VANESSA Deliverable D3.4

Validation round-robin (ILS) report

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Task 3.2: Computational solid mechanics model validation

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1.0 Executive summary

This report collates and interprets the results from the Inter Laboratory Study (round robin) on Validation of computational solid mechanics simulation models using full-field optical measurements of strain and / or displacement ("validation round robin"). The preparation of the protocol for this round-robin, the organisation of the round robin and the collation of its results fulfils achievement of the first objective of Task 3, i.e. 'to prepare protocols, organise and collate the results from an Inter-Laboratory-Study (ILS) appropriate to a validation procedure of a generic computational model'; furthermore, contribution has been provided to the main objective of VANESSA project, namely 'to conduct international comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field measurement, and the validation protocol for computational solid mechanics models, form a solid base for standardisation'. The conclusions from the round-robin provide evidence that the validation protocol (together with the calibration protocol) enshrined in the CEN Workshop Agreement (CWA) provide a solid base for standardisation, which is a second objective of Task 3. A widespread promotion of the validation ILS has contributed to VANESSA S&T objective 'to raise awareness in the EU industrial base and international engineering community of the validation protocol'.

2.0 Introduction

The main objectives of Task 3.2 are:

a) To prepare protocols, organise and collate the results from an Inter-Laboratory-Study (ILS) appropriate to a validation procedure of a generic computational model;

b) To provide evidence that the validation protocol (together with the calibration protocol derived in T3.1) form a solid base for standardisation.

Preliminary research had established that Inter-Laboratory Studies (ILS) was a more accurate description of the planned activities than round robins. Task 3.2 is concerned with the work for the Validation ILS, with LTSM-UP acting as task-manager.

During the first twelve-month period of Vanessa project, the ILS exercise for validation of computational solid mechanics models was designed and the corresponding ILS protocol was prepared and published via the project website.

The ILS protocol has been designed to evaluate the effectiveness of a methodology for the validation of computational solid mechanics models using full-field optical measurements of strain and / or displacement. The process for validating models of structural components using full-field data from optical methods measurements is described in detail in the protocol. The dimensionality of data fields derived by simulation or experimentation is reduced by the use of image decomposition based on feature vectors, which contain the coefficients of the shape descriptors, such as Fourier descriptors or orthogonal polynomials, employed to describe the data field. This approach enables a simple comparison of data-rich fields from a computational model and a validation experiment to be made utilising the uncertainty to assess the acceptability of the correlation.

The ILS protocol includes three exemplars (shown in Figure 1) to which the validation methodology could be applied, i.e. a thermomechanical analysis of an antenna reflector, a wedge indenter deforming a rubber block and an I-beam with open holes in the web under three-point bending loads. Strong emphasis was placed on selecting industrially relevant components as ILS exemplars. The protocol provided step-by-step guidance for the validation of solid mechanics computational models, using full-field experimental data and the recording of results. Displacement and / or strain plots in 'tiff' format were provided for use in the validation process. An image decomposition software package, which could be used for the image decomposition, together with an excel file for the visualization of the results were also developed, uploaded on the project website and made available to the ILS participants. The Validation ILS process was tested by some of the VANESSA project partners before being distributed to possible external participants; some issues were identified in this phase, which were appropriately resolved.

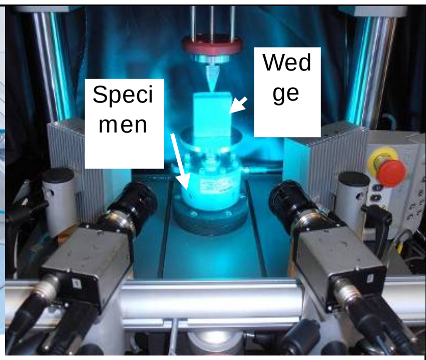
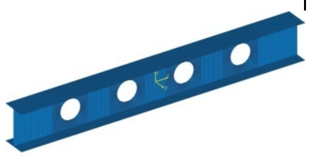
		
Full CFRP space antenna reflector	**Wedge indenter deforming a rubber block (experimental arrangement)**	**I-beam with holes under 3-point bending (simulation model)**

Figure 1: Exemplars of the validation ILS

In addition, test specimens were produced for two of the three exemplars, in order to allow them to be supplied to the ILS participants who would wished to perform their own experimental tests. More specifically for each of the cases 'wedge indenter deforming a rubber block' and 'open hole I-beam', 20 test specimens were manufactured; sample specimens are shown in Figure 2.

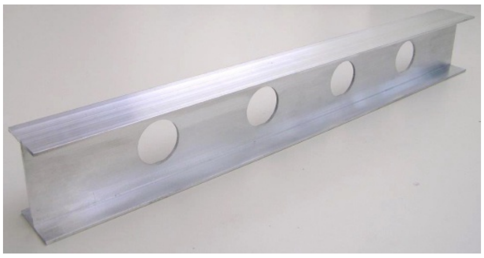
	
Samples of wedge indenter and rubber block	Sample of I-beam with holes

Figure 2: Exemplars of the validation ILS for delivery to the ILS participants.

Table 1: Deliverables and Milestones related to Task 3.2

Item	Description	due	approval
MS3	Validation round-robin initiated: Protocol, materials and promotion strategy for round robin on validation of computational solid mechanics models agreed	m4 May 2013	approved by PSC on June 13, 2013
D3.2	Validation round-robin protocol: Protocol for round robin on validation of computational solid mechanics models	m3 April 2013	approved by PSC on June 13, 2013
D3.4	Validation round-robin report	m16 May 2014	the present report

3.0 ILS promotion activities and feedback

The Validation ILS was formally launched at the second CEN workshop on September 4th, 2013, in Cardiff, Wales. The initial focus of the promotional campaign of the validation ILS to the international engineering community consisted of the personalised invitations to engineers and researchers involved in computational solid mechanics simulations, mainly from the industrial sector, who were carefully selected by the VANESSA consortium.

