An Easily Understood Technique for Measuring Vibratory Bowl Speed and Optimizing Vibratory Bowl Processing Efficiency

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Figure 1—Overhead view of a traditional vibratory bowl showing the toroidal shape of the bowl's operating channel.[2]

Introduction

Preliminary to final electroplating, painting or lacquering, a vast majority of metal stampings, machinings, forgings or die castings are vibratory finished. Where applicable, vibratory finishing offers an economy of scale to the finishing operation because it can be used to replace expensive, laboriously-repetitive, traditional hand-deburring or polishing operations. Cost and time efficiency is derived from the mass finishing of hundreds or even thousands of parts simultaneously thereby eliminating the one-on-one inefficiency of hand finishing operations.

Vibratory equipment manufacturers typically deliver their equipment with amplitude gauges mounted to their sides. By reading these gauges the vibratory bowl operator can determine the range of compression and expansion of the bowl's springs and thereby judge, in a somewhat generalized fashion, the relative performance and efficiency expectations of the equipment.

More comprehensively designed gauges are also equipped with protractor scales that can additionally be used to determine the rolling angle of the mass within the bowl's operating channel.

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Taken together these two traditional measurement tools offer some basic knowledge regarding the operational characteristics of a vibratory bowl. However, they in no way are capable of monitoring one of the most influential bowl operational characteristics, the mass rolling speed. The distance a part travels per minute of time is proportional to the speed in which it will be finished. The greater the distance traveled per minute, the shorter the processing time that will be required to finish the part.

After years of experience in assorted production, vibratory finishing departments nationwide the author realizes that monitoring mass rolling speed is not a common practice. In fact, few operators know how to determine simple rolling motion of the mass, let alone determine the mass rolling speed. This article presents a description of the proper mass rolling action that should occur in a properly set-up, vibratory bowl. An easy-to-perform technique for monitoring mass rolling action is introduced. Finally, an easy-to-perform calculation is described, which can then be used to determine the distance the mass travels per minute of processing time. The techniques presented here can be applied to any bowl, anywhere.

Mass rolling action

The geometrical shape of the operating channel of a vibratory bowl is a toroid. For those not familiar with the geometrical shape of a toroid, envision the shape of a bagel (Fig. 1[2]). During use, the parts to be finished are placed in the bowl's operating channel into which vibratory media has previously been added. When the bowl's motor is started, the mass - parts plus media - begins to tumble.

The tumbling action in the bowl is the movement required to refine the parts. As the mass tumbles, the abrasive media rubs against the parts to improve their surface finish mechanically and/or deburr sharp edges properly. It therefore becomes a logical expectation that optimizing the tumbling action of the mass will produce the shortest and therefore most efficient processing time.

Understanding proper mass roll motion

Observation of an operating vibratory bowl reveals that the mass moves through two planes of motion, vertical and horizontal.[4] Vertically, the mass rises at the O.D. wall, crests at the mid-point of the channel and plunges downward at the center hub (Fig. 2[5]). This vertical motion is called roll.[4,5] Simultaneously, the mass will horizontally move through the bowl's channel. Envision cars lapping a circular race course (Fig. 3). This horizontal motion is called "slide."[4,5] Combined, the two motions, vertical roll plus horizontal slide, produce a helical or spiral pathway through the bowl's operating channel.[1,3] (Fig. 4)

During vibratory processing the most efficient refinement locations within the bowl's channel occur as the mass rolls downward at the hub and moves outward across the base of the channel towards the O.D. wall.[5] At these points, the compressive force created by the weight of the media bearing down onto the parts results in efficient, forceful, abrasive media-on-part contact.[5] Obversely, the rising of the mass against the bowl's O.D. wall results in a decrease in the applied compressive pressure of the media, minimizing abrasive contact efficiency.[5]

As parts lap the bowl's channel, only half of the vibratory processing time occurs in the more efficient portions of the roll pattern - downward and across the bottom. This is true, regardless of the openness or tightness of the spiral pattern.[5] Additionally, vibratory bowls having deeper operating channels are more efficient because of the greater depth of media above, and the resultant greater applied media force. It therefore becomes obvious in the understanding of vibratory bowl operating efficiency that the tighter or more closed the roll pattern can be made, the more compressive abrasive media contact can be applied to the parts per lap.

