SEARCH CORPORATION OF THAILAND

RESEARCH RROGRAMME NO. 7

MANUFACTURE OF FERROUS AND NON-FERROUS CASTINGS

RESEARCH PROJECT NO. 7/8

PRECISION CASTING IN BRASS AND BRONZE

REPORT NO. 1

A THAI TECHNIQUE FOR PRECISION CASTING OF BUDDHA IMAGES

BY

KASEM BALAJIVA

MINERALS AND METALS GROUP

TECHNOLOGICAL RESEARCH INSTITUTE

ASRCT, BANGKOK 1968

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

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F O R E W O R D

An announcement was made about 3 years ago that His Majesty the King wished to create a religious fund and invited His subjects to join Him in this cause. As a token of appreciation the King offered to present each contributor to the fund with a brass Buddha image carrying His Majesty's initials. Following the announcement of the Royal invitation, over 20,000 applications to join in this good cause were received and the Royal Mint of the Treasury Department was commissioned to cast the Buddha images required by the King.

The traditional Thai method of production which is used by the Royal Mint is time-consuming and produces erratic results which have to be rectified in the final finishing operations and it was soon realized that the commitment could not be fulfilled within a reasonable period of time. ASRCT's Technological Research Institute was therefore requested to assist in finding means of improving the manufacturing technique so that a faster rate of production and more consistent quality could be achieved. The study which was undertaken by TRI deserves special consideration since, although the manufacture of Buddha castings is not likely to be a large scale industry of Thailand from the economic point of view, it has been and will always be an important part of the Thai people and their tradition.

A THAI TECHNIQUE FOR PRECISION CASTING OF BUDDHA IMAGES

By Kasem Balajiva*

SUMMARY

As part of an investigation to assist the Royal Mint in the production of over 20,000 brass Buddha images for the King's charity programme, a critical review has been made of the Thai precision casting process which has been used by the Royal Mint as the method of manufacture. It was seen that the process requires highly skilled craftsmen and long in-process time, and is suitable only for small production batches. The longest production time is in the mould preparation stage which not only controls the as-cast quality but also influences the finishing operation time. For relatively large scale production, such as in the case of the Royal programme, and for the future well being of this industry, a more efficient moulding technique requiring less skilled labour is highly desirable.

The review has also served the useful purpose of recording a process which has been part of the Thai tradition for over 1,000 years and which has been handed down through generations in unwritten form.

INTRODUCTION

Precision casting is generally accepted as being a technique for the production of objects which are not possible or are uneconomic to make by conventional methods of machining or fabrication. Precision cast products are expected to possess not only fine details and high surface quality but also a high degree of dimensional accuracy of the order of $\pm$ 0.1 mm or less. The Buddha image falls in this category because of the intricate design and complex geometry of the object, although the dimensional accuracy required is not of a particularly high order. It is logical, therefore, that precision casting by the lost wax process has been adopted by the Thai as the method of manufacture. The technique used by the Royal Mint is the same as that practiced by the number

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of small foundries of the cottage industry style who specialize in this type of casting.

The study which was aimed to assist the Royal Mint was divided into two parts; the first was a critical review of the present Thai method of precision casting to compare with the basic techniques employed in other countries, notably in Europe and America. The review aimed to identify where the weakness lies in the Thai method and where action on the part of TRI should be directed to correct it. The second part of the study dealt with attempts to adapt and to introduce modern techniques of manufacture to specific stages of the Thai process to shorten the production time and improve the casting quality. The new technique can no doubt be applied to the manufacture of other castings where reproduction of intricate designs and dimensional accuracy are essential. The first part of the study which is contained in the present report also serves the valuable purpose of recording a process which has been associated with the Thai tradition for several hundred years and which has been handed down through generations to this day in unwritten form.

THE LOST WAX PROCESS

Although it is primarily intended in this study to examine the Thai method of manufacture in some detail, it is desired to include a brief account of the basic technique which underlies the modern version of the process which has reached wide scale commercialization today.

The lost wax process for precision casting was first practiced by the ancient Egyptians over 4,000 years ago and later, about 2,000 years ago, by the Chinese in the Shang Dynasty, mainly for making jewellery and art objects. It has been used in Europe and America on commercial scale for the manufacture of jewellery, surgical appliances and statues, and in dentistry since before the World War II. As far as can be traced back, the process was adopted by the Thai about 1,000 years ago for making Buddha images and statues.

