

Susan La Niece

Sand Casting in the Islamic World

Summary

Sand casting leaves little evidence compared to other casting mould materials. Archaeological discoveries of sand casting flasks in the Islamic world date the method to at least as early as the 11th century AD. The history of sand casting in China and Europe is also considered.

Keywords: Sandcasting; Islamic world; metal; casting flask; Middle East; China; Europe; India.

Der Guss in zweiteiligen Formen aus Sand hinterlässt nur wenige Spuren im Vergleich zu Gussformen aus anderen Materialien. Archäologische Funde von so genannten Formkästen in der Islamischen Welt ermöglichen eine Datierung dieser Gießmethode bereits in das 11. Jahrhundert n. Chr. Neben diesen Funden wird im Beitrag auch die Tradition des Gießens in Sandformen in China und Europa betrachtet.

Keywords: Guss in Sandform; Islamische Welt; Metall; Formkasten; Mittlerer Osten; China; Europa; Indien.

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I Introduction

Shaped moulds have been used for casting metal items from the earliest times. Stone, clay, and even metal have all been used to make moulds and these are often preserved in the archaeological record. Sand, because it takes an impression easily, can also be used as a mould material if a binder is added, but it does not retain the shape of the casting in the way that baked clay and other mould materials will, even when broken up; sand becomes unrecognisable as a mould once discarded. A simple impression made in sand to make an open mould no doubt dates back to the beginnings of metalworking, but the use of sand in two part moulds is a much more advanced concept, requiring considerable skill, but enabling mass production of identical copies from an original model. It is the known history of this technique which forms the subject of this paper.

In China there is evidence for the method being used in the 6th century AD (Northern Wei period) for casting coins with designs on both faces,¹ supplanting the stone and clay moulds of earlier periods of coin production which were not as suitable for manufacturing the large numbers of coins required at this time. Much later, in the late Ming dynasty, there is literary evidence for sand casting mirrors with decorated backs from a technical handbook by Sung Ying-Hsing, published in AD 1637.² Because coins and mirrors are flat they are relatively simple to cast by this method, especially when a real coin or mirror is used to make the impression in the sand.

In India, the inlaid and black patinated zinc alloy wares known as 'bidri' can be traced back to at least the mid 18th century AD and it is suggested that this traditional craft dates back to the 15th century AD.³ Bidri wares are made today by sand casting⁴ and it is likely that they always were (Fig. 1).

An absence of moulds in the archaeological record of the earliest metal-using periods in Europe has led to the suggestion that sand was used in the Bronze Age even for hollow forms requiring cores,⁵ though evidence for this practice is inconclusive from the study of the microstructure of the metal.⁶ It seems unlikely that the method was completely unknown in Europe; but if it was widespread in medieval Europe it would seem surprising that there is no mention of sand casting in the treatise of Theophilus,⁷ compiled circa AD 1125, which describes only lost-wax casting. In Europe it is not until the Renaissance that there is incontrovertible evidence for sand casting. The eighth book of the 16th-century metallurgical treatise of Biringuccio, *Pirotechnia*, begins with a preface on casting small items: "[...] I shall also tell you of the methods of moulding in boxes and in frames, and how the said powders are to be prepared for casting

1 Ying-Hsing 1966, 247.

2 Weirong 2003.

3 Stronge 1985.

4 Untracht 1968.

5 Eccleston and Ottaway 2002; Kuijpers 2008.

6 Wang and Ottaway 2004.

7 Theophilus 1933; Theophilus 1979.



Fig. 1 Metal sand casting flask, length c. 25 cm (above) and assembled with front and back boards, showing ingate (below), for casting of bidri ware in modern Hyderabad, India.

either dry or green.”⁸ The ‘powders’ described by Biringuccio are composed of a variety of granular materials such as gravel, tuff, river silt, crushed bricks and moist sand. In the Renaissance the method was used to produce items both small and flat, such as medals⁹ and large and hollow, such as candlesticks, bells and mortars.¹⁰ From the 19th century sand casting has been widely used in industry, particularly for cast-iron components, though other metals and alloys can be cast by the method. Sand casting has also been used in art foundries, particularly in Paris in the 18th and 19th century for producing editions of bronze sculpture. Such castings were too complex to cast in one piece and

⁸ Biringuccio 1959, 323.