In Fig. 4, we can see that the spiral pattern on the left shows four rolls per lap and the spiral pattern on the right shows eight rolls per lap. The right-hand spiral pattern is therefore twice as efficient in downward-and-across-the-bottom rolling action per lap and therefore will provide twice the abrasive contact on the parts per lap.[4,5] Consequentially, the right-hand spiral pattern will refine the parts in a shorter processing time since twice the work is being applied to the parts per lap.

Imagine that the spiral patterns shown in Fig. 4 were pieces of string that could be removed from the vibratory bowl. If these strings were then laid-out flat on the ground, it would be possible to record their lengths with a tape measure. The resulting measurements would show that the string produced by the closed spiral pattern would be longer than the string produced by the open spiral pattern. The longer string represents the longer path the parts traversed per lap. The longer this pathway is, the more contact the parts will have with the media and the more work will be done to the parts.[4] The tighter spiral pattern used the available bowl volume more efficiently per lap thereby increasing process efficiency.

Traditional techniques for monitoring bowl motion efficiency

Typically, an amplitude gauge is mounted on the O.D. wall of most vibratory bowls (Fig. 5). Unfortunately, this device is not the most efficient way of determining part distance traveled, but since it is the most commonly found measurement device in the vibratory room, a brief description of its use is presented here.

The amplitude gauge, as its name implies, is used to determine the bowl's amplitude. Amplitude is actually the amount of compression and expansion on the bowl's springs.[4,5] Typically measured in millimeters, amplitude is an approximation of the bowl's and therefore the mass' vertical rolling motion.[4,5] In order to determine bowl amplitude, the operator turns on the bowl and squats to observe the gauge at eye level (Fig. 6).

Figure 6 is a representation of the gauge's appearance as would be seen on an operating bowl.[4] When observing an amplitude gauge on a moving bowl, a duplicated optical illusion will appear showing double rolls of circles. Additionally, all protractor lines will appear blurred, except one line that will be crisp and easy to read. Figure 6 shows the 70° line to the left as being easy to read. This indicates that the mass in the bowl's operating channel has a forward rolling angle of 70° and this would be the recordable rolling angle for this bowl.

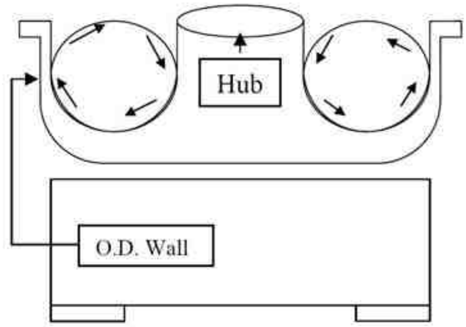

Figure 2—A side, cut-away view of a vibratory bowl showing the proper vertical plane of motion during vibratory bowl operation. The mass rises at the O.D. wall and plunges downward at center hub establishing the vertical rolling motion.[5]

The rolling angle line can also be used to indicate the mass' slide direction. In this example, since the readable line appears on the left side of the protractor scale, the mass will be sliding in a clockwise direction as observed from above. A counterclockwise sliding mass would produce a readable line on the right side of the protractor scale as observed from above.[4,5]

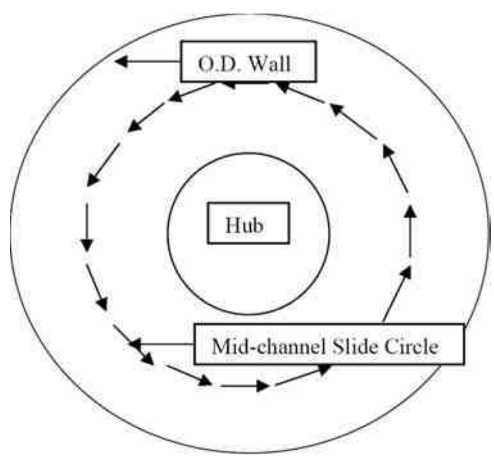

Figure 3—An overhead view of the vibratory bowl showing the circular, horizontal plane of motion during bowl operation. The motion is known as "slide."

