GRAVITY PROBE PROGRAM

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Gravity Probe B Relativity Mission

GRAVITY PROBE B PROGRAM
PROCESS SPECIFICATION

SPHERICITY MEASUREMENTS PROCEDURE FOR GP-B ROTORS

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SPHERICITY MEASUREMENT PROCEDURE FOR GP-B ROTORS

General

The sphericity is measured during the process and at the end for a finished rotor. The measurements during the process are usually performed for four meridians and equator. The final measurements are performed on 17 planes for each sphere produced. These planes correspond to the 16 meridians and the equator.

The sphere is supported during the measurement by the three (3) small spheres, see Figure 1 The device permits lifting the sphere and rotating it about the horizontal (y) and vertical (z) axis. Rotation about the horizontal axis is indexed so that eight (8) clicks correspond to a 90 degrees rotation. For the rotation about the vertical axis, one has to count the teeth in the gear: 120 teeth corresponding to the full 360 degrees rotation.

Cleaning the Sphere

Before measuring the diameter the following procedure should be used to clean the sphere

1. Wash the sphere without rubbing, without rubbing, using deionized water.
2. Dry using lint-free paper (Kimwipes EX-L or Texwipe TX 4009).

If particles are observed on the sphere during measurement, they may be cleaned using a small piece of lint free paper (Kimwipes EX-L or Texwipe TX 4009) and either acetone or alcohol.

1. Lightly wet a small piece of lint free paper (Kimwipes EX-L or Texwipe TX 4009) with either alcohol or acetone.
2. Place paper under Talyrond stylus and use Talyrond instrument to move stylus around the sphere.

Calibration of Talyrond Roundness Measuring Instrument

Calibration of the Talyrond Roundness Measuring Instrument should be checked at regular intervals. The spindle error may be checked using the reversal technique or by comparing the measurements with a standard sphere supplied by Rank-Taylor-Hobson. The scale factor error may be checked by measuring the polished flat on a cylinder supplied by by Rank-Taylor-Hobson.

Five Plane (4 meridians+equator) Measurement

The five planes measurement gives a good idea about the progress of polishing. It is performed in the following way:

The program used for measurement is ROTORSAV invoked by RR. Bat. Use menu C for both several planes and 17 planes.

Procedure for the five planes (4 meridians+equator) measurement.

All of the following operations must be performed by using gloves when handling the sphere. Measurement is done using the Talyrond 73.

2.1) Assure the cleanliness of both the support and the sphere.
Move the stylus in the same way as it moves by motor drive so as to clear the access to the device.
(Important: the rotation of the Talyrond measuring head is in a right handed way with +z axis, with the z-axis up; opposite rotation would break the instrument). Unpack the sphere from the labeled container.

2.2) Load the sphere in the device lifting the plate, and sitting the sphere on the teflon tabs. Then slowly lower the sphere to the stable support of the three small spheres.

2.3) Measure one great circle. If the measurement is not satisfactory e.g. closure >.1 micro-inch or some lint on the sphere, repeat the measurement. The lint can be removed using wet paper tab or compressed gas. Be careful not to exert any excessive force on the sphere, including tangential force which could make the sphere slide on the hard legs, and damage the surface.

2.4) Lift the sphere with the plate and grab the sphere by the two mechanical cups. Lower the plate and rotate four (4) clicks (45°) in a right handed way around +y axis. Raise the plate and open the mechanical cups completely. Lower the sphere slowly to sit on the three (3) support spheres.

2.5) Measure another two great circles at 45° and 90° to the previous one, to complete four (4) meridians.

2.6) As in No. 4 but, after lifting sphere, rotate the plate using gears by 90°. (small gear rotates by 180° counterclockwise, the sphere rotates by 90° left hand mode around +z axis). Then grab the sphere and do the additional rotation as in No. 4, but 8 clicks (90°)

2.7) Measure the equator.

2.8) After obtaining satisfactory measurement, lift the sphere on the plate and remove it from the device carefully avoiding touching anything. For this operation, the stylus has to be on the opposite side of the sphere path for loading and unloading.

2.9) Put the sphere back in the box.

17 Plane Measurement

The 17 planes measurement has to be in particular sequence, so as to correspond to the sequence assumed in the program which is used for the analysis. The sequence used presently is the one given by Thorwald in the sketch. It is important not to skip or to add any positions.

Let's establish the laboratory right hand coordinate system with the sphere positioned at origin and +y axis pointing to the right. +x axis will be toward the operator and +z axis up. The sphere rotation for 0-16 consecutive positions is right handed with respect to the+y axis. In order to measure the equator, the sphere is rotated by 90° left handed around +z axis and then 90° right handed about +y axis. In this way the measurements cover the sphere as the meridians counting longitude west if the north pole is assumed originally in +y. The measurement number 16 is a sequence in opposite direction to 0 and should overlap with it. The equator is measured from 16 west. This sequence should correspond to the sequence in the SPHERE program. It was derived from T. Hooydonk's sketch, Figure 2.

Precautions: The most important is for the sphere to be as clean as possible. This is not easy as the wipes leave lint. Remember that we are trying to measure a fraction of micro inch, or say few nanometers. First, both the machine and the sphere are cleaned. The sphere has to be very carefully placed first on the raised plate with teflon pads and then slowly lowered to a firm position on three small spheres.

One can then perform coarse adjustment of the stylus position (if necessary) and first coarse and then fine centering. It is advised to perform the centering while the stylus is rotating. Otherwise, the film on which the spindle rotates will not have the same thickness and spurious centering will be

obtained. In order to do this properly, one has to learn the sense of rotation of a micrometer x and y screws in order to perform the correction. Once centered to better than 1 micro inch, one can perform the measurement using ROTORSAV computer program for the new Talyrond (and rotors1 program for the old).

