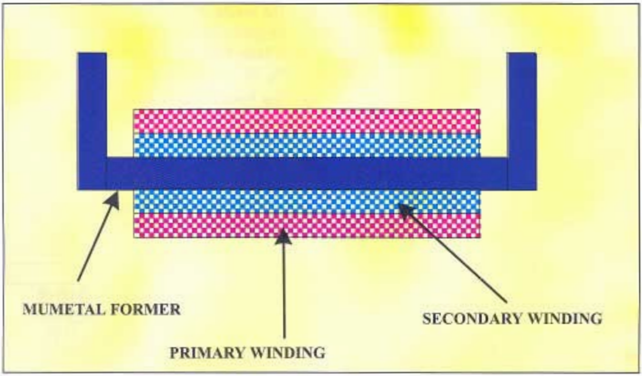

Fig. 2 Schematic of sensor

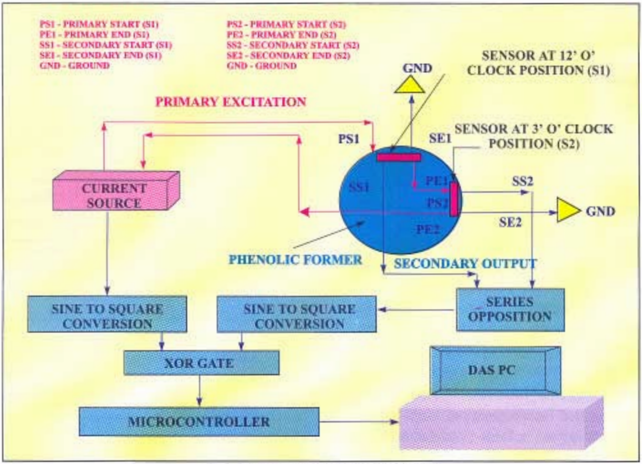

Fig.3 Schematic of signal conditioning hardware

The eccentricity detection transducer consists of two eddy current sensors embedded in the bearing of the TFT. The sensors are located at 3 O'clock and 12 O'clock positions on the periphery of the bearing. The sensor at 3 O'clock position is used as reference sensor. The sensor in 12 O'clock position is used as the measurement sensor. These sensors are configured in differential mode by which the thickness variation and temperature variation of tube, which in turn affects the conductivity, will be compensated. By configuring the sensors in differential mode, the common mode signals have been nullified.

The schematic of the sensor used in the system is shown in Fig. 2. It consists of C-shaped former made of Mumetal surrounded by secondary and primary windings. The primary winding of the sensors will be excited by a constant current source. The outputs from the secondary windings are configured in series opposition mode and fed to the Sine to Square wave converters. The pulse width variation, which is caused due to the change in the phase shift, which in turn depends upon the eccentricity between the metallic tubes, is measured by using XOR gate and micro-controller. The eccentricity information is displayed on Data Acquisition System (DAS) PC by DAS software.

Fig. 3 shows the schematic of the signal conditioning hardware associated with the transducer system.

Experimental Observations Using Prototype System

The prototype transducer system developed has been used to measure the effect of lift-off error at various frequencies in order to optimise the operating parameters for the transducer system. The phase angle variation of signal, while varying the full range of eccentricity between the tubes (0 to 16mm) for a typical setup, have been studied.

a) The results of Test Frequency vs Worst possible Lift-off % is given in Table-1 and the respective graph is shown in Fig. 4A.

b) The results of Eccentricity (-7 mm to +8mm) Variation versus Phase Angle variation is given in Table-2 and the respective graph is shown in Fig. 4B.

c) The Pressure/Stress induced in metallic tube (due to TFT actuation) vs. Phase Angle variation of the transducer is shown in Fig. 4C.

d) The sensor performance showing the Phase Angle variation for various eccentricities under different operating pressures is shown in Fig. 4D.

Table-1

Sl. No.	Test Frequency	%Lift-off Contribution
1	2.5kHz	13.04
2	3.0kHz	10.83
3	3.5kHz	14.28
4	4.0kHz	19.2
5	4.5kHz	20
6	5.0kHz	23.8
7	5.5kHz	27.7
8	6.0kHz	33.3

Table-2

Sl. No.	Eccentricity Variation in mm	Phase Angle variation in Deg.
1	-7	134.13
2	-6	134.4
3	-5	134.93
4	-4	135.4
5	-3	136
6	-2	136.6
7	-1	137.26
8	0	137.66
9	+1	138.26
10	+2	139
11	+3	140.46
12	+4	141.53
13	+5	142.66
14	+6	144.2
15	+7	145.73
16	+8	147.73

