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Analysis of strain distribution in overmatching V groove weld using digital image correlation

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Abstract

Welded joints are treated as critical sites when constructing and calculating welded structures due to inhomogeneity and anisotropy of materials at the welded joint site. Because of the change in the geometry of the elements, the welded joint is viewed as the location of the stress concentration and therefore as a place that weakens the overall load capacity of the structure. Due to this approach in the design of welded structures, practice requires that in most cases welded joints are performed with better mechanical properties compared to the base metal. A welded joint that is made so that the mechanical properties of the weld metal exceed the mechanical properties of the base metal is called the overmatching welded joint. This paper presents the measurement of the strain over the 'overmatching' welded V joint using the DIC (Digital Image Correlation) method and the analysis of the strain distribution is provided. The strain distribution obtained is interesting because it shows that in the stress concentration points the strain have almost minimal values.

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Keywords: *Strain distribution analysis; Overmatching weld; Digital Image Correlation; Welded joints*

1. Introduction

Welded structures have a large share in almost all industries. Bearing this in mind, it is easy to conclude that the knowledge of the stress-strain condition of welded structures is crucial for the integrity of the construction itself and for the safety of the people who are using it. Since welded joints are by their nature heterogeneous and anisotropic, every effort is made to their stress and strain state fully determine. Since the strain distribution mechanisms are not fully known, in practice it usually goes, that the mechanical properties of the weld metal to be better than the mechanical properties of the base metal in order to ensure structural integrity. Such joints are called "overmatching" welded joints.

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There are several obstacles in the examination. Namely, the previous experimental methods provided only partial insight into the behavior of the welded joint because it was not possible to construct and examine samples with complex geometry or samples that are of small size to provide us with information on the behavior of different zones of welded joint. During the tensile test, two values of tensile strength were determined. Tensile strength of welded joint as a whole was determined on samples in which the face of the weld metal (WM) are grinding, which is rarely performed in practice, and as a result we got a test value, without information on the strain distribution around the joint. Determination of tensile strength of the weld metal, in overmatching welded joint, carried out such that at the site of the weld metal we narrowing cross-section of the specimen in order to initiated fracture on that spot. Some corrective factors have been used to calculate the final tensile strength. This approach is not applicable for the determination of strain and certainly does not provide information on its distribution.

By using DIC (Digital Image Correlation) method can perform an analysis of the strain distribution of the sample complex geometry and thereby obtain information about the value of strain in each zone of the welded joint and in every moment of the examination. This method allows us to observe and compare strain values in all zones, taking into account their mutual influence. Since areas with different mechanical characteristics are in contact, they certainly affect one another in terms of deformation, and with the DIC method we can notice this effect.

2. Testing procedures

During this test, material S235 JR G2 was used which was welded with MAG procedure in a protective atmosphere of CO_2. The chemical compositions of the base and filler materials are shown in Table 1. The filler material for welding was, welding wire G 42 5 C / M G3 Si1, which is provided for welding these steels. This filler material gives a significant overmatching effect. Mechanical properties of the base and filler materials are shown in Table 2.

Table 1: Chemical composition of steel S235 JR G2 and welding wire G 42 5 C/M G3 Si1

Maximal volume of elements (%)									
S235 JR G2									
C	Si	Mn	Ni	P	S	Cr	Mo	Al	Cr+Mo+Ni
0,2	0,55	1,4	0,3	0,045	0,045	0,3	0,08	0,02	0,48
G 42 5 C/M G3 Si1									
C	Si	Mn	Ni	P	S	Cr	Mo	Al	Cr+Mo+Ni
0,08	0,90	1,50	/	0.025	0.025	/	/	/	/

Table 2: Mechanical properties

	Re (MPa)	Rm (MPa)	A (%)
S235 JR G2	215	340	24
G 42 5 C/M G3 Si1	410	510	22

One can see that the size of "overmatching" effect for the yield strength is 52% while the value for tensile strength is 67%. This is a significant difference, but it is such a recommendation for welding of structural steel with MAG procedure. Appearance of test specimen and its dimensions are shown in Figure 1.