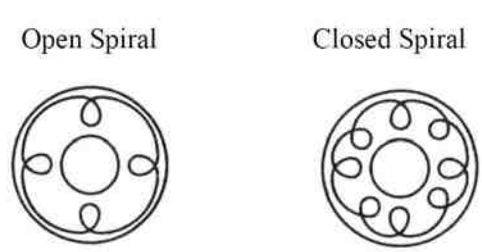

Figure 4—Two of an infinite number of possible spiral patterns. The left image shows an open spiral pattern having four rolls per lap around the bowl. The right image shows a closed spiral pattern having eight rolls per lap around the bowl.[1,3,4,5]

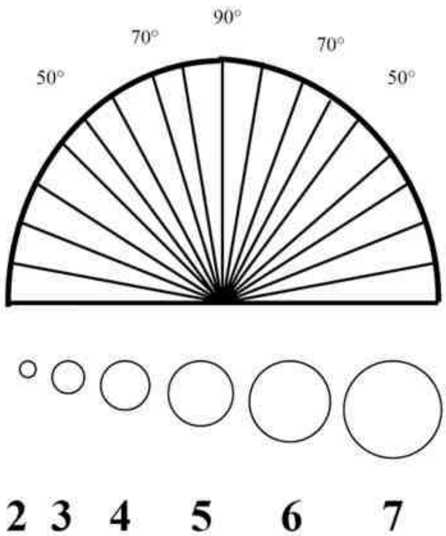

Figure 5—A typical amplitude gauge. The protractor scale on the top is used to determine the mass' rolling angle. The circles below are used to measure the bowl's amplitude. In this image, amplitudes between 2 and 7 mm can be determined.

As noted earlier, the circles on the lower portion of the gauge will appear as vertical pairs. The upper circle in this pair marks the furthest height of spring expansion and the lower circle marks the furthest depth of spring compression. Referring again to Fig. 6, we see that the smaller circles on the left are separated by a gap. Whereas, the larger circles on the right overlap one another. There is however, one set of paired circles that align perfectly, to form the figure "8." The number beneath the figure 8; in this case, a "5," is the operating amplitude in millimeters of the bowl. When charting the performance of this vibratory bowl, an amplitude reading of 5, would be the recordable value.[4]

As recordable statistics; amplitude and rolling angle can be used to compare and contrast the action of the same vibratory bowl as a function of time, or to compare and contrast two adjacent bowls of the same size. As recorded amplitudes rise or fall, or as mass rolling angle increases or decreases, the operator will have a better understanding as to the efficiency of bowl operation. Variables, such as media attrition and/or the weight of the work load placed into the bowl, will affect these measurements. Unfortunately, neither measurement amplitude nor rolling angle can be used to determine the distance traveled per lap by the work pieces placed in the vibratory bowl's operating channel.

A technique for determining the bowl's spiral pattern

Let us envision that you are standing before a vibratory bowl filled with thousands of small parts. Imagine that you are trying to follow the rolling pattern of just one of the thousands of parts in the channel. Reality quickly shows that this is a virtual impossibility since there are too many parts simultaneously in motion that will confuse the eye. Additionally, as the part being followed disappears at the center hub it will be impossible to identify it among the thousands of its identical neighbors as it rises against the bowl's O.D. wall. Therefore, we must determine the spiral motion of the bowl using a procedure that is independent of the work pieces but which duplicates the work piece spiral pattern. The author has found that by placing a golf ball in the bowl's channel (Fluorescent orange, yellow or green balls are exceptionally easy to track with the eye.), it becomes a simple task to follow the mass' rolling pattern.

