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PEOPLE  
MARIE CURIE ACTIONS

**Intra-European Fellowships (IEF)**  
**Call: FP7-PEOPLE-2011-IEF**

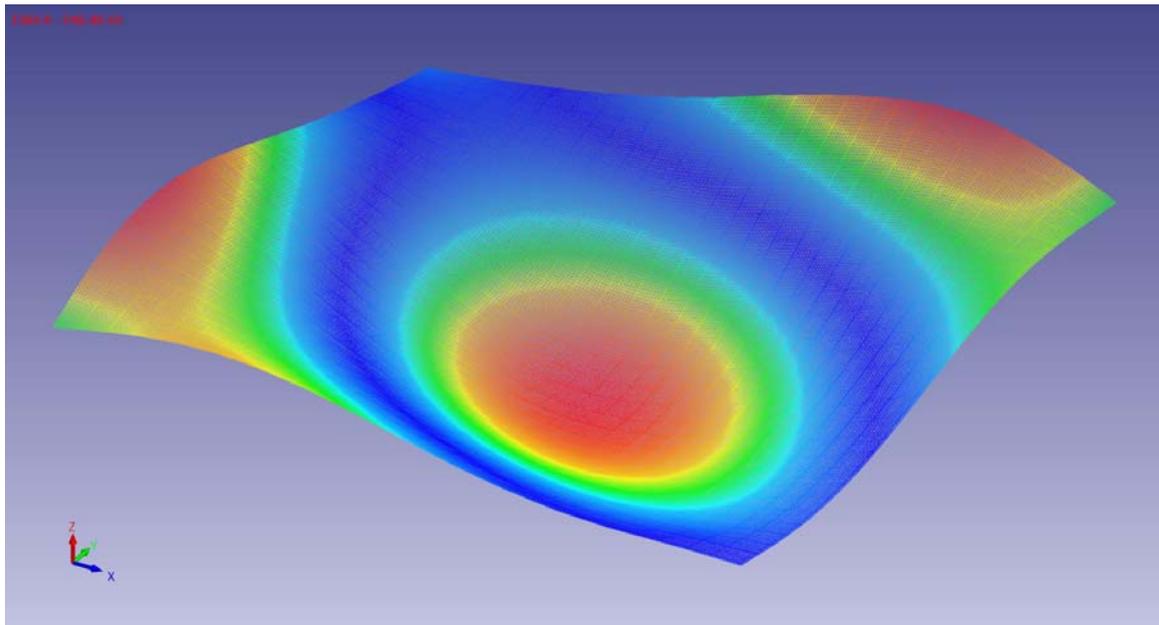
Final report of the project:

**Towards Experimental Full Field Modal Analysis**

acronym: **“TEFFMA”**

**PIEF-GA-2011-298543**

## 1. Overview of the results and their exploitation and dissemination



The improvements in the electronics of modern cameras have raised the attention on image based technologies also for the measurement of complex vibration patterns for dynamic analyses in a broad extent beyond Holography. The advent of digital cameras has brought Electronic Speckle Pattern Interferometry (ESPI) techniques to a recent success. Besides, the production of hi-speed digital cameras has recently raised Digital Image Correlation (DIC) technique as another competitive technology in the full field domain; the Scanning Laser Doppler Velocimeter (SLDV), thanks to its ability to scan discrete locations over the surface, can also be considered close to full field technologies (even if not native) and was used, up to now, as a reference technique in studying the structural dynamics of light-weight components.

Present dynamic testing and analysis approaches, based on traditional transducers, do not yet take full advantage of the growing optical measurements, while full field techniques have proved to be increasingly effective in complex dynamic analyses.

At the Institut für Mechanik und Mechatronik of Vienna University of Technology (TU-Wien), Austria, there is the quite unique and well equipped laboratory for optical measurements on vibrating components, hosting 3 different challenging sensing technologies for full field approaches (SLDV, Hi-Speed DIC and dynamic ESPI in stroboscopic laser light) and many advanced tools for dynamic characterisations.

TEFFMA fundamental research project at TU-Wien had the great chance to revisit the procedures & algorithms in experimental structural dynamics to prove the feasibility of emerging full field measurement technologies in proven procedures for vibration related studies, for advanced design and manufactory methodologies. The activity was deployed on:

- Tuning of the equipment and the experimental set-up for relevant quality and comparability of measurement datasets; acquisition of great expertise in running complex dynamic tests with optical metrology and custom software programming for numerical treatment and visualisation of the experimental data; enhancement of the comprehension of complex structural dynamics problems
- Comparison of full field optical technologies (SLDV, DIC, ESPI) for accurate hi-resolution spatial description of the same modally dense structural dynamics (a vibrating lightweight plate) in broad frequency ranges; quantitative assessment of the measurement quality obtainable from the three approaches under the same testing conditions; benchmarks on the emerging full field technologies
- Evaluation of direct full field experimental models by means of Full Field Frequency Response Functions, to map, over the surface, the dynamic behaviour of the structure to broad band inputs, retaining the real boundary conditions and material features, without the need of a numerical model, which might be source of prediction errors, if not properly calibrated on dynamic events

