Monitoring and Measuring Plate Flatness During Lapping

1.0: Purpose

Lapping and polishing processes are typically performed on a hard, metal plate used in conjunction with abrasive suspensions such as diamond, silicon carbide (SiC), aluminum oxide (Al_2O_3), or boron carbide (B_4C). The metal lapping plate selected depends upon the desired material removal rate, the surface finish desired, the hardness of the workpiece being lapped, and the flatness requirement. During the lapping process material is removed from both the workpiece and the lapping plate, which eventually can lead to a lapping plate that is out of flatness. Understanding the dynamics of plate wear and the tendencies a plate has with respect to flatness can be helpful in process monitoring and general instrument maintenance. This paper describes a measurement technique used for monitoring the plate flatness at various stages to understand the mechanisms behind plate wear.

2.0: Experiments and Procedures

2.1: Measurement Technique

Establishing a measurement technique to evaluate the surface of a cast iron lapping plate, Model LP 920M, was first developed. The lapping plate was placed onto a three point adjustable table on the top of a granite leveling plate. A digital depth gauge (DDG) with 0.001” resolution was used in conjunction with an analog dial gauge (ADG) with 0.0001” resolution. The gauge was used to measure the plate surface at the three contact points. Based upon these three points the plate could be adjusted so that it was parallel. The gauge was then used to measure various points on the lapping plate surface and the data points were plotted to show total variation in plate flatness. This setup is illustrated schematically in Figure 1 below.

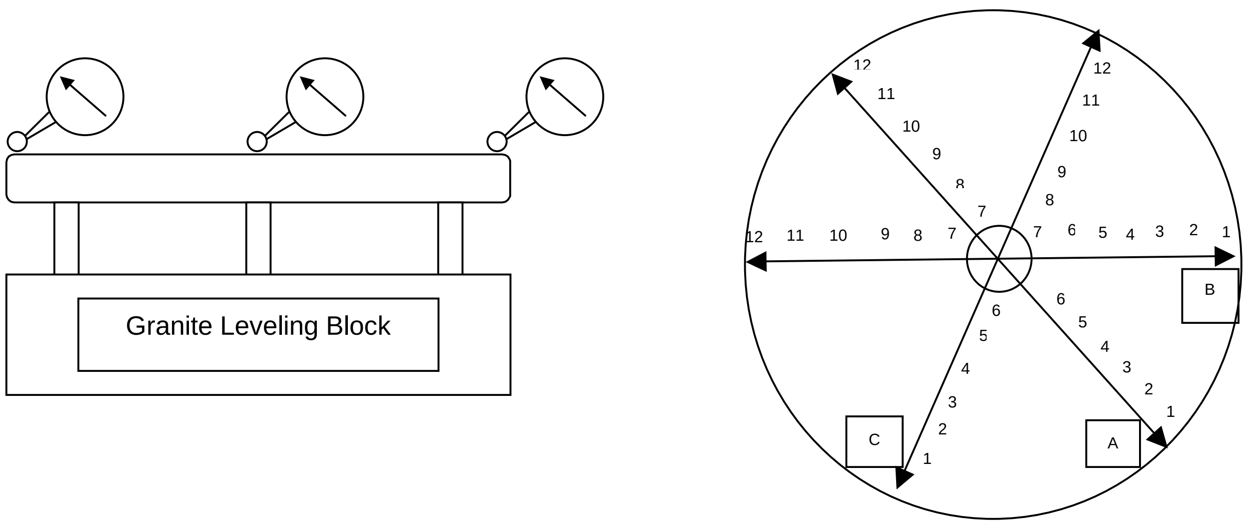

Figure 1: Schematic illustration of the technique used for measuring plate flatness. The plate is first made parallel on a granite leveling block using a dial gauge and three adjustment legs. After the plate is level, measurements are taken at various points on the surface of the lapping plate with the dial gauge. Each data point is then plotted to provide a surface plot illustrating the flatness of the plate after any given process.

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2.2: Lapping Plate Characteristics

The cast iron lapping plate (Model LP 920M) is manufactured to specific tolerances prior to use. Understanding this tolerance limit will help to demonstrate the effects that lapping have on the overall flatness and plate life during processing. The lapping plates are generally manufactured with the following plate specifications:

a. Plate Flatness: +/- 0.0001” (2.54 µm)
b. Plate Parallelism: +/- 0.001” (25.4 µm)

All of the cast iron lapping plates are manufactured to these tolerances. Using these as a guideline for measuring the flatness of the plates and to determine if they are within specifications helped during this test.

