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LAMBDA TECHNOLOGIES

DIFFRACTION NOTES 5521 Fair Lane, Cincinnati, OH 45227 (513) 561-0883 No. 35 Spring 2009

INCREMENTAL RING-CORE DETERMINATION OF THE PRINCIPAL RESIDUAL STRESS IN A DUPLEX STAINLESS STEEL CENTRIFUGE

INTRODUCTION

Large separator centrifuges are widely used in the production of corn oil, cornstarch, and starch derivatives found in many household products including bread, toothpaste, diapers, and filters. A photo of a large centrifuge is shown in Figure 1. Centrifuges are used to efficiently separate the lighter corn germ from a slurry mix at extremely high centrifugal forces. Components in contact with the slurry mix are made of high-grade stainless steel.

Figure 1: Photo of centrifuge system manufactured by Fluid-Quip.

At the heart of the centrifuge system is the centrifuge bowl that contains nozzles allowing the solids to pass through for proper corn germ separation. Figure 2 shows a schematic of the centrifuge assembly, manufactured by Fluid-Quip, with the bowl shown in red. The centrifuge bowl is manufactured from Ferralium 255 duplex stainless steel, a material specifically designed for enhanced chemical corrosion resistance.

ANNOUNCEMENTS

WEBSITE

We are continuously updating our website. Please stop by to see the many changes and new and exciting things that Lambda has to offer, as well as all of our historical publications at www.lambdatechs.com.

UPCOMING CONFERENCES

Lambda Research will be presenting results from a recently completed research program at NACE Corrosion 2009 Conference being held in Atlanta, GA on March 22-26, 2009. Mr. Jeremy Scheel will be presenting his technical paper, "Mitigation and Prevention of Stress Corrosion Cracking via Low Plasticity Burnishing," on Monday March 23, 2009 at the Research In Progress Session II. Mr. Scheel's presentation details the use of designed compressive residual stresses, imparted via LPB, for complete mitigation of stress corrosion cracking in 300M steel landing gear material and 304SS weldments. To read the full abstract, or for more information about the NACE Corrosion conference, please visit our website at http://www.lambdatechs.com/news/events.html.

FATIGUE DESIGN DIAGRAM (FDD) CODE COMPLETED

Lambda has recently completed an SBIR funded program to develop software that greatly enhances the design of residual stresses. The FDD code is an adaptation of the existing software developed by Lambda to allow the calculation of the required residual stresses based upon a finite element model of the applied mean and alternating stresses. The software provides a graphical interface providing an interactive design tool that allows the designer to adjust the desired fatigue strength and assess the results in real time. For more information see our website or contact Dr. Jayaraman at njayaraman@lambdatechs.com

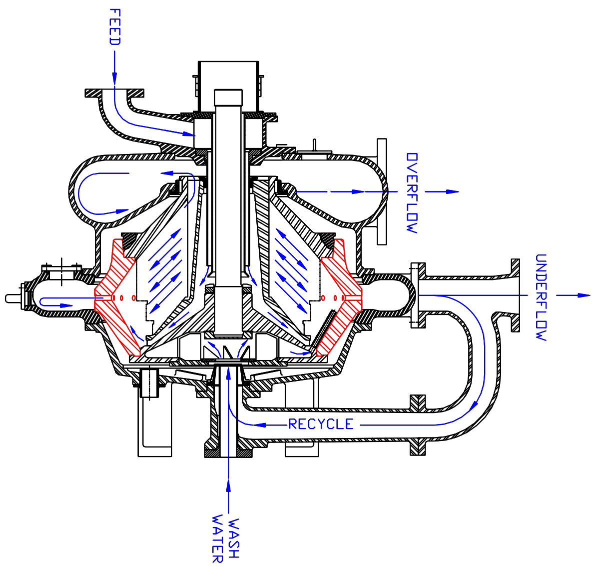

Figure 2: Schematic of internal components showing centrifuge bowl in red.

