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Residual stress measurements by hole drilling method

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ABSTRACT: Almost every structural or machine component contains residual stresses which may significantly influence their performance. Hence the necessity of knowing the measurements of these stresses in order to guarantee a good functioning of component within the established limits of safety.

This work apply "The Center Hole-Drilling Method" for determination of the residual stresses, and presents the experimental results of the analysis carried out on a prototype of the "BIBLIS PWR Fuel Element Up End Piece".

1 INTRODUCTION

The "Centro de Desenvolvimento da Tecnologia Nuclear" (CDTN) has developed a process for fabrication of fuel element nozzle used in the nuclear power plant Angra II, Bibles B type. Stainless steel is the material of the fuel nozzle. The fabrication process includes the machining of nozzle components in the following order: top frame, corner piece and bottom plate. After this, the top frame and bottom plate are welded to corner piece by TIG process.

The fabrication process of the fuel element nozzle generates residual stresses. The residual stresses must be quantified to allow corrections in the fabrication process and to provide an adequated utilization of the component.

There are many methods to measure the residual stresses in metallic materials: destructives, semi-destructives and non destructives.

The method utilized in this work is a semi-destructive method, normalized by ASTM in 1981 and revised in 1989. It is the HOLE DRILLING METHOD.

The residual stresses were measured on the bottom plate, corner piece and top frame of the fuel element nozzle.

The maximum residual stresses measured at the bottom plate are in the heat affect zone by welding process. They are located at the corner piece at the middle, between top frame and bottom plate. At the top frame the residual stresses are in the middle, between the corner pieces.

2 STRUCTURAL COMPONENT: FUEL ELEMENT NOZZLE

The Fuel Element Nozzle is an structural component that supports the fuel rods, spacer grids, springs, guide tube and, is also utilized to hold the fuel in the reactor core. These Fuel Element Nozzle is manufactured in stainless steel, built with perforated plate, welded to four corner pieces. Figure 1, shows the Fuel Element Nozzle in the fuel assembly structure.

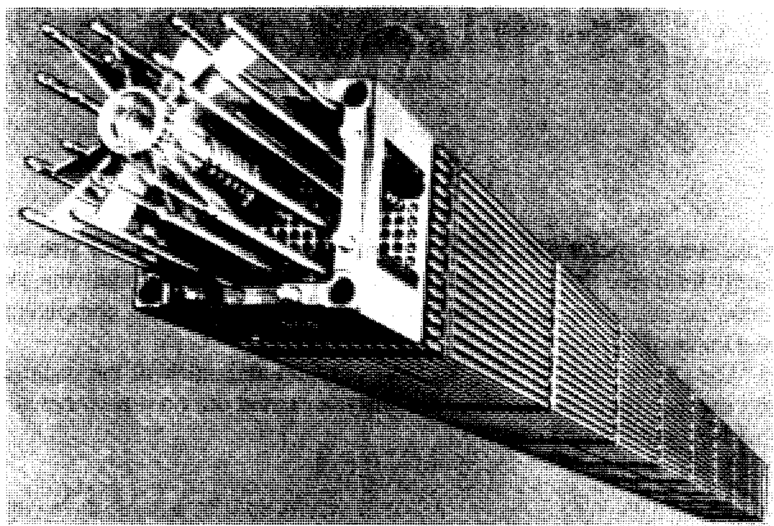


Figure 1 - Fuel Element Nozzle in the fuel assembly structure

3 SELECTION OF THE POINTS FOR RESIDUAL STRESSES MEASUREMENTS

The points where the residual stresses measurements were performed were selected from dimensional analysis results, after welding of the components; top frame, corner piece and bottom plate.

Eleven points on face of the nozzle that had highest geometrical deformation and, one point on bottom plate were selected.

The Figures 2a and 2b show these points.

The Figure 3 shows the installed rosettes for measurements.

4 METHOD AND MATERIALS

The Blind Hole drilling was the method used on the rosettes installed on the surface having the point to be tested.

The rosette is made of TML-JAPAN FRS-2-11 Type, with gage length 1.5 mm, nominal resistance 120 Ω and gage factor 2.06.

Cyanoacrylate adhesive (Loctite 496) was used to bond the rosettes on the points,. Three lead-wire system was utilized to connect the rosettes to the measurement equipment.