2.3: Plate Conditioning

Plate conditioning is a process by which the lapping plate surface 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 is important for lapping applications where flatness and parallelism of the specimen is critical. Specimen quality is a direct result of plate condition, and therefore proper maintenance of the lapping plate is crucial in preparing high quality specimens.

Conditioning of the lapping plate is affected by two primary parameters: a) position of the conditioning ring, and b) weight of the conditioning ring. In this experiment both the position and the weight of the conditioning ring was studied for effective plate conditioning. Understanding the mechanisms of plate conditioning will help in determining a process for effective lapping and polishing techniques.

Conditioning was done and the plate was measured after each conditioning setup. Two conditioning ring arrangements were used, both in various positions on the lapping plate depending upon the desired effect.

a. Plate conditioning using the standard conditioning ring (01-02221-01).
   Weight: 335 grams Inner Diameter: 3.25” Material: Stainless Stee
   Outer Diameter: 3.75” Thickness: 0.5”

b. Plate conditioning using a modified conditioning ring setup.
   Weight: 1815 grams Inner Diameter: 1.25” Material: Stainless Steel
   Outer Diameter: 3.25” Thickness: 2”

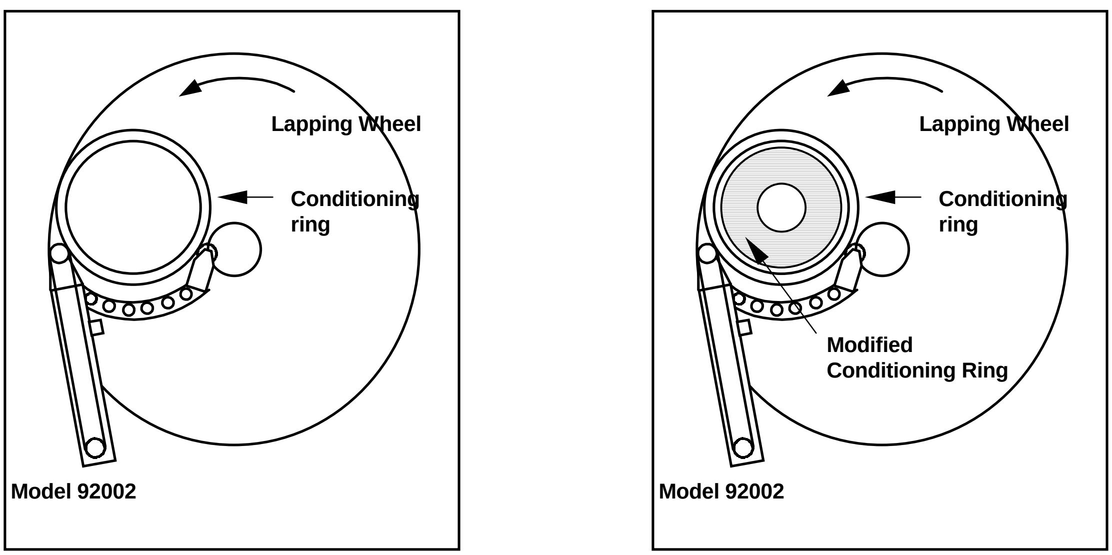


Figure 2: Illustration of the two conditioning arrangements. The left shows the ‘standard’ method of conditioning with the current conditioning ring design (01-02221-01). On the right is the modified conditioning arrangement where a large, heaving ring is placed in the center of the existing conditioning ring. Both arrangements were used at various locations on the lapping wheel.

