MEASUREMENT OF LOCAL DEFORMATION FIELDS IN DENTAL COMPOSITES USING 3D OPTICAL SYSTEM

MILOS MILOSEVIC\textsuperscript{a}, VESNA MILETIC\textsuperscript{b*}, NENAD MITROVIC\textsuperscript{a}, DRAGICA MANOJLOVIC\textsuperscript{b}, TATJANA SAVIC STANKOVIC\textsuperscript{b}, and TASKO MANESKI\textsuperscript{c}

\textsuperscript{a} Innovation Center of Faculty of Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11000 Belgrade, Serbia, \textsuperscript{b} School of Dentistry, University of Belgrade, Rankeova 4, 11000 Belgrade, Serbia
\textsuperscript{c} Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Kraljice Marije 16, 11000 Belgrade, Serbia
vesna.miletic@gmail.com

Keywords: dental composites, polymerization shrinkage, deformation, light curing units, digital correlation

1. Introduction

Polymerization shrinkage remains one of the most important disadvantages of dental composites and leads to the loss of marginal integrity of the tooth-restoration interface\textsuperscript{1}. Shrinkage is caused by shortening the intra-molecular distances between monomer units in the polymer compared to inter-molecular distances between free monomers. The formation of microgaps between the cavity walls and the restoration allows the penetration of salivary fluids and microorganisms which may lead to secondary caries. Attempts have been made to develop low-shrinkage composites based on the silorane technology\textsuperscript{2,3}. However, polymerization shrinkage has not been eliminated even in the most contemporary materials available on the market.

A variety of contact or non-contact methods have been used to study polymerization shrinkage of dental composites. Recently, digital image correlation based on a single-camera system has been used for this purpose.\textsuperscript{4}

The aim of this study was to investigate the possibility to analyze local deformation fields of a dental composite upon polymerization using 3D optical system of digital image correlation based on two cameras.

2. Materials and Methods

A conventional, microhybrid composite Filtek Z250 (3M ESPE, St. Paul, MN, USA) was used in the study. It contains about 20 wt.% of dimethacrylate monomers: Bisphenol A diglycidyl ether dimethacrylate (BisGMA), Diurethane dimethacrylate (UDMA), Bisphenol A polyethylene glycol diether dimethacrylate (BisEMA6), Triethylene glycol dimethacrylate (TEGDMA), and about 80 wt.% of silane treated ceramic fillers.

The material was placed in custom-made Teflon molds. The surface facing the cameras was sprayed with a fine layer of black paint to produce irregular-shaped speckles used as reference points for ease of tracking and analysis by the image correlation system. The unsprayed surface of each sample, opposite the one facing the cameras, was light cured for 40 s using a conventional halogen light curing unit at an intensity of 450 mW cm\textsuperscript{-2} and 1 mm tip-to-surface distance. Standardized conditions were created by mounting each mold onto a fixating device that allowed maintaining the same distance from the cameras. Also, the light curing unit was fixed in a holder at the specified distance from each sample. Fig. 1 and 2 illustrate the experimental setup.

The digital image correlation system (Aramus 2M, GOM, Braunschweig, Germany) consisted of two digital cameras with the resolution of 1600×1200 pixels and maximum frame rate of 12 Hz and specialist software. Other parts of this system were the stand, device for charging and taking pictures and a PC.

Prior to starting the experiment, system calibration was performed using the calibration panel, depending on the chosen measurement volume. This volume was chosen based on the dimensions of the measured local area, and all other dimensions were set based on it in accordance with the tables in the instruction manual.\textsuperscript{5} Once the measurement volume and the camera position were successfully aligned during calibration, the measurement could commence.

Digital images of each sample were taken immediately before and after light curing. Afterwards, the computations were applied by the software and various software tools
enabled subsequent data processing, such as data filtering, or interpolation, if needed. For diagramatic presentation of results, different types of primitives could be formed inside each state (part of a plane, part of a circle, curved part), or inside the whole object.

3. Results

Polymerization shrinkage of Filtek Z250 is illustrated in Fig. 3 which is a typical Aramis report. The report contains the most important data of the performed measurements and consists of four elements:

A. Section diagram (Multi-Section) shows one or more sections of the current load stage. This diagram shows the selected visualization (Mises strain) with respect to the length of the section per stage. Several sections are displayed in different colours, showing values for the entire section which can be further examined.

