Aluminum mirrors. Manufacture using polishing machine.

The purpose of this paper is to guide the manufacture of aluminum mirrors for astronomical use, through polishing machine.

I will consider that the mirror manufacturer has extensive experience in optical manufacturing and so I will only guide practical and objective topics.

**Most suitable aluminum alloy:**
The aluminum alloys of the 6XXX series proved to be great for mirror making.

**Polishing Machine:** The aluminum mirror polishing machine differs in some respects from the glass mirror machines. The machine must be sturdy (preferably all steel) with clear movements. It should also have the ease of changing the engine pulley, this to vary the speed, when necessary. It should have the ability for rapid arm movement (60 to 140 strokes, typical) and important: it should have a water pump and container. The turntable should rotate between 5 to 30 rpm. The machine should also have, if possible, a spring system to press the arm of the machine into the tool. This spring replaces the traditional weight.

**Compact Polishing Machine**
For aluminum mirrors up to 12 inches:
Requirement for optical polishing:
To be optically polished, aluminum must be constantly lubricated with a liquid chemical solution. This chemical solution aims to prevent the abrasive from sticking to the aluminum and also to prevent the natural and spontaneous oxidation formation on the reflective surface of the aluminum. The polishing mode will therefore be of type CMP. (chemical mechanical polishing)
Lubricating Composition:
300ml of water
5ml of liquid detergent
5ml citric acid
The liquid detergent should be sodium alkylbenzene sulfonate.
Citric acid may be used lemon juice
This solution should be constantly sprayed on the mirror and the tool through the water pump
The type of detergent is crucial for good lubrication. When in doubt, 5ml of hair shampoo may be used.
The polishing tool:
Aluminum has a quality optical polishing and also fast when using hard plastic tools.
Polypropylene tools provide very good optical polishing that can be proven by phase contrast (Lyot test)

Polypropylene tool.
Channels 2mm up to 5mm thick.
Squares 4mm up to 6mm side
The aluminum during polishing releases metal microparticles, so the traditional pitch lap is not good for polishing aluminum, as the metal microparticles accumulate and stick to the pitch. This causes micro holes and scratches in the mirror.

The plastic polisher does not have this problem, and can also be cleaned several times during work. However the plastic polisher has a deficiency:

It does not have the plasticity capacity equal to pitch.

To circumvent this problem, the plastic polisher must first be spherical in a concave mold, and also make minor touch-ups while working.

The initial spherization of the plastic tool, as well as the subsequent touches, should be done with 50 to 80 grit sandpaper. The sandpaper should be fixed on the concave mold. This mold will obviously have the same center of curvature of the mirror that we will polish.

**Mold for roughing the plastic tool.**

Left: Aluminum mold 200mm /1800mm center of curvature.
Right: Gypsum Mold 200mm /2400mm center of curvature

The aluminum mold was made in lathe and spherical cutting device. The plaster mold is homemade.

Both types work perfectly.
This is important as the surface of the plastic polisher should be slightly rough. For this reason, the sandpaper stuck in the mold is 50 to 80 grit.

**Polishing Agent:** Colloidal alumina and submicron calcined alumina have proven to be good for polishing.

**Working pressure on the tool:**
The aluminum mirror is best polished with the plastic tool when applying tool pressure in the range of **0.20 to 0.30 psi**.

**Polishing speed.**
The polishing speed on the stroke should be in the range of 100 to 200 stroke / minute.
Within this range aluminum is better polished, and also in less time.

**About the initial curve and grinding.**
Basically we have two ways to generate the initial spherical curve in the mirror:

- **Cnc lathe:** The curve is generated too close to the correct center of curvature. Well, that will depend on the accuracy of the CNC lathe.
- **Lathe with device:** The curve is generated with the aid of a device coupled to the lathe.

When we do not have the possibility of a cnc service and we do not have a device to attach to the lathe, there is a not ideal option, but it helps:

We can, with the aid of the standard lathe, make a conical cut, leaving the central depth of the mirror equal to the sagitta value.

In all three solutions, the curve must be ground with the aid of sandpaper glued over the tool. With the help of the polishing machine, we will make the correction of the curve. The machine should now be at low speed (60 stroke, typical).

In the case if the option was for a conical cut, the work will obviously be greater, because the conical cut removes only 70% of the material until we reach the desired curve.

Sandpaper stuck to the tool should be 80 grit.

After the initial grinding, finer sandpaper may be used until the scratch marks and holes left by the initial work are removed.

In the phase of working with fine sandpaper, the mirror begins to reflect and then we can make an evaluation with a 100lpi Ronchi grid to check the sphere.

If the mirror is spherical and without zonal defects, we can start the final polishing.

The final polish is made with submicron alumina dissolved in liquid detergent applied on the plastic tool. The water pump of the machine must always be spraying on the tool and mirror (water, detergent, citric acid). Examine the tool after 15 minutes to 30 minutes of work. After this time, clean the tool with water and detergent. Grind the tool into the concave spherical mold. Thoroughly clean the tool before returning to polishing. Plastic residue on the tool may scratch the mirror. Clean well with running water and a brush.

The lubricating solution (water, detergent, citric acid) should be changed after it gets dark and dirty.

Well, these are the basic instructions for learning how to make aluminum mirrors using a machine.
Any questions or suggestions, I am available.

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