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*Research Paper*

# CONDITIONING PARAMETERS FOR MAINTAINING PLATE FLATNESS PRIOR TO LAPPING

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Lapping is a process, generally performed on hard metal plate used in conjunction with abrasive suspensions such as diamond, silicon carbide, aluminum oxide or boron carbide, etc. Selection of the metal lapping plate depends upon the required material removal rate, the surface roughness required on the finished job, the type and hardness of the material being lapped and also on some extent on the skill of the worker for hand lapping. During the process, the material removal takes place from both, the workpiece and the lapping plate, which makes the lapping plate out of flatness and even the surface finish of the lapping plate is getting affected. So it is necessary to adopt a quick and simple method to measure plate flatness for measuring and monitoring the same. In this paper, different flatness error caused on the lapping plate because of the excessive wear, and the different conditioning parameters required to be observed, for maintaining plate flatness along with the different methods have been discussed.

Keywords: Lapping, Conditioning ring, Dial gauge, Flatness

## INTRODUCTION

Lapping is primarily considered to be a three-body abrasive mechanism due to the fact that it uses free abrasive grains that can roll or slide between the workpiece surface and the lapping plate, although some grains become embedded in the lap leading to two-body abrasion. Lapping is a loose abrasive machining process that combines abrasive particles within an oil or aqueous medium depending on the material being finished. Fine abrasive is applied, continuously or at specific intervals, to a work surface to form an abrasive film between the lapping plate and the parts to be lapped. Each abrasive grain used for lapping has sharp irregular shapes and when a relative motion is induced and pressure applied, the sharp edges of the grains are forced into the workpiece material. Each loose abrasive particle acts as a microscopic cutting

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tool that either makes an indentation or causes the material to cut away very small particles. Even though the abrasive grains are irregular in size and shape, they are used in large quantities and thus a cutting action takes place continuously over the entire surface in contact. The conditioning rings and the lapping plate are the most important parts of the lapping machine as they perform the functions of accommodating and rotating the workpiece during lapping, spreading the lapping medium to a thin film with uniformly distributing grit particles, eliminating the abraded materials either through the slots on the lapping plate or by the edge of the plate, dissipating the heat and guiding the conditioning rings and pressure plate. During process, constant material removal of both workpiece and plate material occurs simultaneously, resulting in a change in plate flatness over time. Workpiece quality is a direct result of plate condition, and therefore proper plate conditioning is important in manufacturing high quality workpiece. Plate conditioning is the process by which the lapping plate surface is machined in a controlled manner to re-create the original plate flatness.

## Characteristics of Lapping Plate

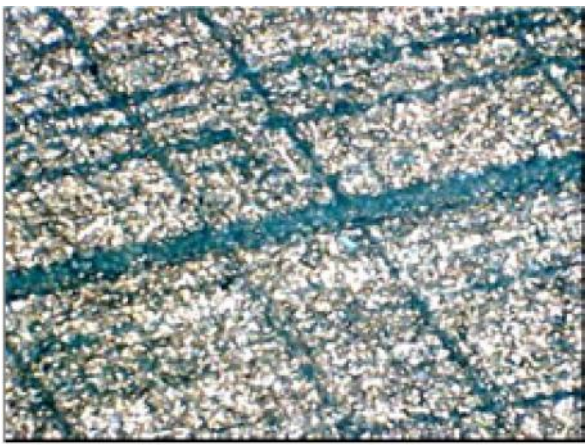
Most commonly used metals for composite plates are tin, copper and iron. The copper (Cu) composite plate is most commonly used to precisely lap and polish for achieving critical flatness and surface roughness requirements. Conversely, cast iron (Fe) plate processes are too aggressive, causing fracturing and chipping to the crystals. However, the wear in Cu plates is higher compare to other lapping plate which makes the same out of flat quickly. As a result, measuring plate flatness and conditioning of the Cu plate must be done at a regular interval. The Cu composite lapping plate is made with a unique blend of powdered metal combined in a resin matrix. This unique combination of materials offers several technological advantages over cast Fe lapping plates, which include reduced mechanical damage to brittle crystalline materials, superior surface finishing capabilities, greater uniformity of abrasive charge onto the lapping plate and ability to provide a semi-polished surface directly from the lapping process. A lapping plate hardness value between 140 HB to 220 HB gives the optimum results. The lapping plate are always manufactured to specific tolerances for achieving great accuracy and surface finish. The lapping plates are generally manufactured with plate flatness ranging from 2 µm to 3 µm and with a parallelism of 20 µm to 30 µm. Lapping plate can be graded into following four categories