B. Camera images (project images) are of particular importance for objects with distinct 3D structure as they can be rotated to an optimal position in the 3D view, and therefore appear to be 3D in the report.

C. Stage point diagram (Multi-Stage-Point) shows one or more stage points through load stages. The current stage is displayed on the bottom left as well as on the bar scale.

D. Visualization of the deformation with an image of Strain overlay (project image). A photograph of a real object is displayed along with the picture processes by the software. The pictures are overlapped, so local zones with largest deformations can be easily spotted.

In the case of Filtek Z250 used in the present study, local deformations were presented as Mises strains. Non-uniform distribution of these strains was observed with higher strains along the periphery and lower strains in central parts of each sample. Mises strains were plotted as a function of distance along each section. The peripheral strain values were between 2 % and 6 % with the average of 3.5 %. The central strain values were about 1–1.5 %.

4. Discussion

Polymerization shrinkage of dental composites has been measured using contact methods, such as water or mercury dilatometry, strain gauges, a linear voltage differential transducer, or bonded discs. These involve contact of the material with a liquid or solid medium. Contact methods may introduce additional forces, gravitational or adhesive, and consequently deformations of non-shrinkage origin. Non-contact methods involve laser scanning, video imaging and digital image correlation, all of which are devoid of any contact between the material and the measuring medium. Recently, laser displacement method was used to determine polymerization shrinkage of flowable and universal dental composites. This method comprised a diffuse-reflection, high-precision laser sensor head which detected dimensional changes of materials placed in glass tubes. In another study, polymerization shrinkage of dental composites was measured using digital image correlation based on a single camera which allowed dimensional changes to be determined in x and y axes but not in the z axis. This out-of-plane shrinkage was then assumed to be equal to the transverse shrinkage and used to calculate volumetric shrinkage.

In the present study, Aramis, the two-camera system, was used in a standardized setup which allowed reproducibility of experimental conditions and control of variables such as sample thickness, distance from the light curing unit, light intensity and the distance between the sample and the cameras.

Aramis is a non-contact and material independent measuring system providing, for static or dynamically loaded test objects, local 3D surface coordinates, displacements and velocities, strain values and strain rates.
The system is applied in solving problems when analyzing local structure integrity, determining local properties of materials, verifying and refining numerical calculations etc. It is suitable for analysis of irregular object geometries made of various materials, such as metal, composite, gum, wood, organic materials, biomaterials, and for analysis of hyper-elastic materials. Numerical simulations can easily be integrated or compared with data generated by digital image correlation using 3D optical system is a promising tool enabling qualitative and quantitative mapping of local deformation fields in dental composites.

Measurements based on multiple Aramis sensors were proven beneficial for multiple applications, for example measuring exact thickness reduction in tensile test situations with two Aramis sensors, but also for synchronous capturing of a complete object or multiple areas, typically if non-homogeneous materials are involved or complex loading situations have to be captured. For capturing fast sequences, multiple Aramis sensors can be adjusted to observe the same area and can be triggered sequentially to capture data with high local resolution and fast data rates. The possibility to combine data captured by multiple Aramis sensors and transformation of these measurement data in customized coordinate systems gives a clear view about object behaviour. In addition, data can easily be integrated or compared with data generated by numerical simulations.

The present results indicated non-uniform distribution of local deformation fields in dental composites with greater deformations peripherally and smaller deformations centrally. Plotting strain values as a function of distance along sample periphery further elucidates heterogeneous nature of local deformation fields. Non-uniform shrinkage deformations were not previously noticed with the aforementioned contact methods and were only reported with the digital image correlation method.

Non-uniform deformations of dental composites have important clinical implications, particularly in Class II and MOD cavities which have different cavity depths. It seems impossible to predict the zones of greatest deformations within the material in clinical conditions where numerous variables are involved. Some of these are operator-wise, such as the placement of the material or light-curing regime, and some are tooth-wise, such as the quality of tooth tissues at various positions within the cavity. Therefore, more research is necessary to understand in situ polymerization shrinkage of dental composites.

5. Conclusion
Polymerization of dental composites is characterized by heterogeneous deformation patterns with variable shrinkage values at different locations within the material. Digital image correlation using 3D optical system is a promising tool enabling qualitative and quantitative mapping of local deformation fields in dental composites.

