

Repair and tuning of Balinese gamelan instruments

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Introduction

This a report of the Gamelan Tuning and Repair workshop, given by Wayne Vitale, that was organized by Codarts Rotterdam during the Bali Summer School 2006 (June 30th - July 14th). The report is intended for the participants of the Bali Summer School event.

Repair

Before (or during) the tuning of the bronze keys, you should repair any damages to the bamboo resonators that might affect the resonance. The most common problem is cracked bamboo.

Repair of bamboo resonators

First, strike each key and listen to the resonance. If a key sounds “thin” (without body), the resonator is probably cracked or damaged and should be repaired. Note that the tiniest crack or fissure in the resonating part of the bamboo will affect its resonance.

Remove the keys from the casing by detaching both ends of the *tali* (leather straps) to which the keys are suspended. If you are going to tune the instruments, you will need to remove all the keys in any case. Clean the inside of the resonators with a vacuum cleaner. Be aware that some tubes may contain a loose piece of cement or other material, used by the smiths in Bali to adjust the resonance pitch. (Don’t worry about removing these pieces, which probably won’t be needed or can be replaced.)



Each key has a resonator which is tuned to the key's pitch. Bamboo resonators are cut in such a way that the length of the resonating chamber matches the frequency of the key that hangs above it. The resonating chamber runs from the top opening of the bamboo tube down to the first node, which completely closes off the tube. The photograph shows a *gender wayang*. The nodes can be seen as darker horizontal markings. The higher the pitch of the key, the higher the node is situated, making the resonating chamber shorter.

To check the quality of a resonator, you can also blow over the top opening like one does with a pan flute (or a bottle of soda). If you hear a faint tone similar to the corresponding key, then the resonator probably does not need mending. Alternately, if the tube can be pulled free of the instrument, tapping the bottom on a hard surface, such as a cement floor, will cause it to resonate, if there are no leaks (i.e. cracks).

Note that the tiniest crack or hole in the tube will destroy the resonance, so the tube must be completely sealed. Small cracks can be filled with silicon caulk¹. Fill the crack from the outside first; but make sure that it is also filled from the inside (smear the silicon with your finger along the inside of the crack). You only need to fill a crack down to the node. The part below the node has no function as a resonator.

¹ Note that silicon cannot be used to repair the bamboo tubes of instruments such as a *gerantang* or *tingklik*. In those cases, the bamboo tubes are not only resonators but also generate the sound—i.e. they are *ideophones*—which makes it necessary to restore cracks with a material that hardens and structurally rejoins the bamboo together. This can be accomplished with high-strength epoxy glue; or, in case of mild cracking, with normal wood glue and hose clamps.

Larger cracks can first be filled with a piece of bamboo or wood which is cut approximately to the size of the crack. Glue the new part with wood glue or epoxy into the crack, filling any pores or openings completely. Again, completely sealing of all holes or spaces is essential for proper resonance.

To avoid long cracks from splitting further, you can wind some fine wire (steel or copper wire) several times around the tube, most effectively near the node.

Re-attaching the keys

After repairing and tuning the instruments as described below, the keys will need to be re-strung on their leather (or other) cord and attached to the casing. Examine the old leather strap for cracks. Pull tightly on both ends to check if the strap is still strong enough. When in doubt, it is better to replace the leather straps. It is very frustrating when a strap breaks when you have almost finished attaching all the keys.

If you need to use new leather cord (Indonesian: *tali* or *jangat*), it helps to soak it in water for at least 30 minutes to make it more flexible and easy to work with. This also makes it slippery so that you can shift the keys slightly into the right position after they have been attached to the instrument. Each strap should be cut to approximately one and a half times the length of the instrument. This will give you enough slack to insert the strap in each key and also to make the knots at the end. When in doubt, leave a little extra.

It is easier to attach all the keys to one strap first, then do the other side. Start by attaching the strap to one of the rings. Insert the strap through the ring from the top and have the end stick out about 10 centimeters (4 inches) below the ring. Pull the end up and insert it through the ring again. Now make a single knot and pull as hard as possible on the end of the strap to thoroughly tighten it.

Now fold the strap to form a loop where the first key should be attached, and insert the loop into one of the holes of the first (or last) key. If the strap is too thick, you may need a tool to push it through. Alternately, you can insert one end of the strap through the hole, pull it all the way through, then insert the end back through the hole to form a loop.