Let us consider the following illustrative example. The vibratory bowl has been properly filled with parts and media mass. As the operator, you are standing before the bowl at the six o'clock position. You place the golf ball into the bowl channel as the mass plunges downward, at the hub, at the six o'clock position while simultaneously depressing the start button on a stop watch. You then count the number of times the golf ball surfaces as it makes one lap around the bowl and returns to the 6 o'clock position. Likewise, you depress the stop watch stop button once the ball returns to 6 o'clock.[4] You will now have two pieces of recordable data. They are; the number of rolls of the golf ball and the time in seconds it took to complete one lap around the bowl (Fig. 7).[1,3,4,5]

Let us assume that during the first bowl motion measurement, the golf ball required 75 sec to complete four rolls in one lap. After making adjustments to the bowl's weight segments and weight alignment angles, a repeat measurement showed that 90 sec were required to complete one horizontal lap and that the golf ball rolled eight times during that lap. We can now use this data to calculate the actual distance the parts traveled per each minute of vibratory processing time.[4,5]

Calculating distance traveled

Since the roll pattern in the bowl is that of a spiral, it is in actuality a spring form. Envision a child's Slinky™ toy, bent back around upon itself.

It is possible to use an engineering/physics formula known as Hooke's Law to calculate for the distance traveled.[5] In such a determination, the coils of the spring would be the path of the golf ball. Knowing the spring coil diameter; (bowl's operating channel diameter) and the spring's overall coiled length (bowl mid-channel diameter), it would be possible to back calculate for the length of wire that would be required to form the spring's coils (distance traveled.)[5]

The differential calculus calculations required to perform this determination are however somewhat complex, and it has been the author's experience that they are too intimidating for the average vibratory room operator or mass finishing technician.[5] Therefore the challenge has become to determine the distance traveled by using friendlier, less intimidating math.

Most operators and/or metal finishing technicians are familiar with π (pi), the ratio of a circle's circumference to its diameter.

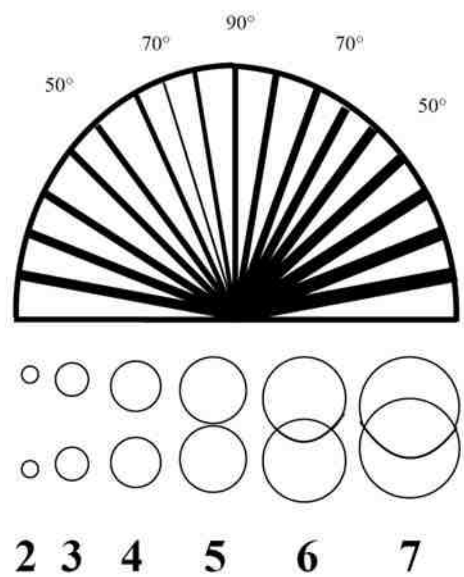

Figure 6—The appearance of the amplitude gauge on a moving bowl. This image shows 5 mm of amplitude and a 70° clockwise rolling angle.

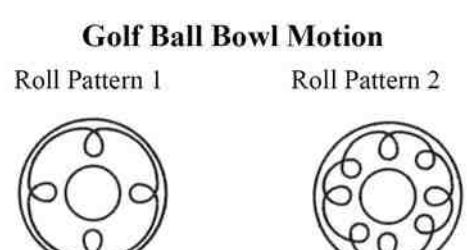

Figure 7—Golf ball roll pattern results:[1,3,4,5] left image - four rolls per lap in 75 sec; right image - eight rolls per lap in 90 sec.

From the basic formulas related to π, the formula for a circle's circumference, πd, can be used to determine the distance the golf ball travels (Fig. 8).