- Soft Working Plate for example paper, cloth, plastic, wood, tin aluminum alloy, copper, etc.
- Hard working plate for example cast iron, mild steel, etc.
- Hardened Working Plates for example hardened cast iron, hardened steel, hard ceramic, etc.
- Multi-metal plates for example combination of different metals or sintered metal powder.

## Plate Conditioning Principles and Practice

During processing, constant removal of both specimen material and plate material occur simultaneously, resulting in a change in plate flatness over time. Specimen quality is a direct result of plate condition, and therefore proper plate conditioning is crucial in preparing high quality specimens. Plate conditioning is the process by which the lapping plate surface is machined away in a controlled manner to re-create the original plate flatness. A diamond plated conditioning ring is used to remove material from the lapping plate, resulting in a change to the surface flatness of the plate. Lapping plates conditioning usually takes place by means of a charging process in which submicron size diamond particles are embedded into the surface of tin alloy plates. Conditioning is performed by running diamond plated conditioning ring with lubricant to create "random groove pattern". Diamond-plated conditioning rings have the cutting diamond particles randomly bonded and oriented and at varying depths throughout the ring. The resulting texture is similar to cross-hatch pattern, as can be seen in Figure 1. As the ring wears, the texture will change over time. As the ring position changes, the plate curvature will change, too. This results in a variable plate texture and a process with large amount of operator attention and less consistency.

Figure 1: "Random Groove" Plate Texture by 60/80 Grit Diamond Plated Conditioning Ring at 50X Magnification



Over the course of the last two decades, "facing devices" have become available for maintaining plate flatness and conditioning lap plates as an improvement over the use of diamond plated conditioning rings. Facing device uses a PCD tool bit to shave off top layer of plate's surface in well controlled manner and to calibrated flatness. This process is much easier to control and reproduce, as there is no guesswork involved in how far inboard or outboard to position the conditioning ring to correct the worn plate. The facing system produces a spiral microgroove texture that serves as basis for structured embedding of diamond particles. The texture depends on tool bit radius, feed speed and rotation speed of the plate and can be adjusted to achieve best performance with sizes of diamond. Example of faced plate texture is shown in Figure 2.

## Flatness Errors

Because of the excessive wear due to the workpiece, following flatness errors can result

Figure 2: PLate Texture by Microgrooving (Facing) at 50X

**Concave Working Surface:** The concave error as shown in Figure 3, results because of too many workpieceses in the center of conditioning ring. The same error can be reduced by using template, not locating the parts at the center and by increasing intrinsic weight of the conditioning rings. The concave error may also be occurred if the pressure plate is not flat. The same can be remided by giving the pressure plate a slightly concave shape by lapping it on a convex lapping plate.

**Convex Working Surface:** The convex error as shown in Figure 4, is caused very rarely because of the excessive adjustment of the conditioning rings. This error occurs if the conditioning rings are located far out. The same may be avoided by placing the conditioning ring at the center, load several workpiece in the center and lap until the error is removed.