2.3.1: Initial Plate Measurements

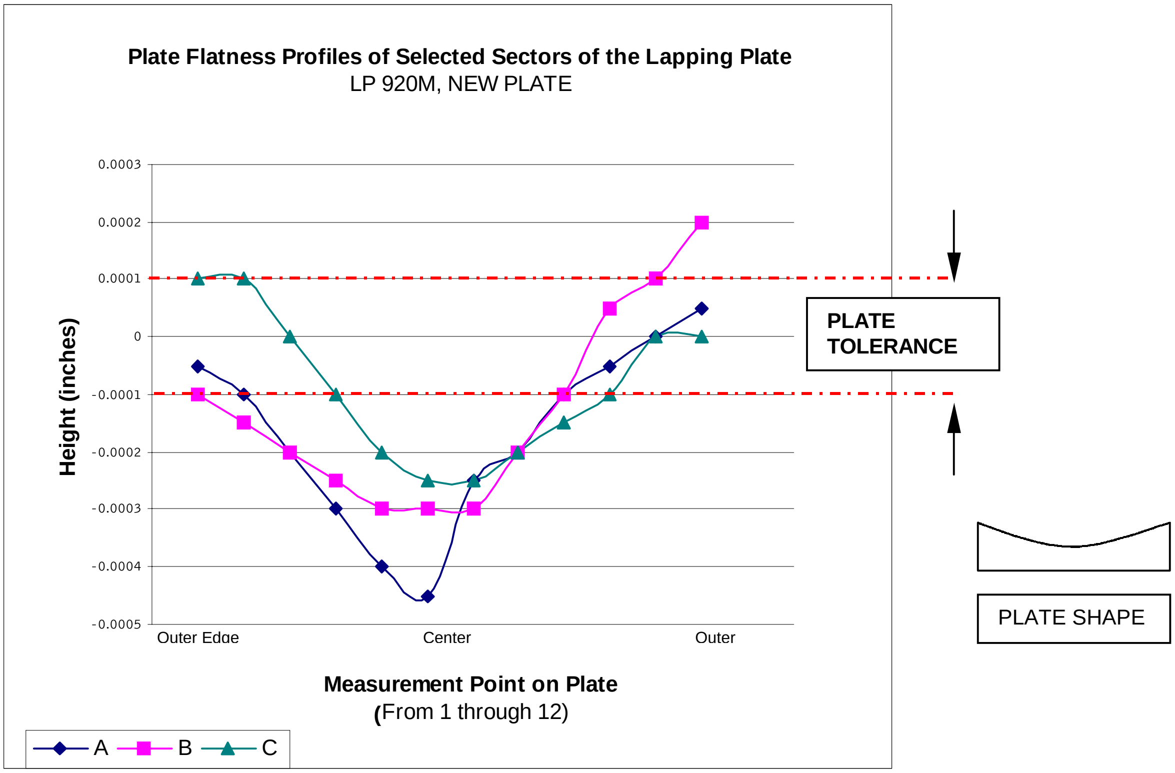


Figure 3: Plot of a new cast iron lapping plate prior to use. The plot shows three plotted series which represent the data series A, B, and C shown in Figure 1. From this plot you can see that the lapping plate is far from the tolerance specifications given for new lapping plates. The plate is dipped in the center, creating a concave plate shape.

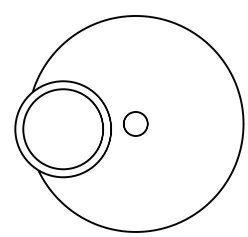
From the plot above it can be easily seen that the lapping plate started off being concave in shape, exhibiting a severe flatness issue with the existing plate. These plates must be within the specified plate tolerances, otherwise poor specimen quality and unflat specimens will result.

2.3.1: 'Standard' Plate Conditioning Process

Plate conditioning was done using the 'standard' conditioning ring arrangement. The following parameters were used for conditioning:

LAP SPEED: 2.5 (125 rpm)
ARM SPEED: 10
ABRASIVE: 23 µm BORON CARBIDE (B_4C)
LAPPING PLATE: LP 920M FLAT CAST Fe
CONDITIONING TIME: 30 MINUTES

