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APPLICATION OF DIGITAL RADIOGRAPHY (DR) IN AN APPROACH TO EVALUATE THE TECHNICAL CONDITION OF MIG-29'S VERTICAL STABILIZERS

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Abstract

The purpose of the work presented was to evaluate the capabilities of digital radiography to detect cracks in the internal structure of MiG-29 vertical stabilizers. The test object was a stabilizer previously subjected to fatigue testing and partially torn down for the needs of visual inspection. An inspection of three regions containing cracked parts was performed, with use of a pulsed x-ray generator and digital detector array. The results confirmed the method could be used to detect cracks in an internal structure which could not be inspected with other methods without affecting the stabilizer's integrity.

Keywords: NDT, digital radiography, inspection of internal structures, composite structures
Article Category: Research Article

INTRODUCTION

The paper's purpose is to present the application of digital radiography NDT method in evaluation of the technical condition of internal structural elements of MiG-29 vertical stabilizers. MiG-29 vertical stabilizers are stressed-skin structures, consisting of an aluminium frame of spars and ribs, and a carbon fibre (CFRP) skin stiffened with carbon fibre stringers. The Polish Air Force MiG-29 fighters' vertical stabilizers are inspected regularly in search for carbon fibre damage and delamination as well as composite stringer disbonds. A fatigue test of this part was carried out as part of the MiG Project underteken by AFIT, and conducted until a drop in the structure's rigidity occurred [10]. Further teardown and visual inspection revealed cracks in the internal structure despite lack of visible external damage [9]. The number of load cycles leading to this event significantly exceeded the actual service life predictions. Nevertheless, the question arose about possibilities of in-service inspections of vertical stabilizers' internal metal structure. This paper presents the work undertaken to address this question.

THE TEST OBJECT

The objects of the inspection are aluminium ribs and spars making up the internal structure of vertical stabilizers. As stabilizers are enclosed structures direct access to all internal components is not possible. Inspection of load-bearing parts in such structures can be partly performed through visual inspection with a borescope, but some areas remain inaccessible. Although the eddy-current method is commonly used to detect cracks in metal parts its application here is largely limited by the complex spatial orientation of overlapping metal parts being covered with several millimetre-thick composite skin [3]. The digital radiography method was chosen to perform the inspection as it is capable of inspecting the object's full volume and sites otherwise inaccessible and because it is commonly use in detecting damage in metal structures [2],[6],[7],[8],[12].

A post-fatigue test vertical stabilizer was used as the test object. One of its composite skins was removed during teardown inspection, and a visual and eddy-current inspection was performed. Cracks were detected and marked. In the work presented, a group of cracks was chosen to be registered with the digital radiographic method in order to evaluate the method's capability in this field. The cracks are located on the front spar and the rib adjacent to it in an area marked with letter *A* in Figure 1. Additionally, a crack detected on another stabilizer of the same type in an area marked with letter *B* in Figure 1 was inspected. The crack in *B* area is on the edge of an inspection opening, under a removable metal lid and could have been caused by an accidental impact during maintenance.

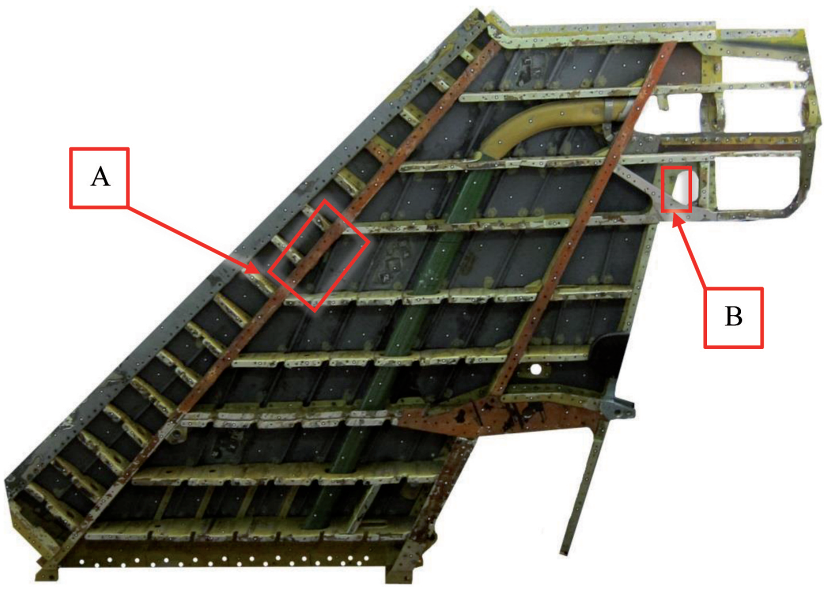

Figure 1. Inspected structure of MiG-29 vertical stabilizer with inspected areas marked red.