The term lost wax process, often referred to as the investment casting process, stems from the fact that the pattern, which is the replica of the object to be produced, is customarily made of wax. The wax pattern, which is slightly larger than the object to compensate for contraction of the metal during casting, is prepared by pouring or injecting liquid wax into a mould made of plaster of paris, metal or epoxy resin. The wax pattern is then

extracted from the mould and sprues, runners and risers, also made of wax, are attached. The pattern assembly is then coated with a slurry of refractory filler and bonding agent, either by dipping or spraying, and is further coated with a coarser refractory filler either by sprinkling or in a fluidized bed.

The pre-coated pattern, when dried, is 'invested', i.e. placed in a steel flask and a mixture of coarse refractory and binding agent is filled around the pattern. This is a block mould type. It is allowed to set and dry out completely; it is then heated to melt away the wax and to partly sinter the refractory, and finally liquid metal is cast into the cavity which the wax previously occupied.

An alternative mould-making method which is claimed to be a major improvement over the block mould type is the shell technique where, instead of investing the pre-coated pattern in a steel flask, it is dipped into a slurry made up of refractory and binder, coated with a layer of refractory, and dried until a hard shell is formed. The operation is then repeated successively until a sufficient shell thickness is obtained. The shell is dewaxed and finally cast either unsupported or loosely packed in dry coarse sand or refractory backing. The economic advantage of the shell technique over the black mould type is mainly due to its simplicity.

The development of the lost wax process since the last World War, mainly in the preparation of the mould and the dewaxing technique, has been discussed in detail elsewhere (Turnbull 1955; Beer 1963). It is sufficient to summarize here that the pattern may now be made of wax or frozen mercury. Clays, cereal by-products and synthetic resins have been employed as bonding materials but ethyl silicate is the most widely used today owing to its superiority in many ways over the other types of bonds.

MANUFACTURE OF BUDDHA IMAGES IN THAILAND

The manufacture of Buddha images in Thailand is in the hands of a limited number of specialized cottage foundries and the technique used in the manufacture has been handed down through generations to the present day with almost no significant modification. The only changes have been in the features of the image which indicate the three main periods of Thai civilization before the present era. These periods are the Chiang Saen, the Sukhothai and the Ayutthaya.

The Chiang Saen Buddha has some Burmese influence and has some degree of seriousness of expression. History tells us that the Thai people were continually competing with their neighbours for existence and to gain power, and during the Sukhothai period which followed the Chiang Saen days the Thai were powerful and enjoyed the longest period of peace and prosperity. The Buddha images made during the Sukhothai period have, therefore, been regarded as having the most beautiful form and expression of all. This is the style of Buddha which the King has chosen to be made on the present occasion.

The Ayutthaya period which followed the Sukhothai saw much fighting between the Burmese and the Thai which ended with a defeat of the Thai and the expression of the Buddha image produced reflects the hardship and sadness of the Thai people during those difficult days.

The present Ratanakosin period has not produced a new style and most of the Buddha images made are reproductions of the Sukhothai form.

In the castings which are being produced by the Mint the figure is in a typical sitting position as shown in Figure 1. It measures about 12.5 cm across the lap and 25 cm high. The casting is hollow inside and weighs about 2.5 kg. The processing technique comprises 4 main stages.

(i) Preparation of the wax pattern

A master model, which is the replica of the Buddha image to be cast, is made with plaster of paris. From the master model, several master moulds are made. Each master mould will produce several models. Several moulds which are used for the production of wax patterns for casting are made from each working model. Plaster of paris is used throughout. The precedure is necessarily lengthy since, owing to the complex geometry of the design, each mould has to be made up with no less than 14 separate pieces to facilitate withdrawal of the patterns. Mould life is consequently short due to mechanical damage to the edges of the plaster pieces under service conditions. Soft soap is used throughout as the parting agent in this process. Figure 2 shows the type of plaster mould employed. It will be noted that the arms are cast in separate plaster moulds and are subsequently attached to the body to complete the form.

The hollow wax pattern is made by filling a plaster mould with molten wax and after about 1-2 minutes, when a layer of solidified wax has been formed, the remainder of the liquid wax is poured out. The mould is next filled with

Figure 1. A Buddha image casting.

Figure 2. Plaster of paris mould for wax pattern.

Figure 3. Filling sand core in wax mould.

a sand/clay mixture to form the core (Figure 3), which is allowed to dry overnight. The cored wax pattern is finally extracted from the mould and dressed by hand to the final form.

