FABRICATION OF AN ULTRA SMOOTH LINER FOR RANCHERO

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Abstract

Recent calculations indicate that Atlas liners must have waviness amplitudes less than 10 nm over spatial wavelengths near 1 cm [1]. A liner for Ranchero has been produced, on equipment at LANL, with waviness amplitudes as close to 10 nm as was possible. A lathe, with air bearing slideways and spindle, was used in concert with a single crystal diamond tool to produce this part. Since the dimensional characterization of this liner can be as challenging as the production, on-machine gauging techniques were used for much of the dimensional inspection. This paper discusses the fabrication and metrology of this ultra smooth liner.

I. INTRODUCTION

Liners used to drive Pegasus experiments for the Los Alamos High Energy Density Hydrodynamics (HEDH) Program have typically been fabricated from 1100 series Al using carbide insert tooling on either an air bearing spindle lathe or conventional bearing high precision spindle lathes [2]. Surface finish has typically been 10 nm rms and waviness normally has not been characterized. The Los Alamos Precision Automated Turning System (PATS), a unique air bearing spindle lathe, was proposed as a high precision and high speed liner manufacturing resource to produce liners for the Atlas pulse power facility under construction at Los Alamos prior to the most recent calculations of Atlas liner requirements. The PATS was recently evaluated for that application and was found to be deficient in some key attributes [3]. That led to an evaluation of an alternate air bearing spindle lathe that was used to fabricate the liner that is the subject of this paper. The Ranchero explosively driven generator is planned to drive a series of liner experiments leading to a simulation of the Atlas waveform prior to completion of the Atlas facility. The liner described here, and shown in Figure 1, was used in these experiments [4].

Figure 1 – Photograph of finished Ranchero Liner.

II. RANCHERO LINER FABRICATION

The first use of the Ranchero Liner type was in a conservative, slow liner experiment to verify issues of fuses, powerflow channel and diagnostic trigger timing that did not require a highly finished liner. The liner that is described here is the second usage of the general design and was fabricated to be a high performance liner.

The machine used to do the final machining was an ultraprecision lathe called a MSG 325 built by Pnuemo Corporation (currently called Precitech located in Keene, NH). This lathe is depicted in Figure 2 in the Liner measurement mode. Features of the machine include air bearing translation axis (X and Z) and an air bearing spindle. Encoders attached to the lead screws are used to determine the location of the X and Z axes. The positioning resolution in this configuration is 25 nm. The tooling was arranged so that both the inside and the outside of the Liner could be fabricated without removing the Liner from the spindle. Single crystal diamond cutting tools were used to do the final machining which provided a very smooth surface finish.

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14. ABSTRACT
Recent calculations indicate that Atlas liners must have waviness amplitudes less than 10 nm over spatial wavelengths near 1 cm [11. A liner for Rancher0 has been produced, on equipment at LANL, with waviness amplitudes as close to 10 nm as was possible. A lathe, with air bearing slideways and spindle, was used in concert with a single crystal diamond tool to produce this part. Since the dimensional characterization of this liner can be as challenging as the production, on-machine gauging techniques were used for much of the dimensional inspection. This paper discusses the fabrication and metrology of this ultra smooth liner.

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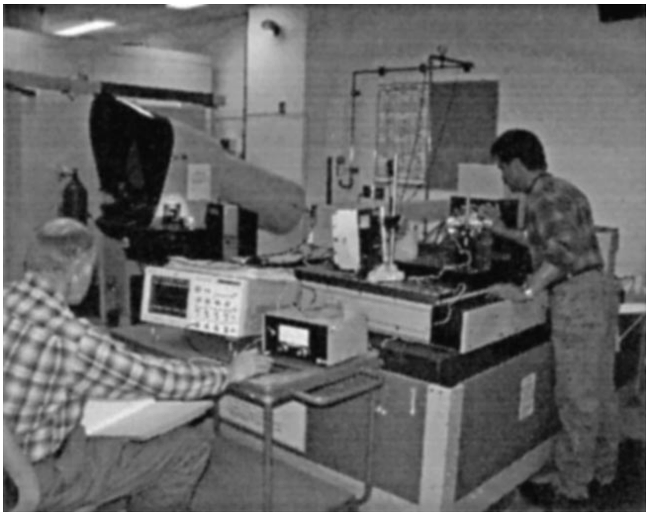

Figure 2 – Photograph of ultraprecision lathe in the Liner measuring configuration.

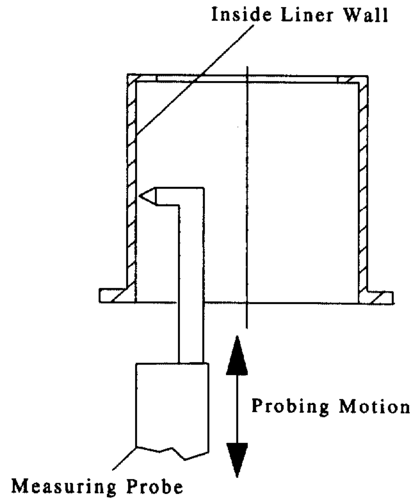

Figure 3 – Schematic of wall waviness measurement.