⁹ Hill 1978.

¹⁰ Biringuccio 1959, 327.

were made in sections and assembled, requiring extensive tooling to finish the surface and to conceal the joins.¹¹

The Middle East has a long tradition of metallurgical innovation and might be expected to be an area in which to look for early application of the technique. It has been suggested, for example, from examination of objects and comparison with modern small-scale casting carried out in Iraq, that sand casting dates back to the 3rd millennium BC in Mesopotamia.¹² This may be true but substantive proof that the two-part moulds were sand, not clay, is so far lacking. The aim of this paper is to bring together firm literary and artefactual evidence, in particular from the Middle East, for the earliest dates for which we can be confident that casting in two-part sand moulds was being carried out.

2 The materials of sand casting

The simplest form of sand mould can be made by impressing moist sand with a model of the object to be cast. This model is commonly known as a pattern. The pattern can be of any resilient, easily shaped material such as wood. A metal item itself can be used as a pattern to cast copies. The sand preparation is important, and different workshops have their own preferences, in particular for the binding media added to the sand.¹³ As a general rule, sharp sand is sieved and mixed with clay, oil or other binding media to give the sand cohesion. 'Green sand', a mixture of sand with clay and water is sold today as a prepared medium for casting. It is necessary to use a dusting of fine powder as a parting agent to prevent the pattern and mould parts from sticking together. The 16th-century Italian treatise of Biringuccio¹⁴ describes dusting with ash for this purpose. Talc, chalk dust, graphite or proprietary powders are used as parting agents in modern casting.

The sand is usually confined to a box or frame. A flat item with a design on one side can be cast in a simple box of sand, for example the decorative cast-iron plates made in large numbers from about the 16th century onwards to protect the brickwork at the back of fire-places. The back of such a simple sand casting made in an open sand mould will be uneven because of surface tension of the liquid metal and shrinkage during solidification.

The more sophisticated method of sand casting examined here uses a two-part mould frame sometimes known as a casting flask. It is a frame, rather than a box: it is open, back and front, to allow access for filling with sand and removing the pattern. Separate boards are bound to the back and front of the frame to support the sand during

11 Rich 1947.

12 Müller-Karpe 1990.

13 Walker 1938.

14 Biringuccio 1959, 326.

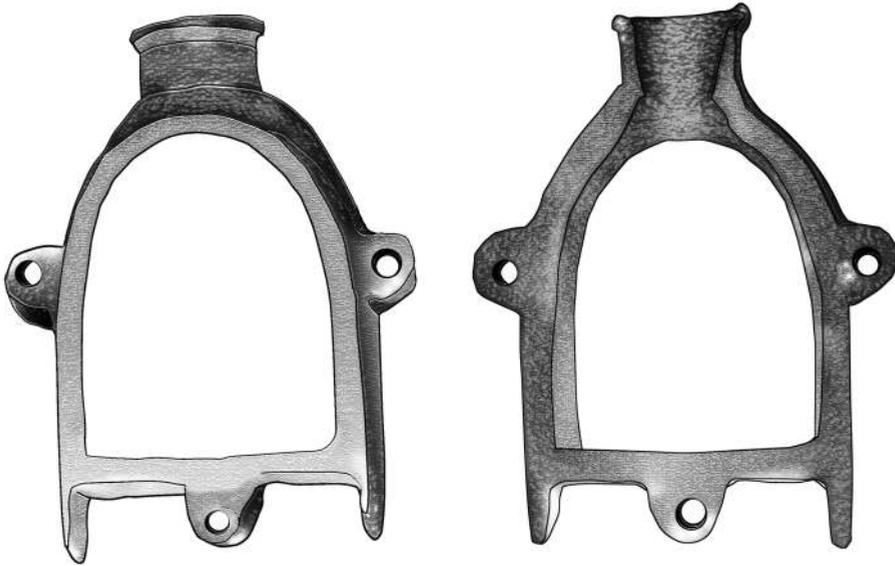


Fig. 2 A stirrup-shaped metal sand casting flask with ingate at top and three lugs for locating pins. The projections at the bottom assist in positioning the flask upright for pouring in the molten metal.