REFERENCES

M. Milosevic, V. Miletic, N. Mitrovic, D. Manojlovic, T. Savic Stankovic, and T. Maneski, Innovation Center of Faculty of Mechanical Engineering, University of Belgrade, Serbia; School of Dentistry, University of Belgrade, Serbia; Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia; Measurement of Local Deformation Fields in Dental Composites Using 3D Optical System
Polymerization shrinkage is the single most important local deformation of dental composites that has a substantial effect on the quality of the tooth-restoration interface in clinical conditions. The aim of this study was to investigate the possibility to analyze local deformation fields of a dental composite upon polymerization using the 3D optical method of digital image correlation with two cameras. Conventional, microhybrid composite samples were prepared in custom-made Teflon molds and polymerized with a conventional halogen light. Local deformation fields were determined using the two-camera system, Aramis 2M, by correlating sample dimensions before and after polymerization. The greatest deformations of up to 6% with the average of 3.5% were observed along the periphery of the samples in contrast to substantially lower deformations of about 1–1.5% in the central part. Polymerization of dental composites yields heterogeneous deformation with variations in shrinkage values. The 3D optical system is a promising tool enabling qualitative and quantitative mapping of local deformation fields in dental composites.
EVALUATION OF THE LOCAL TENSILE PROPERTIES OF AUSTENITE-FERRITE WELDED JOINT

RADOMIR JOVICIC*, ALEKSANDAR SEDMAKB*, KATARINA COLICA, MILOS MILOSEVICA, and NENAD MITROVICA

A Innovation Center of Faculty of Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11000, Belgrade, Serbia, B Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Kraljice Marije 16, 11000 Belgrade, Serbia
asedmak@mas.bg.ac.rs

Keywords: weldment heterogeneity, tensile test, numerical simulation, finite element method, strain gauges

1. Introduction

Integrity analysis of welded joints requires knowledge of complex stress and strain distribution in a heterogeneous material, consisting of weld metal (WM), heat-affected-zone (HAZ) and base metal (BM) of different microstructure and mechanical properties1-5. This is even more complex problem when two different base metals are welded, like in the case of ferrite-austenite welded joint6.

Due to very complex microstructure of HAZ and its extremely small size compared to WM and BM it is not possible to determine the tensile properties of HAZ. This problem is also more pronounced if ferrite-austenite welded joint is analysed, because two different HAZ are involved7. Therefore, the HAZs tensile properties have to be estimated. In this paper will be presented an estimation procedure of the HAZs tensile properties, based on numerical simulation of an experiment.

2. Materials and methods

One plate, dimensions (1000×1000×12 mm) was welded and used for experimental investigation, out of which tensile testing and microhardness measurement are presented here. The shielded manual metal arc welding (SMAW) process was used.

Vickers microhardness measurements, with load 10 N, were carried out to determine the local mismatch levels for various regions of weld metal and HAZ, as shown in Fig. 1.

Empirical formula between micro hardness and yield strength for the ferritic steels:

\[ \sigma_{0.2} = 3.18 \times HV - 168 \text{ [MPa]} \]  
(1)

indicates that the yield strength is proportional to the microhardness. Although no literature data was available for the austenite microstructure, a similar formula was assumed, based on the known yield strength of the WM:

\[ \sigma_{0.2} = 2.30 \times HV - 145 \text{ [MPa]} \]  
(2)

Table I

<table>
<thead>
<tr>
<th>Material</th>
<th>HV</th>
<th>YS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM - 4572</td>
<td>195</td>
<td>355</td>
</tr>
<tr>
<td>BM - Nioval</td>
<td>190</td>
<td>455</td>
</tr>
<tr>
<td>WM</td>
<td>295</td>
<td>545</td>
</tr>
<tr>
<td>CGHAZ-ferrite</td>
<td>228</td>
<td>550</td>
</tr>
<tr>
<td>FGHAZ-austenite</td>
<td>166</td>
<td></td>
</tr>
<tr>
<td>FGHAZ-austenite</td>
<td>300</td>
<td></td>
</tr>
</tbody>
</table>

Results for the hardness measurement (average from several values at different positions) and yield strength predictions are shown in Tab. I.