Several bowl dimensions must be known to complete the calculation of basic distance traveled. The example in Fig. 8 shows the diameter of the vibratory hub at 25." The distance across the bowl's channel is also shown to be 25." It should be noted that this distance is also the diameter of the circle that is the vertical roll circle of the mass.[5] From this information we can determine the circumference of the bowl's operating channel which in actuality, is the distance traveled per vertical golf ball roll:

Channel Diameter = Vertical Roll Circle Diameter (Golf Ball) = 25"

Vertical Roll Circumference = πd = 3.14 × 25" = 78.5"

When viewed from overhead, as in Fig. 9, the horizontal slide channel can be bisected by an imaginary line that splits the channel into O.D. and I.D. halves. We can assume that during operation 50% of the time, parts will be on the I.D. side of this circle and 50% of the time parts will be on the O.D. side of this circle. Therefore, for general calibration principles, on average, the horizontal distance traveled by the parts is equal to the circumference of this mid-channel circle.[5] This can be calculated as follows:

Mid-channel Diameter = Horizontal Slide Diameter (Golf Ball) = 50"

Horizontal Slide Circumference = πd = 3.14 × 50" = 157"

It is now possible to calculate the distance traveled by parts using these two bowl dimensions and the stop watch timing information, as follows:

Distance Traveled Using Set-up No. 1:
4 rolls/lap in 75 sec = (4 × 78.5") + (1 × 157") = 471".

Correct distance traveled/min of processing time = (471" × 60 sec)/75 sec = 377 in./min[5]

Distance Traveled Using Set-up No. 2:
8 rolls/lap in 90 sec = (8 × 78.5") + (1 × 157") = 785".

Correct distance traveled/min of processing time = (785" × 60 sec)/90 sec = 523 in./min[5]

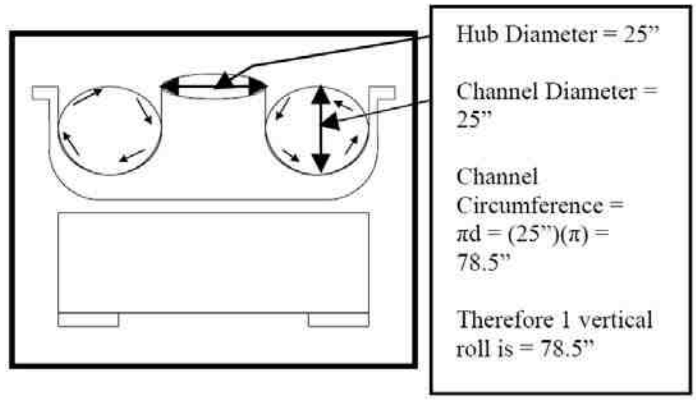

Figure 8—Cross-sectional view of a vibratory bowl showing operating channel dimensions.[5]

Efficiency comparison of results

In the previous examples, it was determined that with set-up No. 1, parts in the bowl mass would travel 377 in./min of processing time. Set-up No. 2 will generate a travel distance of 523 in./min. The difference in distance traveled per minute of processing time is 146 in./min. This represents an efficiency increase of:

(523" ÷ 377")(100) = 138.73%.

Table 1 compares processing run times possible from a better understanding of rolling speed and using the described examples. The table can be interpreted as follows: if a load of parts is processed according to example No. 1 in 10 min, the same travel distance through the media can be achieved with example No. 2 in 7 min 15 sec.

Table 1
Cycle process time differences based on the two operating examples

Processing Time at 377" per minute	Processing Time at 523" per minute
10 min 00 sec	7 min 15 sec
15 min 00 sec	10 min 52 sec
20 min 00 sec	14 min 30 sec
30 min 00 sec	21 min 44 sec
45 min 00 sec	32 min 52 sec
60 min 00 sec	43 min 28 sec

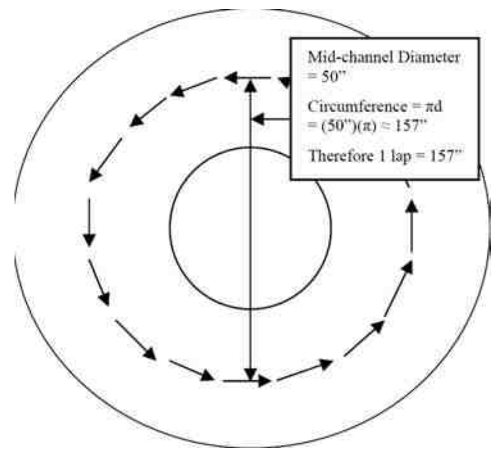

Figure 9—Overhead view of the vibratory bowl with arrows showing the position of the imaginary mid-channel diameter.[5]