**Axial Runout in the Working Surface:** The axial runout error takes place as in Figure 5, if the lapping plate is having different hardness at different places or having the different microstructures. This may also happen because of the irregularities in the base plate as both are bolted together, and the distortion results because of the fluctuations in the temperatures of both the plates. This causes the longer machining time and poor surface finish on the workpiece. If the axial runout is too large, correction by using the conditioning ring will be difficult. The same error can be eliminated by providing the support layers and by using the larger size conditioning ring. If required, a special conditioning ring with half the diameter of the lapping plate should be used. If the error is too large, the same can be eliminated by turning on lathe machine.

Figure 3: Concave Working Surface

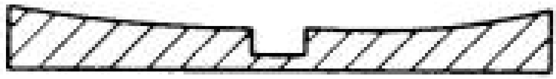


Figure 4: Convex Working Surface

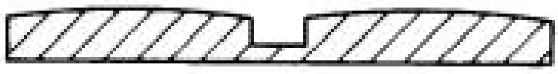
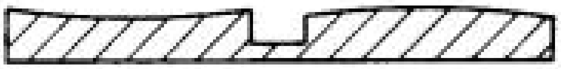


Figure 5: Axial Runout Working Surface



Conditioning of the lapping plate is affected by three primary parameters:

**Position of the Conditioning Ring:** The position of the conditioning ring has a drastic affect on the shape of the lapping plate. By proper positioning of the conditioning ring, one can bring a plate back into flatness if the plate has become ‘out of flat’. Often times the plate will resemble a wavy shape due to the positioning of lapping and polishing fixture inside the radius of the lapping plate. If the lapping plate has become concave in shape, then the conditioning ring should be adjusted to the outer diameter of the plate as shown in Figure 6. Positioning the conditioning ring on the outer diameter of the plate will cause the highest point of the plate to be lapped faster than the inner portion, creating a flat plate surface. If the plate shape is convex, the conditioning ring should be positioned on the inner portion of the plate as shown in Figure 7. By positioning the conditioning ring to the inner portion of the

Figure 6: Schematic Illustration of the Conditioning Process for Concave Shape Plate

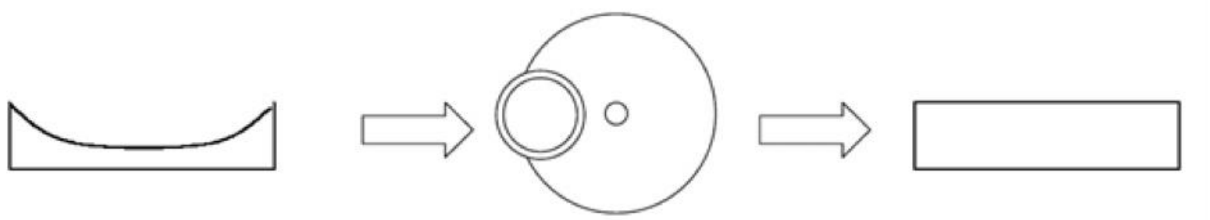



Figure 7: Schematic Illustration of the Conditioning Process for Convex Plate

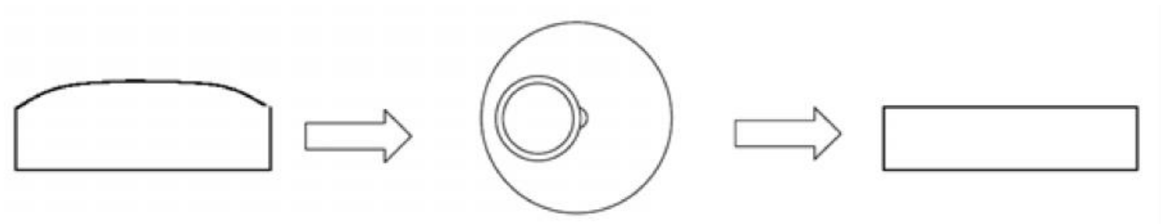



Figure 8: Schematic Illustration of the Conditioning Process for Runout or Wavy Plate