The inspected spars and ribs are made of aluminium alloys, with the wall thickness ranging from 1 to 3 mm depending on the zone.

METHOD DESCRIPTION

Various materials absorb electromagnetic radiation of certain energy to a different degree. More dense materials absorb more of the ionizing radiation of the X-ray range. Emitting x-ray radiation in the direction of a radiation detector (or radiographic film) creates a projection of the inspected object placed between the source of radiation and the detector [11]. In the presented work, a direct digital radiography method was used. It utilizes a digital detector array (DDA) instead of radiographic film, allowing the inspector to analyze the radiograms immediately after performing the inspection [4],[5]. A 100µm resolution XRpad 4336 panel was used as the detector. A XRS-4 pulsed x-ray generator was used as the radiation source.

The radiograms' quality and resolution were determined using wire image quality indicators (IQI) as well as duplex-wire IQI [1].

The complex geometry of the inspected object made it necessary to use several different positioning variants of the radiation source-object-detector system. The significant width of the stabilizer's structure (up to 15 cm in the inspected areas) made it necessary to inspect the opposite the flanges of the spar and the ribs on separate radiograms to keep the unsharpness acceptably low and to make it possible to distinguish the zones under inspection. The significance of positioning of the x-ray source correctly is presented in Figure 2.

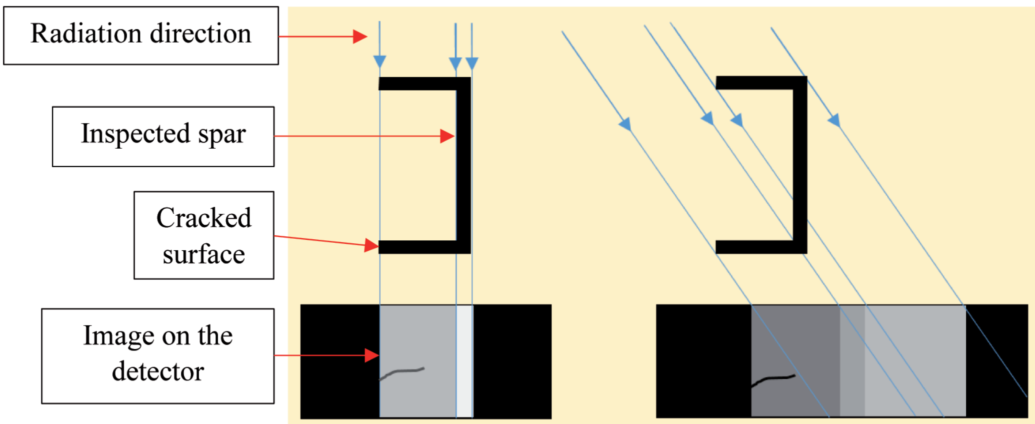

Figure 2. Schematic presentation of radiographic images of a spar achieved with positioning the x-ray source at different angles.

RESULTS

The inspection results are presented in Figures 3÷8 below. The photographs of cracked areas are presented next to the radiograms for reference.

The radiographic testing was preceded with visual inspection whose purpose was to locate the cracks. The result presented in Figure 3 was obtained at 500 mm source-to-detector-distance (SDD). The crack's length was 15 mm.