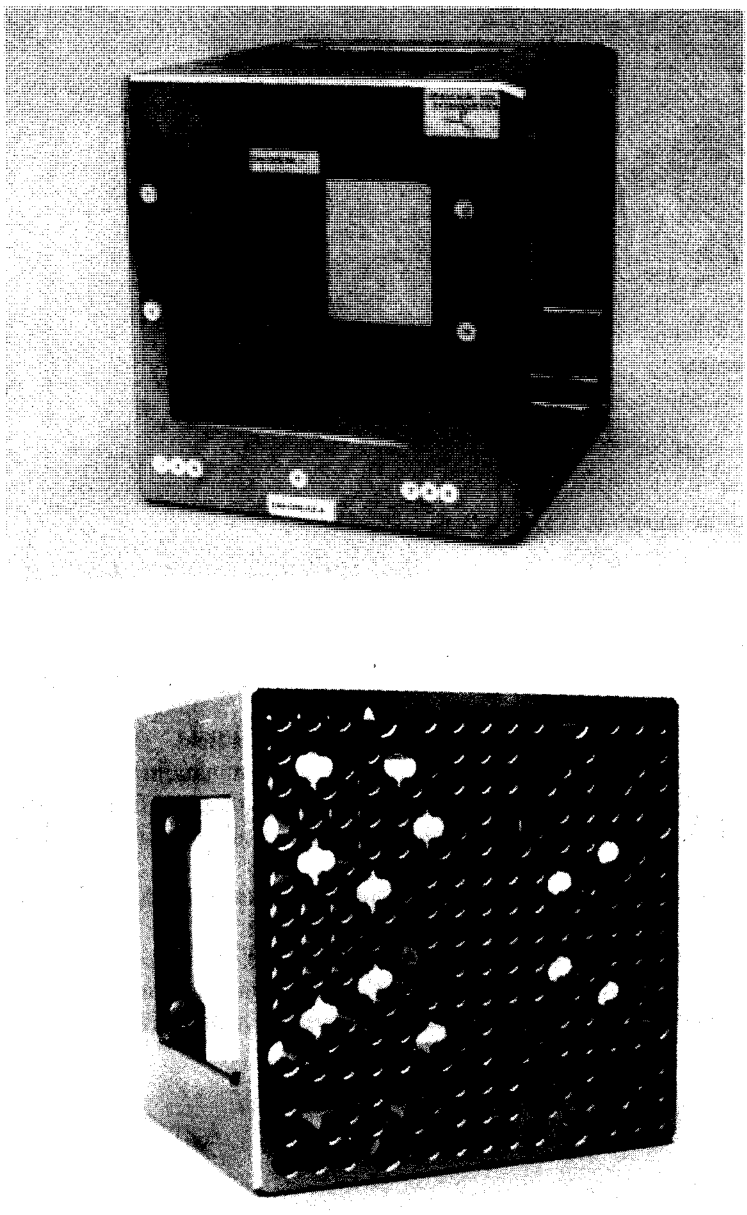
M-COAT A, MM-USA was the coating utilized the system for drilling the rosettes centre is an adaptation of the RS-200 Milling Guide MM-USA.

A Hi-Speed accessory was utilized during the drilling, Running freely, Hi-Speed turbine turns at hundreds of thousands of revolutions per minute and, an special carbide cutter was utilized.

The Nozzle and cutter were cooled with special oil during the drilling of the hole,.

The measurements were done with microvoltimeter Fluke (1 μV of resolution).

The procedure used for testing was ASTM-E 837-89.



