

FATH RAIHBĀR - THE MASSIVE BRONZE CANNON AT PETŁĀ BURJ OF GOLCONDA FORT

R. BALASUBRAMANIAM*

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The massive bronze cannon by name *Fath Raihbār* “Guide to Victory”, located on the Peṭlā Burj of the Golconda fort outer rampart, is described here. The measured dimensions of the cannon have been set forth. The total length of the cannon is 486 cm. The diameter of the muzzle is 70 cm, bore 26 cm and end of the barrel 84 cm. The total weight of the cannon is 16.59 tons. The engineering design of the cannon has been explained. Some aspects of the manufacturing methodology of the cannon (i.e. casting) have been obtained by careful metallurgical observation of the surface. Sixteen iron rods, spaced at regular intervals along the outer circumference of the end plate, have been inserted into the rear of the barrel. Their relation to the manufacturing methodology is not known. This must have provided additional strength at the powder chamber location. Analysis of composition of the material of construction indicates that it was leaded bronze. The relatively large percentage of lead (9-12 wt. %) facilitated casting. This cannon is a wonderful example of the Mughal bronze cannon manufacturing technology prevalent during the time of Aurangzeb (1658-1707).

Keywords: Aurangzeb, Bronze, Cannon, Casting, Engineering design, Leaded bronze, Manufacturing.

INTRODUCTION

The use of gunpowder and cannons in warfare became increasingly important from the later half of the 15th century in the Indian sub-continent. The technology for manufacturing cannons advanced in the 16th century. The preferred material of construction was bronze. The Indian developments in bronze cannon technology closely followed the advancements in Europe and the Ottoman Empire and, therefore, underwent significant modifications till the end of Akbar's reign¹. Following Akbar (1556-1605), there was a period of stagnation in the technology of manufacturing large bronze cannons, because the focus shifted to the production of light cannons, which could be easily

*Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur 208 016, INDIA.

carried and used in sieges as well as in field battles. Beginning from the later half of the sixteenth century, cannons were also constructed using forge-welded wrought iron in the Indian sub-continent. Although the wrought iron cannons were cheaper compared to bronze cannons, it required enormous skill and effort to forge weld wrought iron cannons because the construction methodology required carefully engineered iron rings shrunk fit (i.e. hooped) over a central cylindrical bore, consisting of longitudinally-laid out iron plates (called staves). Unfortunately, the Indian rulers of this period (17th and early 18th centuries) did not realize the importance of cast iron technology for cannon and cannon ball manufacture and this ultimately resulted in the domination of European powers in India.

The number of heavy cannons in the Mughal artillery under Akbar's reign was significant. In a recent book, which provides a detailed historical review of artillery under the Mughals among other aspects of gunpowder and warfare in India, Khan notes that the majority of bronze cannons used in Akbar's period were of similar design¹. Khan concludes that there was not much change in the technique of manufacturing bronze cannons in the seventeenth century by noting that the bronze cannons depicted in paintings of Aurangzeb's period were also of similar design¹.

There was a considerable revival of interest in manufacturing large cannons during the reign of Aurangzeb (1658-1707) and this has been generally attributed to his continuous wars in Deccan. However, the efficiency of these cannons in warfare and siege operations needs to be looked at critically. The Golconda fort was not captured by military power but rather by deceit². A European observer noted in 1662 that the Mughal artillery that attacked Daman was ineffective and that the Mughals used artillery "only to frighten the besieged with thunder."³. A similar view is also held by Deloche⁴ based on his detailed studies of Indian fortifications^{5,6}. Deloche opines that the Indian cannons were not powerful enough to break down fortifications as revealed in the design philosophy of the Indian forts when compared with European forts of this period. He points out that while the European forts lowered their ramparts in order to make them less vulnerable to being breached by cannon fire, the Indian forts increased the height of fortification walls. However, it must be noted that the Deccan forts were redesigned, with the entry of cannon in siege

warfare, such that an outer line of fortification was added to existing forts (from the second half of the fifteenth century onwards)^{7,8}. The purpose of this addition was to make it difficult for cannons to destroy the strategic buildings within the main fort.