III. LINER METROLOGY

After the Liner was fabricated, its critical dimensions were measured on the machine to assure that the most accurate dimensional data would be acquired. The attributes of on-machine inspection that give it the high accuracy are: the part is aligned to the spindle as well as is possible, the ultraprecision lathe's geometrical errors are very small, and it is very easy to subtract systematic errors from the data. The three critical dimensional measurements that were made on the lathe were inner and outer wall waviness, and the wall thickness measurement.

A. Waviness Measurements

A schematic representation of the technique used to make the waviness measurements on the Liner is shown in Figure 3. The measuring probe for making these measurements consisted of a Linear Variable Differential Transformer (LVDT). The LVDT's distance resolution was approximately 1 nm. The waviness measurement was made by using the ultraprecision lathe to traverse the LVDT along the inner wall of the Liner. The voltage changes (which corresponded to distance changes) were recorded with the Hewlett-Packard storage oscilloscope shown in Figure 2. The distance vs. voltage calibration of the LVDT was performed with the ultraprecise lathe. A photograph of the wall waviness measurement being made on the inner wall is shown in Figure 4. The inner wall's waviness data is shown in Figure 5. The outer wall's waviness measurement was made in a similar fashion. A plot of this data is shown in Figure 6.

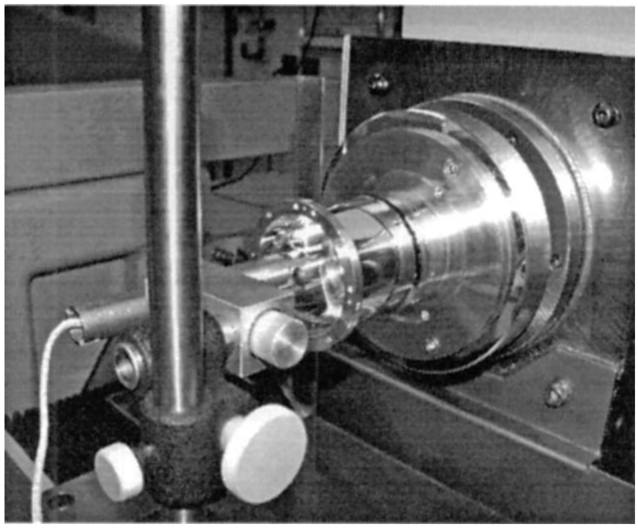

Figure 4 – Photograph of Liner as its inner wall waviness is being measured.

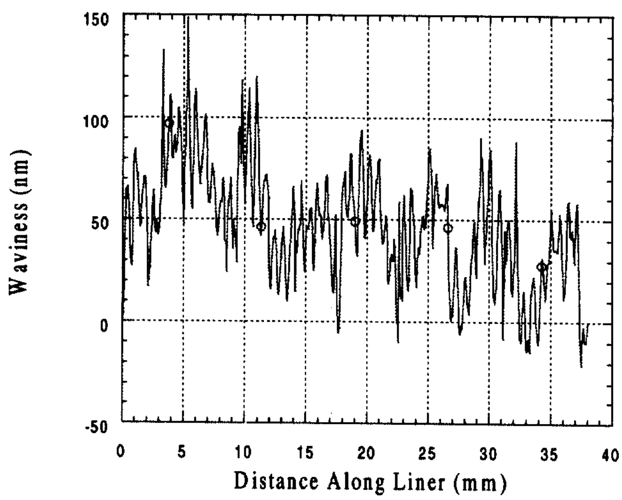

Figure 5 – Plot of Waviness vs. Distance along the inside wall of the Ranchero Liner.

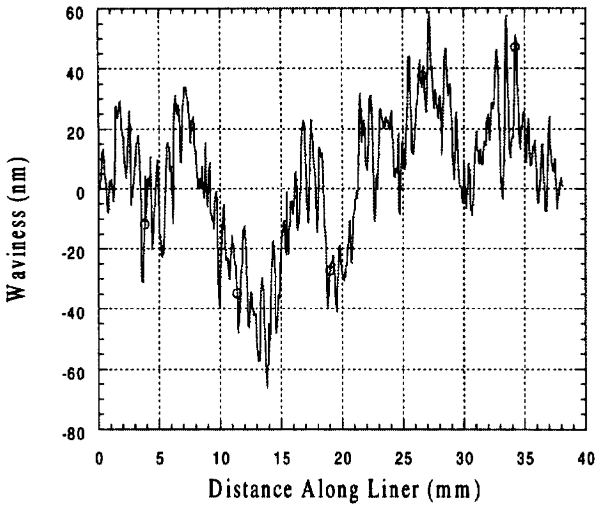

Figure 6 – Waviness vs. Distance along the outside wall of the Ranchero Liner.