Other considerations pertinent to determining the most efficient vibratory bowl roll pattern

The diameter of the circle that forms the vibratory bowl hub is smaller than the diameter of the circle that forms the vibratory bowl O.D. wall. If the vibratory bowl could be divided into individual segments extending from the hub wall to O.D. wall, the segments would be pie-shaped. As such when the mass rolls downward at the hub, the parts in the mass, as a consequence, come closer together.[4]

If the vibratory room is processing hardened steel parts, *i.e.*, Rockwell Hardness Rc ≥ 40, part-on-part contact near the center hub is of little consequence. In such cases, the right hand roll pattern as seen in Fig. 7 will be favored, roll speed will be quicker and processing time will be shorter.[4]

However if parts of a softer metallurgical hardness are being processed, *i.e.*, Rockwell Hardness Rc ≤ 39, such as brass, aluminum turnings and/or extrusions or zinc castings, then roll speed and the tightness of the roll at the hub must be taken into consideration.[4] In such cases, the left hand roll pattern as seen in Fig. 7 will favor less part-on-part impingement minimizing damage.4

Conclusion

Experience has shown that in general, when vibratory bowls are placed into operation, little consideration is typically spent in adjusting bowl amplitude and roll angle. Where amplitude gauges are found, they are rarely if ever used nor do operators typical know how to use them.

In addition, there is little understanding as to the rolling pattern of the mass, how to determine the roll pattern and additionally how to determine the speed of the mass. Finally, an understanding of how mass speed affects time efficiency is also typically lacking.

A properly set-up vibratory bowl will roll the mass from O.D. wall inward and down at the center hub. Likewise the forward slide action of the mass will form a spring-like roll pattern. The tighter the pattern, the further the distance parts must travel to complete a single lap around the bowl and the greater the media rubbing efficiency will be.

By placing an easy to see, brightly colored golf ball in the media mass, it becomes easy to monitor the bowl roll pattern. Using a stop watch, an operator can time the duration in seconds it takes to complete a lap. Knowing the bowl's dimensions, the linear speed of the mass can be calculated and used to calibrate the machine and/or increase process throughput efficiency.

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About the Author

William P. Nebiolo received a B.A. degree from The University of Connecticut in 1976 and an M.S. degree from Long Island University in 1978. He began work in 1978 at the Union Hardware Div. of Brunswick Sporting Goods as a waste treatment operator and a plating lab technician. After tours of duty at Eyelet Specialty Co. in Wallingford, CT, Nutmeg Chemical in New Haven, CT and The Stanley Works Corporate Laboratory in New Britain, CT, he accepted a position at REM Chemicals, Inc. in Southington, CT as a sales engineer in 1989. He has been with REM ever since and currently serves REM's Midwestern Sales Territory.

He joined the AESF as a member of the Waterbury Branch of AESF and has served as the 1984-85 Branch President and as Branch Secretary from 1991 until the branch's assimilation into the Connecticut Branch in 2004. He has served as the Connecticut Branch Secretary since its creation. He represented the Connecticut Branch as a Delegate and recently accepted the position of Connecticut Branch Vice-Treasurer. He chaired the merger committee that resulted in the merger of the Waterbury, Bridgeport and Hartford Branches into the Connecticut Branch.

He has published more than a dozen papers through a number of professional organizations and with a number of technical journals including Plating & Surface Finishing. Since 1996, he has been one of the Mass Finishing Technical Training Program instructors for SME and has taught vibratory finishing at more than two dozen seminars across the United States. He prepared one of the training manuals that has been used for years with the SME training course.