moulding and casting, but the process, as described below, requires the craftsman to have access to all sides of the frames at different stages in the process. Casting flasks are made in any suitable rigid material such as bronze, steel or wood. No ancient wooden examples have survived but metal casting flasks are sometimes recorded from excavation, as discussed below. They are not necessarily recognized for what they are: one typical form is illustrated in Fig. 2. As with any two-part mould, the casting flask often incorporates locating pins to prevent misalignment of the two halves. The pouring ingates are often integral to the wall of the casting flask (see Figs. 1–3).

There are several advantages to sand over other types of mould material; in particular it is well suited to mass production by the repeated use of the same pattern. The sand allows good gas permeability, lowering the risk of porosity, though the surface tends to be rougher or more matt than that produced in fine clay moulds for example.

As with other casting techniques it is possible to cast hollow items by fitting a disposable core in the mould, to block the molten metal from flowing where it is not wanted, for example filling the interior cavity of a bell. In modern foundry practice, cores are made of sand, usually mixed with a binder and are prepared in a core-box, which is a special mould, often in two parts, in which a core of exactly the right size and form is moulded.¹⁵ If the core is too small, for example, the walls of the casting will be too thick.

¹⁵ Roper 1958.

A core should be strong enough to hold together when the molten metal flows around it but should accommodate shrinkage of the cooling metal and permit removal of the core material from the finished casting.

3 The method

The description in Biringuccio's *Pirotechnia* Book (VIII, chapter 3) dating to AD 1540¹⁶ is recognisable when compared with modern practice.¹⁷ Variations in the technique and materials occur between workshops but the basic steps to sand cast a two-sided medal, for example, can be summarised as follows, and a search of the Web will find several sites demonstrating the method:

1. Place one part of the casting flask onto a flat board and ram tightly with sand;
2. Scrape the excess sand off to level the top and dust with parting powder;
3. Press the pattern half way into the sand;
4. Dust over the pattern with parting powder and blow away the excess;
5. Place the other half of the casting flask on top with the pattern which is still in place;
6. Pack with sand and scrape the excess off the top;
7. Place a board over the top, lift and turn over the top frame;
8. Remove the pattern and patch any areas where the sand comes away with the pattern;
9. Cut channels in the sand to make an ingate for the metal to enter the mould and vents for escaping gas;
10. Reposition the halves of the flask and the boards, bind tightly together then pour in the molten metal;
11. After cooling, open the flask and extract the casting;
12. Finish as required, cutting off the runners and risers.

¹⁶ Biringuccio 1959, 120; Biringuccio 1925. The German translation by O. Johansen differs in some interpretations of the original Italian text.

¹⁷ For example Aspin 1972.

There are variations in the procedure, for example to cast some forms it is more efficient to start by placing the pattern on the base board and then position half the flask, face down, around it. The pattern is then dusted with parting powder, sand is rammed in over and around the pattern before levelling it, turning over the flask and continuing from step 4 above.