Full thickness flat tensile specimens were machined from two base metals and tested to determine the stress-strain curves. The weld metal itself was tested by using a specimen with circular cross-section, whereas the whole welded joint behaviour was assessed by the flat specimen. The results indicate different behaviour of two base metals – continuous curve for 4572 steel and the curve with a yielding behaviour for Nioval. Anyhow, one should notice large difference when comparing the weld metal round and flat specimens, being a consequence of different directions being tested – in the first case it was the weldment direction and in the second one it was perpendicular to the weldment. Having in mind the practical application of the weldment, the second one was taken as the relevant.

According to the results, the modulus of elasticity, yield strength and hardening coefficient were determined and given in the Tab. II for both base metals and the weld metal as well. The hardening coefficient were determined as the ratio of the difference between the ultimate tensile strength and yield strength and 1/2 of total strain (4572), 2/3 (Nioval) or 4/7 (weld metal)6,7.
3. Experimental procedure

In order to evaluate strain distribution, 2 tensile panels have been instrumented with strain gages. A total of 12 strain gages and 4 strain chains were used for each tensile panel, positioned at each side of the specimen, Fig. 2, 3. The strain chain has 10 strain gages of 0.625 mm length and 12 mm length for the chain. The strain chains were cut in two pieces (5 strain gages each) in order to cover two HAZs as precise as possible. In this way three SG actually covered each HAZ, with one SG at the end points of HAZs and the remaining third one in the center of HAZs. The forth SG was positioned in the MW and the fifth one in the BM. A personal computer (iBook Mac) collected the test data via multi channel data acquisitions.

The results are shown in Tab. III for all four measurements at four sides of a specimen (up, down, left, right). Bold numbers indicate strain chain measurements, whereas the bold & italic numbers indicate the SC fifth point being in BMs. The average of four measurements is also given in Tab. III and used as the relevant data for the comparison with numerical results.

4. Numerical simulation

The finite element method has been used to simulate the strain distributions obtained experimentally. The three-dimensional model of V-joint (45°) specimen without crack is shown in Fig. 4. The three-dimensional isoparametric finite elements with 20 nodes were used to create a mesh. The maximum remote stress was 425 MPa. The specimen was modeled with seven materials, as defined in Tab. IV.

The heat affected zones were divided into two regions – fine grain HAZ (FG HAZ) and coarse grain HAZ (CG HAZ). Tensile properties of CG HAZ and FG HAZ, needed for the calculation (yield strength Re and hardening coefficient H'),
Table IV  
Data of iteration procedure for property estimation, YS (MPa), H’ (MPa)  

<table>
<thead>
<tr>
<th></th>
<th>BM - 4572</th>
<th>BM-Nioval</th>
<th>WM</th>
<th>CGHAZ-f</th>
<th>FGHAZ-f</th>
<th>CGHAZ-a</th>
<th>FGHAZ-a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>355.1400</td>
<td>455.730</td>
<td>545.700</td>
<td>550.300</td>
<td>400.1000</td>
<td>400.400</td>
<td>300.1000</td>
</tr>
<tr>
<td>2</td>
<td>355.1400</td>
<td>455.730</td>
<td>545.700</td>
<td>650.400</td>
<td>400.1000</td>
<td>400.400</td>
<td>300.1000</td>
</tr>
<tr>
<td>3</td>
<td>355.1400</td>
<td>455.730</td>
<td>545.700</td>
<td>650.400</td>
<td>450.1200</td>
<td>400.400</td>
<td>300.1000</td>
</tr>
<tr>
<td>4</td>
<td>355.1400</td>
<td>455.730</td>
<td>545.700</td>
<td>650.400</td>
<td>450.1200</td>
<td>630.400</td>
<td>300.1000</td>
</tr>
<tr>
<td>5</td>
<td>355.1400</td>
<td>455.730</td>
<td>545.700</td>
<td>650.400</td>
<td>450.1200</td>
<td>630.500</td>
<td>400.1600</td>
</tr>
</tbody>
</table>