Deloche concludes that the shots fired from cannons were inefficient in breaking fortifications. One possible reason for this could be the widespread use of stone balls rather than metallic shots in the cannons of this period (16th to 18th century). There is an interesting account wherein the Mughal commander of Ausa fort sends a report in 1671 to Aurangzeb (the artillery was always in the direct command of the Mughal emperor right from the time of Babur) for purchasing iron cannon shots using the already sanctioned amount for purchase of stone balls because he understood the effectiveness of metallic cannon shots¹. It may be relevant here to note that the development of cast iron technology in Europe from the 16th century onwards permitted large-scale production of cheaper cast iron cannon balls. The use of cast iron for cannon ball manufacture was one of the first major applications of cast iron in Europe. Unfortunately, the Indian rulers did not pay much heed to developing cast iron technology and the cannon balls were primarily made of stone. This may explain the ineffectiveness of Indian cannon fire in breaching fortifications.

Artillery, nevertheless, played a very major role in the military campaigns of Aurangzeb. His campaigns against the Deccan kingdoms were usually based on long sieges of the forts. For this purpose, he employed large cannons. In the present paper, the engineering design and construction details of a massive bronze cannon belonging to Aurangzeb's reign will be described. The name of the cannon is *Fath Raihbār*, which is now located on the Peşlā Burj of the outer rampart of the Golconda fort. Another aim of the paper is to highlight the skill of the medieval Indian *rekhtagars* (technician specialized in the smelting and casting of bronze and copper) in manufacturing such large bronze cannons.

HISTORY

The *Fath Raihbār* is located on the Peşlā Burj (see Fig. 1) and is accessible to the general public. This bastion is built in the western wall of the Golconda fort and popularly known as Peşlā Burj meaning “Fat Belly Bastion”

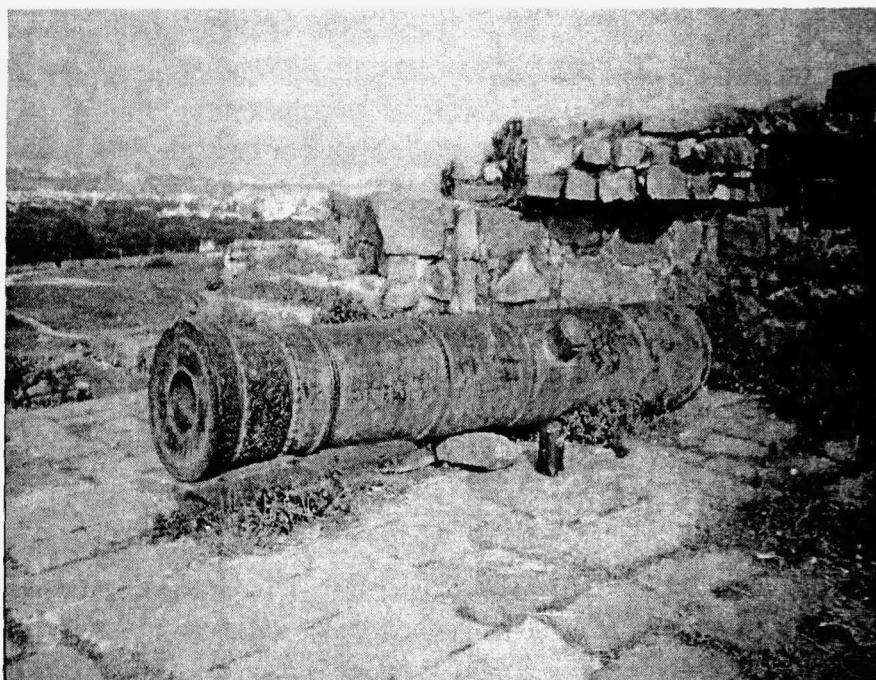


Fig. 1: The *Fath Raihbār* cannon located on the Petlā Burj of the Golconda Fort Rampart.

on account of its body protruding from the line of fortification. There is no properly maintained footpath to reach this cannon. One has to walk through bushes and damaged steps to reach this Burj. The locals call this area as *āttāra siḍī* (eighteen steps). There is a segmented wall just behind the back of the cannon (Fig. 1) and this absorbed most of the energy of recoil when the cannon was fired. Additional stresses were, therefore, not induced in the swivel and pivot arrangement that supported the cannon.

The history of the Golconda fort has been dealt in detail while addressing two forge-welded iron cannons on the outer ramparts^{9,10}. The point of interest is the siege and subsequent capture of the Golconda fort by Aurangzeb. After the Golconda fort was captured by Aurangzeb in 1687, he stationed there some of the massive cannons that he had brought along with him to capture Golconda. The *Fath Raihbār* is the largest of such cannons. This cannon finds mention in *Ma'athir-i-Ālamgiri*¹¹ in the description of Golconda siege.