The wax which is used for the pattern is made up essentially of paraffin wax to which a gum from a local plant (Chan) is added as a hardener. A colouring agent such as iron oxide is usually incorporated to enable fine details to be easily seen during the touching up operation. No fixed formulation of the wax is exercised and the wax quality is variable from time to time.

(ii) Mould making

The three basic mould materials are clay, buffalo dung and sand. The plastic clay, which is obtained from a carefully selected locality, is made into a slip by an elutriation technique well known in the ceramic industry. The dung is first mixed with water and fibrous materials extracted before it is added to the clay slip to improve its plasticity. The sand used is of two approximate gradings, fine and medium size grains.

Before mould making begins, wire nails are pushed through the wax to its core to serve as anchorage (chaplets) between the core and the outside mould to be formed. Three primary coats of the clay slip are applied to the wax pattern with a soft brush (Figure 4), each coat being allowed to dry for at least 3 hours before the next coat is applied. The total thickness of the 3 coats is about 1 mm. The outside shell of the mould is then built up by hand pressing with 3 secondary coats of clay-bonded sand, fine sand being used for the first coat and medium grain sand for the subsequent coats (Figure 5). Each coat has to be dried sufficiently, taking up to 24 hours, although this drying time could be accelerated somewhat by forced draught. The coating thus completed hides all the nail chaplets.

After attaching wax runners and sprues to the pattern at appropriate places where part of the shell previously formed has been scraped away, a coarse wire mesh is strapped around the mould as reinforcement (Figure 6). Again 3 more coats of sand clay mixture are applied with similar intermediate drying to complete the whole moulding operation; such a mould appears as shown in Figure 7.

(iii) Wax removal and casting

The completed mould is slowly heated in a furnace up to a temperature of about 900-1000°C, taking 7 to 8 hours, during which period most of the wax is

Figure 4. Primary coating of clay-buffalo dung slip.

Figure 5. Secondary coating being applied.

Figure 6. Mould reinforced with wire mesh.

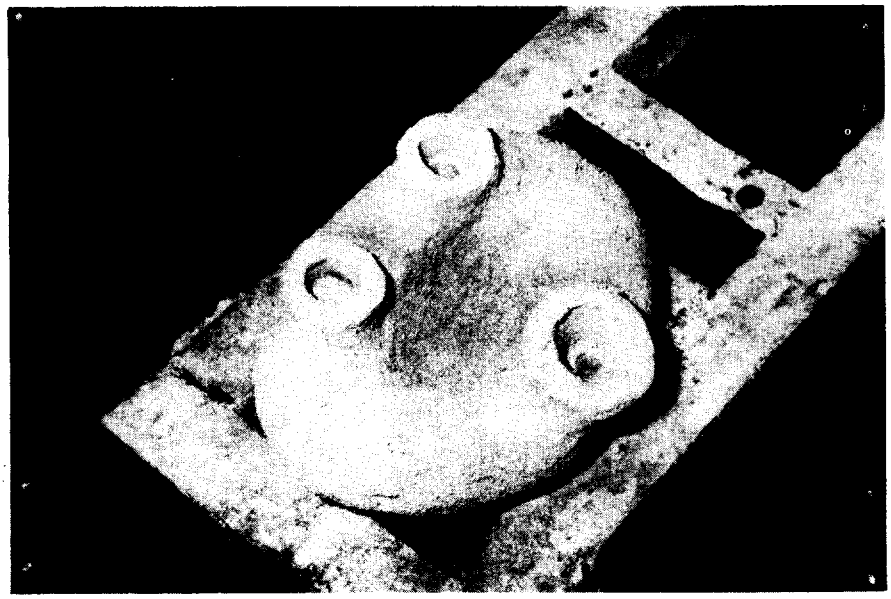

Figure 7. Completed mould ready for firing.

melted out at low temperatures and the remainder of the wax is burnt away at the final temperature. After the complete firing, the hardened mould is removed from the furnace and cast while it is still hot, about 700-800°C.

The metal used for casting is generally brass with about 62 % copper, 36 % zinc, and 2 % lead, the lead being added to improve the machinability of the alloy in the final dressing operation. The melting is effected in clay or graphite crucibles in charcoal fired furnaces, but nowadays some of these furnaces have been replaced by a conventional type of oil-fired furnace (Figure 8). The casting temperature is around 1100°C.

