FATIGUE BEHAVIOR OF WELDED STRUCTURES

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Abstract:*Fatigue is a phenomenon consisting of the accumulation of stresses and deformations that cause cracking and sometimes dismantling or even destruction of structures as a consequence of applying variable loads over time as intensity and position (load cycles). The applied loads have values below the yield limit of the material from which the structure is made. These loads having values below the yield limit, under static stresses, would not have the effect of causing the fracture to fail. The paper aims is to present the basic mechanism of fatigue fracture by fatigue on the one hand and on the other hand presents some experimental researches regarding the evaluation of the quality of fillet welded joints of “GiurgeniVadulOii” bridge.*

Keywords:fatigue, cracking, fracture

1.Introduction

Fatigue is a process of destruction of the structures under the action of time-varying loads and wich accumulatingcycle after the cycle has as a consequence the failure and the removal of the operation of the respective structure [1], [2]. Specifically for the the fatigue is that the failures occur under stresses below the yield limit. This stresses in the case of static loads would not cause either deformation or failure of the structure. For structures in service, the cumulative destruction process may take several years until a critical level is reached that results in a failure or in the removal from operation. The fatigue process is usually divided into three phases. The initiation of the crack, phase A, usually occurs on the surface of the material, in the vicinity of a notch. The phenomenon is explained by a sliding mechanism at the microscopic level determined by the maximum shear stresses. When the load is applied, a few grains will plastic deform due to the sliding of the crystallographic planes. The mechanism includes only a few grains, where those crystallographic planes have an unfavorable orientation relative to the maximum shear local stress. When the applied load is changed, the planes that have slipped initially will not realise at the initial position due to the hardening effect, so that the final result at the microscopic level will be the appearance of some intrusions and extrusions on the surface of the material. Intrusions will behave like microcracks, determining the subsequent crack extension during the subsequent load cycles.In Phase B, after the crack initiation was made inside a few grains, the crack growth at the microscopic level would extend the crack over a few grain boundaries. When the fracture front will pass over a few grains, the crack will continue to grow in a direction perpendicular to the highest main traction tension. It is important to understand that even if the crack initiation phase depends on the state of the material surface and is governed by the shear stresses, the crack growth continues to depend on the properties of the material, the crack being driven by the main cyclic stress . In the growth phase, the process is explained by a mechanism for opening the crack and smoothing its peak, followed by a crack closing mechanism and sharpening of the tip over each load cycle. After a complete cycle, the cracking front advanced with a small increment that may be on the surface subjected to fatigue. This advance corresponding to a loading cycle is actually the distance between so-called two striations that can be seen with the eye at a fatigue fracture surface. This advance depends on the variation of the stress intensity factor. The fracture in phase C will occur when the crack becomes so large that the remaining cross section of the remaining link is too small to transmit the load cycle of the stress peak, or when the local stresses and distortions of the cracking front cause a locally fragile fracture. In the first case the average stresses acting on the insufficient net section cause the fracture occurrence. In the second case, the local fragile fracture, which is determined by the maximum stress intensity factor, causes fracture occurrence. This factor uniquely characterizes the magnitude of the stressfield at the fracture front in linear elastic conditions.

The fatigue fracture of the welded structures is influenced by a number of factors, such as: the external loads and stresses on a structural element, the stress concentrator geometry, the material properties, the manufacturing quality and surface preparation and the environmental influences [3], [4], [5].

External loads can produce traction / compression, bending, and torsion effects on structural elements, associating corresponding stresses near to the potential fracture points. When acting on an element with a variable load in time, it mainly counts the load variation and the number of cycles that act. Frequency of repetition of the loads usually does not influence the process of failure. If on the element acts multiple forces from the outside, things get complicated because the external forces applied can have different frequencies and can be more or less correlated over time.

Regarding the geometry of the stress concentrators, it is very important the general state of stress and the local stresses generated by certain discontinuities. The stress concentration is defined as a local increase in tension caused by a change in geometry or a discontinuity of the respective structural element. We often call notches these local geometry changes more straight or deep. Typical examples in this regard are threads and welding seams.The basic properties of materials such as the yield limit, the static traction resistance, the modulus of elasticity,influence the fatigue life time of the element.