CONDITIONING RING LOCATION



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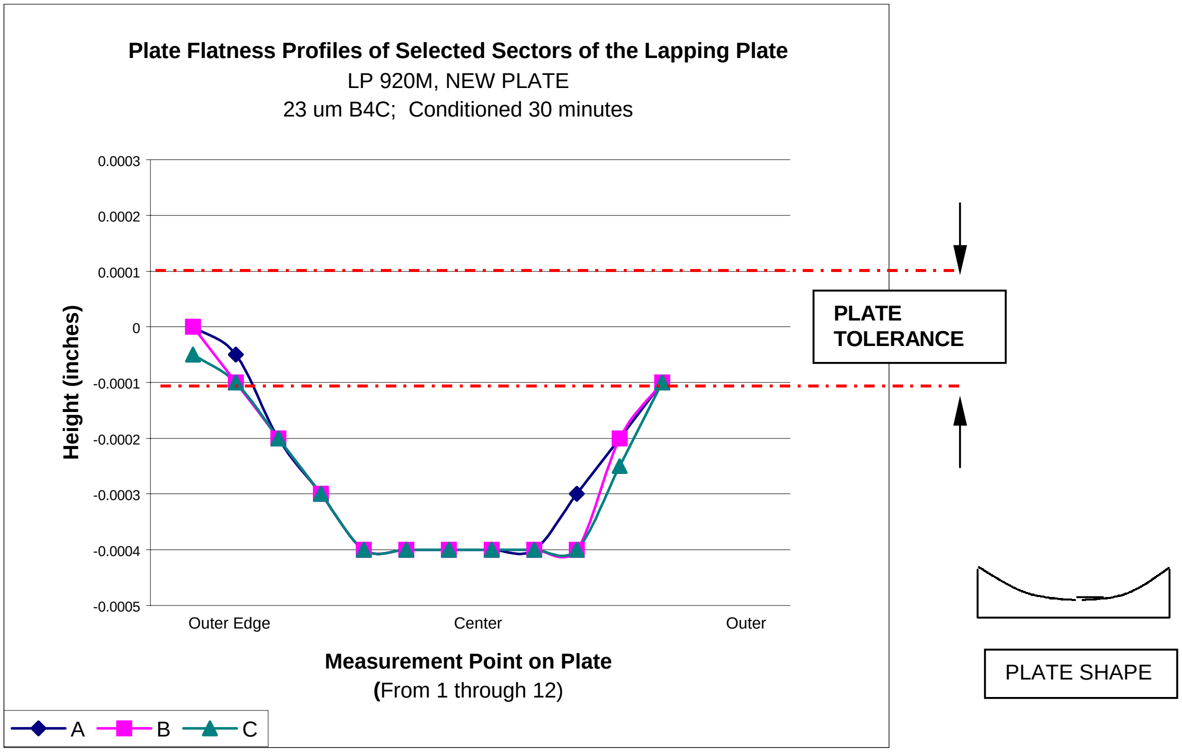


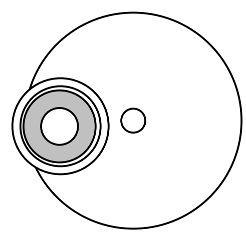
Figure 4: Plot of a new cast iron lapping plate following conditioning using the 'standard' conditioning ring method. As can be seen, the plate has flattened at the bottom, however no appreciable change in the plate shape can be observed. The plate still has a severe concave shape that will hinder proper specimen preparation.

2.3.2: ModifiedPlate Conditioning Process

Using a modified plate conditioning arrangement the lapping plate was conditioned for 30 minutes using the same parameters used in Section 2.3.1.

LAP SPEED: 2.5 (125 rpm)
ARM SPEED: 10
ABRASIVE: 23 µm BORON CARBIDE (B_4C)
LAPPING PLATE: LP 920M FLAT CAST Fe
CONDITIONING TIME: 32 MINUTES

