Study on the Technique of Clay-Mold Assembly of Yinxu Ritual Bronze Vessels

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The production process of clay-mold assembly of Yinxu bronze ritual vessels includes several steps: the selection and treatment of clay material for mold; making model, core and mold; the drying, baking and assembling of clay-molds.

Selection and Treatment of Clay Material for Casting

Analyzing the composition of clay-molds excavated from the foundry sites is a useful method to know the technique of the selection and treatment of clay material for casting in Yinxu period. Some clay-mold samples excavated from Miaopu North Foundry site and Xiaomintun Southeast Foundry site in Anyang, Henan Province, have been analyzed by physical and chemical methods so far. The results show that the clay material for molds in Yinxu is done after several steps such as the selecting of raw material, kneading, floating, tempering, precipitating and decaying, etc.

Since the large demand for clay material for mold-making, in the traditional foundry people often search for the natural resource such as the alluvial soil underground and in the river bed until modern times. The three foundry sites are all located near the Huan River. Several deep pits found in the foundry sites are guessed for catching soil, and a thick layer of mud is piled up in some of them. It is inferred that the clay material are caught locally from the deep underground or the alluvial soil in the river bed which contains silty sand. The analyzing result showed that the composition of clay molds is different from the local soil because of adding additives. The compositions of molds and cores are different, but the latter is similar to the red baking earth, the back soil and the model. It means that some difference existed on the choice of raw materials among the molds, cores and models.

Sands are tempered in the molds and cores. Some white carbonate grains are tempered in the molds. It is not clear whether those grains are from clam shells or natural carbonate minerals. The white carbonate grains are usually tempered much more in the back layer of molds than the face layer of them. It is even more in the cores. The ash of plants maybe tempered both in the molds and cores.

Tempering additives can raise the refractoriness, the strength against high temperature and the size stability, and reduce the tendency of deform and crack. This technique is derived from the pottery making technique since Neolithic period.

The molds from Houma site contain two layers, the face layer and the back layer, and the material is different. In Yinxu period the face layer material is not commonly used, just in some cases the face layer with motif was made of the fine clay material.

A pit with fine soil residues on the bottom is found in Xiaomintun foundry site. It probably showed that the material was settled and leavened.

The carefully treated materials have high plasticity and strength to make molds assembly. It is easy to copy from model and carve the motif out of the molds. In some degree, high level of section-mold technique and separate casting technique, as well as the delicate motif on the bronzes speculated depend on the good characteristic of clay materials.

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Method of Making Model, Mold and Core

Making model

Making model is the first step in the production process. The process of sculpting model is just a design process. Making model includes two steps: sculpting outline of the model and carving motif on the model. Through the models excavated from Xiaomintun site, we know that the shape of model is designed to fit making molds. Different parts of the model of a big bronze vessel are usually designed and made separately. Sometimes the unnecessary part will be omitted in the whole model. For example, a Ding-tripod model excavated from Xiaomintun Village South site is hollow. There is only the rough outline of convex animal mask motif and flat simple leiwen (Thunder pattern) on the surface.

To cast the animal head decorated on the shoulder of bronze vessel, the separate model is used to make molds. The animal head models usually have a flat back to make molds separately.

Making molds

The assembly is composed of section-molds and cores. The section-molds form the appearance of bronze vessels, and the cores form the hollow parts and the holes.

In Yinxu period, there were two types of molds. The type I mold is thin without mortises and tenons on the parting surface, and has smooth backside just with a vertical or horizontal ridge on it (Figure 2). Most of molds belong to the type II mold, which is thick with mortises and tenons on the parting surface, and has coarse backside.

Those type I molds are mainly excavated from Xiaotun Northeast foundry site, and also from Miaopu North foundry site and Xiaomintun foundry site. It is suggested to appear and be used earlier than the type II mold, and the latter mainly appeared after the 2nd phase of Yinxu period.