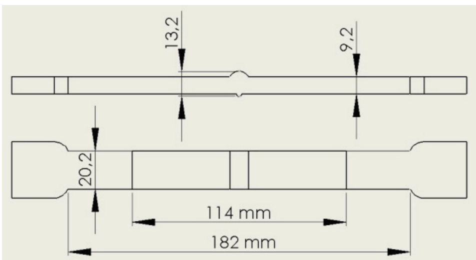
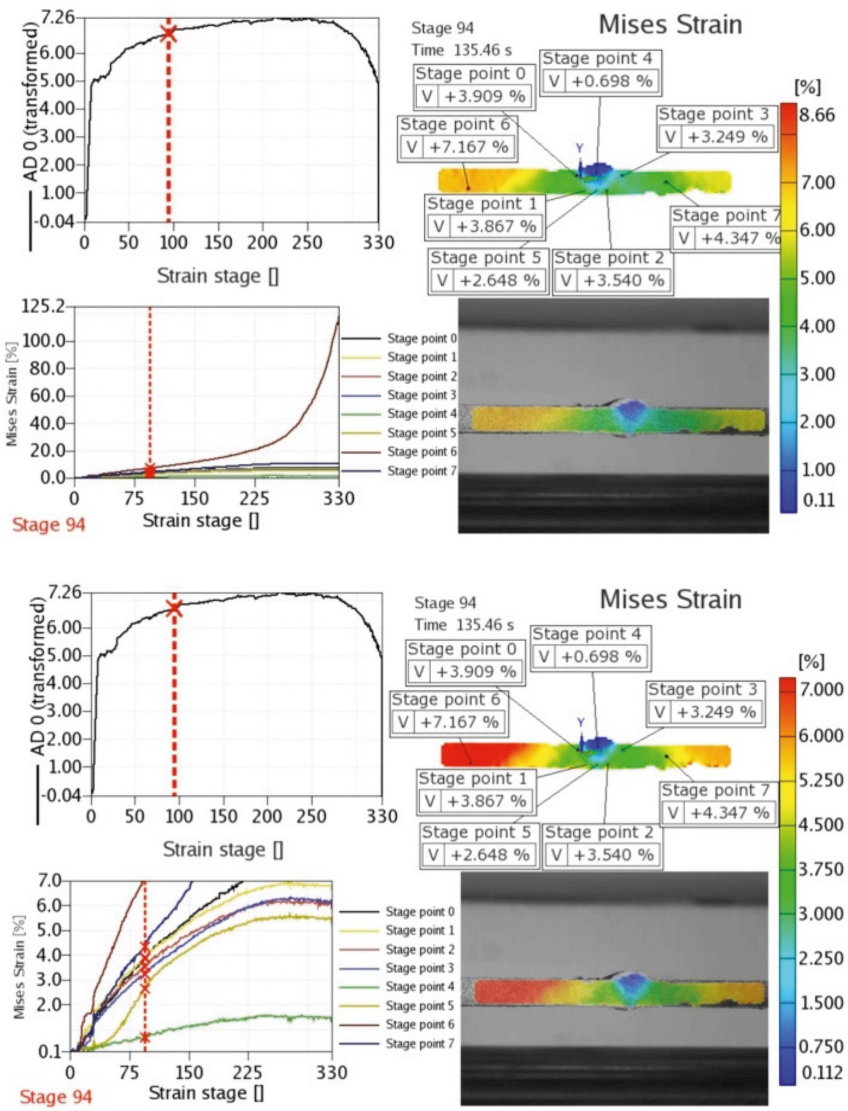


Fig. 1. Dimension of the specimen

One can see (in Figure 1) a specimen with parallel sides. This type of specimen is also used in determining the tensile strength of the welded joint as a whole but with removed weld reinforcement. The specimen shown in Figure 1 is closest to the real welded joint we can see in welded construction. Reinforcements on the face and root of weld are not removed, which is the most common case in practice, unless otherwise provided by welding technology. The specimen was examined on a hydraulic testing machine and two cameras were used for shooting, which gives us 3D insight into the field of deformation. The Aramis software package was used to process the results.