The inscriptions on the top surface of the cannon (Fig. 2) provide its history. Inscriptions are also engraved on the front face of the cannon near the

outer circumference (Fig. 3). The reading of the inscriptions by Yazdani¹² is shown in Fig. 4. Yazdani provided the following translation for the inscription that appear on the top surface:

“Abu-l-Muzaffar Muhammad Muhiu-d-din Aurangzeb Bahadur Ālamgir, Bādshāhī Ghāzī (the victorious king)

In the sixteenth year of the auspicious reign (corresponding to) 1083 of the Holy Era of the Flight (1672 A.D.)

Fath Raihbār (Guide to Victory) gun

Made by Muhammad Ali Arab

Charge: one *maund*; Gunpowder: thirteen and a quarter *seer* according to the Shāhjahānī weight”

The inscriptions on the front face of the cannon have been translated¹² as follows:

“Since the (wine) flagon learnt smiling from the lips of the mistresses, fire has issued forth from its mouth and encircled the assembly”.

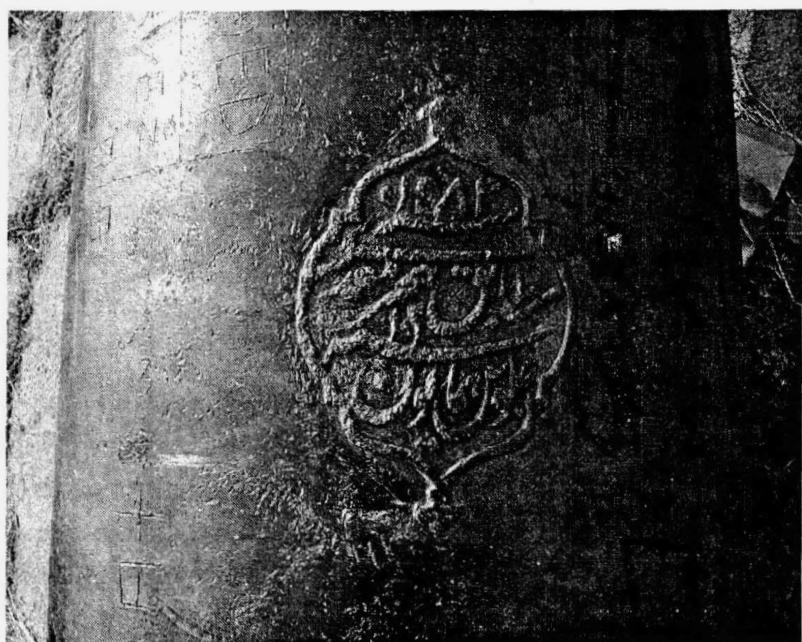
It is interesting that the above sentence also appears on the *Mālik Maidān* “Battle King”, a cannon manufactured in 1663 and now located at Parenda Fort¹³. This cannon was executed by one Muhammad Hussain Arab¹³, most probably the father of Muhammad Ali Arab who supervised the construction of *Fath Raihbār*.

The weights of the gunpowder and shot have been provided in Shāhjahānī weight units. In terms of modern weights, one *maund* or *man* of Shāhjahānī unit corresponds to 33.5 kgs and one *maund* was composed of 40 *seers*¹⁴. Therefore, the weights of the gunpowder (33.5 kgs) and shot (11.1 kgs) used in this cannon are precisely known. The ratio of shot weight to gunpowder weight is approximately 3. The earliest cannons of Babur threw stones while in later Mughal period shots were also made of copper, bronze (hollow as well as solid), brass, wrought iron and lead¹.

The inscriptions mention the name of chief engineer, Muhammad Ali Arab. The same engineer supervised the manufacture of three other Aurangzeb’s cannons that are currently located in the Golconda Fort. These cannons are the *Qila Kusha* “Fort Opener” (located on a bastion to the northwest of Baradari and manufactured in 1666)¹⁵, the *Azdāha Paikār* “Dragon Body” (located on the Musā Burj and manufactured in 1674)^{12,16} and the *Atish Bār* “Raining Fire”



Fig. 2: Inscriptions on the top surface, sequence from the muzzle end: (a) First,



(b) Second



(c) Third



(d) Fourth, and



(e) Fifth, at the extreme rear near the fuse hole.