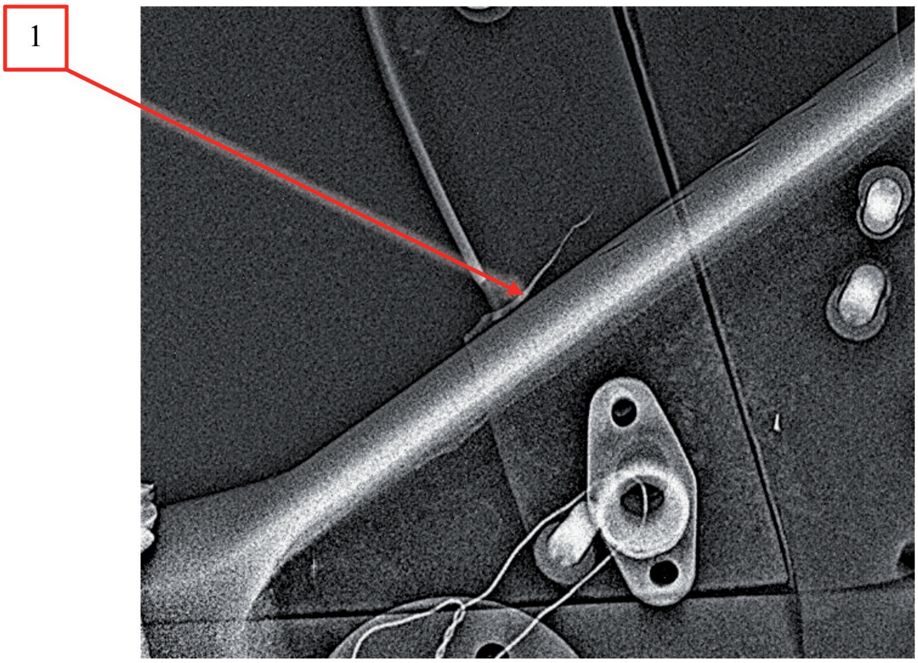

Figure 3. Crack detected on a rib near the rear spar.

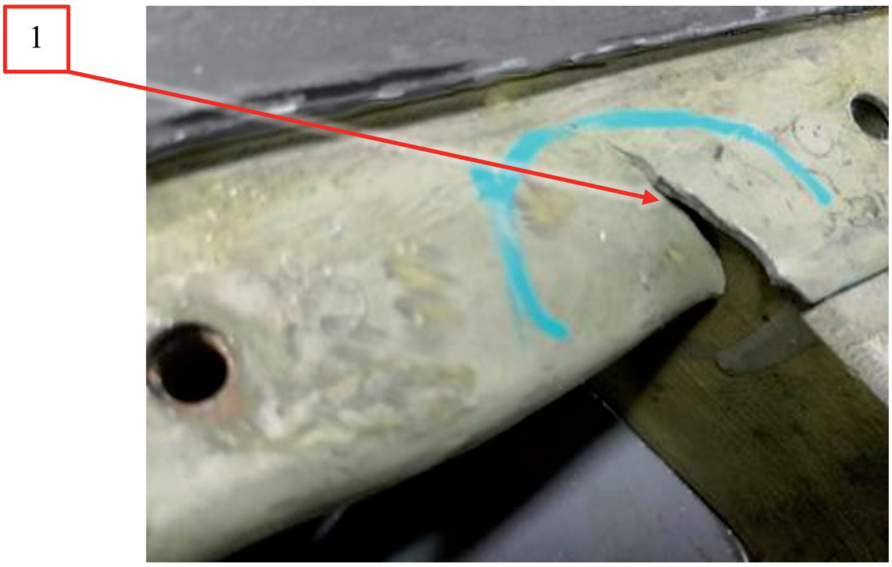

Figure 4. Photograph of the crack presented in Figure 2.

The significant width of the stabilizer's structure in the area of inspection affects the sensitivity of detecting damage. The radiographic image of cracks located near the detector's surface is noticeably sharper than that of cracks located far from the detector. This can be seen in Figure 4, where the sharpness of the longest crack (marked with number 2) changes along the spar. The visible cracks' length ranges from 7 mm (cracks marked with numbers 6,7) to approximately 150 mm (crack number 2). The results presented in Figures 5 and 7 were obtained at 1500 mm source-to-detector-distance (SDD). The crack presented in Figure 7 (marked with number 8) has length of 33 mm.