There were probably two methods to make molds from models. One is adding thin pieces of clay material onto the model, then make it thicker. All the type I molds and some type II molds are done like this. The other one is that the section-molds are made one by one. After one piece mold is put on the model, the parting surface is trimmed to make the mortises and tenons, then is the neighbor section-mold. All the type II molds are done in this way.

Yinxu ritual vessels have complex types of section-mold divisions. In general, vertical division and horizontal division are the main methods.
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Figure 3. Gu-goblet Mold from Xiaomintun Foundry Site (04AXST2013H570 @:1)

Figure 4. Xiaomintun Foundry Site, a Compound Mold of Gui Vessel (2000AGT14 @ disturbed pit:1)

Three sorts of connection existed between the animal head on the shoulder with the body on the bronze vessels such as Zun, Lei, Gui, etc. in Yinxu period. The totally three-dimensional animal appendage was connected with the body by separate casting technique; some low relief of animal head appendages can be cast through the body molds; some high relief of animal head appendages are usually cast through the “compound molds” which are molds with square space to put a piece of clay material to shape the animal head by pressing the animal head model (Figure 4). Sometimes the square space extends several millimeters along two sides of the bottom to inlay the animal head mold. It is a common method in Yinxu period for solving the problem to make such high relief of animal head and to take the molds off from the model. Seldom defects owing to assembling appeared in that period because of superb craftsmanship.

Making Core

Shih Chang-ju first suggested that the core was done by scraping the model a wall thick. Other scholars then quoted his saying again and again, making his guesses almost as reality. Unfortunately, this is not all the whole picture.

The material for core needs better refractoriness, yielding capability and better dispersibility than the model. The core often looks different from the model, the former is red, coarse and loose, and the latter is grayish-yellow, fine and smooth. Furthermore, the model is made just for making mold. For example, the Ding-tripod model mentioned before is hollow, but a body core of Ding-tripod must be solid. The blind core of leg of Ding-tripod has clay spacers to fix position (Figure 5). The body core for vessel often has “core head” which has mortise on the flank and tenon in the middle part to assemble with the bottom mold.

The core is probably made by scraping the model when using a whole model to make molds for some small vessels. The core is probably assembled by those parts which are rammed of coarse sandy clay material upon the different part molds of a large size vessel. A piece of core with tenons in the edge excavated from Xiaomintun Southeast foundry site is inferred to be a case of above method.

Method of Casting Inscription and Motif

Inscription are often cast on the inner walls of Ding-tripod, Zun or under the handles of Jia and Jue-cup. Sev-
eral scholars discussed how to cast the inscription. The inscription was cast through such progress as follows: first, writing and carving inscription on the model into intaglio characters; then pressing a piece of clay material on the model to make a clay core with relief characters, or inlaying it to the body core; at the end, the intaglio inscription is done after casting. Sometimes the method of relief inscription is by carving intaglio characters directly on the core or on the fine layer of clay material which is pasted on the coarse core. The relief characters need to be trimmed again to make it legible. The carving marks can be seen at the side of the inscrip-

Most motifs on the molds are carved carefully after copying from the model with the motif outlines on it. The specialized motif model is used to press motif on the mold such as to shape the “whirl” motif on the shoulder of round Lei (Figure 7). The motif on the model is done by heaping and carving. The rough style motif is probably copied directly on the mold. Few motifs are carved directly on the molds such as relief string or slim line “Yun-leiwen (Cloud-and-thunder Pattern)”, etc. Even some “Yun-leiwen” still need to make an outline stroke on the core excavated from Xiaomintun Foundry site (Figure 6).

Figure 5. Xiaomintun Foundry Site, Core of Ding-tripod Leg with Clay Spacer on it (03AXST2206H232:35)

Figure 6. A Piece of Core with Inscription Excavated from Xiaomintun Foundry site (2001AGH2:2)

Figure 7. A Model with “whirl” Motif (2000AGT10 disturbed pit:3)

Figure 8. A Motif Model with Clay Piece Stuck onto it (2001AGT15 Western Extension H31:25)
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on the model just as the case of Ding-tripod model (Figure 1). Clay piece stuck to mold’s surface to make relief motif is also found. The concrete method is decided by the line space, the degree of intaglio or relief and the difficulties of copying.