The closure error indicated by the program is for y direction but the drift is also experienced in x direction. Moreover, the drift is in the form of small relaxation's for the mechanical components and in more continuous form for the electronics. Nevertheless, the closure error is good indicator and should be kept <0.1 micro inch.

The diamond stylus does not seem to leave any marks on the uncoated spheres. Nevertheless, it is possible to damage the sphere by improper handling or contaminated support spheres. Any sliding on the metal support spheres should be avoided.

Procedure for the 17 planes measurement.

Follow the same procedure as for the five plane measurement except that the rotations will be one (1) click, so 4) and 5) change to 16 rotations from 0 to 16, i.e. the circle 0 is measured twice.

For the measurements Talyrond is normally used at maximum sensitivity: 20,000 times amplification.

SS. Bat is used to invoke the new SPHERE program.

The menu appears and one has to do in sequence.

A - convert Talyrond

B - Calculate coefficients—(use max 16 coeffcients)

E - Produce topographical maps from coefficients.

Plot separately all, even, odd and L=2.

Complete measurement records are enclosed with documentation on each sphere. The computer measurement files on disk are also enclosed with documentation.

Each plot, see attached sample, includes the following details:
Sphere and measurement identification, date when performed, peak to valley value, seale and some other parameters.

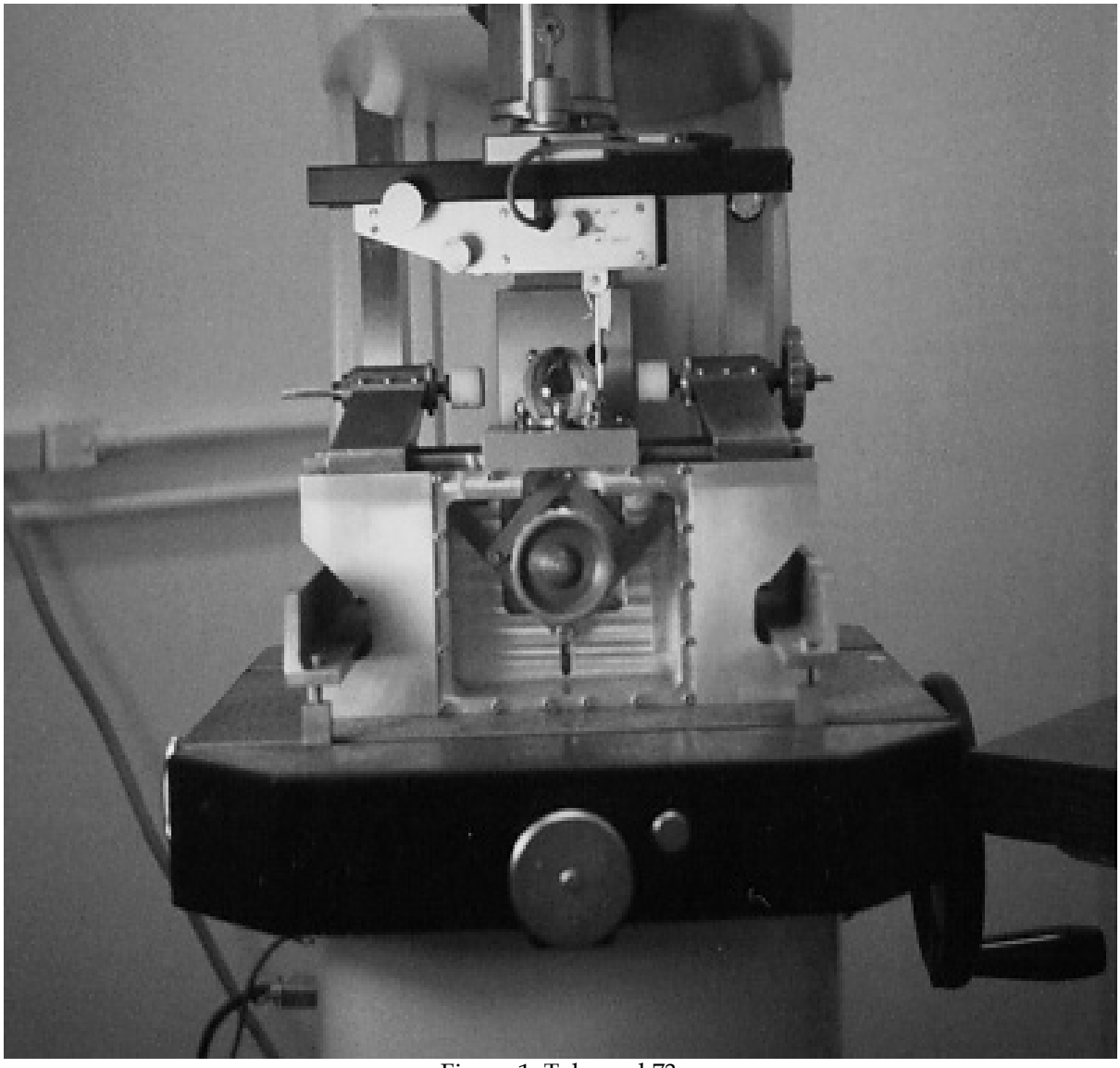

Figure 1 Talyrond 73

SEE HARD COPY FILE

for

Attachment I and II

Attachment I:
Talyrond Measurement of a Great Circle

Attachment II
Reconstruction of a Complete 17 Planes Measurement of a Sphere