- Derivation of new experimental quantities from high quality Full Field FRFs: dynamic rotations and surface strains were obtained (always as maps of direct experimental models in frequency domain), which are instead of difficult measurability with other approaches, and might not reach such a detailed description
- Use of Full Field FRFs with traditional approaches in dynamic analysis, Noise-Vibration-Harshness & Experimental-Modal-Analysis studies, with commercial & custom codes
- Evaluation of dynamic stress maps from dynamic strain measurements and constitutive data, to be exploited in fatigue and damage distribution predictions, as well as danger maps or fault tolerance assessments;
- model updating with Full Field Experimental Modal models to enhance the precision of numerical model tuning, due to the redundancy of clean experimental data fields

The experimental results & methodologies obtained from this fundamental research project draw the attention of the scientific community in recent specific international conferences and will have a wide applicability & deep impact to strengthen the path of full field technologies in mechanical engineering and many other fields, ranging from aerospace to vehicle technologies, measurement techniques, electronic component testing in harsh environments, advanced material behaviour analysis, risk assessment, quality assurance in production.

The enhancements in experimental methodologies obtained with TEFFMA project can provide new targets for standardisations and protocols in engineering practice on risky & challenging activities; therefore, the training of skilled people in this field can promote a better understanding of the real behaviour of many material things and promote the development of our knowledge. Also, the expertise matured on image-based techniques can be fruitful for many interdisciplinary future projects, for fundamental as well as applied researches.

## 2. Exploitation and dissemination of the results

### Dissemination at conferences & courses: GEF2013, ICAIM2014, ISMA2014, ICoEV2015

The results obtained in Model Updating were presented in A. Zanmarini, "Full field optical measurements for operational modal analysis and model updating" at "Settima Giornata di studio Ettore Funaioli", July 19th 2013, Bologna, Italy. They have also been accepted in a different critical approach in A.Zanmarini, "On the role of spatial resolution in advanced vibration measurements for operational modal analysis and model updating", presented at ISMA2014 – International Conference on Noise and Vibration Engineering, 15-17 September 2014, Leuven, Belgium.

The results on dynamic strain & stresses were presented in A. Zanmarini, "Dynamic strain & stresses for enhanced reliability: from full field optical measurements to simulations", in Proceedings of the ICAIM 2014 - International Conference on Applications for Image based Measurements, June 24-25, 2014, Leipzig, Germany. ISBN 978-3-00-045317-5.

A comprehensive paper on receptance modelling of experimental data from TEFFMA full field measurements appeared in A. Zanmarini, "On the estimation of frequency response functions, dynamic rotational degree of freedom and strain maps from different full field optical techniques", ISMA2014 – International Conference on Noise and Vibration Engineering, 15-17 September 2014, Leuven, Belgium. It deserved the attentions of renown professors & specialists from industry, in particular of Janko Slavic, who offered the chairing of a thematic Mini-Symposium on Full Field Measurements for Advanced Structural Dynamics at the ICoEV2015 Conference on Engineering Vibrations.

At ICoEV2015 Dr. Zanmarini presented the latest developments on the pointwise comparisons in the field of receptance estimation, in A. Zanmarini, "Comparative studies on Full Field FRFs estimation from competing optical instruments", paper ID 191; in the field of rotational dofs and dynamic strain maps in A. Zanmarini, "Accurate FRF estimation of derivative quantities from different full field measuring technologies", paper ID 192; in the field of fatigue predictions directly from experimental data and without structural numerical models, in A. Zanmarini, "Full field experimental modelling in spectral approaches to fatigue predictions", paper ID 193; in the field of Experimental Modal Analysis and Model Updating, in A. Zanmarini, "Model updating from full field optical experimental datasets", paper ID 196. All four presentations were included in the Proceedings of ICoEV 2015 - International Conference on Engineering Vibration, Editors: Miha Boltezar, Janko Slavic, Marian Wiercigroch, ISBN 978-961-6536-97-4.

During the chaired Mini-Symposium, Dr. Zanmarini received very positive responses for the tremendous work done since ISMA2014, where the earlier results were previously shown, without the pointwise comparisons.

### 3. Socio-economic impact of the project

Based on the results of this project and with the quite unique and well equipped laboratory for optical measurements on vibrating components, hosting 3 different challenging sensing technologies for full field approaches (SLDV, Hi-Speed DIC and dynamic ESPI in stroboscopic laser light) and many advanced tools for dynamic characterisations at the Vienna University of Technology further research projects and cooperation's with the industry can be done.

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Dr. Ing. Alessandro Zanarini  
DIN - Dipartimento di Ingegneria Industriale  
Facoltà di Ingegneria - Università di Bologna  
Viale Risorgimento 2, 40136 Bologna, Italy  
tel. +39 051 2093442, fax. +39 051 2093446  
e-mail: a.zanarini@unibo.it  
[http://diem1.ing.unibo.it/personale/zanarini/Zanarini\\_index\\_EN.htm](http://diem1.ing.unibo.it/personale/zanarini/Zanarini_index_EN.htm)

Univ.-Prof.Dr.techn. Johann Wassermann  
Measurement and Actuator Division  
Institute of Mechanics and Mechatronics / E325-A4  
Getreidemarkt 9 (BA06)  
A-1060 Vienna, Austria  
tel.: ++43 664605883031  
e-mail: johann.wassermann@tuwien.ac.at  
<https://tiss.tuwien.ac.at/adressbuch/adressbuch/orgeinheit/1675>

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