Next, insert a small bamboo peg (Balinese: *jeluluk*) through the loop and pull the strap tight. Check the position of the key by stretching the strap across the instrument, resting on the brass holders (*cagak*) and pulling it very tight. If the leather is wet, you will be able to move the key by pulling at it while feeding strap with the other hand. If this does not work, you will need to push one end of the strap through the hole and pull the slack from the other end. Finally, pull the strap tight and move the key back and forth to make it settle in position. Proceed like this for each key, always pulling the strap tight and adjusting the position before proceeding to the next key. Finally, attach the end of the strap to the opposite eye-ring.

Repeat the whole operation with the other strap.

To replace missing pegs, you can use any similar piece of wood. If you have a broken *panggul* (mallet), you can use a sharp knife to split the grip (which is made of bamboo) into .5cm² strips,

shave the strips into a cylindrical shape, and cut them with shears or pliers to make new pegs. Another easy option is a *saté* stick, though it may be too thin for the heavier keys such as *jegogan*.

Tuning

Two types of instruments were tuned during the workshop: *gong kebyar* and *semar pagulingan*. In the remainder of this report, we will refer to the instruments with metal keys hanging over bamboo resonators as metallophones, as opposed to the *reyong* and *trompong*, which are usually referred to as gongs or gong chimes.

Intervals

For gamelan sets that are extremely *bero* (“false” i.e. out of tune), it is necessary to establish the precise interval structure on the initial two instruments—usually, two *pemade*—which then become the standards or guides for the other instruments in the *gamelan*. The setting of the intervals is based on several factors, including type of gamelan (e.g. *gong kebyar* vs. *semar pagulingan*), type of repertoire to be most commonly played on its (e.g. *gong kebyar* used mostly for dance vs. one used mostly to play *lelambatan*) and others, including taste and regional style. This is a complex topic which lies outside the scope of this paper. Here it is assumed that the overall interval structure in the tuning of the gamelan is clear enough, and does not require significant change. However in every case, it is essential to tune two *pemade* as perfectly as possible, which can then function as guides for all the other instruments.

Ombak

All of the metallophone instruments in Balinese orchestras—except for the *giying* (*ugal*), *reyong*, *trompong* (see below) and the non-melodic instruments—are tuned in pairs. The two instruments of a pair are tuned in such a way that the frequency difference is about 5 to 10 Hertz. This gives the characteristic *ombak*, or “waves” (pulsation) to the resultant sound. The lower partner is called *pengumbang*, the higher one *pengisep*. The frequency of the *ombak* is determined according to the tuner’s taste, and differs for each type of orchestra. The following table gives typical values for several kinds of gamelan.

instruments	<i>ombak</i> frequency
gender wayang	3 to 6 Hertz
semar pagulingan	6 to 8 Hertz
gong kebyar	7 to 10 Hertz
angklung	6 to 10 Hertz

Table 1: typical *penyorog* (beating values) for the *ombak* in Balinese gamelan.

Note: The *reyong* and *trompong*, though they lie in different registers, may be considered partners of sorts: the *reyong* should be tuned to *pengumbang*, the *trompong* to *pengisep*. (However some tuners have experimented with the opposite.) If there is only one *ugal*, it should be tuned to *pengumbang*. If there are two, the “lead” (forward) instrument is the *pengumbang*.

Note: bamboo instruments are all tuned in a similar way; however often they do not resonate long enough to produce a clear *ombak*.

Tuning octaves

The *ombak* introduces an additional problem when tuning an orchestra which spans more than one octave. This is best illustrated with an example.

Suppose a note has a frequency of 400 Hz on a *pengumbang* instrument, and that the *penyorog* (distance between partner instruments) is 8Hz. In that case the corresponding *pengisep* tone would be at 408 Hz, resulting in *ombak* of 8 Hz. If both instruments were tuned with exact octave intervals (exactly double the frequency), the higher *pengumbang* tone would have a frequency of 800 Hz and the *pengisep* octave would be at 816 Hz. This would result in an incorrect *ombak* of 16 Hz. (Keep in mind that ALL partner tones in a gamelan, from the *jegogan* to the *kantilan* should have the same *penyorog* or *ombak*.)

pengumbang	400 Hz	-----	800 Hz
pengisep	408 Hz	-----	816 Hz
ombak	8 Hz		16 Hz

Figure 1: tuning with exact octaves

One way to solve this “error” is to lower the octave of the *pengisep* instrument, resulting in consistent *ombak*.