CONDITIONING RING LOCATION



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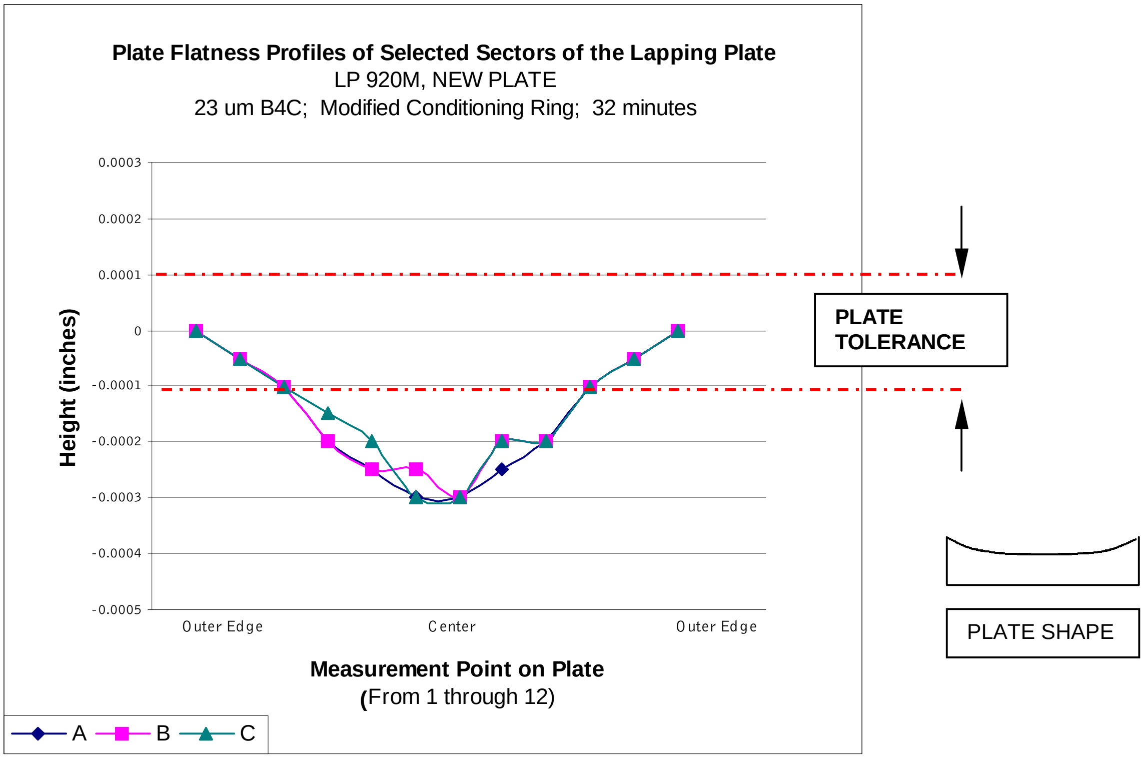
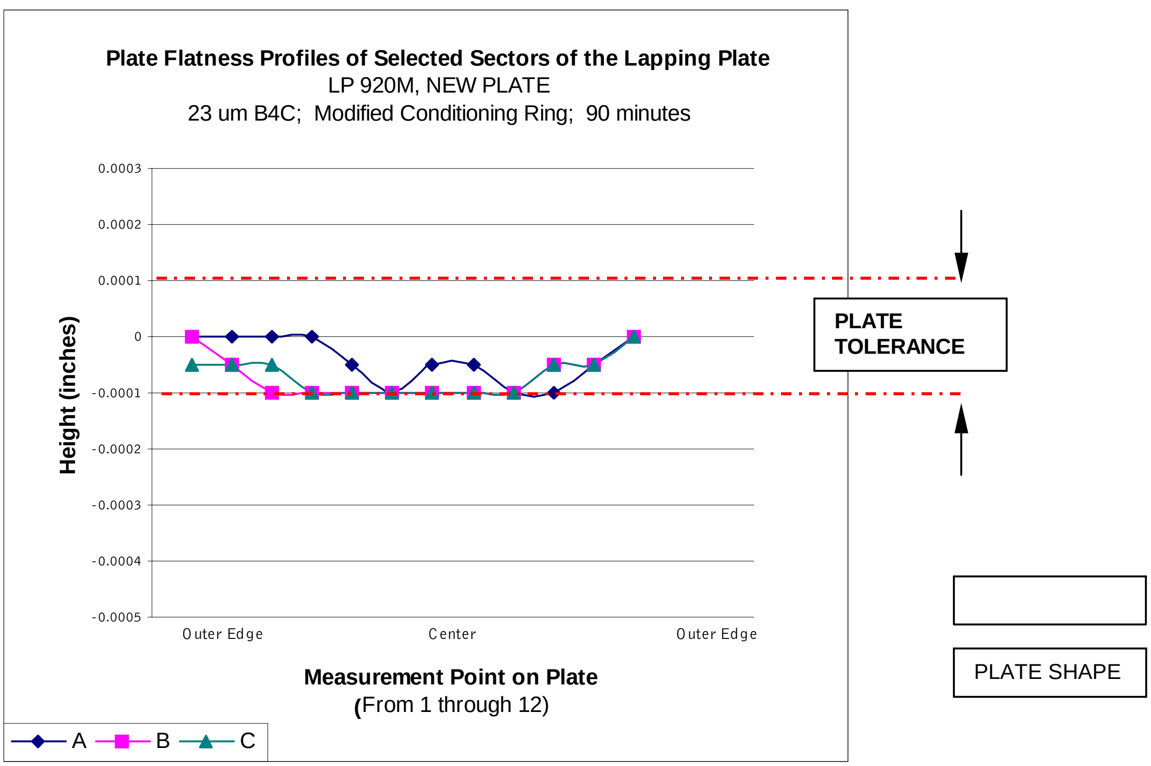


Figure 5,6: Plot of cast iron lapping plate following conditioning with the modified arrangement. As can be seen in Figure 5 (above) the lapping plate has become close to the tolerance limits specified in the manufacturing drawings of the plate, indicating conditioning using the modifed arrangement is much more effective in producing flat plates. In Figure 6 (below) the plate has been conditioned to be within the specifications of the lapping plate.