Sometimes the environment can change the fatigue behavior and drastically decrease the parameters associated with the phenomenon.An important example is the fatigue behavior of steels in salty sea water, the steel does not have any corrosion protection. In this case, a synergistic effect will arise between thecorrosion damage mechanism and the fatigue fracture process. Also, the loading frequency becomes important because the corrosion phenomenon is dependent in time on an electrochemical process.

2. Experimental research

The experimental researche refer to the evaluation of the quality of the welded joints at the "GiurgeniVadulOii" bridge. As known the welded bridges are structures that are subject to fatigue due to variable loads over time. The research presented in this paper consists in the non-destructive examination of the quality of the fillet and cruciform fillet welded joints of these bridges. The cruciform fiilet welded joints have been chosen for the study because they have the largest share in the construction of the bridges and in the most cases they have a convex shape of the seams, which causes the stress concentrators at the passes between the filler and the base material. Non-destructive control methods aimed at highlighting the discontinuities that could produce catastrophic damage in the future. The non-destructive control methods magnetic powders method and ultrasound method examination. With magnetic powders , we can highlight surface and interior discontinuities in the immediate vicinity of the surface, and with ultrasound method we can determine the depth of discontinuities from the surface. It is intended to detect macrostructural discontinuities that can cause future damage.

Several pictures regarding the magnetic powders examination of thewelded joints at “GiurgeniVadulOii” bridge are presented in figure 1.

Fig. 1. Images taken during the examination with penetrating liquids at “Giurgeni Vadul Oii” bridge
a-surface preparation; b-delimitation of the surface to be examined; c- application of liquid magnetic particle; d-magnetization; e; f- examination in ultraviolet light; g; h - temperature control of the controlled area; i-delimiting the controlled area

Figure 2 shows the positions of the ultrasonic tuchprobe for the calibration in case of the ultrasonic investigation. The USM 35 defectoscope was used, using a 45 ° / 2MHz tuch probe.