It is appropriate to record here that the casting of the Buddha image in Thailand is closely connected with the religious rite. It is customary before casting that part or all of the metal which is to be melted should be blessed and the casting produced should again be annointed in the final stage before the image goes on the place of worship. In the Royal programme, both the religious ceremonies are part of the routine before the images are distributed to the people.

(iv) The final dressing operation

The final treatment of the casting is a major part of the manufacturing process. A high proportion of the castings made contain defects caused by breakdown of mould materials during casting and by slag inclusions and defects due to misruns. The defects are removed and metal deficiency is filled up by brazing. Any surface roughness is dressed by filing and scraping and finally the casting is polished and buffed to a high lustre, the total time required being of the order of 2 days for each casting. Figure 9 shows the casting as cast, and Figure 10 shows it being dressed and completed before the blackening treatment.

In many cases, including this Royal requirement, the finished casting is surface treated to give a lustrous black colour. The casting is dipped in a hot solution of ferric chloride and hypo (3 % of each) for about 5 minutes, washed in hot water and dried. Alternatively the solution may be poured over the casting as shown in Figure 11. This treatment effects solution of some of the zinc and deposition of iron in its place due to the difference in their electromotive potentials. The procedure may be repeated until the Fe-deposited surface of the casting is uniformly black and can be given light buffing to the

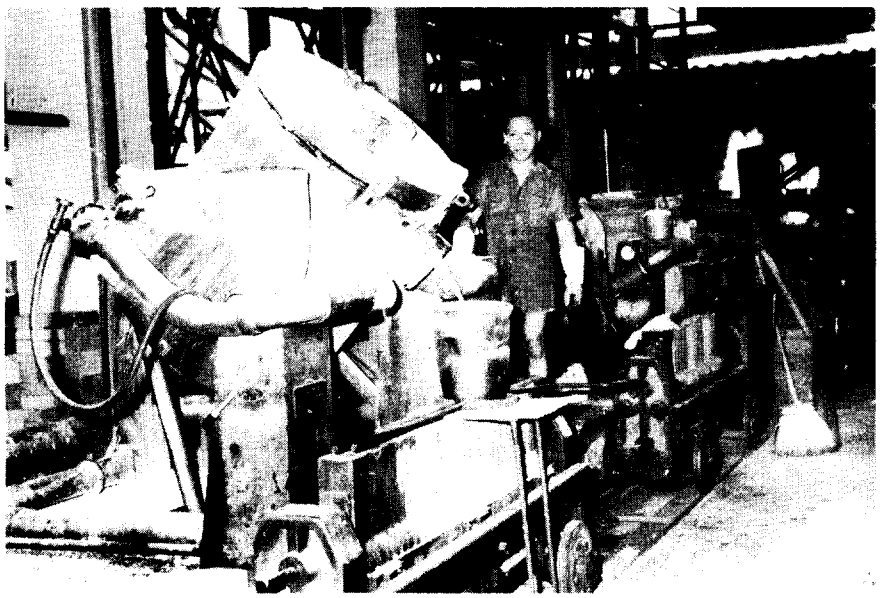

Figure 8. Melting unit.

Figure 9. As-cast Buddha image.

Figure 10. Part of dressing operation.

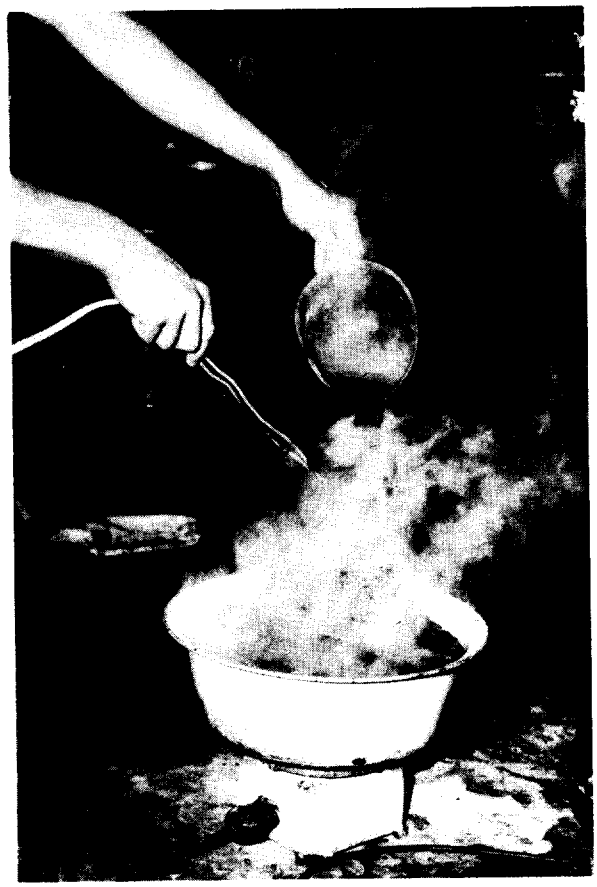

Figure 11. Blackening treatment.