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3.0: Lapping Experiments

Once a flat lapping plate had been produced, the effects of lapping a specimen using a Model 155 Lapping and Polishing Fixture were examined to determine the rate of material removal on the cast iron lapping plate during specimen processing. Understanding how long specimens take to make the plate unflat will help in determining the proper amount of time before plate condtioning is required.

A Model 155 Lapping and Polishing Fixture was set up with a series of glass/Si/glass sandwhich samples for lapping. A total of four specimens were mounted for vertical edge polishing, with each specimen assembly approximately 10mm in thickness. Lapping was completed in 40 minutes using a 23 µm boron carbide abrasive slurry. The load selected for lapping was 300 grams and the lap speed and arm speed were 2 and 10, respectively. Below is a schematic illustration of the lapping fixture position on the lapping plate (A), the plot of the surface (B), and the resulting plate surface after lapping was completed (C).

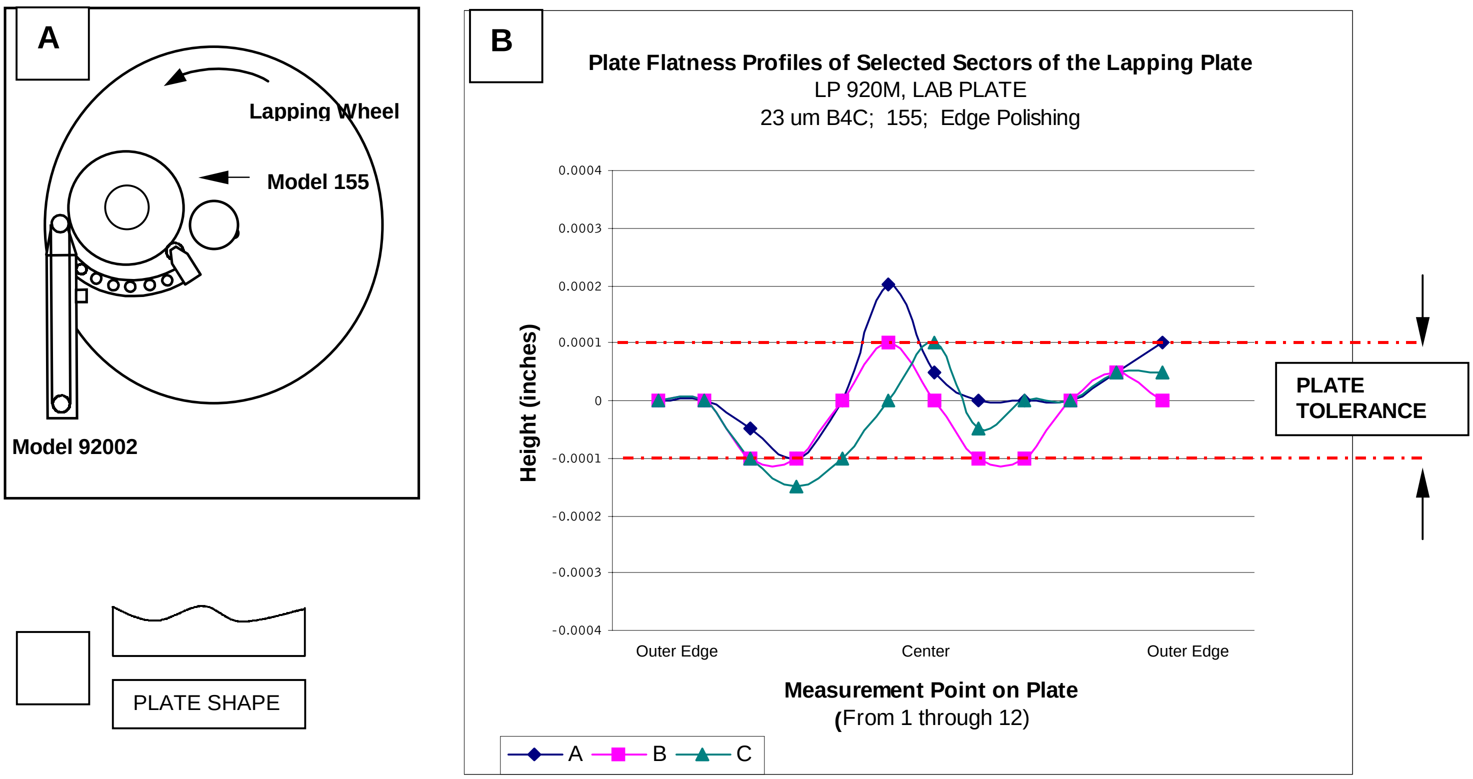

Figure 6: Illustration of the lapping arrangement when using the Model 155 Lapping and Polishing Fixture on the Model 920. In A) the Model 155 is being used as normal. In B) the resulting plate surface plot after lapping with the lapping fixture. In C) a schematic illustration of the resulting plate shape after lapping. The lapping fixture removes material faster where it is being used and the areas not exposed to the fixture are not removed as quickly. Although the plate is still relatively flat, conditioning is needed to get the plate back into it's specified range of flatness.