Table V  
Data of iteration procedure for strains  

<table>
<thead>
<tr>
<th>mat.</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>7</th>
<th>7</th>
<th>6</th>
<th>6</th>
<th>3</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>exp.</td>
<td>11.38</td>
<td>12.18</td>
<td>12.67</td>
<td>11.05</td>
<td>7.75</td>
<td>4.88</td>
<td>4.12</td>
<td>2.22</td>
<td>5.16</td>
<td>11.92</td>
<td>12.44</td>
<td>11.92</td>
</tr>
<tr>
<td>5.it.</td>
<td>8.49</td>
<td>11.88</td>
<td>12.44</td>
<td>11.92</td>
<td>7.10</td>
<td>5.54</td>
<td>4.99</td>
<td>4.15</td>
<td>4.09</td>
<td>2.76</td>
<td>1.53</td>
<td>4.15</td>
</tr>
<tr>
<td>4.it.</td>
<td>8.49</td>
<td>11.88</td>
<td>12.44</td>
<td>11.92</td>
<td>7.70</td>
<td>6.64</td>
<td>6.91</td>
<td>4.15</td>
<td>4.09</td>
<td>2.76</td>
<td>1.53</td>
<td>4.15</td>
</tr>
<tr>
<td>3.it.</td>
<td>8.49</td>
<td>11.88</td>
<td>12.44</td>
<td>11.92</td>
<td>7.70</td>
<td>6.64</td>
<td>7.91</td>
<td>6.95</td>
<td>6.20</td>
<td>2.76</td>
<td>1.53</td>
<td>4.15</td>
</tr>
<tr>
<td>2.it.</td>
<td>8.49</td>
<td>11.88</td>
<td>12.44</td>
<td>11.92</td>
<td>7.70</td>
<td>6.64</td>
<td>7.91</td>
<td>6.95</td>
<td>6.20</td>
<td>2.76</td>
<td>1.53</td>
<td>4.15</td>
</tr>
<tr>
<td>1.it.</td>
<td>8.49</td>
<td>11.88</td>
<td>12.44</td>
<td>11.92</td>
<td>7.70</td>
<td>6.64</td>
<td>7.91</td>
<td>6.95</td>
<td>6.20</td>
<td>2.76</td>
<td>1.53</td>
<td>4.15</td>
</tr>
</tbody>
</table>

Strain $\varepsilon_y$ (%) for $\sigma$=425 MPa (points 1–12)  

<table>
<thead>
<tr>
<th>mat.</th>
<th>3</th>
<th>3</th>
<th>3</th>
<th>5</th>
<th>5.4</th>
<th>4</th>
<th>4.1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>exp.</td>
<td>1.53</td>
<td>1.35</td>
<td>1.41</td>
<td>1.42</td>
<td>3.19</td>
<td>4.06</td>
<td>4.04</td>
<td>6.36</td>
<td>6.70</td>
<td>6.34</td>
<td>2.80</td>
</tr>
<tr>
<td>5.it.</td>
<td>1.53</td>
<td>1.35</td>
<td>1.41</td>
<td>1.42</td>
<td>3.19</td>
<td>4.06</td>
<td>4.04</td>
<td>6.36</td>
<td>6.70</td>
<td>6.34</td>
<td>2.80</td>
</tr>
<tr>
<td>4.it.</td>
<td>1.53</td>
<td>1.35</td>
<td>1.41</td>
<td>1.42</td>
<td>3.19</td>
<td>4.06</td>
<td>4.04</td>
<td>6.36</td>
<td>6.70</td>
<td>6.34</td>
<td>2.80</td>
</tr>
<tr>
<td>3.it.</td>
<td>1.53</td>
<td>1.35</td>
<td>1.41</td>
<td>1.42</td>
<td>3.19</td>
<td>4.06</td>
<td>4.04</td>
<td>6.36</td>
<td>6.70</td>
<td>6.34</td>
<td>2.80</td>
</tr>
<tr>
<td>2.it.</td>
<td>1.53</td>
<td>1.35</td>
<td>1.41</td>
<td>1.42</td>
<td>3.69</td>
<td>4.56</td>
<td>4.54</td>
<td>6.36</td>
<td>6.70</td>
<td>6.34</td>
<td>2.80</td>
</tr>
<tr>
<td>1.it.</td>
<td>1.53</td>
<td>1.35</td>
<td>2.21</td>
<td>2.22</td>
<td>4.10</td>
<td>4.56</td>
<td>4.54</td>
<td>6.36</td>
<td>6.70</td>
<td>6.34</td>
<td>2.80</td>
</tr>
</tbody>
</table>

Strain $\varepsilon_y$ (%) for $\sigma$=425 MPa (points 12–23)  

<table>
<thead>
<tr>
<th>mat.</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
</table>

were varied until numerical strain distributions matched closely enough the experimental ones. Five different sets of tensile properties were used to match the experimental strain distribution, as shown in Tab. V. In the case of hardening coefficient one can notice that even for BMs and WM some variation had to be made. The results of this procedure are given in Tab. V.