More specifically, in a first promotion round 34 personalized invitations were sent, while in a second round another 36 personalized invitations were e-mailed. In addition, the consortium reached out to organisations such as SAGE and NAFEMS in order to bring attention to the study of the wider engineering community. The study was promoted via both internal and external websites and via social media (Twitter and Wordpress blogs[1]) as illustrated in Figure 3.

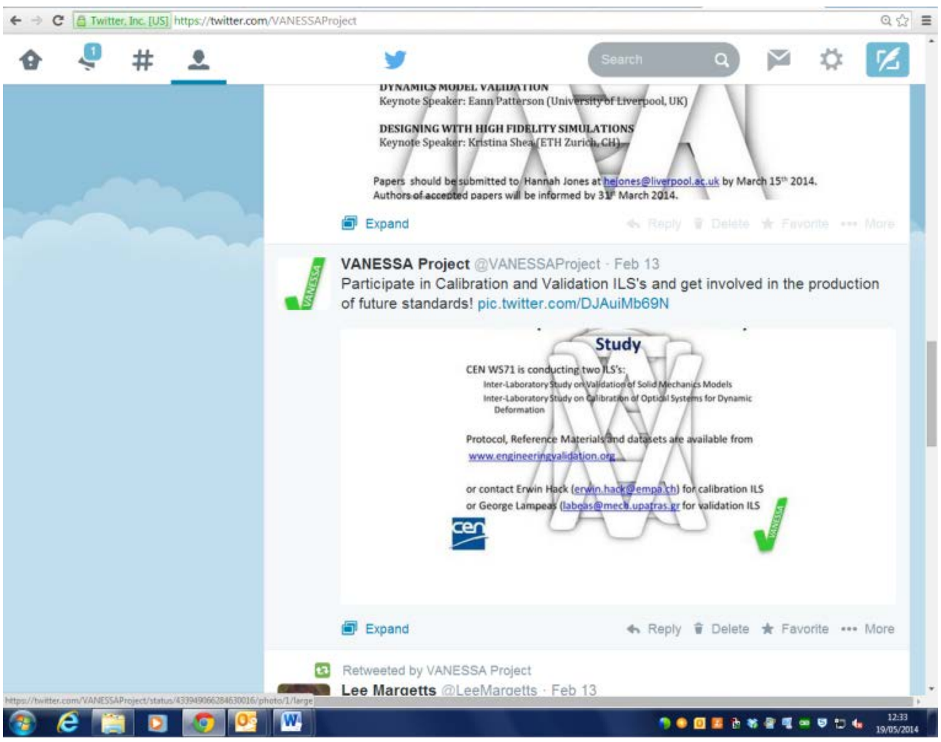


Figure 3: ILS promotion via social media circulated by organisations such as SAGE Publishing and NAFEMS

[1] e.g http://realizeengineering.wordpress.com/2014/01/29/setting-standards/

Subsequently, an open invitation was issued via the project website and at conferences, followed by some 100 serial emails, including the participants of the 1st Knowledge Exchange Workshop, which took place in British Museum , London , on December 6th 2013. Finally, the validation ILS was promoted personally by VANESSA consortium partners, in conferences, related project meetings and other relevant occasions.

The feedback received from the international engineering community comprises 18 completed ILS protocols, as well as comments received about the validation methodology and the ILS protocol from 3 participants (these 3 participants did not completed the ILS protocol). Two participants performed their own experimental tests (using the specimen shown in fig. 2). One participant developed a computational simulation model and used it in the validation process.

In the following table 1, a collation of the main comments or conclusions received by the ILS participants is presented. In case the same participant made validation and provided feedback for more than one exemplar, this is indicated by letters in his/her id.

	Exemplar used by the participant	Main comment or conclusion provided by the participant
Participant 1	Wedge indenter deforming a rubber block	Methodology is easy to follow and software is adequate
Participant 2	I-beam with open holes	Globally this validation methodology is a useful tool to assess the FE models
Participant 3	Wedge indenter deforming a rubber block	No major comment
Participant 4	I-beam with open holes	No major comment
Participant 5	Antenna reflector	A lesson learned is the importance of same ROI for measurement and simulation.
Participant 6	I-beam with open holes	The right selection of the ROI is most important
Participant 7-A	Antenna reflector	The provided geometry (full-field) is not suitable for the decomposition methods available in the software
Participant 7-B	Wedge indenter deforming a rubber block	It is important that both the experimental and the simulation images are based either on the deformed or on the original object shape
Participant 8	I-beam with open holes	No major comment
Participant 9-A	Antenna reflector	This example has a complicated geometry and requires the 3 data sets to be masked to equivalent ROI.
Participant 9-B	I-beam with open holes	Overall the main problem has been the apparent misalignment of the DIC/Model region of interest. The only 'acceptable' case is the one (UX Side) which has the least high ordered shape.
Participant 9-C	Wedge indenter deforming	For the larger displacements it is obvious that the sample

	a rubber block	rotated as shown by the tapered dark blue edges.
Participant 9-D	3 point bend of ceramic beam (participant exemplar)	ESPI is used to measure the response of the material under test which is compared with a computer model in which the boundary properties are adjusted until the model output matches the ESPI measurements.
Participant 10-A	Antenna reflector	No major comment
Participant 10-B	I-beam with open holes	No major comment
Participant 10-C	Wedge indenter deforming a rubber block	No major comment
Participant 11	I-beam with open holes	The whole validation procedure is easy to follow
Participant 12	I-beam with open holes	This is an interesting exercise to see if image decomposition is a valuable and valid approach for comparing simulated and experimental data sets without the usual requirements of accurate coordinate transformation and scaling, and may in some instances be useful.
Participant 13	N/A (*)	Overall a solid validation methodology but requires DIC equipment for its implementation, which we do not have available.
Participant 14	N/A (*)	I found it extremely easy to use, and a really useful tool, which would be really effective both in the university research and industrial field.
Participant 15	N/A (*)	From what I have seen it looks to be a powerful and useful method for validation of FE models, using full field data rather than just comparing individual point results or profiles.