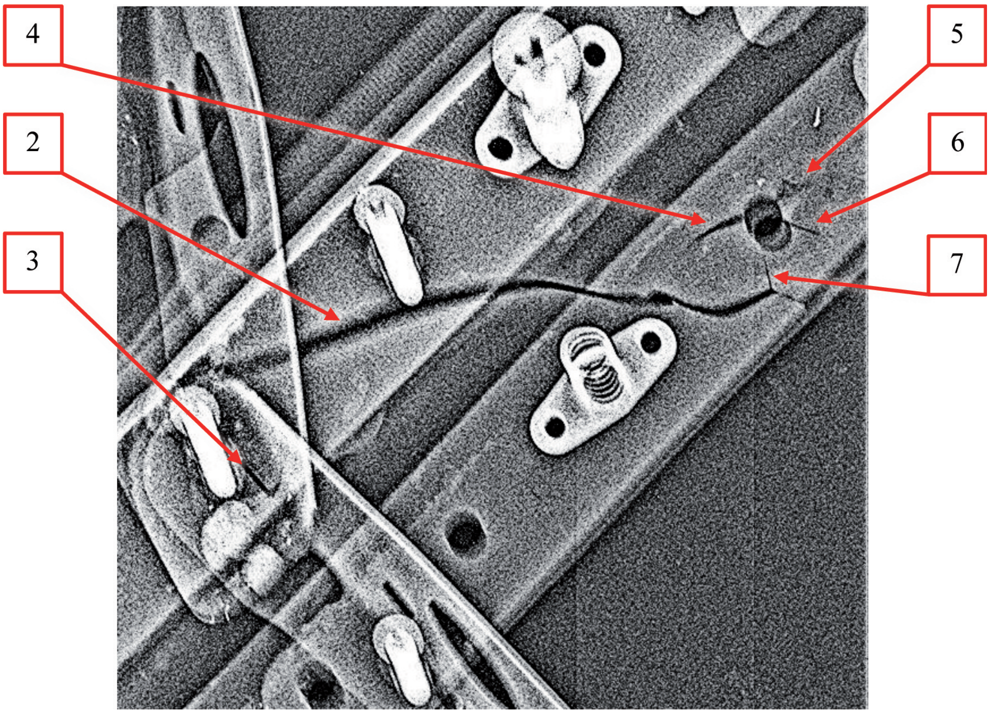

Figure 5. Six cracks detected on the front spar.

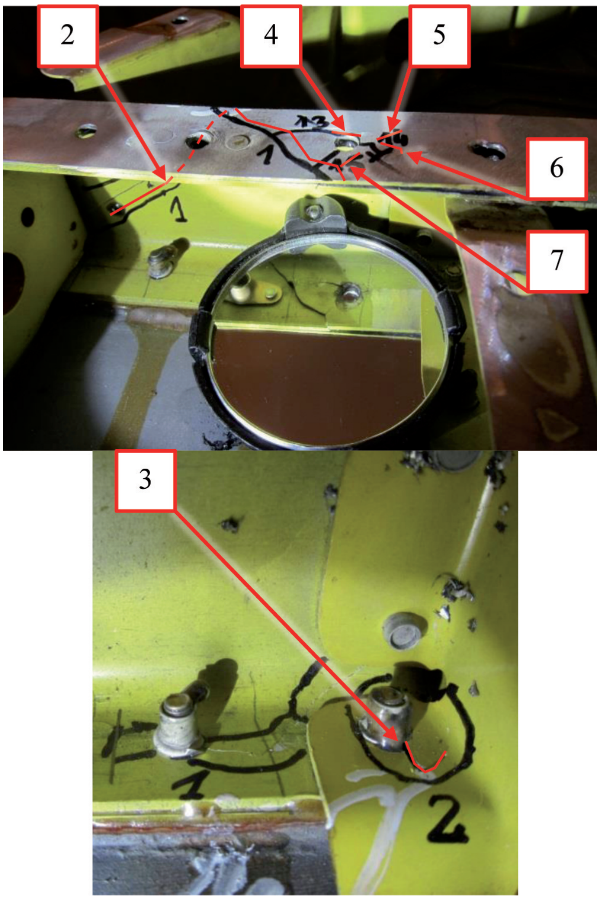

Figure 6. Photograph of six cracks presented on Figure 5.