Figures 2a, 2b - Selected Points

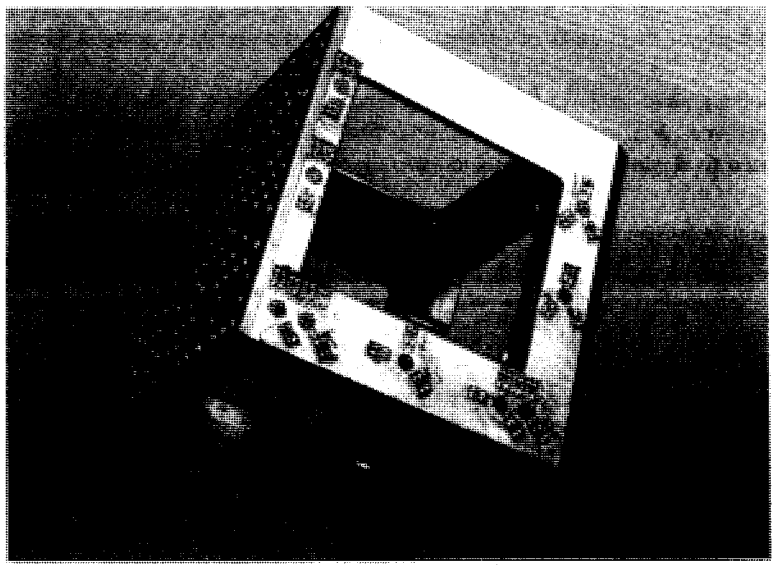


Figure 3 - Installed rosettes

5 RESULTS

The results of the tests are shown in next diagrams.

6 CONCLUSIONS

The results show that residual stresses presents in the Nozzle are not uniform, but can be considered as Equivalent Uniform Stress.

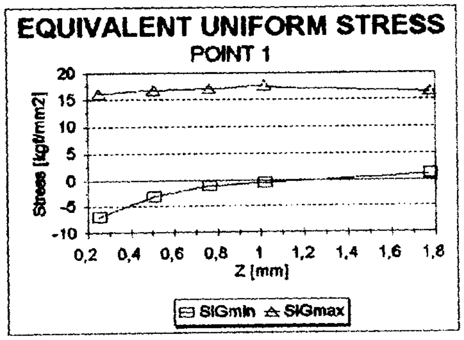
Some points (1, 2 e 7) present stress fields near the uniform stress field.

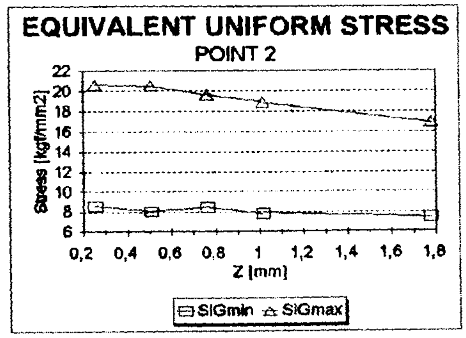
The maximum stress are in the bottom plate and top piece; the minimum stress are in the corner piece. The points 3, 10 and 12 presents stresses higher than the field strength of the material in the uniaxial stress field. The test was repeated and, similar stress were found.

Probably, those high stresses were due to the hardening of the material during griding of the components.

Another important remark is that around 50% of the depth of the hole at the each rosette, for many points on the bottom plate, the residual stresses tend to a same value.

The same remark can also be done for the top frame, corner piece and weld.