(*) N/A means no values provided, as these participants did not returned a completed protocol but only their comments)

Table 1: Collation of major comments received by the participants

4.0 Results from Validation ILS

The collection of the completed validation ILS protocols was followed, by collation, interpretation and dissemination of the results. In the present section, the collected feedback is divided hereafter in comments referring to (1) the validation methodology and the ILS process: (2) remarks on the implementation of the methodology and (3) comments about the three exemplars provided in the ILS.

4.1 Comments on the validation methodology and the ILS

a) Many interesting comments about the proposed validation methodology were received; in general these were positive comments, e.g. '... a useful tool to assess the FE models... ', '...the validation procedure is easy to follow...', '...it looks to be a powerful and useful method for validation of FE models, using full field data rather than just comparing individual point results or profiles...'.

b) The main feedback from the engineering community with respect to the ILS, revealed that it refers to a novel validation methodology, which was not widely known or applied. For those familiar with traditional validation approaches, a change to the proposed methodology would require adjustments in their internal procedures, which could not be performed immediately, especially in the industrial sector.

c) It was suggested by an ILS participant that:

- *'Both experimental and computational images should be in the same format, i.e. either in the deformed or in the undeformed state'*

This suggestion has highlighted the importance of a common basis for the measurand maps from experiment and model, and has resulted to a suggestion for change in the CWA (ILS V2).

d) It was observed by an ILS participant that:

- *'the magnitude of the moments is directly dependent on a calibration accuracy; the moments are dependent on number of pixels and their size and the magnitude range of processed data. i.e. the 4 displacement data sets here have a factor 10 range of* *moments. Trials on generated data shows that for a percentage change in source, ALL Tchebichef moments will vary by the same percentage, the acceptance boundaries should both pass though zero.'*

The issue was discussed between VANESSA partners and the implicit importance of employing normalised orthogonal shape descriptors was highlighted. It has also resulted in a suggestion for a change in the CWA (ILS V3).

e) It was observed by an ILS participant that:

- *The various image decomposition methods all (in my understanding) generate errors when they are reconstructed. That is to say that the shape descriptors / moments / parameters of the decomposed image never entirely capture all features in the original image; The loss of information is most severe when the local gradients in the data (displacement, strain etc.) are largest; Structural failure usually occurs in these regions! And so – again in my understanding – at the very locations where we would usually take the very most care in making the data comparison between simulated and experimental data, the image decomposition approaches perform least well.*

The issue has highlighted the major importance of 'Recommendation #5' of the CWA, which suggests:

Recommendation #5: The goodness of fit of the reconstruction of a displacement or strain field to the original data field should be assessed using the average squared residual

$$u^2 = \frac{1}{N}\sum_{i,j}^{N}\left(\hat{I}(i,j) - I(i,j)\right)^2$$

where $\hat{I}(i,j)$ *is the reconstructed value of I(i, j); and the average residual, u should be no greater than the measurement uncertainty,* u_{meas} *obtained from the instrument. In addition, no location should show a clustering of residuals greater than 3u, where a cluster is defined as a group of adjacent pixels comprising 0.3% or more of N, the total of number of pixels in the region of interest.*

4.2 Remarks on the implementation of the ILS methodology

a) Many ILS participants highlighted the importance of perfect match between the Region of Interest (ROI) selected in the experiment and the simulation. Some of the comments related to this issue from different participants are presented below:

- *'For a straight and easy test setup like (exemplar) 2.2 and 2.3 it is quite easy (to match the images), as the straight borders provide a fine reference; however, for more complex set-ups with different view angles and rotations, references have to be established on the test subject to help in ROI adjustments'*
- *'it would be helpful, when selecting a ROI, that the program would provide feedback on position and size of the selection'*
- *'if only square ROI are possible why not limit this during the definition of the ROI ?'*
- *'In cases that ROI is not square, data may be scaled and masked so as to produce the same shape in each data set, keeping the area where data are missing to a minimum; however, the discontinuity in surface produces notable ringing even at very high moment orders'*

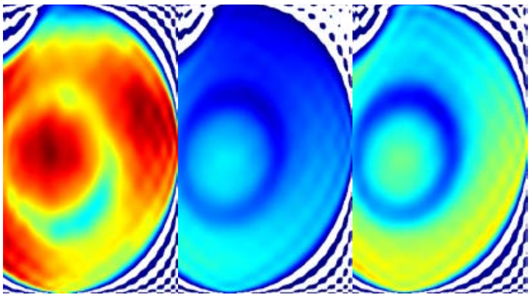


Figure 4: Masking of non-square image data (Antenna reflector exemplar)

The issue was discussed between VANESSA partners and the importance of using identical ROI for model and experiment was agreed and a change in the CWA (ILS V1) was suggested.

b) Some participants reported a few issues about the installation and application of the image decomposition software, as well as about the provided excel comparison software, specifically:

- *'The Image Decomposition SBE User Guide does not correspond with the actual version of the program, also, the program VANESSA201113.exe only works with Matlab version 8.1 (2013a) and not with the newer version 8.2 (2013b)'*

- *'It seems not necessary to sort shape descriptors in descending order, since descriptors are plotted against each other.'*

The above remarks will be taken into account when updated versions of the image decomposition software and excel comparison software are developed. However, neither pieces of software are deliverables for the VANESSA project nor are they an integral part of the CWA.

