UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR: Prof. Harmesh Kumar
2. NAME AND ADDRESS OF THE Co-PRINCIPAL INVESTIGATOR: Dr. Shankar Sehgal
3. NAME AND ADDRESS OF THE INSTITUTION: UIET, Panjab University, Chandigarh
4. UGC APPROVAL NO. AND DATE: F. 42-869/2013 (SR) dated 31.03.2013
5. DATE OF IMPLEMENTATION: 01.04.2013
6. TENURE OF THE PROJECT: Four Years
7. TOTAL GRANT ALLOCATED: 10,42,000/- (Rupees Ten Lac Forty Two Thousand Only)
8. TOTAL GRANT RECEIVED: 10,22,000/- (Rupees Ten Lac Twenty Two Thousand Only)
9. FINAL EXPENDITURE: 9,17,425/- (Nine Lac Seventeen Thousand Four Hundred Twenty Five Only)
10. TITLE OF THE PROJECT: Development of efficient finite element model updating techniques
11. OBJECTIVES OF THE PROJECT:

Following objectives had been set during submission of the present Major Research Project:-

i. To evaluate and compare the effectiveness of different FE model updating objective functions (FRFs, eigenvalues, eigenvectors or their combinations) using design of experiments technique and identify the best to use it as a benchmark for further model updating evaluation.
ii. To include the effect of excitation frequency in objective function by weighting the sub-objectives through different kinds of weighing modes to obtain best match near excitation frequency.
iii. To determine the best weighing method to objective function.
iv. To extend the model updating method developed in objective 3 by incorporating damping effect to best represent the real life application.
v. To design and develop the experimental set-up to generate the experimental data for FE model validation.
vi. To validate the proposed FE model updating technique by comparing with experimental data.

12. WHETHER OBJECTIVES WERE ACHIEVED: Yes. All the objectives were achieved.

(GIVE DETAILS)

Following objectives had been set during submission of the present Major Research Project:-

i. Literature survey of existing research papers related to Finite Element Model Updating (FEMU) was done. Different FE model updating objective functions (FRFs, eigenvalues, eigenvectors or their combinations) were evaluated using design of experiments technique and their effectiveness was compared. Best objective function was identified to be used as a benchmark for further model updating evaluation. More details available in papers published out of this work as per Reference [1-6].

ii. Effect of excitation frequency was included in objective function by weighting the sub-objectives through different kinds of weighing modes to obtain best match near excitation frequency. More details available in paper published out of this work as per Reference [7].

iii. Best weighing method to objective function was determined. More details available in paper published out of this work as per Reference [7].

iv. Model updating method developed in previous objective was extended by incorporating damping effect to best represent the real life application. More details available in paper published out of this work as per Reference [8].

v. Equipments and software purchased out of the grant received from this major research project were used to design and develop the experimental set-up as shown in Fig. 1 at UIET premises for generating the experimental data for FE model validation.

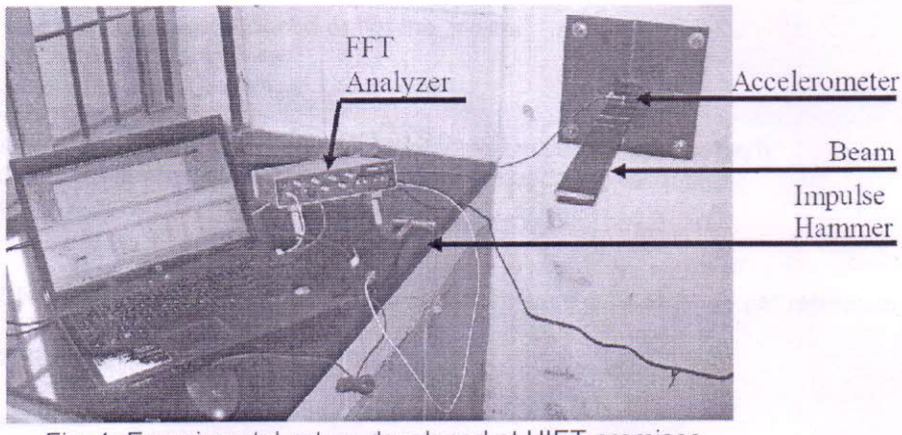

Fig. 1: Experimental set-up developed at UIET premises out of funds of UGC major research project

vi. Proposed FE model updating techniques were validated by comparing with experimental data.