4 Lands under Islamic rule

Cast round mirrors, like those from the late Ming dynasty in China mentioned above with relief decoration and a perforated knob in the centre of the back through which a cord may be threaded, are also found in the Islamic world. One distinctive group, examples of which are found in relatively large numbers, share the decorative motif of a pair of sphinxes and Kufic inscriptions which run round the rim. Many of the Islamic mirrors with the sphinx decoration have similar dimensions, suggesting that they were made with a standard mould or pattern. The relief decoration on some of this group is not sharply defined, indicating either the use of a worn pattern for making the mould or wear on a re-used mould. Unlike the Chinese examples discussed above, there is no literary evidence for how these Islamic mirrors were cast but sand casting is certainly a possibility, bearing in mind the simple form and the numbers of similar mirrors that seem to have been produced.¹⁸

The discovery of a casting flask constitutes clear evidence for sand casting: a handful of stirrup-shaped casting flasks have been excavated (and recognized). Excavations at Tiberias, on the western shore of the Sea of Galilee, uncovered three large storage jars filled with bronze scrap, apparently ready for melting down and recycling.¹⁹ The metal scrap included parts of cast vessels and a distinctive small metal frame of the type illustrated in Fig. 2. This hoard contained over 50 coins, the latest of which, a coin of the Byzantine emperor Michael VII (AD 1071–1078), provides the *terminus post quem* for its deposition, placing it in the Fatimid period.

From the northern extremities of Islamic influence, at Golden Horde sites north of the Caspian Sea, some of these stirrup-shaped casting flasks are also known,²⁰ though the only one with a dated archaeological context is one half of a small copper alloy casting flask from the 13th to early 14th-century Islamic levels at Ukek, a town on the River Volga.²¹

A much larger, circular two-part frame (31 cm in diameter × 24 cm deep) in the Islamic collections of the British Museum has all the necessary features of a sand casting

18 See La Niece 2003 for a survey of manufacturing techniques of Islamic brasses.

19 Hirschfeld and Gutfeld 2008.

20 Polyakova 1996, Fig. 58,12; Volkov 2011.

21 Nedashkovsky 2004.



Fig. 3 Bronze sand casting flask from Iran, unknown date. The ingate for pouring in the metal is at the top. Note the relief keying on the inner face. Diameter: 31 cm.

flask, in particular an opening for the molten metal to be poured in (see Fig. 3). It was itself made by casting, in leaded bronze, complete with pins to accurately locate the two halves and prevent misalignment. On its inner surface there are relief patterns which presumably would have provided keying to help hold the sand in place. Its date and provenance are unknown except that it was donated to the Museum with a group of Persian objects and it has Arabic script cast in relief on the interior which translates as “work of [– –] Mohamed”. The plastic appearance of the relief keying suggests that the flask was probably made by lost-wax casting. If this is so, it would indicate that both casting methods were being used together, presumably for different products.

There is literary evidence too for sand casting: the court inventor al-Jazari, writing in the city of Amid, near Mosul (in present day Iraq) around AD 1200, described the process of sand casting openwork brass plaques to form an interlocking facing for a wooden door to a palace.²² Al-Jazari describes cutting (wooden) patterns to make impressions in the sand “as the founders do in the foundry (*ālat-al-Ṣabb*)”, an indication that sand casting was being more generally used in the local foundry. Al-Jazari also describes an ingenious variation to the technique; nails were partly embedded in the sand mould before pouring in molten brass around the heads of the nails, producing plaques equipped with fixings, ready to hammer into the wooden door. An example of the type

²² al-Jazari 1974.



Fig. 4 Copper alloy panels and openwork knocker on the Puerta del Perdon Seville cathedral, Spain, 1172–1196 AD.

of decorated doors to which he might be referring are the 12th–13th-century doors of the Great Mosque of Cizre, on the Tigris in south-eastern Turkey, now in the Museum of Turkish and Islamic Art, Istanbul. Another possible example is the Puerta del Perdon, the main entrance to the only surviving section of the mosque now incorporated into the cathedral in Seville, Spain. These doors are dated to AD 1172–1196 and are over nine metres tall, covered with a large number of lozenge-shaped plaques with Koranic inscriptions and Almohad floral ornament (Fig. 4). It is not known how these particular plaques were made, though examination may be able to establish whether they could have been made by sand casting.

