High Volume Manufacturing of Large Segmented Telescope Mirrors
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INSTRUCTIONS
Currently there are two extremely large telescopes under design. The European Extremely Large Telescope (EELT) and the Thirty Meter Telescope (TMT). Both are based on large segmented mirrors. They are designed for observations from the near-ultraviolet to the mid-infrared. By design, these telescopes complement the scientific capabilities of the James Webb Space Telescope and Atacama Large Millimeter Array. These telescopes will require more than 1200 mirrors combined, which need to be machined from low CTE materials such as Zerodur.

FIGURE 1. Artist rendering of the TMT telescope

The manufacturing of these mirrors has to be carried out over a timeframe of 2-3 years. Even if they are carried out at several manufacturers they will require a very efficient polishing process.

Stress Mirror Polishing [SMP]
In order to achieve high removal rates and therefore fast convergence on these large mirrors small tool polishing is not fast enough in terms of throughput. Therefore a large tool process was developed based on the SMP process used in the machining of the Keck telescopes.

FIGURE 2. Stress Mirror Polishing (SMP)

SMP starts (a) with a plano or spherical form (curvature constant across the surface). A bending fixture applies forces and moments (b) in a controlled manner, causing the surface to assume the inverse of the form desired. The assumed form does not need to be axis symmetric, and in the case of TMT, none are axis symmetric. A large (nearly full size) tool efficiently removes material from the intended surface. Since volumetric removal rates are proportional to tool area, the method assumes most rapid finishing, provided that the final figure can be achieved. Once the mirror has been optically finished to the process goal while held in the bending fixture, it is released from the fixture and (d) will elastically assume the desired form. [1, 2]

Computerized Bending Fixture

FIGURE 3. Stress Mirror Polishing (SMP) Fixture
The segment must be supported in a manner that allows it to accurately flex to the desired shapes, both during polishing and relaxed (unloaded) for measurements. With 24 arms there are 48 force actuators, two on each lever arm [3]. The force actuators must be very accurate and reliable in a set-and-hold application. A motor driven screw compressing and extending a spring, with a load cell in series to sense the applied force.

**FIGURE 4. Stress Mirror Polishing (SMP) Fixture**

**Metrology**
The shape of the mirror is measured using a bar with 9-Heidenhain probes with a 4um grating period [4]. The bar is wound from carbon fiber in a neutral CTE configuration. 11 measurements at different azimuth positions are superposed and converted to a surface map

**FIGURE 5. Segment Sag Measurement Bar (Sag-Bar)**

**Results**
Surface shape errors of less than 0.9um over the 1.5m diameter mirror have been achieved for an EELT demonstration segment. Due to the use of a full size lap a very low surface micro-roughness of <8A can routinely be attained.

**REFERENCES**