13. ACHIEVEMENTS FROM THE PROJECT

i. Five model updating techniques were developed during this project.

ii. These techniques were found to be working efficiently in terms of reducing the errors in prediction of natural frequencies, Modal Assurance Criterion (MAC) values and Frequency Response Functions (FRFs).

iii. Experimental set-up facility was designed and developed at UIET premises.

iv. All five techniques worked well when checked under experimental conditions in addition to numerical verifications.

14. SUMMARY OF THE FINDINGS

Five FEMU techniques were developed viz. Derringer's Function based Updating Technique (DFUT), Benchmark Objective Function Formulation based Updating Technique (BOFFUT), Excitation Frequency based Weighted Updating Technique (EFWUT), Multi-Stage Updating Technique (MSUT) and Damped Updating Technique (DUT). First four techniques (DFUT, BOFFUT, EFWUT and MSUT) are useful in reducing errors in prediction of natural frequencies, MAC values and elastic modulus based physical input parameters. These are not meant for reducing errors in peaks and valleys of FRFs, which is taken care of by the application of DUT.

Overall comparison of updated results of DFUT, BOFFUT, EFWUT, MSUT and DUT shows that MSUT is most efficient in reducing errors related to natural frequencies, MAC values and physical parameters. While, only DUT can be successfully used in reducing the errors in peaks and valleys of FRFs. But DUT alone cannot work properly. It requires updated mass and stiffness matrices as input. Hence the use of DUT must be preceded by the application of MSUT.

15. CONTRIBUTION TO THE SOCIETY

Model updating techniques are useful in structural dynamics and advanced machine design areas, especially for designing for applications wherein vibration and noise related concerns are high such as in bullet trains, metros, luxury buses etc. Development of FEMU techniques will contribute towards the society by providing more avenues towards better design of such societal assets.

16. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT:

Yes. One Ph.D. was enrolled and produced out of the project.
Details of Ph.D. produced are as follows:
Name of Ph.D. candidate: Shankar Sehgal
Regd. No. 2008-EZ-10
University: Faculty of Engineering and Technology, Panjab University, Chandigarh
Title of Ph.D.: Development of efficient finite element model updating techniques
Ph.D. awarded in the year: 2015

17. NO. OF PUBLICATIONS OUT OF THE PROJECT: Eight papers were published as per reference list.

(PLEASE ATTACH RE-PRINTS)

Printed papers attached.

(PRINCIPAL INVESTIGATOR) **(REGISTRAR/PRINCIPAL)**

(CO-INVESTIGATOR)

Director, UIET

Director
U.I.E.T Punjab University
Chandigarh

References:

[1] S. Sehgal and H. Kumar, "Structural dynamic model updating techniques: A state of the art review," *Archives of Computational Methods in Engineering*, vol. 23, pp. 515-533, 2016.

[2] S. Sehgal and H. Kumar, "Structural dynamic finite element model updating using Derringer's function: a novel technique," *WSEAS Transactions on Applied and Theoretical Mechanics*, vol. 9, pp. 11–26, 2014.

[3] S. Sehgal and H. Kumar, "Development of benchmark objective-function-formulation for Derringer's function based model updating method," *WSEAS Transactions on Applied and Theoretical Mechanics*, vol. 9, pp. 60–79, 2014.

[4] S. Sehgal and H. Kumar, "Development of efficient model updating technique using multi-stage response surfaces and Derringer's function," in *Proceedings of International Conference on Recent Advances in Engineering and Computational Sciences*, 2014, pp. 1–6.

[5] S. Sehgal and H. Kumar, "Response surface based modeling of mechanical system," in in *Lecture Notes in Mechanical Engineering: Proceedings of the International Conference on Research and Innovations in Mechanical Engineering*, S. S. Khangura, P. Singh, H. Singh, and G. S. Brar, Eds. India: Springer, 2014, pp. 73–81.

[6] H. Kumar and S. Sehgal, "Comparative study of objective functions for quality improvements of a model using response surface methodology," in *Third International Conference on Production and Industrial Engineering*, 2013, pp. 1406–1411.

[7] S. Sehgal and H. Kumar, "Damage detection using Derringer's function based weighted model updating method," in in *Structural Health Monitoring, Volume 5: Proceedings of the 32nd IMAC, A Conference and Exposition on Structural Dynamics, 2014, Conference Proceedings of the Society for Experimental Mechanics Series*, A. Wicks, Ed. USA: Springer, 2014, pp. 241–253.

[8] S. Sehgal and H. Kumar, "Novel dynamic model updating technique for damped mechanical system," *Journal of Theoretical and Applied Mechanics*, vol. 47, no. 4, pp. 75-85, 2017.