required lustre. A further sulphiding treatment of the surface may sometimes be given by the use of potassium or sodium sulphide solution and the finished product may also be lacquered to complete the whole process. The time from casting to the final product is about 5 days.

CONSIDERATION OF THE THAI TECHNIQUE

The Thai method of manufacture is capable of producing good surface quality and fine reproduction of details of the wax pattern by virtue of the fact that the mould facing material is essentially clay of fine particle size, under 20 microns. The process relies heavily on availability of suitable natural raw materials, particularly plastic clay and sand, and relatively cheap skilled labour. Highly skilled craftsmen are required at all stages of the operation, a factor of serious concern to this industry as time advances and as attractions to other more remunerative employment increase.

It will be noted that the mould which is formed around the wax pattern in the Thai process is a thick shell reinforced with wire mesh to resist expansion of the wax during slow heating in the wax removal operation. This shows some similarity in principle to the modern shell process which has been developed in Europe and America since the last World War. The basic differences between the Thai and the modern shell techniques lie in the fact that, in the modern process which is capable of large scale commercialization, the mould materials are of controlled characteristics and the mould-making process is so standardized that reliable and reproducible results can be expected.

The Thai process, however, is time-consuming and suffers from certain practical and technical disadvantages:

(1) Plaster of paris which is used for the wax mould is suitable only for short run work. For quantity production, such as at the Royal Mint, the short mould life requires a considerable number of replacement moulds. Each mould is made up with about 14 pieces to facilitate extraction of the wax pattern and the fragile edges enable only about 10-15 patterns to be produced. A metal die with a wax injection machine, such as is used where dimension accuracy is required, could be considered but the complex geometry of the hollow wax pattern may present some engineering difficulties. Alternatively, moulds made of synthetic resin or low-melting point Pb-Sn alloy could be used instead of plaster of paris moulds. Both these materials have been used for successful

production elsewhere.

(2) The clay used for the preparation of moulds for casting has an appreciable contraction on drying and during firing to high temperatures. This, together with the expansion associated with phase transformation at critical temperatures, make the mould material prone to cracking and delamination prior to casting. The problem is accentuated by variation of the physical characteristics of the mould material through its thickness due to admixtures of sand to provide cold strength and to withstand handling. The technique was formerly used in other countries but has long been abandoned for these reasons.

(3) Another disadvantage of the Thai process is the long drying time at the various stages, which cannot be accelerated if drying contraction of the material is to be under control. Each mould requires 8-10 days from the wax pattern to casting. Once the moulding operation has begun, any mould defects cannot be known until after the casting is made and defects which have occurred in the casting add to the time required for the final dressing of the casting.

(4) It is clear that mould making is where the bottleneck of the whole operation lies and the future success of the Thai precision casting industry depends largely on introduction of modern and efficient techniques where less skilled labour can be employed.

CONCLUSIONS

A detailed study of the Thai method of precision casting as applied to the manufacture of Buddha images has enabled the following conclusions to be drawn.

(1) The technique has been part of the Thai tradition for about 1,000 years and appears to have been handed down through generations to the present day with no significant modification.

(2) The precision casting in Thailand is used mainly for reproduction of fine details and intricate designs, the dimensional accuracy being of secondary importance.

(3) The process is slow and requires considerable hand manipulation by highly skilled labour. The process is suitable only for small scale production where relatively cheap skilled labour is available.

(4) For large scale production, such as the Royal requirement of over 20,000 castings, it is not anticipated that the commitment can be fulfilled in reasonable time unless some improvement in the technique is introduced to effect reduction in in-process time and less skilled labour can be employed.

(5) Improvement is most needed in the mould making operation where defects in the casting occur, originating from the mould materials. Such defects have subsequently to be rectified and add to the time consumed in the final dressing operation.

ACKNOWLEDGEMENTS

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