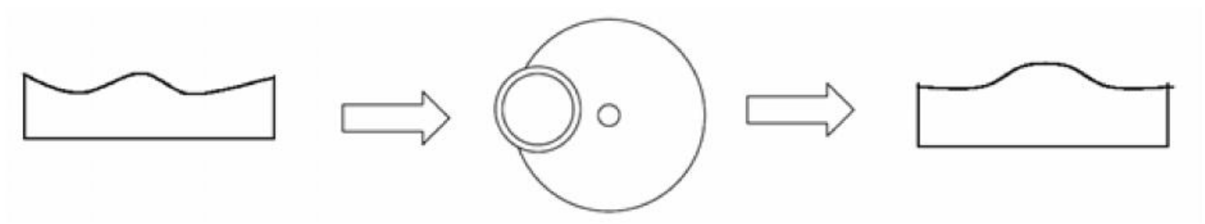
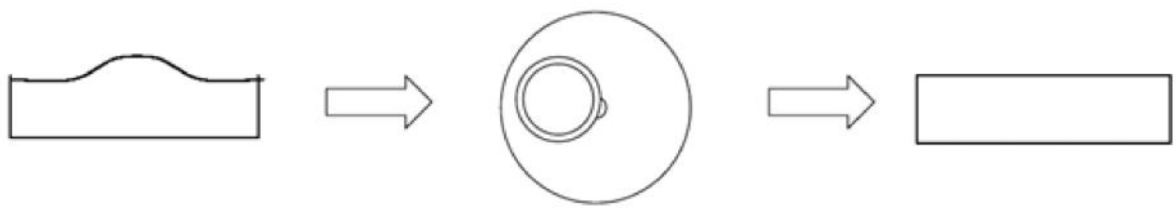



Figure 9: Schematic Illustration of the Conditioning Process for Runout or Wavy Plate




plate, make the region in the center to be lapped faster than the outer diameter, creating a flat plate surface. Figure 8, shows a plate with a wavy surface, wherein the initial conditioning is completed with the conditioning ring on the outer diameter of the plate. Once the outer portion of the plate has been lapped down, the conditioning ring is moved to the centre of the plate for flat lapping as shown in Figure 9.

**Weight of the Conditioning Ring:** If the lapping plate is heavily out of flatness (hundreds of microns), additional weight should be added to the conditioning ring, which increases loading force and also increase the material removal rate of the plate, reducing the processing time for conditioning. Precaution must be taken while machining, as the increase in load will increase material removal rate, which tend to cause rapid changes in shape of the plate.

**Polishing Machine Parameters:** Polishing machine parameters will also affect the conditioning process. In most cases, the workstation speed should approximately match the wheel speed. The advantage of using matching speed and complementary direction is a highly uniform removal across the plate surface by the diamond-conditioning ring.

## Plate Conditioning

Plate conditioning is a process by using which the lapping plate is machined to maintain the flatness of the lapping plate and to “pre-condition” the lapping plate surface with the abrasive being used for the lapping process. Plate conditioning plays a vital role in achieving the desired output as workpiece quality is a direct result of plate condition. Conditioning of the lapping plate is affected by three primary parameters position of the conditioning ring, weight of the conditioning ring, and abrasive size used for lapping. In this experiment, the process of the conditioning was studied for achieving the effective lapping plate flatness.

## Procedure

The lapping plate flatness was measured at six different points using the Flatness Dial Gauge. The gauge was first zeroed on a granite-leveling block to find the zero position as shown in Figure 10 and use that as a reference point from which to measure the plate. Plate measurements were taken and the plate was processed by inserting ceramic plate in conditioning ring, mediated by diamond abrasive paste of Grade 8 for rough cutting and faster removal of material and then by Grade 3, diamond abrasive paste for achieving a good surface finish and flatness, as shown in Table 1. Results are measured at six different measurement locations on lapping plate and plotted on a Graph1. Measurements were done after each conditioning step to illustrate the change in plate shape, as shown in Table 2 to 8. An illustration of the measurement technique is given below.

