Title
A UNIVERSAL 10 x 20 INCH MEASURING MICROSCOPE FOR LBL METROLOGY

Author
Hodges, James.

Publication Date
1980-08-01

UC-37
LBID-293 c.1

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Engineering & Technical Services Division

For Reference

Not to be taken from this room

DISCLAIMER

LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA

ENGINEERING NOTE

CODE	SERIAL	PAGE
AA0501	M5567	1 of 6

AUTHOR	DEPARTMENT	LOCATION	DATE
JAMES HODGES	MECHANICAL	BERKELEY	AUGUST 27, 1980

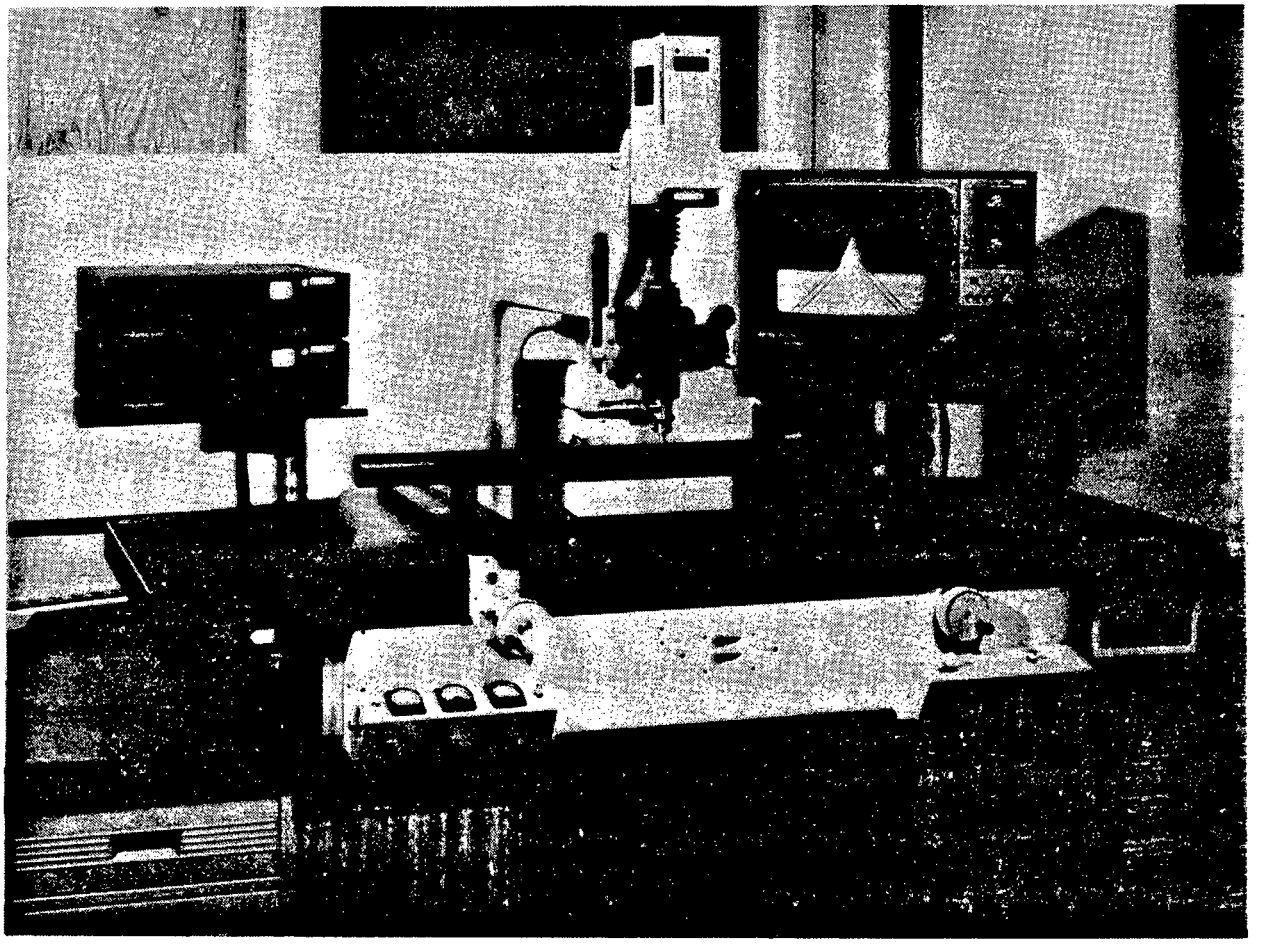
PROGRAM — PROJECT — JOB

MECHANICAL TECHNOLOGY: MICRO DEVELOPMENT GROUP

OPTICAL INSTRUMENTATION AND TOOLING

TITLE

A UNIVERSAL 10 x 20 INCH MEASURING MICROSCOPE FOR LBL METROLOGY



Universal 10 x 20-inch Measuring Microscope. Displayed on the TV screen is one of 880 radial "V" grooves machined in the 36-inch long cylindrical workpiece. Groove-to-groove spacing was measured to 0.0002" accuracy for all grooves on 14 similar bars.