pengumbang	400 Hz	-----	800 Hz
pengisep	408 Hz	-----	808 Hz
ombak	8 Hz		8 Hz

Figure 2: One method of octave treatment (*pengisep* octave lowered)

Note that the higher *pengisep* note (808 Hz) will also produce an *ombak* of 8 Hz with the first harmonic (the octave) of the lower *pengisep* note ($2 \times 408 \text{ Hz} = 816 \text{ Hz}$). This can be heard by striking the lower tone strongly with a padded mallet, and then immediately striking the higher tone with a harder mallet, but very softly. This relationship is important when tuning the instruments.

However this solution—in which compressed octaves appear on the *pengisep*—is seldom used. A more typical, and traditional, solution is to raise the *pengumbang* octave note. This is the solution that was used during the workshop for both the gong kebyar and the semar pagulingan instruments.

pengumbang	400 Hz	-----	808 Hz
pengisep	408 Hz	-----	816 Hz
ombak	8 Hz		8 Hz

Figure 3: Another, more traditional, strategy for octave treatment (*pengumbang* octave raised)

Here, the *pengisep* instruments all have perfect octaves, while the *pengumbang* all have stretched (wide) octaves. Note also that the higher *pengumbang* note (808 Hz) will produce an *ombak* of 8 Hz with the first harmonic of the lower *pengumbang* note ($2 \times 400 \text{ Hz} = 800 \text{ Hz}$). Again, to hear this hit the lower octave strongly, and the higher one very quietly.

A third way to treat octaves, now common in South Bali, consists in raising both the *pengumbang* and the *pengisep* octave notes. This results in a more 'aggressive' sound that is considered desirable by many tuners for gong kebyar instruments. Note that all octaves are stretched (wide).

pengumbang	400 Hz	-----	816 Hz
pengisep	408 Hz	-----	824 Hz
ombak	8 Hz		8 Hz

Figure 4: Another, more 'aggressive' tuning (raised *pengumbang* and *pengisep* octaves)

Tuning the reference instrument

As mentioned above, the tuning process should start with the tuning of a reference *pengumbang* metallophone in the middle range, typically a gangsa pemade. The reference tuning is performed according to the tuner's taste and can vary quite a lot from one gong to the other. More information about the tuning of gong kebyar instruments can be found in Michael Tenzer's book on the gong kebyar² (also see his references). We will not elaborate on this part of the tuning because it was not treated during the workshop. In the remainder of this report, we will assume that a tuned reference instrument is available. This will usually be the case if the instruments have previously been tuned and the tuning only needs to be adjusted.

The reference instrument should be reassembled before tuning the other instruments.

Changing the pitch of a key



Use an electric disc grinder, sometimes called an angle grinder, with a 4½" or 12½ cm grinding wheel for metal.

To raise the pitch of a key, gently grind one of the ends. To determine which end to grind, measure the distance of each end from their respective holes. If one is larger (often the case), grind on that side. This will keep the key symmetrical. One to three seconds of grinding should be enough to begin with; work slowly at first until you get a feel for the amount of grinding needed to produce a given change.

² Michael Tenzer, 2000, *Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music*, The University of Chicago Press, ISBN 0-226-79283-8, pp. 25-33

To lower the pitch, grind the bottom part of the key—in Bali, they call it the “belly” (*basang*) between the two holes. Examine the bottom of several keys to see how this should be done: some will no doubt show grinding marks from a previous tuning session. (Note that machine grinders are now commonly used in Bali.) Here also, do not grind more than two or three seconds to begin with.

Be aware that the higher the pitch of the key is, the more effect grinding will have on the tuning, simply because they’re smaller. This means that you should grind higher keys less than lower keys to produce the same effect.

The friction of grinding warms up the key. This is why after the grinding, you should cool the key by immersing it in cold water for several minutes before checking the tuning. The slightest temperature change will affect the pitch, since warmer keys will expand slightly and become lower in pitch. Dry it well with rags or towels to avoid corrosion.

Tuning pengumbang metallophones

Before you start tuning, detach all the keys from the strap.

Comparing a key with the reference instrument



Hold the key you are tuning with two fingers, directly on the holes (which are located at the nodes) as in this photo. Strike the corresponding key of the reference instrument with a mallet, then strike the key you are holding and hold it near your ear. If the sound of the key you are holding damps too quickly, try holding the opposite side. In rare cases where it still does not sustain, try inserting a peg through the hole and holding the peg with two fingers so that the key can hang loose.