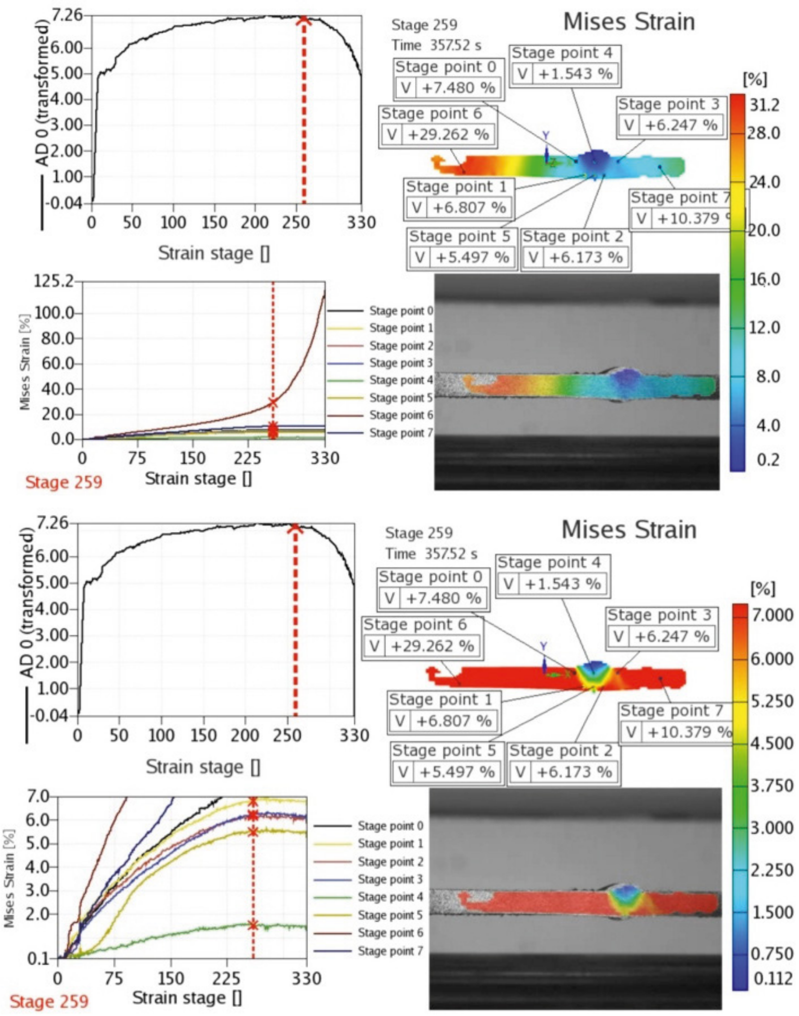
3. Results

After completion of the examination, the data were processed in Aramis and the following figures show the characteristic phases. Phases of the pre-yield point are not shown due to the small values of the strain and the impossibility of detecting the essential differences in the different zones of the welded joint. Figure 2 shows the strain distribution after the yield point. The strain values for the maximum force are shown in Figure 3.



a) b)

Fig. 2. (a) Strain distribution after yield point, with no limit on strain values; (b) with limitation on 7% of strain



a) b)

Fig. 3. (a) Strain distribution after reaching maximal force with, no limit on strain values; (b) with limitation on 7% of strain

In Figures 2a) and 3a) the strain distribution along the welded joint is show, but still there is little noticeable difference in HAZ and WM. In order to see more clearly the distribution of strains in and around weld metal, the strain for display is limited to 7%. The results obtained are shown in Figures 2b) and 3b).

4. Discussion

The welded joint with reinforcement has some stress concentration. These places are transition from the basic material to WM and to stress concentration caused by changes in geometry. The points at which stress concentration occurs is typically the place where initial crack occurs and subsequently comes to breakage of a machine part. This led to the conclusion that in the case of welded joints at the toe of weld, in addition to the stress, the strain is concentrated to, and because of that these are critical points, from the point of view of the material's resistance.

This strain analysis shows something completely different. Specifically, in Figures 2 and 3 can be clearly seen that the values of strain in the HAZ almost two times lower than in the base material away from the WM. What's more, it can be noticed that with the distance from the welded joint strain grows. Weld metal with its better mechanical properties (overmatching) helps the surrounding material, starting from the HAZ to the BM to suffer less strain.

The basic material has a lower yield limit and earlier entering the field of plasticity and strain grow faster relative to the zone around the WM which are still found in the area of elastic or have just moved into the plasticity. Because of this difference strain fastest growing away from WM at the point where the first yield limit is reached. We can also conclude that the side-top at the overmatching of the welded V joint almost does not participate in the load transfer since the strain values in this zone are very small at the time of the break.

This analysis shows that the stress concentration in a defectless reinforced V welded joint does not interfere with the overmatching effect and provides the possibility of planning the position of the welded joints in relation to the stress state and the integrity of the construction itself.

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