Calculations [1] have shown that waviness on the outer wall with a peak-to-valley amplitude of 20 nm with a wavelength of 1cm will cause the Liner to become unstable during an implosion. An examination of Figure 6 shows that between 10 and 20 mm the amplitude is 80 nm; this is about four times as large as that required according to the calculations. Future experiments using the Ranchero generator should determine if the calculations are accurately predicting the instability growth. If the calculations are correct, different machine technology will need to be used to produce liners of sufficient quality. Fortunately, great strides have been made in recent years in the commercialization of three technologies that may provide enough machine accuracy to enable the liners to be built. These technologies are: hydrostatic bearings, linear motors, and very high resolution glass scales. Lathes using the combination of these technologies are just beginning to become commercially available.

Hydrostatic bearings use a pressurized oil film to provide a very straight, smooth, and easily controlled motion [5]. In addition to these features they are extremely stiff and, since the moving components do not come into contact with each other, these bearings do not wear. All of these advantages make these bearings excellent candidates for a building block to be used in a liner fabrication machine.

Linear motors are brushless DC servo motors that operate exactly as rotary motors except, as the name implies, the moving portion of the motor moves linearly as opposed to rotating. Some advantages of these motors, from a precision motion control viewpoint, are that there are no contacting elements, there is no mechanical hysteresis, and the force generated transverse to the direction of motion can be made to be very small. These attributes allow linear motion to be controlled very accurately and very smoothly.

When using linear motors to position a carriage the acceleration, velocity, and position information is provided by some type of encoder. Finer motion control is provided by finer encoder resolution. Scale resolutions are becoming increasingly finer and scales with a resolution of 0.15 nm are comercially available [6]. Another advantage of having high resolution encoders is that they may provide a way to correct any straightness errors inherent in the machine.

These emerging technologies allow those responsible for producing liners with extremely demanding dimensional requirements to have an optimistic view of what can be made in the near future.

B. Wall Thickness Measurement

An accurate Liner wall thickness measurement is very important since the timing of many of the high speed diagnostics are dependent upon its value. The Ranchero Liner had not been moved since the time it was machined; therefore, it was inherently centered with respect to the spindle's centerline. Before making the wall thickness measurement, the location of the measuring probe's position relative to the spindle axis must be determined. A schematic showing how this measurement was made is shown in Figure 7.

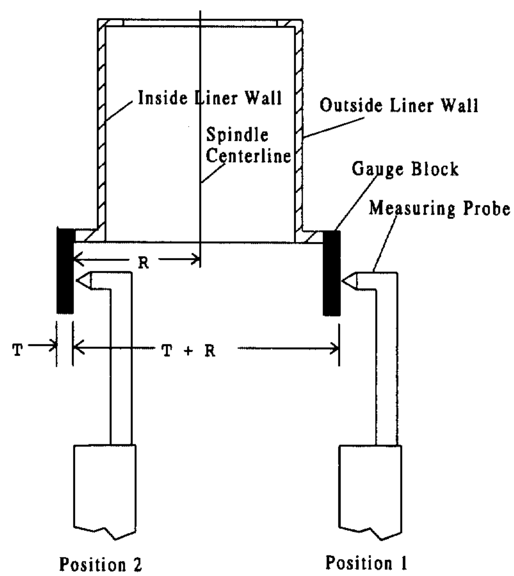

Figure 7 – Schematic showing how the absolute position of the measuring relative to the spindle axis was determined.

To determine the absolute location of the measuring probe relative to the spindle centerline, a gauge block of known thickness (T) is attached to a non-critical diameter of the Liner. The lathe moves the measuring probe, until it touches the gauge block at position 1 (see Figure 7). After recording the machine coordinates at position 1, the Liner is rotated 180 degrees about the spindle centerline until the gauge block is in position 2. The lathe moves the measuring probe until it touches the gauge block at position 2. The machine coordinates are recorded at position 2. The distance traveled from position 1 to position 2, (T + R), is determined by subtracting the machine coordinates at position 1 from those at position 2. Since the gauge block thickness, T, is known and T + R is known, a simple subtraction gives the radius, R, at position 2. By knowing this absolute radius, the wall thickness of the Liner can easily be measured by touching the inner and outer wall radii and subtracting the machine coordinates at these positions from each other. The accuracy of this measurement is about 0.5 micrometer.

IV. SUMMARY

On-machine gauging techniques worked very well for characterizing the Ranchero Liner that was produced on the MSG 325 ultraprecision lathe. Even though the quality of the liner was excellent by most standards, there were regions along the outer wall where the peak-to-valley waviness amplitude was about 80 nm over the 1 cm wavelength. This exceeds the 20 nm criterion that has been established by the theoretical calculations. Emerging lathe building technologies such as hydrostatic bearings, linear motors, and scales with sub nanometer resolution, are being commercially developed which may enable future liners to be fabricated that will exceed these demanding dimensional requirements.

V. REFERENCES

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