4.3 Remarks related to the three ILS exemplars

4.3.1 Thermomechanical analysis of an antenna reflector

- *This example has a complicated geometry and requires the 3 data sets to be masked to equivalent ROI. The circular shape is not suited to Tchebichef but allowing for the ringing at the discontinuity, the process appears to still be valid.*
- *The modelled reflector is 'stiffer' than the real one, an approximate factor to bring the moments closer to the 45° line may be applied, in order to better compare the shapes. This technique can be used to 'examine' the effect of changes in the model in attempt to determine what changes will be required to align with that of the experimental measurements.*
- *There are several reasons for the non fitting modes of the pictures, one is the high influence of the bonding thickness to the deformation, which is very difficult to precisely determine.*

4.3.2 Wedge indenter deforming a rubber block

- *The colour map used for the model data set contained 'colour' which do not exist in the Jet colour map; these values are displayed as dark blue discontinuities on the presented images; the scaling ranges presented appear to be inconsistent at the higher distortions but could be because of the discontinuities.*
- *The supplied data fields have been supplied as image Tiff files but with only 64 levels of 'colour', which introduces a stepped profile which cannot be reconstructed without very high order moments*

- *For the larger displacements it is obvious that the sample rotated, as shown by the tapered dark blue edges, e.g. in the 9mm indentation, the top surface of the block is still shown as a straight line, but the model does not behave the same way.*

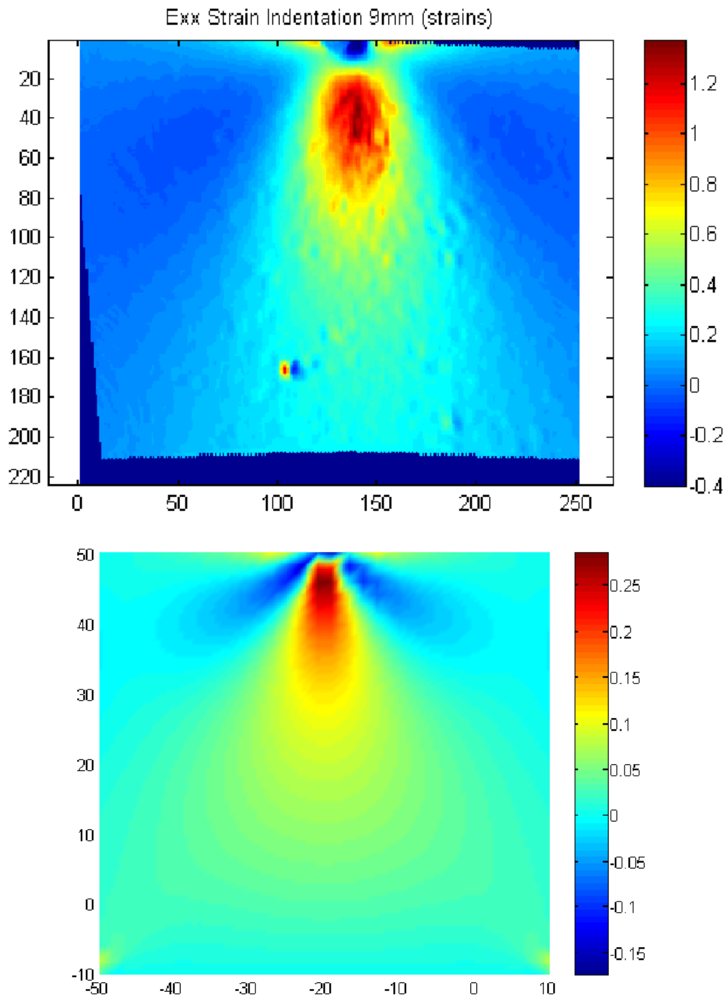


Figure 5: Comparison of strains at 9mm wedge indenter displacement

4.3.3: Three-point bending of an I-beam with open holes

- *Overall the main problem has been the apparent misalignment of the DIC/Model region of interest. The only 'acceptable' case is the one (UX Side) which has the least high ordered shape.*
- *The supplied data fields have been supplied as image Tiff files, but with only 64 levels of 'colour', which introduces a stepped profile which cannot be reconstructed without very high order moments.*

- *It is described in Section 2.3.1 of the protocol that the I-beam was loaded in the middle of the top flange and supported under the lower flange, instead it was loaded by the two rollers under the lower flange.*
- *The datasets for the side area are also provided, however, the location of this side area is unknown from the protocol.*
- *The applied load in the protocol is 9.8kN. From finite element analysis, 9.8kN load will cause plastic deformation in the loading area of the I-beam. The magnitude of the applied load may be reduced for the reusability of the specimen.*

4.3.4: Other exemplar

- *A participant has also run the ILS in a 3-point bending of a 6x6x20mm ceramic beam on a 15mm span fully articulated jig; it indicates how this procedure can be used in a practical way, i.e. to determine the mechanical properties of an unknown material. ESPI is used to measure the response of the material under test which is compared with a computer model in which the boundary properties are adjusted until the model output matches the ESPI measurements.*

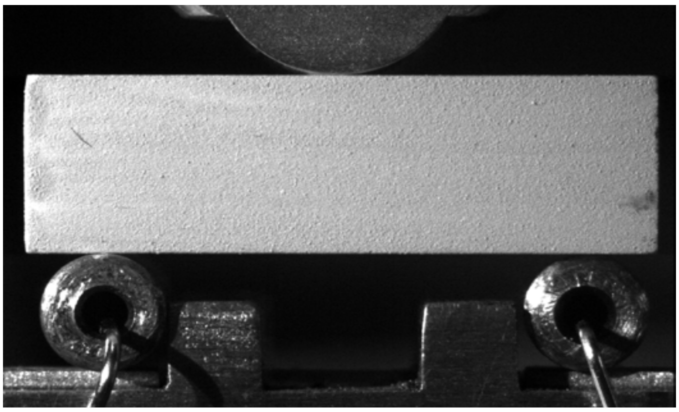


Figure 6: 3-point bending of a 6x6x20mm ceramic beam

The comments received by the ILS participants and related to the three ILS exemplars (thermomechanical analysis of an antenna reflector, wedge indenter deforming a rubber block, three-point bending of an I-beam with open holes and a participant's own exemplar) indicate the strong interaction with the international engineering community, through the validation ILS. However, as they refer to the exemplars themselves and not to the validation methodology or its implementation, these comments to not raise issues related to suggestions for changes in the CWA.

5.0 Conclusions

Based on the guideline for the validation of computational solid mechanics models using full-field optical data, which was developed and published within the framework of the ADVISE project, an Inter Laboratory Study (round robin) was designed and an ILS protocol was formulated with the aim of providing a framework for the validation of analyses and simulations of structural components. The ILS protocol included an overview of the methodology for validation of computational solid mechanics models, as well as a procedure for the step-by-step application of the validation process and the recording of results. The participants in the ILS were provided with a choice of three exemplars to which the validation methodology could be applied, including industrially relevant cases.