5. Results and discussion

One should notice the following regarding points as defined in the bottom row of Tab. V: 1 & 23 are given only for as numerical, because they were too close to grips (boundary conditions can explain low values); 2,3,4 & 22,21,20 gives matching results for BMs; 5 & 19 – only experimental, too close to HAZ (no node at these positions); 6,8,10,11 & 18,16,14,13 matching results for HAZs and WM; 7,9 & 17,15 – only numerical, no space in HAZs for SG; 12 – only numerical, no space in WM for SG.

The basic aim was to simulate the experiment and compare displacements, strains and stresses, having in mind specimen heterogeneity, and specific behaviour of base metals (ferrite BM with higher yield strength $\sigma_Y$ but strengthening coefficient $H'$ than austenite BM) and weld metal with the highest $\sigma_Y$ and strengthening coefficient $H'$ similar to the ferrite BM, not to mention two HAZs with two different regions – CG and FG.

Based on the comparison of numerical and experimental results one can see that minimum seven different materials (WM, two BMs, two CGHAZ and two FGHAZ) should be modeled in the case of austenite-ferrite welded joint. Since it was neither possible to extract tensile specimens from small regions like CG and FG HAZs, nor would be the microhardness measurement appropriate procedure in this case, an iteration procedure has been applied, providing reliable results for all 7 regions.

One should notice that not only these two basic tensile properties differ, but the whole tensile behavior as well. It is...
also to be noted that the austenite BM has the largest strengthening modulus and the smallest yield strength, whereas the WM has the smallest strengthening modulus and the largest yield strength. Finally, one should keep in mind that heat-affected-zones in both base metals, being heterogeneous even by themselves, present yet another source of material heterogeneity, which is modeled here by taking into account the fine grain and coarse grain regions.

6. Conclusion

Experimental and numerical models have been used in this study. Experimental analysis has been limited to welded tensile panels made from dissimilar base metals. Numerical analysis, detailed three-dimensional finite element model of the same welded tensile plate, without surface crack, has been performed. Based on these analyses, the following conclusions may be drawn:

- Three-dimensional finite element analysis is essential for analysis of welded joint behaviour, even without presence of a crack, because of complex material behavior, involving different yield strength and strengthening levels.
- The original iterative method for evaluation of elastic-plastic properties of different regions in the weldment has been introduced, based on matching of numerical and experimental results. This method turned out to be very efficient.
- The iterative method proved that HAZ has to be modeled with at least two different regions, coarse-grain and fine-grain, for precise evaluation of elastic-plastic properties.
- The iterative method should be improved in order to get next step automatically on the basis of the previous one and its difference in comparison to the experimental results. This procedure has to be verified with more examples and eventually introduced as a convenient method for this purpose.

REFERENCES


R. Jovicic\textsuperscript{a}, A. Sedmak\textsuperscript{b}, K. Colic\textsuperscript{c}, M. Milosevic\textsuperscript{c}, and N. Mitrovic\textsuperscript{a} (\textsuperscript{a}Innovation Center of Faculty of Mechanical Engineering, University of Belgrade, \textsuperscript{b}Faculty of Mechanical Engineering, University of Belgrade): Evaluation of The Local Tensile Properties of Austenite-Ferrite Welded Joint

Local mechanical properties (Yield Strength Re and Hardening Coefficient H\textsuperscript{'} ) of austenite-ferrite welded joint has been evaluated by using finite element method to simulate the strain distributions obtained experimentally by tensile test using strain chains and strain gages. The three-dimensional model of V-joint (45\textdegree) specimen has been used with seven materials, simulating both base metals (BM), the weld metal (WM) and two sub-regions of two heat-affected zones (HAZ) – fine grain (FG) and coarse grain (CG) HAZ. Tensile properties of CG HAZ and FG HAZ, needed for the calculation, were varied until numerical strain distributions matched closely enough the experimental ones, whereas tensile properties of BMs and WM were kept constant. Five different sets of tensile properties were used to match the experimental strain distribution. In this way local tensile properties of the whole austenite-ferrite welded joint have been evaluated.