EQUIVALENT UNIFORM STRESS
POINT 1
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax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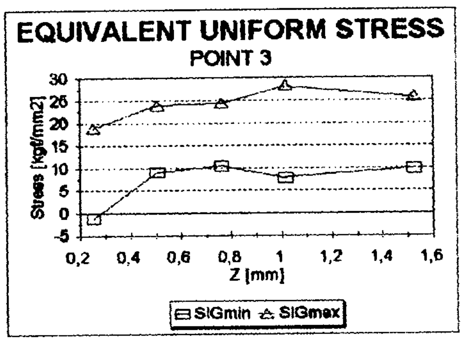
POINT 2
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax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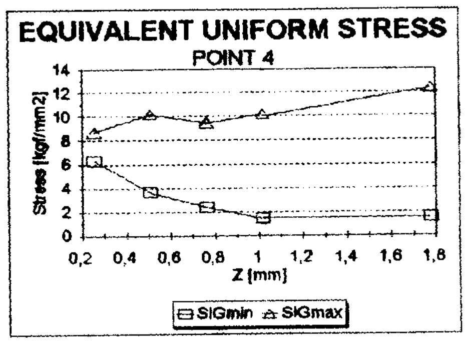
POINT 3
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax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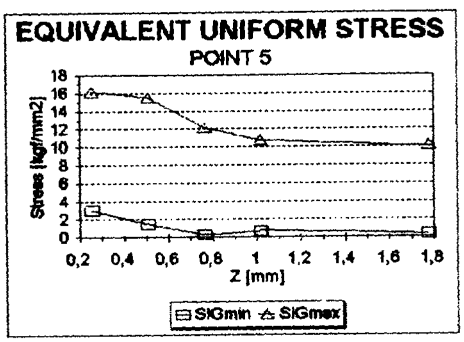
POINT 4
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax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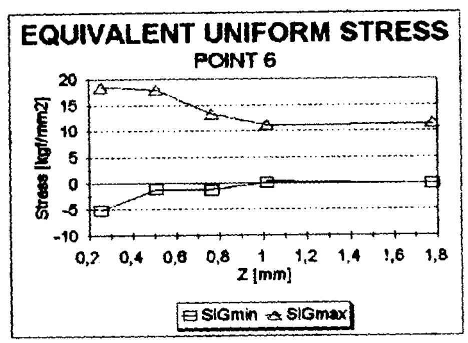
POINT 5
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax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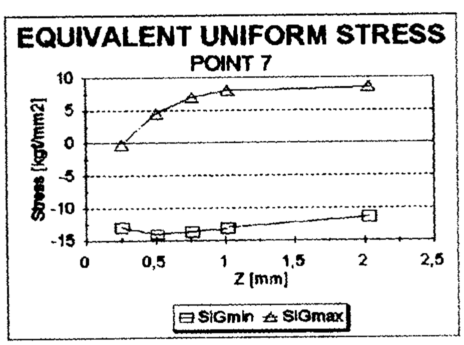
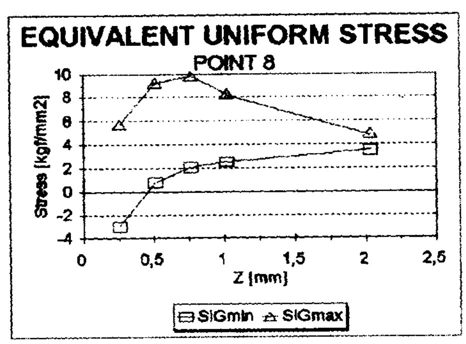
POINT 6
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax


EQUIVALENT UNIFORM STRESS
POINT 7
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax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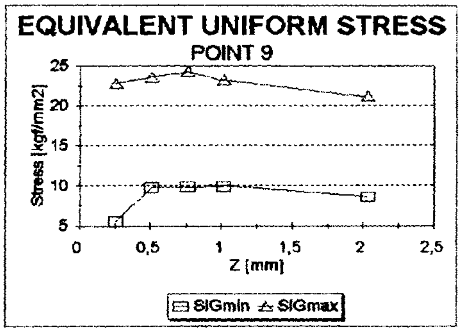
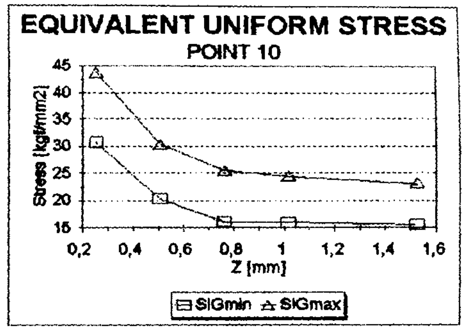
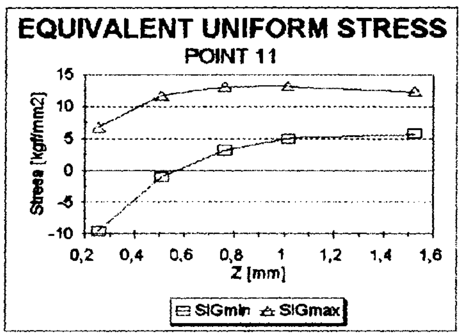
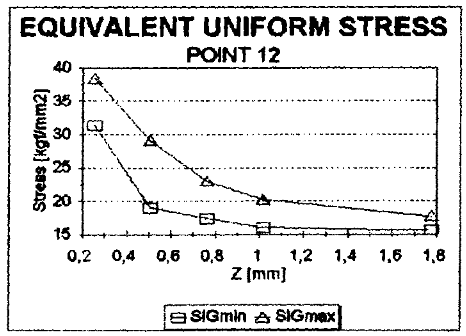
POINT 8
Stress [kgf/mm2]
Z [mm]
SIGmin SIGmax









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