By the collection of ILS protocols completed by the ILS participants, as well as by comments received by some participants who did not filled-in the ILS results form, the effectiveness of the proposed methodology for the validation of computational solid mechanics simulation models using full-field optical measurements of strain and, or displacement was successfully evaluated.

Furthermore, evidence has been provided by the collected ILS feedback, that the validation protocol (together with the calibration protocol) form a solid base for the VANESSA standardisation activity. Some of the comments received by the participants have raised issues for the relevant CEN Workshop Agreement (CWA) and suggestions for appropriate changes to the CWA have been made.

The participation of the engineering community in the inter-laboratory study and especially the contribution of organisations outside of the project consortium who supported this ILS activity has resulted to an increase of the awareness about the validation methodology. By the dissemination of the ILS activity results, it can be expected that the proposed validation methodology and the related CWA will gain further international acceptance.

The preparation of the protocol for this round-robin (milestone 3) as outlined in section 2, the organisation of the round robin as described in section 3 and the collation of the results as reported in section 4 fulfil one of the three objectives of Task 3. The conclusions from the round-robin provide evidence that the validation protocol enshrined in the CEN Workshop Agreement (CWA) has a solid base, which is a second objective of Task 3. Together these activities contribute very substantially to the achievement of one of the VANESSA project's three S & T objectives, namely 'to conduct international comparison (round-robin) exercises that will generate evidence that the reference material, for calibration of optical systems for strain field measurement, and the validation protocol for computational solid mechanics models, form a solid base for standardisation'. Finally, the widespread promotion of the validation ILS or round robin has contributed to a second VANESSA S&T objective 'to raise awareness in the EU industrial base and international engineering community of the validation protocol'.

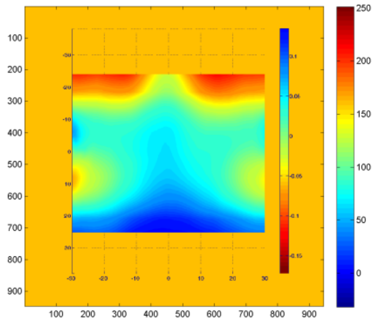
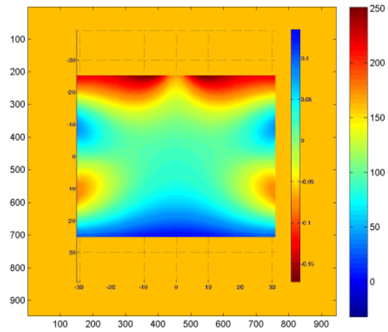
APPENDIX A

A sample of the collected completed validation ILS protocols is presented hereafter. It refers to 'Validation results for three-point bending test of an I-beam with open holes, sample 2.3, middle section.'

Table 1: General data		
	Participant data	
	name / email address:	*anonymized*
	organization / department :	*anonymized*
	main role	*anonymized*
	date	22-04-2014
	Validation exemplar selected (2.1, 2.2 or 2.3)	2.3, middle section
	Resources used	Vanessa
	simulation software used	
	experimental test performed, machine used, DIC used	
	shape descriptor decomposition software used	
	other resources description	

Table 2-1: Feature vectors calculation

	Dataset id: 2.3_ex-middle_full
Comment:	Information about the region of interest (ROI) Full area of DIC_ex-middle.tif / FEM_ex-middle.tif selected
	Component of strain / displacement used

	Strain ex		
	Original data plot from experiment 		Original data plot from model 
	Type of polynomial used in decomposition: Tchebichef		
	Average reconstruction residual for the data from the experiment , u_E 3.793		
	Average reconstruction residual for the data from the simulation, u_M 4.818		
	Shape descriptor	Shape descriptor from exp.	Shape descriptor from model
	1	88,86982	104,7306637
	2	-36,9216	-38,058566
	3	1,266829	-0,001868951
	4	5,459205	5,838646483
	5	-2,45332	-0,001449991
	6	13,5977	7,192410595
	7	-13,8406	-17,91382308
	8	0,244568	0,00545523
	9	1,805924	6,402000049
	10	-1,21556	0,002017189
	11	-1,2895	-0,547275302
	12	1,362864	-0,001827258
	13	0,937478	1,151716817
	14	1,109385	0,002089076

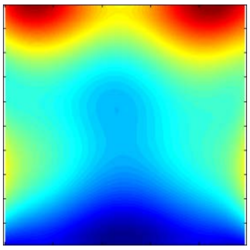
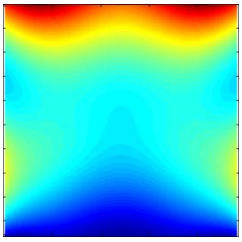
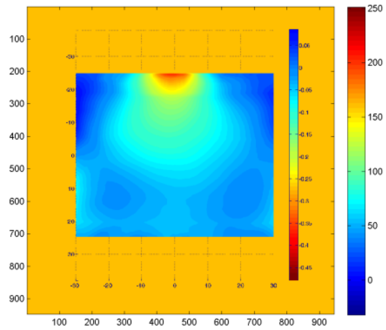
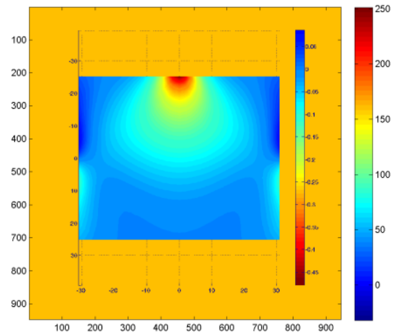
	15	-5,03636	-3,719713502
	16	5,183055	3,076858995
	17	-0,35631	0,001442913
	18	-4,09878	-6,293395863
	19	-0,26778	-0,006003316
	20	3,751957	3,686895437
	21	1,213593	0,001161767
	22	-0,19121	0,089808113
	23	-0,422	-0,001310941
	24	-0,88178	-1,391339777
	25	-0,34451	0,004267321
	26	-2,45557	-1,916233712
	27	-0,20382	-0,00079902
	28	2,111357	1,797630931
	29	0,198891	-0,4064635
	30	0,081354	0,003932403
		reconstructed plot from experiment 	reconstructed plot from model 