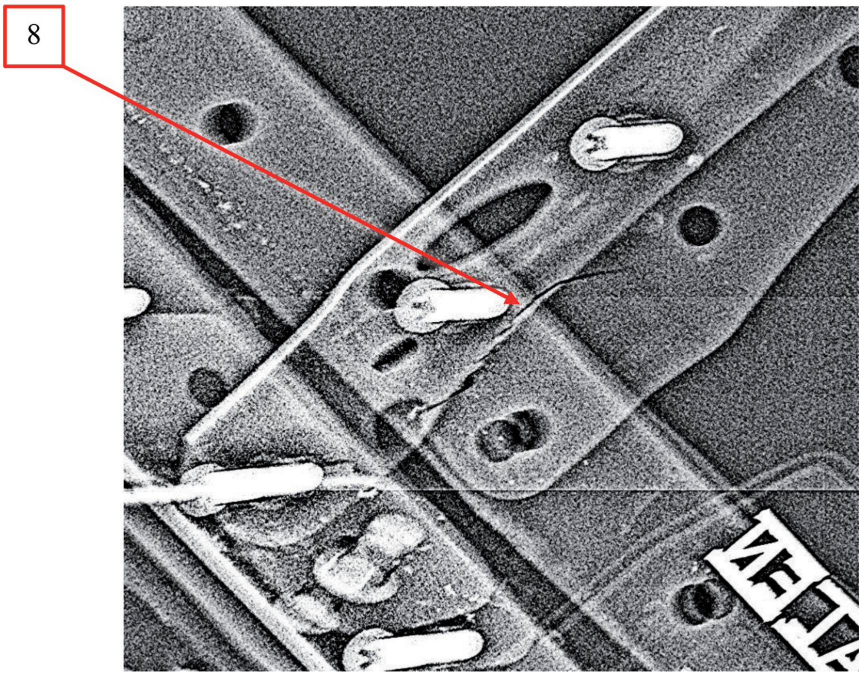

Figure 7. Crack detected on one of the ribs near the front spar.

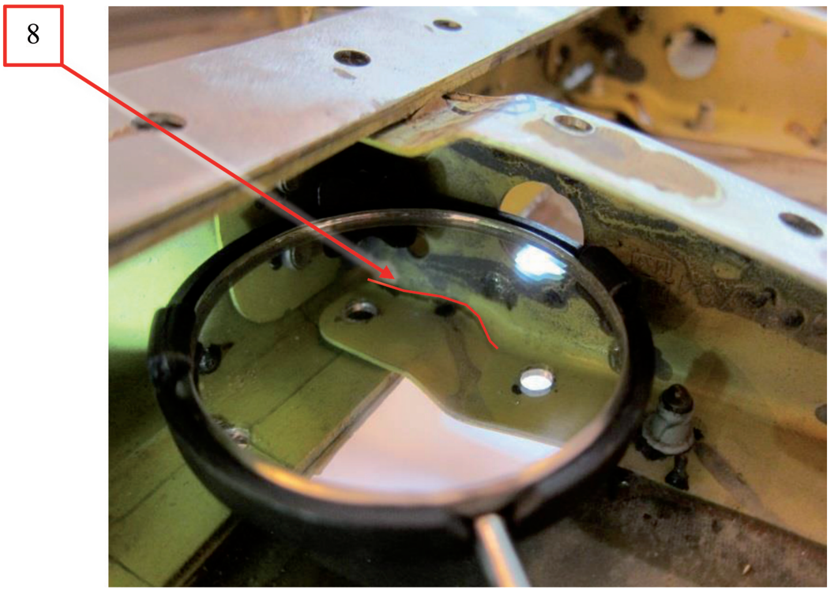

Figure 8. Photograph of the crack presented on Figure 7.

SUMMARY

The inspection conducted proved the digital radiographic method suitable for the described application of detecting cracks in the internal structure of MiG-29 vertical stabilizers. The complex geometry of the inspected object makes the mobility of the utilized radiation source an important feature since the source needs to be placed in various positions and angles. The XRS-4 pulsed x-ray generator seems to be well suited for this application due to its light weight and relatively small dimensions, compared to standard industrial x-ray tubes. The DDA detector allows the inspector to analyze the results immediately, but its rigid flat surface whose shape cannot be adjusted to the inspected object's surface limits the area that can be inspected in one exposition.

Each of the inspected areas of spars and ribs needs to be inspected from two opposite directions in order to provide sharp and conclusive results of both flanges since the contours of the surfaces positioned further from the detector can be too unsharp to provide information.

Further work is needed to create a plan of full inspection of the entire structure of a vertical stabilizer. Such a plan should contain creating a "map" of necessary expositions, as well as determining optimal angles, SDD and the number of radiation pulses to provide a reliable image of the internal structure's condition. Comparison of direct radiography with DDA against computed radiography with phosphor imaging plates can also be carried out.

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