INTRODUCTION:

The 10 x 20-inch measuring microscope replaces a well-worn "Brower" machine which for 18 years was the mainstay of our Bldg. 25 Dimensional Metrology Services. The new microscope's measuring stage follows a design fully tested on instruments our group built for NASA, LASL and others. Everything else has been custom-tailored to meet highly diversified measuring needs at LBL. Facilities are included for handling nearly every item in the long list of jobs we were forced to turn down due to limitations of the Brower's optics, measuring accuracy, or workpiece capacity. The result is probably the world's largest "universal" measuring microscope.

LAWRENCE BERKELEY LABORATORY • UNIVERSITY OF CALIFORNIA

ENGINEERING NOTE

CODE	SERIAL	PAGE
AA0501	M5567	2 OF 6

AUTHOR	DEPARTMENT	LOCATION	DATE
JAMES HODGES	MECHANICAL	BERKELEY	AUGUST 27, 1980

This report outlines the microscope's basic measuring capabilities. Some special features of interest to experimenters and support groups with out-of-the-ordinary measuring needs are discussed. A brief evaluation of the microscope's first months in operation is made.

SPECIFICATIONS & FEATURES:

A. Specimen or Workpiece Capacity:

The microscope is designed to accept and measure workpieces much larger than its 10-inch x 20-inch stage travels. Specimens having a straight reference edge, reference lines, or benchmarks can be moved and accurately realigned for continuing measurements(1). Maximum workpiece parameters are:

Length 70 inches (limited by room wall) Height: 18 inches

Width: 40 inches (measurable to center) Weight: up to 100 lbs.

B. Measuring Stage Specifications:

1. Longitudinal (X-axis) travel: 20-1/4 inches (514 mm)
2. Cross (Y-axis) travel: 10-1/4 inches (260 mm)
3. X-axis measuring accuracy +/- 0.0001 inch over full 20 inches travel
4. Y-axis measuring accuracy +/- 0.0002 inch over full 10 inches travel
5. Max. X-stage departure from a true straight line: 0.0001 inch.
6. Y travel perpendicular to X travel: within 8 seconds of arc(2).
7. Repeatability of settings, either axis: +/- 0.00005-inch.
8. Blacklash, either axis: Max. of 0.0001-inch difference in readout when same setting point on 25-lb. workpiece approached from either direction.

---

(1) For workpieces lacking suitable re-aligning marks, a diamond-stylus ruling deviced is attached just behind the microscope objective lens. Benchmarks too fine to be seen with the unaided eye, but ideal for magnified crosshair settings, can be ruled at exact intervals on the workpiece and used for realignment and as measuring pickup points after the extra-long workpiece has been shifted.

(2) The Y-axis way system shows evidence of curvature. This slightly reduces accuracy of measurements along the Y axis and more significantly affects coodinate measuring routines. At 8 arc-seconds orthogonality error, an X-coordinate setting can shift as much as 0.0004-inch as one moves through 10 inches of Y travel. This error can be reduced by at least a factor of two, once down-time is available.

C. Measuring Stage Features:

1. The large stage table has an 11" x 21" clear opening for illumination from below (transmitted) over full X-Y travels. A thick plate-glass insert normally fills the opening. For high-resolution microscopy, this glass is exchanged for holders taking 1 mm-thick glass in sizes from microscope slides to 11" x 15" nuclear emulsion plates, or the latest 4" x 20" spectrographic plates.

2. Fine-pitch lead screws provide both the measuring increments and the smooth, positive feel essential to precise handwheel positioning. Rotary encoders attached to the screws send X and Y stage-position data to digital displays with selectable 0.0001-inch or 0.001 mm least-unit resolution.

3. Motor drives clutch automatically to X and Y lead screws via joystick speed-direction controls. Drives are used for back-and-forth slews in workpiece alignment, for moving rapidly between widely separated measuring points, and for slow, continuous scanning for defects in PC artwork, etc.

D. Overarm and focusing Units:

1. The massive right-angle overarm suspends some 25 lbs. of optics and peripherals 20 inches outboard from the rear of the microscope. A motor drive quickly elevates the overarm as needed to accommodate workpieces of various thicknesses up to 18 inches..

2. Two focusing assemblies interface the overarm to the microscope optics and TV camera. The first is a precision roller-slide assembly with 5 inches travel. It is controlled by a 1 mm-per-turn lead screw(1) and handwheel, giving a very efficient focusing ratio for low-and-medium-power optics. A Leitz fine-focus unit with a ratio of 0.1 mm per turn, provides exacting focus control for high-power optics.

---

(1) Plans are to fit this lead screw with an encoder and digital readout to realize 5 inches of precision Z-axis (vertical) measurement. This would be especially useful in conjunction with the electronic probe, noted in section "G" below.