Identifying objects that may have been made by sand casting is difficult, particularly where the surface of the casting has been well finished, removing any texture left by the mould material. There is a group of candlesticks, probably made in Anatolia and dated



Fig. 5 Three identical brass candlesticks cast in one piece and inlaid with silver. Anatolia, second half of the 13th century AD. Height of all: c. 20 cm.

to the 13th and 14th centuries, which may have been made by sand casting (Fig. 5). They are more complex in form and larger than items discussed so far, but the casting flask in Fig. 3 would be almost large enough to cast these. Biringuccio recorded that he had seen muskets of three hundred pounds apiece and large candelabra cast, so the size of these candlesticks should certainly not have been a problem.²³ They were clearly mass produced – more than seventy such candlesticks survive today and all those examined were cast in one piece, and have very similar dimensions and weights: height and diameter circa 20 cm to 19.5 cm, weight circa 1.8 kg, metal thickness circa 3 mm.

A factor suggesting that these were made by sand casting is the evidence for the positioning of their casting cores. The candlesticks were cast in a single piece, with cores for both the hollow candle socket and the base. These cores were removed after casting but the evidence of their form and position in the mould is preserved on the inside of the candlesticks. The thin metal wall at the bottom of the candle socket, designed to prevent the candle falling into the hollow base, is pierced by a small hole about 8 mm in diameter, curiously off centre in all cases. There is no functional necessity for this hole. Inside the base and candle socket there is a linear discontinuity in the surface of the metal (Fig. 6). These internal linear features indicate that the cores were made in two-part moulds which did not join tightly, creating flash lines down the side of the cores which were then imprinted on the cast metal in negative.

The method of making cores in two-part core boxes is well documented for sand casting from more recent times.²⁴ As the hole in the thin metal between the two candlestick cavities is too small to serve as a core print, it is suggested that there was a rod running between the cavities, piercing the cores like a kebab stick. The ends of this rod would have been embedded in the wall of the mould to hold the cores in place during casting. To do this for a sand casting, the ends of the core rod would need to be held between the two halves of the casting flask. The obvious way of positioning the ends

23 Biringuccio 1959, 120 (Book VIII, chapter 3).

24 For example Roper 1958.



Fig. 6 Features of the core preserved in the metal at the bottom of the candle socket on a damaged candlestick of the type seen in Fig. 5. Note both the linear discontinuity indicating the core was made in a two-part mould, and the small hole linking the candle socket core with the core in the hollow base of the candlestick. Scale: 5 mm divisions.

without obstructing the tight closure of the two-part flask would be to make a notch in the rim of one half of the flask to accommodate the rod. This is described well by Biringuccio: “If they are things that need a core inside in order to make them hollow and light in bronze [...] such as pedestals, candlesticks, small or large bells, mortars, or similar things, make the core on a suitable iron, either using the same powder in a mould, or forming it by hand [...] put them in their places in the frames [...]. Then join the frames together and press them between two flat boards with a clamp or with a rope [...] to hold them tight [...] cast them in whatever metal you wish”²⁵

Positioning the cores as described would result in the rod being slightly off centre in the sand impression; so, to compensate for this lack of symmetry and ensure the even thickness of the walls of the casting, the core would need to be slightly thicker on one side than on the other. This minor asymmetry of the cores is a feature which can be observed on the interior of these candlesticks. It is not absolute proof of how they were made, but the unusually large number of virtually identical candlesticks further supports the suggestion that they were made by sand casting, a method well suited to mass production.

5 Conclusions

The history of sand casting in two-part moulds is still far from complete, largely because of the poor preservation of evidence in the archaeological record. It would seem that the earliest surviving evidence for the method is in China, where it was used for mass-production of coins in the 6th century AD. It was known in the Islamic world by at least as early as the 11th century AD where it was used to cast brass artefacts and

25 Biringuccio 1959, 327.

decorative plaques, and it had certainly reached Europe by the 16th century. It cannot be claimed that the process was invented in China and spread westward, only that the survival of evidence can be traced back to these dates in different areas of the world. It is possible, some would say likely, that the method is considerably earlier in many parts of the world and it might be hoped that in future more casting flasks will be reported from dated contexts.

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