Strike the keys several times one after the other, and try to determine which one has the higher pitch. If the keys are very close in pitch, listen for a pulsation. The rate of the pulsation is equal to the difference in frequency. If you hear a pulsation but can't decide which of the keys is higher, use your best judgement or guess, and grind accordingly. If you guessed correctly, the pulsation will have slowed down after the first grinding round. If you were wrong, you can easily go in the opposite (correct) direction.

As always, let the key cool down and then re-check the tuning. If any pulsation was heard before the grinding, it should have slowed down. If it has become faster, you went the wrong way and should tune the key in the other direction during the next pass.

Repeat the whole procedure until the two keys (reference and the one being tune) are exactly the same in pitch, meaning that no pulsation can be heard. Balinese or Javanese tuners refer to this as *pleng* or *mati* (dead). After the last tuning round, allow the key to cool down in cold water and then sit for at least ten minutes, then check the tuning again. You will often need to tune the key

once more. Sometimes it will even change again slightly overnight, because of some tiny amount of residual heat that was still in the key; for that reason it's smart to check all work the following day.

Tuning a key outside the range of the reference instrument

We will consider the tuning according to the 'traditional' tuning illustrated in Figure 3 on page 5.

If the key is within the range of another instrument that has already been tuned, then use this instrument as a reference. Otherwise, select a key on the reference instrument that is an octave higher or lower than the key that needs tuning.

Strike the lower key quite hard, then strike the higher key. The first harmonic of the lower key will interfere with the base frequency of the higher key, causing a faint pulsation if they are not in perfect octaves. This pulsation is much less distinct than the pulsation that can be heard when striking two partner (unison) keys. It is best heard when the lower key is hanging over a resonator, and the other key is held close to the ear.

For the *pengumbang*, tune the higher octave in such a way that the difference in pitch between the two keys is slightly more than one octave. The target pulsation rate is the same as the rate of the *ombak* you have chosen for the orchestra (e.g. 8 Hz), which is the frequency difference between the *pengumbang* and *pengisep* instruments.

Tuning a pengisep instrument

As a reference, use a *pengumbang* instrument with a range that contains the note of the key you are tuning. The tuning is performed in a manner similar to that described in the chapter 'Tuning a key within the range of the reference instrument', except that in this case the tuning should result in an *ombak*.

Polishing the keys

When you have finished tuning a set of keys, pass the grinder quickly along all the edges to round them off, then polish the ends with sandpaper. This will be greatly appreciated by the players.

Tuning reyong and trompong pots



As explained before, a reyong should be tuned according to the *pengumbang* instruments, and a trompong according to the *pengisep* instruments.

To lower the pitch of a pot, grind the flat surface. Wayne Vitale grinds the surface of the larger pots from the inside. (The smaller ones have insufficient room to allow the machine inside.) This makes it unnecessary to polish the surface after the tuning. To raise the pitch, grind the knob of the pot to lighten it; however great care must be taken or a hole may appear³. After each grinding round, let the pot cool down in cold water for at least five minutes.

Sometimes a pot may sound loud when struck and decay rapidly—with short sustain. If this is the case, cut a cardboard disk to a size that is slightly larger than the opening of the pot and insert it into the pot. When the pot is turned the right side up, the disk should rest on the bottom. This may improve the resonance.

If the frequency of the pot is too high, another way to lower the pitch is to add weight to the boss, which slows down its vertical motion (i.e. causes it to vibrate at a lower pitch). You can do this by filling the knob from the inside with molten wax or solder (solder does not always adhere well to the surface; however it is heavy which is desirable.) If wax is used, one way to add extra mass—that is, if the mass of the wax itself is insufficient—is to press pieces of metal, such as metal shot or ball bearings, into the warm wax. The advantage of using wax is that it is easily removed, all or in part, if you change the pitch too much.

List of necessities for tuning and repairing instruments

- angle grinder with a 4½" or 12½ cm grinding wheel
- bucket of water
- lots of old towels or rags
- paper towels
- transparent silicon kit
- grinding paper
- metal wire
- pliers
- cutter (for metal wire)
- vacuum cleaner
- mouth caps
- leather cord (tali)

³ Note: The technique of grinding pots was not covered in detail in this workshop