Two ways are used to apply the motif on the model: most models’ motifs are carved or heaped directly on the model, sometimes are carved after drawn; A few models’ motifs are carved on the layer of fine clay coated on the designed model.

Because the motif on the mold just copying from the model is not clear and deep enough, re-carving and repairing the motif on the mold is necessary. The carving mark can be seen beside the line of the motif on the mold.

Drying, Baking and Assembling

Molds need drying and baking to assemble. After assembling, the section-molds assembly needs to be baked again (also a step for preheating) for pouring alloy into it.

Assembly drying

After taking the molds off the model, the molds should be put in the shady place to dry naturally in order to get rid of the water slowly and evenly. It is very important to reduce the deforming of molds to ensure the compact structure of the assembly. Three pits found in the Xiaomintun Foundry site with much charcoal on the bottom are inferred for drying molds. The charcoal can keep the underground water away from the molds. It shows that the models, molds and cores might be dried in the cellar in Yinxu period to prevent crack and reduce the deforming when drying.

Baking Technique and the Study on the Sintering Temperature

Assemblies of small vessels are heated in the baking kiln whose structure is familiar with small pottery kiln. A study by Liu Xinyi et al. manifests that the measuring temperature will be higher than its real data by pushrod dilatometer (PRD) when the samples’ primary sintering temperature is lower than 900°C. Nevertheless, if the samples are reheated many times, the message of the samples’ primary sintering temperature is maybe hidden in the thermal dilatometric curve and the change law of coefficient of linear expansion.

Six samples’ primary sintering temperature data were measured by the authors cooperating with Dr. Liu Xinyi. The samples include fragments of two molds, two cores and one piece of red baked clay and one pottery shard whose compositions are all analyzed. The results are shown in Table 1.

Analyzing result shows that the sintering temperature of cores and molds is at 550–650°C, lower than the pottery. The red baked clay’s sintering temperature is lower than 550°C. The result suggests that the clay molds need baking in a low temperature in order to well ventilate.

Fix position and Assemble

In Yinxu Period, the mortises and tenons are set on the parting surface. Triangle and round mortises and tenons are often used on the small molds, and the square ones are often used on the large size molds. Sometimes the different shape mortises and tenons are used on the different sides of molds, just as the upper mold of Ding-tripod, in order to easily be identified without mismatch when assembling.

In early phase the assembly of round Ding-tripod and Gu-goblet include a lengthened body molds to assemble with the body core instead of using the bottom mold. The assembly of big vessels like Fang Ding must have bottom mold connected with the body core in order to make it stable and easy to assemble. The bottom molds of some very large vessels are rammed on the ground such as the bottom mold of round vessel excavated from Xiaomintun Foundry site and the bottom mold of Fang Ding excavated from Miaopu North foundry site.

The pouring dish system usually set on the legs of three-legged vessels’ assembly, and one leg is as pouring dish and the two others are as risers. The pouring dish system usually set on the foot of round-foot vessels.

<table>
<thead>
<tr>
<th>No.</th>
<th>Samples No.</th>
<th>Samples name</th>
<th>Sintering temperature data</th>
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<tbody>
<tr>
<td>A1</td>
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<td>Upper Mold of Gu</td>
<td>Below 550°C</td>
</tr>
<tr>
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<td>2001AGT6H19:2</td>
<td>Clay core</td>
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<td>2000AGT15H31:917</td>
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<td>A18</td>
<td>2001AGT16</td>
<td>pottery</td>
<td>650–750°C</td>
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and sprue was made on the bottom mold. The assembly of large size vessel needs to be reheated before pouring and make it solid by heaping earth around it. The assembly is finished and ready for next step – pouring.

References


Postscript: This paper is abbreviated from the same title paper in Archaeology 2008.12: 80–90 with 19 figures, 1 table. The authors are Liu Yu, Yue Zhanwei, He Yuling and Tang Jinqiong, rewritten and translated into English by Liu Yu.