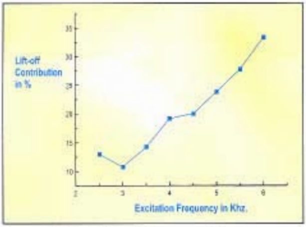

Fig.4A Lift-off Contribution versus Frequency

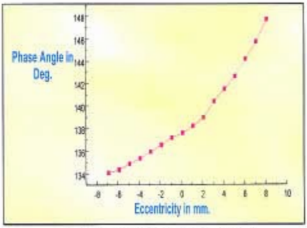

Fig.4B Phase Angle versus Eccentricity

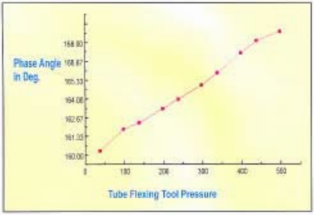

Fig.4C TFT Pressure/Stress versus Phase Angle

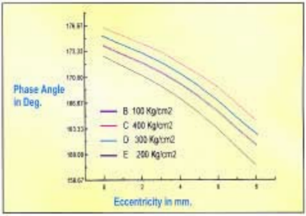

Fig.4D Sensor performance at varying stresses

The following observations have been noted :

a) *Lift-off error :* By using phase measurement techniques, the lift off parameter is less sensitive. The parameter like annular gap variation between the tubes is more predominant.

b) *Transducer signal variation due to effect of mechanical stress on tubes :* It has been observed that when TFT is operated to correct the eccentricity between the metallic tubes, the mechanical stresses are generated in the inner metallic tube due to flexing. These stresses will affect the signal out-put of the transducer. As such the signal contribution due to the affect of mechanical stress generated in the tube should be compensated by using look-up table or by going for multi-parameter technique. The phase angle variation is found to be linearly varying with operating pressure of the TFT/ Stresses induced in the metallic tube for the whole range of eccentricity change.

Conclusion

The prototype of the transducer has been fabricated and tested. The experimental results are found highly encouraging. The transducer can be operated from a distance of 100 metres.Its performance is least affected by lift-off errors. It has been observed that by using high permeability pancake probes, intense magnetic fluxes can be produced. In any application where remote field in non-ferrous tubes is used, this type of design has an advantage. Based on the performance evaluation, a transducer for the use in INGRES (Integrated Garter spring REpositioning System) tool has been fabricated along with necessary signal conditioning unit PCBs. The system is ready for end use.

BARC TRANSFERS TECHNOLOGY TO NUCLEONIX SYSTEMS PVT. LTD.

Dr M.C. Abani, Head, RSSD, BARC, is handing over the Technology Transfer Document to Mr J.N. Reddy, Managing Director, Nucleonix Systems Pvt. Ltd., Hyderabad, after the Technology Transfer Agreement was signed by Mr A.K. Anand, Director, TC&IRG and RPG, BARC

BARC transferred to Nucleonix Systems Pvt. Ltd., Hyderabad, the technical know-how on non-exclusive basis for "PC-based Auto TLD Badge Reader (Model TLDBR-7B) with associated software".

This unit can process upto 50 Personnel Monitoring BARC-made TLD Badges at a time. This badge contains three TL dosimeters sandwiched between energy discrimination filters to distinguish among beta, X-ray and gamma radiation. The read-out time is typically 100 sec. per badge and 50 badges are read in about 90 minutes. The TLD Reader provides controlled heat to the dosimeters, senses the instantaneous light coming out (glow curve signal) and displays the total integrated light output in Rontgen (R) on screen. The operations are controlled through PC.

The technology has been developed at Reactor Safety & Systems Division, BARC. Technology Transfer and Collaboration Division has co-ordinated complete technology transfer process involving preparation of technology documents, technology transfer agreement and advertising of technology.

BARC SCIENTISTS HONOURED

Dr K. Dasgupta of Laser & Plasma Technology Division, BARC, was invited under the "Prof K. Venkatraman Lectureship" endowment of University Department of Chemical Technology, Mumbai, for the year 1999-2000. Dr Dasgupta delivered two lectures entitled, "Dye lasers and applications - the first revolution" and "Laser dyes and organic photonic lasers - the second uprising" at UDCT in October 2000. This visiting lectureship carries an honorarium of Rs 20,000/-.

Dr Sanjay C. Gadkari of Technical Physics & Prototype Engineering Division, BARC, has been awarded the 'K. Suryanarayan Rau Memorial Award-2001' for Smart Technology Development. The award comprises a trophy, a citation certificate and cash amount of Rs 6,000/-. The award was given by the Indian Society for Advancement of Materials and Processing Engineering to Dr Gadkari for his Research & Development work in the area of thin/thick film based sensors and monitors for H_2 and H_2S. The H_2 monitor, working in 0-10% v/v range, consists of a catalytic type pellistor sensor and the control unit. The H_2S sensors, based on SnO_2 thin films, are useful to monitor H_2S present in the ambient air in 0-50 ppm range.

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