Duplex stainless steels are solution heat-treated followed by an immediate water quench. Complex residual stress distributions can form as a result of the high thermal gradients experienced during quenching. Quenching can often produce beneficial compressive residual stresses near the surface of the part. Likewise, tensile residual stresses may be present deep within the cross section to compensate for the near surface compression. The part geometry, and the orientation of the part as it is quenched, will impact the cooling rates and ultimately the residual stress field.

The ring core method was used to characterize the through thickness residual stresses of the centrifuge bowl. The ring core measurement method allows for accurate characterization of the deep residual stresses resulting from solution heat treat and quenching process.

RING CORE TECHNIQUE

The incremental ring-core method, also referred to as the trepan method, is a widely used mechanical residual stress measurement method. The ring core method, described in detail elsewhere (1-12), is often a more cost effective and efficient means of determining deep residual stresses in large castings, forgings, and weldments. It offers several advantages over other mechanical methods providing greater accuracy and more reliable data. The technique is based upon linear elastic theory and consists of dissecting a circular plug containing a strain gage as shown schematically in Figure 3. Electrical discharge machining (EDM) is used to machine the annular groove around the strain gage.

During the sectioning operation the residual strain in the part is relieved. The change in strain is monitored as a function of cut depth by an on-line computer. Lambda has two ring core measurement systems. One larger system is used for testing of components at Lambda's facility. The second system is a portable device that allows measurement of larger components at the customer's facility. The method provides a comprehensive assessment of the resolved and principal residual stress field as a function of depth. The ring-core technique can be used on metals, ceramics, and polymers, where linear elastic theory can be assumed.

RING-CORE (TREPANNING) METHOD

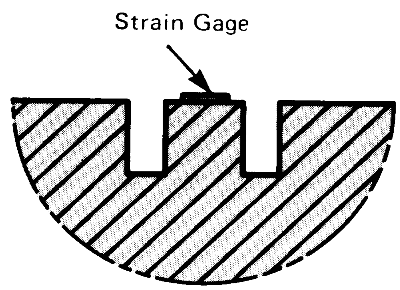

Figure 3: Schematic of ring core test

APPLICATION OF RING CORE METHOD ON CENTRIFUGE BOWL

Ring core residual stress measurements were made on the duplex stainless steel centrifuge bowl to characterize the through-thickness residual stress distribution. Measurements were made as a function of depth from the outside diameter of the bowl. The bowl was fully machined with exception to the nozzle holes. In order to allow for the bowl to be used for production purposes, the ring core measurements were made in the material to be machined for the nozzle holes. After ring core tests, the nozzle holes were finish machined to provide a fully functional production ready centrifuge bowl.

Figures 4 and 5 show the centrifuge bowl under test. Figure 4 shows the automated ring coring system during test. Figure 5 shows a close up of the EDM electrode. The nozzle holes were predrilled to various depths allowing for ring core residual stress measurements through the entire centrifuge bowl wall. Strain gages were placed at the bottom of the predrilled holes and subsequently ring cored.

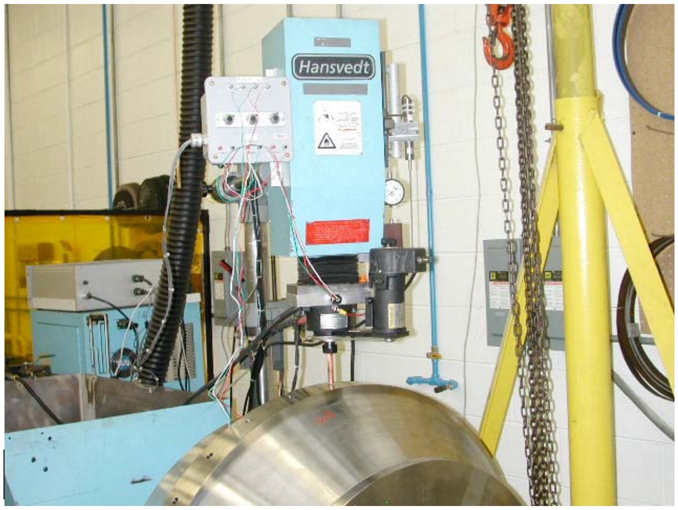

Figure 4: Ring core residual stress measurement set-up of centrifuge bowl.