Table 2-2: Feature vectors calculation

	Dataset id: 2.3_ey-middle_full		
Comment:	Information about the region of interest (ROI) Full area of DIC_ey-middle.tif / FEM_ey-middle.tif selected		
	Component of strain / displacement used Strain ey		
	Original data plot from experiment 		Original data plot from model 
	Type of polynomial used in decomposition: Tchebichef		
	Average reconstruction residual for the data from the experiment , u_E 3.939		
	Average reconstruction residual for the data from the simulation, u_M 5.575		
	Shape descriptor	Shape descriptor from exp.	Shape descriptor from model
	1	64,49142034	62,5816965
	2	-12,99695887	-18,88843604
	3	-1,730339514	0,001327497
	4	1,45527966	0,181260525
	5	0,860516721	-0,004096548
	6	-14,2814845	-12,18107839
	7	2,177774868	2,925782895
	8	-0,578773831	0,002352725
	9	11,82217809	12,14027346

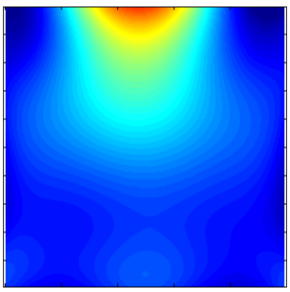
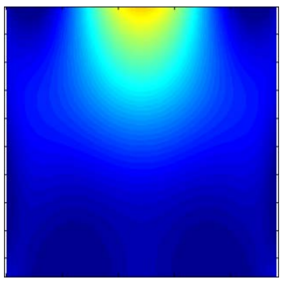
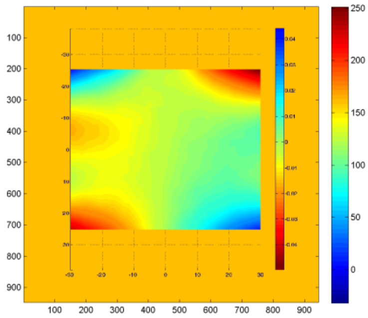
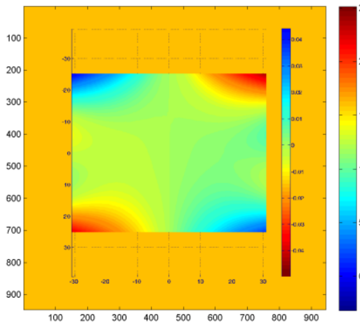
	10	1,122739147	-0,003619265
	11	1,367567903	-0,011993569
	12	0,133617534	-0,000927393
	13	-5,070154558	-4,243636637
	14	-1,794492572	0,005929716
	15	4,109612126	4,776241804
	16	-1,940303548	-0,619672502
	17	-0,195342501	0,001250645
	18	1,531159639	1,000901881
	19	0,708076044	-0,004725196
	20	-3,432658021	-4,606603931
	21	-0,2893264	0,005687454
	22	-0,594692191	-0,0549351
	23	0,347916493	0,001802812
	24	-0,554669886	-0,067299928
	25	0,308420048	0,002157162
	26	3,402863988	3,855214994
	27	0,382852638	-0,005257024
	28	-1,183357405	-2,098798247
	29	0,128127096	0,07926841
	30	-0,074428315	-0,001406192
		reconstructed plot from experiment 	reconstructed plot from model 

Table 2-3: Feature vectors calculation

	Dataset id: 2.3_ux-middle_full		
Comment:	Information about the region of interest (ROI) Full area of DIC_ux-middle.tif / FEM_ux-middle.tif selected		
	Component of strain / displacement used Displacement ux		
	Original data plot from experiment 		Original data plot from model 
	Type of polynomial used in decomposition: Tchebichef		
	Average reconstruction residual for the data from the experiment , u_E 1.684		
	Average reconstruction residual for the data from the simulation, u_M 1.352		
	Shape descriptor	Shape descriptor from exp.	Shape descriptor from model
	1	124,472531	117,3953095
	2	-4,660498841	-0,002497851
	3	-11,26064897	-3,720357525
	4	0,081502569	0,00655571
	5	-18,99945131	-18,98820275
	6	0,279696915	0,004317907
	7	1,231118611	0,01335549
	8	4,216063706	2,46451376
	9	-0,763946971	0,003092551
	10	2,746081896	1,378647466

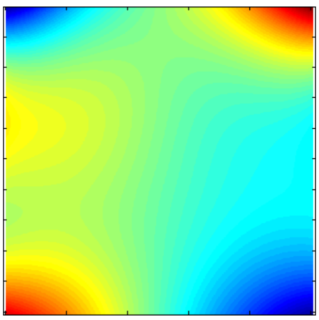
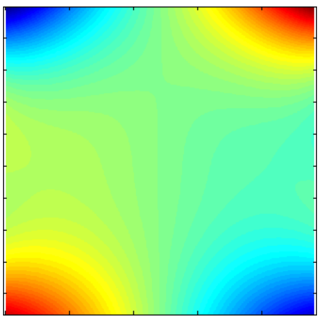
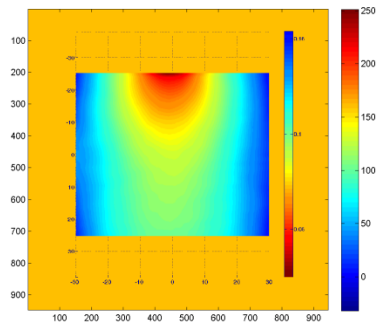
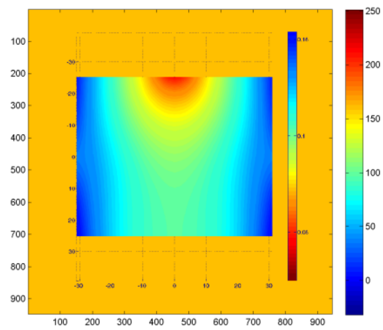
	11	-0,039485977	0,013854968
	12	-9,079800054	-7,032817485
	13	0,135835557	0,034617869
	14	-0,29594404	0,455989033
	15	-0,185200884	0,014700397
	16	-0,232410571	-0,001992886
	17	0,067386974	-0,036354424
	18	0,593434346	-0,014223434
	19	0,59664077	0,355077823
	20	0,050179585	-0,004164751
	21	-0,776645368	-0,366579422
	22	-0,076396361	0,019742961
	23	1,132156264	0,86993016
	24	-0,014803628	0,033513721
	25	-0,85079205	-0,882516838
	26	-0,015620561	0,008503293
	27	0,717443874	0,500925714
	28	0,120208186	-0,021480697
	29	0,080709923	-0,008907024
	30	0,076818206	0,096268456
		reconstructed plot from experiment 	reconstructed plot from model 