Figure 10: Flatness Dial Gauge


Table 1: Conditioning Parameters

| | |
|---|---|
| Lapping Plate Diameter | 356mm |
| Lapping Plate Material | Cast Iron |
| Internal Diameter of Conditioning Ring | 135 mm |
| Lapping Paste Used for Run 1, 2, 3 and 4 | Diamond Abrasive Paste of Grade 8 |
| Lapping Paste Used for Run 5 and 6 | Diamond Abrasive Paste of Grade 3 |

**Table 2: Initial Flatness of Lapping Plate (µm)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 5 | 5.5 | 5.5 | 4.5 | 5 | 4.5 |

**Table 3: Flatness of Lapping Plate After 20 Minutes Conditioning (Run 1)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 5 | 5 | 4.5 | 4.5 | 5 | 4.5 |

**Table 4: Flatness of Lapping Plate After 40 Minutes Conditioning (Run 2)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 4.5 | 4.5 | 4 | 4 | 4 | 4.5 |

**Table 5: Flatness of Lapping Plate After 60 Minutes Conditioning (Run 3)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 4 | 3.5 | 3.5 | 4 | 3.5 | 3.5 |

**Table 6: Flatness of Lapping Plate After 80 Minutes Conditioning (Run 4)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 4 | 3.5 | 3.5 | 4 | 3.5 | 3 |

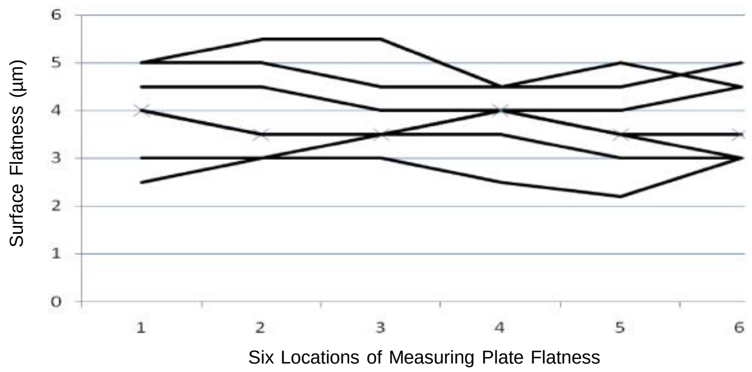
**Table 7: Flatness of Lapping Plate After 100 Minutes Conditioning (Run 5)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 3 | 3 | 3.5 | 3.5 | 3 | 3 |

**Table 8: Flatness of Lapping Plate After 120 Minutes Conditioning (Run 6)**

| Readings at Six Different Places on Lapping Plate | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Surface Flatness (µm) | 2.5 | 3 | 3 | 2.5 | 2.5 | 3 |

**Graph 1: Plate Flatness Profile of the Selected Sector of Lapping Plate**



## RESULTS

Surface roughness of a used cast iron lapping plate was measured. The plate was subsequently conditioned until the plate shape resulted in a relatively flat lapping plate, within the specified tolerances of the manufacturing process. The conditioning parameters is shown in Table 1 and progression of plate conditioning are shown in the Tables 2 to 8.

## CONCLUSION

Different flatness errors caused due to lapping and the different conditioning parameters required to be observed for removal of the same has been discussed. Further, it has been observed that, Plate Flatness Gauge has been proved to be very useful equipment to monitor the flatness of a given lapping plate, in keeping a plate within a specific tolerance level during lapping. The gauge is simple and easy to use, to determine possible errors in the flatness and used to control of precision lapping applications. With this simple technique it is easy to determine the shape of the lapping plate and the subsequent conditioning parameters required to make the lapping plate flat. During this study, it has been further observed that once lapping plate acquires an imperfect profile (convex, concave, etc.), correcting the same will take a long time. In this context, it is better if the machines are fitted with a device for rapid shape correction or the plate must be conditioned at regular interval.

## ACKNOWLEDGEMENT

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