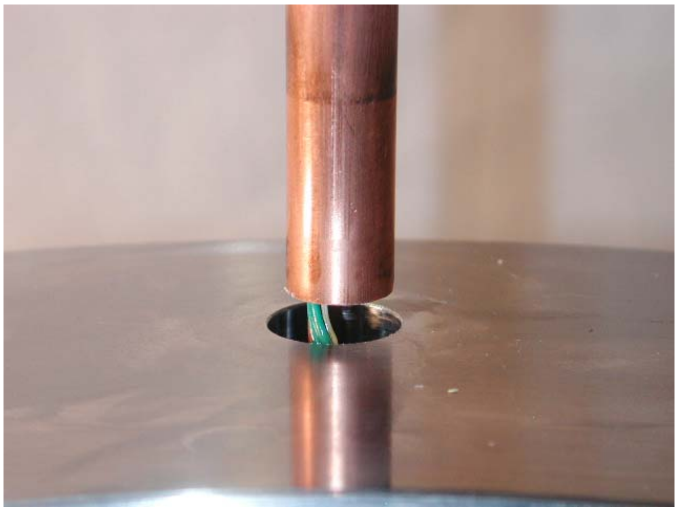

Figure 5: Close up of EDM electrode.

Residual stresses measured by ring core are shown in Figure 6. Results are shown in the circumferential, 45 deg. and axial directions as a function of depth from the outside diameter of the bowl.

Ring core measurements reveal high compression on the outside diameter of the bowl. The depth of compression is on the order of 1.0 in. (25 mm). Peak compression of approximately –50 ksi (-345 MPa) was measured. The compression is highest in the circumferential direction. Peak tensile residual stresses are located in the core of the bowl cross section. The tensile residual stresses reach a maximum value of nominally +25 ksi (+172 MPa).

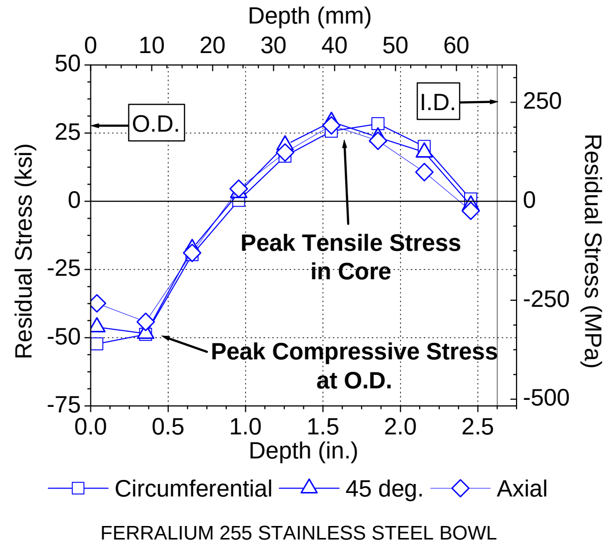

Figure 6: Ring core residual stress distribution through the wall of the centrifuge bowl showing high o.d. compression and tension in the core as a result of heat-treat and quench process

Lambda is currently conducting a finite element analysis of the bowl to determine the applied stress resulting from centrifugal forces and internal pressures. The applied stresses will be added to the residual stresses measured by ring core to characterize the total stress state of the bowl.

CONCLUSIONS

- Ring core was successfully used to characterize the deep residual stresses introduced by heat treatment and quenching process of the duplex stainless steel centrifuge bowl.
- Heat treat and quenching produces a deep compressive residual stress on the outside diameter of the bowl.
- Tensile compensatory stresses were measured near the center of the bowl cross-section and reached a value on the order of +25 ksi (+172 MPa).
- Residual stresses measured are consistent with those expected for a heat treat and quenching process.

ACKNOWLEDGEMENT

Lambda would like to thank Dave Buck and Andrew Franko from Fluid-Quip for all of their contributions and support in this program.

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