E The Microscope's Optical System:

A measuring microscope is only as good as its optics. The operator must obtain a sharp, high-contrast image of the edge, feature detail, or reference mark he is bringing into coincidence with eyepiece or TV crosshairs if his setting precision(1) is to approach the basic accuracy of the measuring stage. The following optical features have been included to handle imaging requirements for the diverse array of opaque, translucent and transparent specimens submitted for measurement:

1. Transmitted Illumination:

   a. Standard tungsten microscope illuminator, thermally isolated.

   b. High-intensity monochromatic illuminator for fluorescence and interference microscopy.

   c. Focusable substage condenser mount with quick change bracket to take low and high aperture brightfield, darkfield, phase and interference contract condensers. Precise centering and focusing controls at front of microscope.

2. Overhead illumination:

   a. Leitz "Ultrapac" (peripheral darkfield illumination).

   b. Incident through-the-lens illuminator, brightfield, interference contrast.

   c. Oblique illuminators on adjustable goosenecks.

3. Illumination control panel: Operator can combine light in any intensity ratio from the above sources to minimize glare & shadowing.

4. Viewing head & oculars: A Leitz microscope trinocular head is used: binocular tubes inclined at 45 degrees for viewing, and a vertical tube for photographic unit or TV camera. Some 12 sets of eyepieces are at hand, fitted with fine-ruled reticles in configurations found most useful for setting on various-width lines & filaments, holes, gear and rack teeth, screw threads, crystal interfaces, etc.

5. Objective Lenses: Interchangeable objectives for the microscope include all types used on metalurgical and biological microscopes. Total magnification range available is 6X through 2500X.

---

(1) The operator determines "setting precision" by making a series of repeat settings on a typical measuring point of the specimen. Illumination, magnification, and reticle configurations can be interchanged and adjusted until the error spead from repeat settings is minimized.

F. The Closed-circuit TV System:

The Sony color TV camera and monitor do not quite attain the image quality seen through the eyepieces. Yet, for many applications, TV screen settings are advantageous:

1. Efficiency: Measuring time for long sequences such as the V-grooves of the workpiece shown in the photograph, is often reduced by as much as a factor of four.(1)
2. Convenience: The observer can be seated at any comfortable height. Spectacle wearers and persons unfamiliar with microscopes find the TV screen a welcome alternative.
3. Added capabilities: Measuring edge regions of specimens wider than 20" calls for either a makeshift eyetube extension or use of the TV screen. Photographs and video tape recordings can be taken from the screen image. Overlays with special crosshairs, sizing outlines, protractor markings, etc., can be applied directly to the monitor face.

G. Contact Probe Accessory:

Quick-interchange fixtures are at hand for mounting Federal "Electro probe" heads in place of the microscope objective. With approx. 5-grams contact pressure and sensitivities to 5-millionths-inch, these probes can be used as "null-setting crosshairs" in conjunction with stage and focus travels for measurements which would be difficult or impossible to carry out optically.(2)

FIRST EVALUATION:

Although some peripherals are just now being installed, the basic 10 x 20-inch machine was hurried into service six months ago for urgent TPC project measurements. As of July 1, accumulated hours in use included 410 on TPC and an additional 110 on unrelated LBL and LLL accounts. The microscope's usefulness for oversized workpieces has been well tested: much of the TPC Project time involved measurements on 30" x 40" glass photomasters and companion PC boards.

---

(1) The following factors are probably contributory: (a) the field-of-view seen on the TV screen is much smaller than that seen through standard widefield eyepieces, eliminating much distracting background clutter. (b) Contrast and color mixing controls can often be adjusted to make the setting point stand out dramatically. (c) When working without a recording assistant, it is definitely time saving not having to reposition one's head carefully at the eyepieces after each glance at the readout display and the writing tablet.

(2) Measurement of surface roughness, bore depths, height of steps, and other tasks involving the microscope's vertical or focusing axis, are best carried out by some technique which circumvents the eye's tendency to accommodate to slightly out-ot-focus settings.

LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA.
ENGINEERING NOTE

CODE	SERIAL	PAGE
AA0501	M5567	6 OF 6

AUTHOR	DEPARTMENT	LOCATION	DATE
JAMES HODGES	MECHANICAL	BERKELEY	AUGUST 27, 1980

Since the X-axis stage handles 90% of all routine measuring tasks, we are pleased that it continues to hold exceptional straightness and measuring accuracy. Much credit here goes to the Bldg. 77 Precision Shop for an ultra precise grinding job on the X-axis ways. Performance of the Y-axis stage, using commercially ground ways, is much less impressive.

Our endeavors to compensate for the microscope's unwieldy size by incorporating conveniently located handwheels, ample leg room, motor drive assists and TV display have evidently been successful. Many customers are opting to carry out their own measurements, and have put in as much as six hours' measuring time per day without voicing any physical discomfort. However, one suggestion has been offered by every user whose project called for numerous sequential measurements: A simple printout device for recording the positional date.

An item of more pressing concern for us is the upgrading of temperature control facilities for the measuring room. This not only would obviate the need for thermal expansion calculations when making close tolerance measurements, but would add to the overall stability of the microscope itself, with its many precisely-aligned components of steel bolted to aluminum substrates..

With the addition of temperature control facilities, and perhaps a printout device, the Universal 10 x 20-inch Measuring Microscope should have ample serviceability and versatility to meet dimensional measuring needs at LBL for years to come.

/nh

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720