Table 2-4: Feature vectors calculation

	Dataset id: 2.3_uy-middle_full		
Comment:	Information about the region of interest (ROI) Full area of DIC_uy-middle.tif / FEM_uy-middle.tif selected		
	Component of strain / displacement used Displacement uy		
	Original data plot from experiment 		Original data plot from model 
	Type of polynomial used in decomposition : Tchebichef		
	Average reconstruction residual for the data from the experiment , u_E 1.871		
	Average reconstruction residual for the data from the simulation, u_M 1.687		
	Shape descriptor	Shape descriptor from exp.	Shape descriptor from model
	1	106,898118	95,64329011
	2	-17,52318961	-16,31647287
	3	-4,86279094	0,673009492
	4	4,261731864	5,823313211
	5	0,979508055	-0,148948108
	6	-28,13810004	-22,78808996
	7	0,242401026	-0,049249301
	8	-0,362902759	0,088449942
	9	8,388772444	6,328524317
	10	0,566273014	-0,098519595

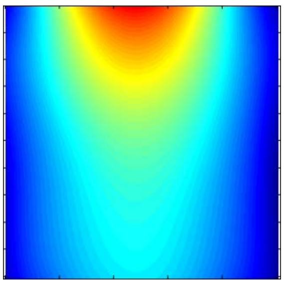
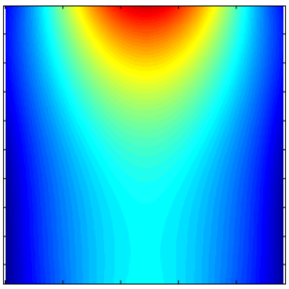
	11	-0,896476812	-0,468191171
	12	0,089122553	-0,008733611
	13	-3,037713803	-3,213541183
	14	-0,674257021	0,092097133
	15	2,170248439	1,915217155
	16	-0,245950178	-0,024881441
	17	0,090019451	-0,004319313
	18	1,046983274	0,772956841
	19	0,626804427	-0,028811937
	20	-2,109941838	-1,824353255
	21	-0,135317157	0,041075087
	22	0,195013888	0,035610837
	23	0,065795608	0,001533496
	24	-0,351682366	-0,153230273
	25	-0,135915982	0,028674337
	26	0,960501389	0,899407772
	27	0,103544773	-0,044035117
	28	-0,465401107	-0,503064701
	29	-0,08901824	0,011567791
	30	-0,073892699	-0,001336482
		reconstructed plot from experiment 	reconstructed plot from model 

Table 3-1: Uncertainty calculation

	Dataset id: 2.3_ex-middle_full	
	$u_{cal}(\varepsilon)$	30
	u_E	3.793
	$u(s_E)$	30.239

Table 3-2: Uncertainty calculation

	Dataset id: 2.3_ey-middle_full	
	$u_{cal}(\varepsilon)$	30
	u_E	3.939
	$u(s_E)$	30.257

Table 3-3: Uncertainty calculation

	Dataset id: 2.3_ux-middle_full	
	$u_{cal}(\varepsilon)$	10
	u_E	1.684
	$u(s_E)$	10.141

Table 3-4: Uncertainty calculation

	Dataset id: 2.3_uy-middle_full	
	$u_{cal}(\varepsilon)$	10
	u_E	1.871
	$u(s_E)$	10.874

Table 4-1: Comparison of simulation and experimental data

<table>
<tr><td></td><td colspan="2">Dataset id: 2.3_ex-middle_full</td></tr>
<tr><td rowspan="2">Your comments:

Plot extracted from xls sheet Dataset B

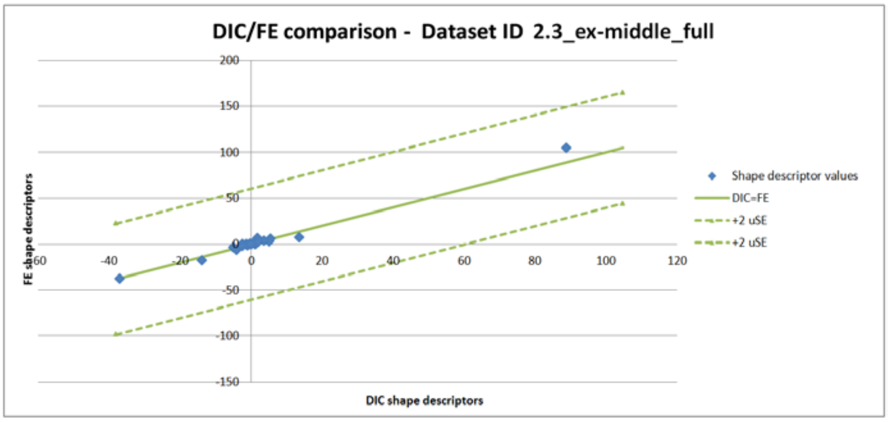
(Dataset A not changed)</td><td colspan="2">Excel plot of model versus experiment shape descriptors

</td></tr>
<tr><td>Is model acceptable?</td><td>Yes</td></tr>
</table>

Table 4-2: Comparison of simulation and experimental data

<table>
<tr><td></td><td colspan="2">Dataset id: 2.3_ey-middle_full</td></tr>
<tr><td rowspan="2">Your comments:

Plot extracted from xls sheet Dataset C

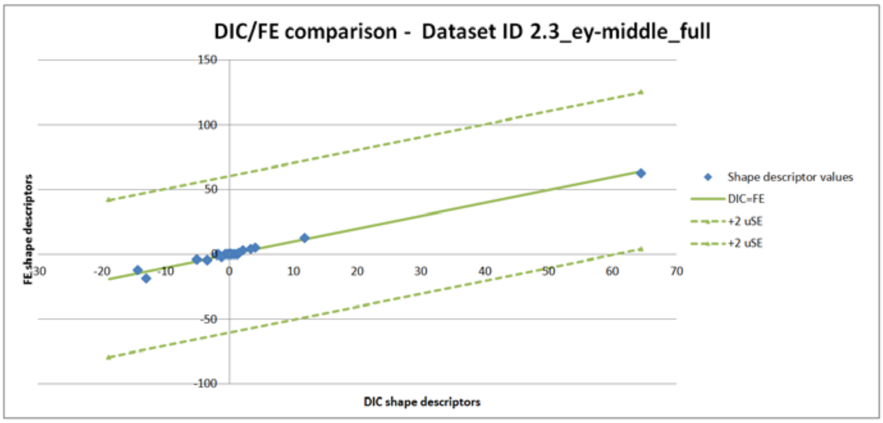
(Dataset A not changed)</td><td colspan="2">Excel plot of model versus experiment shape descriptors

</td></tr>
<tr><td>Is model acceptable?</td><td>yes</td></tr>
</table>

Table 4-3: Comparison of simulation and experimental data

<table>
<tr><td></td><td colspan="2">Dataset id: 2.3_ux-middle_full</td></tr>
<tr><td rowspan="2">Your comments:

Plot extracted from xls sheet Dataset D

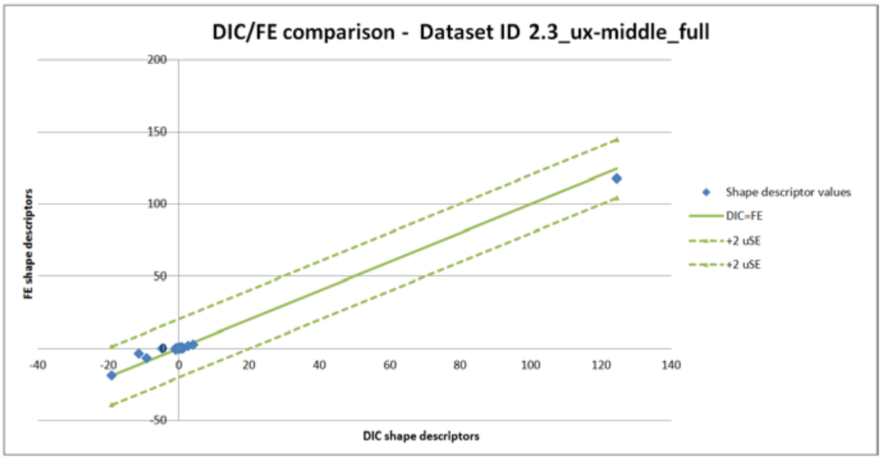
(Dataset A not changed)</td><td colspan="2">Excel plot of model versus experiment shape descriptors

</td></tr>
<tr><td>Is model acceptable?</td><td>yes</td></tr>
</table>

Table 4-4: Comparison of simulation and experimental data

<table>
<tr><td></td><td colspan="2">Dataset id: 2.3_uy-middle_full</td></tr>
<tr><td rowspan="2">Your comments:

Plot extracted from xls sheet Dataset E

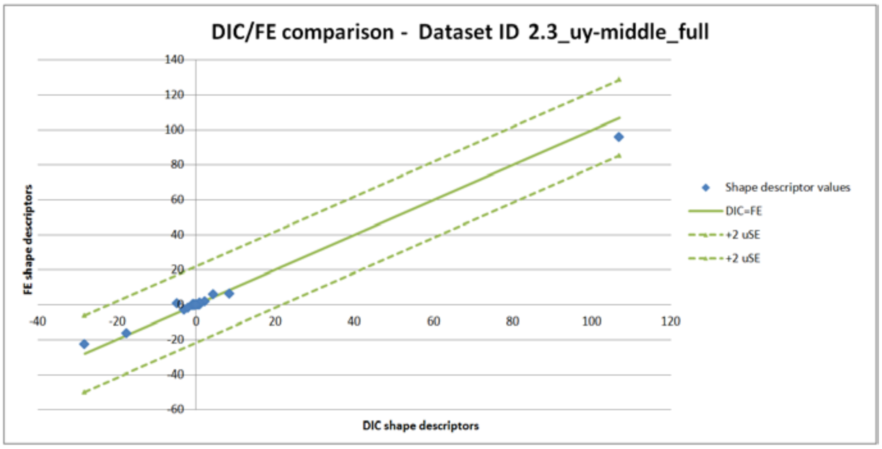
(Dataset A not changed)</td><td colspan="2">Excel plot of model versus experiment shape descriptors

</td></tr>
<tr><td>Is model acceptable?</td><td>yes</td></tr>
</table>

Table 5: Validation methodology feedback

It would be helpful, when selecting a ROI, that the program would provide feedback on position and size of the selection. It seems not necessary to sort shape descriptors in descending order as indicated in the file 'Excel_Shape descriptors comparison - version-Decmber 2013_FINAL', since descriptors are plotted against each other. When sorting them independently, the connection between data pairs will get lost, resulting in errors; we did not sort them. The Image Decomposition SBE User Guide does not correspond with the actual version of the program, for instance: • when opening the program, the Importer screen does not match with the one described in the user manual. • pressing the Import button does not produce the screen mentioned in the manual; instead a window pops up asking for unknown information for the novice user: minimum and maximum value of the image; after entering values 0 and 255 the selection could be made. The program VANESSA201113.exe only works with Matlab version 8.1 (2013a) and not with the newer version 8.2 (2013b).