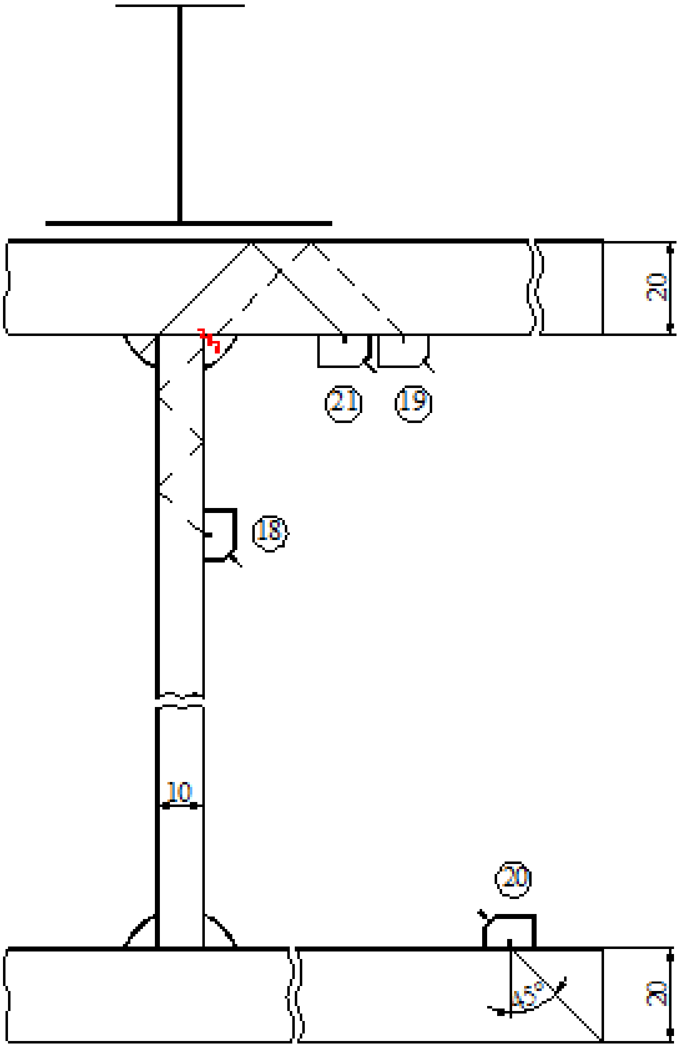


Fig. 2. The Touch probe positions for ultrasound calibration and investigation

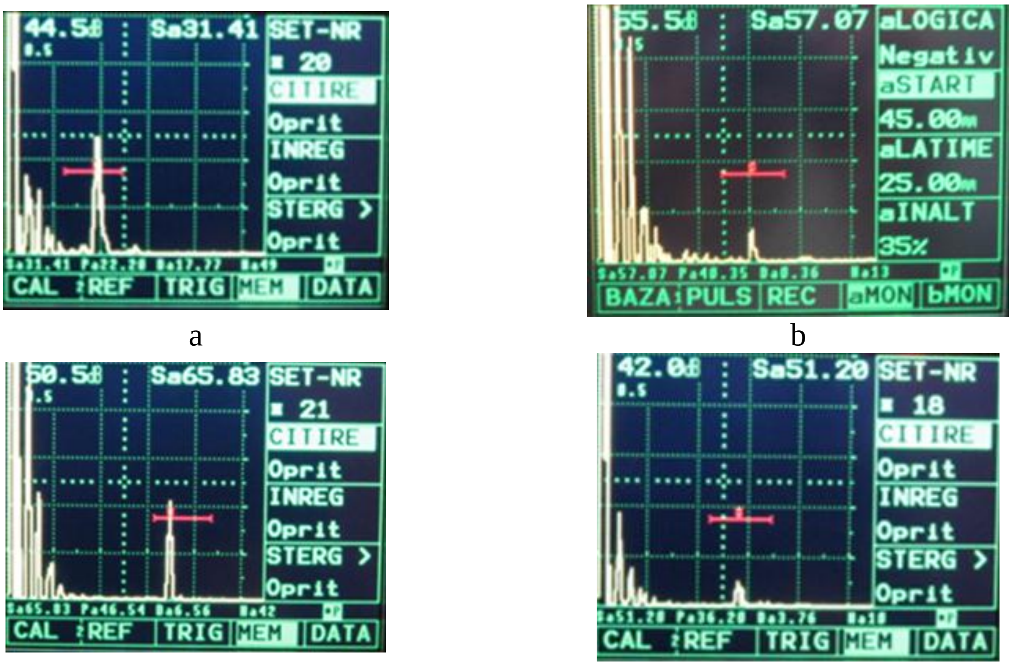
3. Experimental results

Several of the defects detected after the magnetic powders examination of the welded elements of the "GiurgeniVadulOii" bridge are presented in table 1. The following notations were used for the sections where the discontinuities were found: L-line; V-viaduct; Di-aperture; P-panel; Stg- left; Dr- right. The notifications noted in table 1 with "NOT" are: NOT1 - the crack is initiated into the welding and extends to the base material; NOT.2 - the crack is in the heat affected zone HAZ; NOT.3 - no discontinuity has been highlighted; NOT 4 - the crack evolved over time by joining several shorter cracks; NOT 5 - the hole has been initiated at the intersection between filler and the base material, evolving towards the welding.

Tab.1 Discontinuities highlighted at the "Giurgeni Vadul Oii" bridge with magnetic powders

No.	The Symbolize of the section	Discontinuity type	Length [mm]	Notifications
1	L2V1D3P10 Stg	crack	210	NOT1
2	L1V1D3P4 Dr	crack	115+69	NOT 2
3	L1V1D2P10 Stg	crack	-	NOT 3
4	L2V1D2P8 Stg	crack	10+45+10+20	NOT 4
5	L1V1D1P10 Dr	crack	170	NOT 5

The oscillograms obtained from ultrasonic control are shown in figure 3.



a b

c d

Fig. 3 The Oscillograms obtained from ultrasound method

a-position 20 calibrating the touch probe; b-position 19, the echo obtain from the crack; c-position 2, the echo from the surface of the welding cord; position 18, the echo from the crack.

4. Conclusions

In the most cases, the cracks appeared at the fillet welded joints with the convex shape of the welding cord. These cracks have emerged as a result of high stress concentrators placed at the intersection between the filler and the base material, the concentrators beeing introduced by the convex shape of the welding seams. This convex shape not affording a connection and a smooth transition from the filler to the base material, favorstheappearanceof the cracks.

It is known that all bridges and viaducts are subjected to variable loads in time as intensity and position, are affected by the fatigue phenomenon. This phenomenon of fatigue of the bridge or the viaduct, coupled with the inappropriate convex shape of the welding seams, causes the appearance of these cracks nonconformities, with a high density of occurrence and quite long lengths, between 100 and over 1200 mm . These cracks can be very dangerous, even leading to the complete failure of the bridge.

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