3.1: Plate Re-conditioning

Following lapping the plate was re-conditioned using the modified condtioning ring arrangement. Tracking the behavior of the plate was done by taking measurements after each conditioning procedure. All parameters were kept constant for conditioning as in Section 2.3.2, although the position of the conditioning ring was changed to affect the plate shape.

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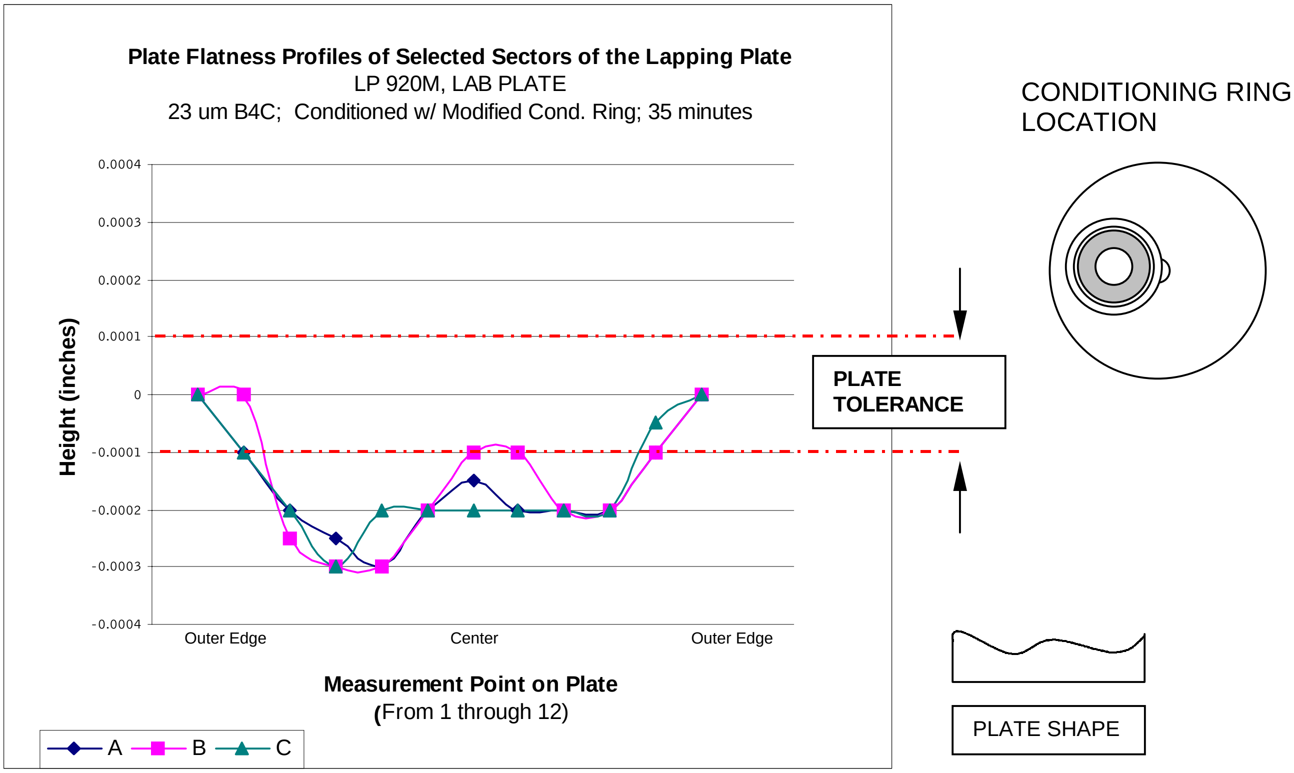
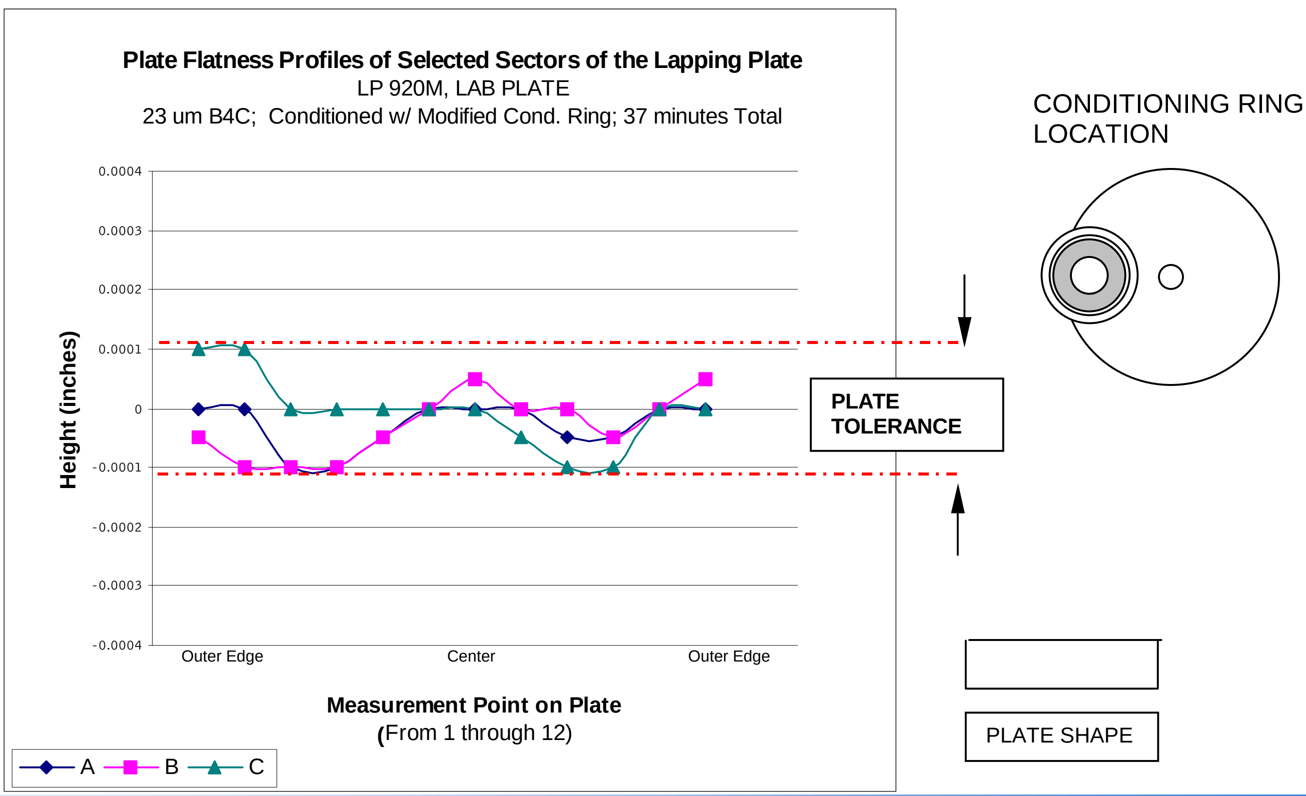


Figure 7,8: Plot of the plate surface following conditioning for 35 minutes. Figure 7 (above) shows the plate surface is beginning to even out, although the edges and center are still higher than the middle portion of the plate area. Adjustment of the condtioning ring is needed to correct the problem. Figure 8 (below) shows the plate after conditioning in the new position for 37 minutes. The plate is now within specification.



4.0: Results

It has been demonstrated that proper plate conditioning is important to maintaining good specimens when flatness is of utmost importance. Cast iron lapping plates, such as the LP 920M, require conditioning almost after every process run to make sure that the plates are maintained. Conditioning during lapping will undoubtedly minimize the amount of time needed for conditioning the plate individually, and will enhance the resulting specimens.

1. Plate conditioning is required when using cast iron lapping plates with free abrasives.
2. The existing conditioning ring may not be the most efficient method for conditioning as it seems to have a negligible effect on the plate surface after a considerable amount of lapping time.
3. Conditioning the plates using a heavier, thicker conditioning ring reduced condtioning time and improved the plate surface flatness.
4. Following the use of lapping and polishing fixtures it appears to be necessary to re-condition the lapping plate to maintain good flatness.
5. A repeatable method for plate flatness inspection was developed.