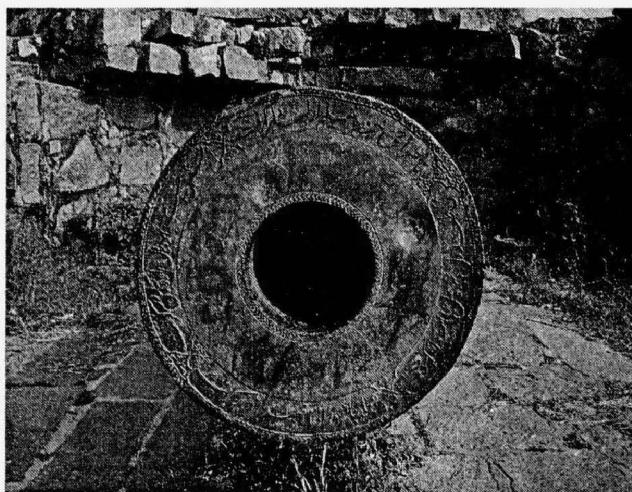


Fig. 3: Front face of the cannon. Notice inscriptions along the circumference.

(located on a bastion at the foot of Bala Hisar Hill towards the south-west and manufactured in 1679) ¹⁵. The *Azdāha Paikār* cannon (a composite cannon made of wrought iron inner barrel and cast with bronze outside) is the only among them one that finds mention in the list of cannons used by Aurangzeb in the siege of Golconda ¹¹. The engineering skill of Muhammad Ali Arab must be

ابو المظفر محمد محيي الدين ارزنگ زیب عالم گیر بهادرز بادشاہ غازی
سنه ۱۶ چلوس همايون مطابق سنه ۱۰۸۳ هجری مقدسه

توب فتح رهبر

عمل محمد علی عرب

گله یک من و باروت سیدزاده آثار پار ڈال بزرگ شاهجهانی

تا صراحی خلده تعلیم از لب دلبر گرفت * آتش جست از دهان او و مجلسی در گرفت
می طاپد دلبر بھر و صل اما لمیداند که سرخست * شعله چانسرز لوتا خضم را در بر گرفت

Fig. 4: Reading of the inscriptions by Yazdani¹⁰.

appreciated, because he was skilled in casting massive bronze cannons as well as composite cannons. Research needs to be conducted on the cannons of Muhammad Ali Arab at Golconda and Muhammad Hussain Arab at Parenda, and to identify other Mughal cannons made by these *ustads* (masters).

ENGINEERING DESIGN

Yazdani first reported the dimensions of the cannon as being 16'2" in length, the diameter near the bore 2'3.5" while the circumference¹² at the other end 8'8".

Detailed dimensions of the cannon were recorded in November 2003. The salient dimensions are shown in the engineering drawing of Fig. 5. The total length of the cannon from the front to back is 486 cm. The length of the barrel alone is 424 cm. The front muzzle diameter is 70 cm and that of the bore 26 cm. The two trunions (each 15 cm long and 12 cm in diameter) are located at approximately the middle of the cannon. The cannon exhibits a taper with the diameter at the end of the barrel being 84 cm.

The estimated weight of the cannon based on the assumption of pure copper density is 16.59 tons. This corresponds to approximately 495 *maunds* in Shāhjehānī units of weight.

Another feature to note is the intricate design and construction of the trunions (Fig. 6). The operation of the cannon will be briefly addressed in order

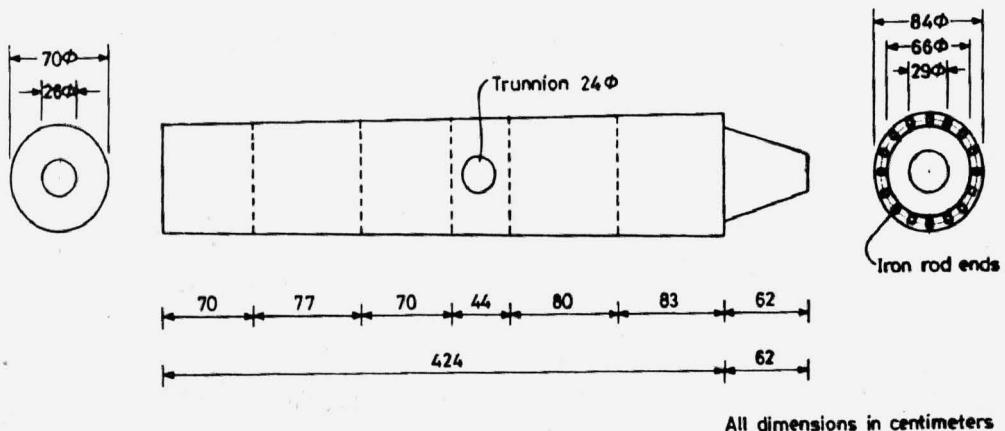


Fig. 5: Engineering drawing of the cannon.

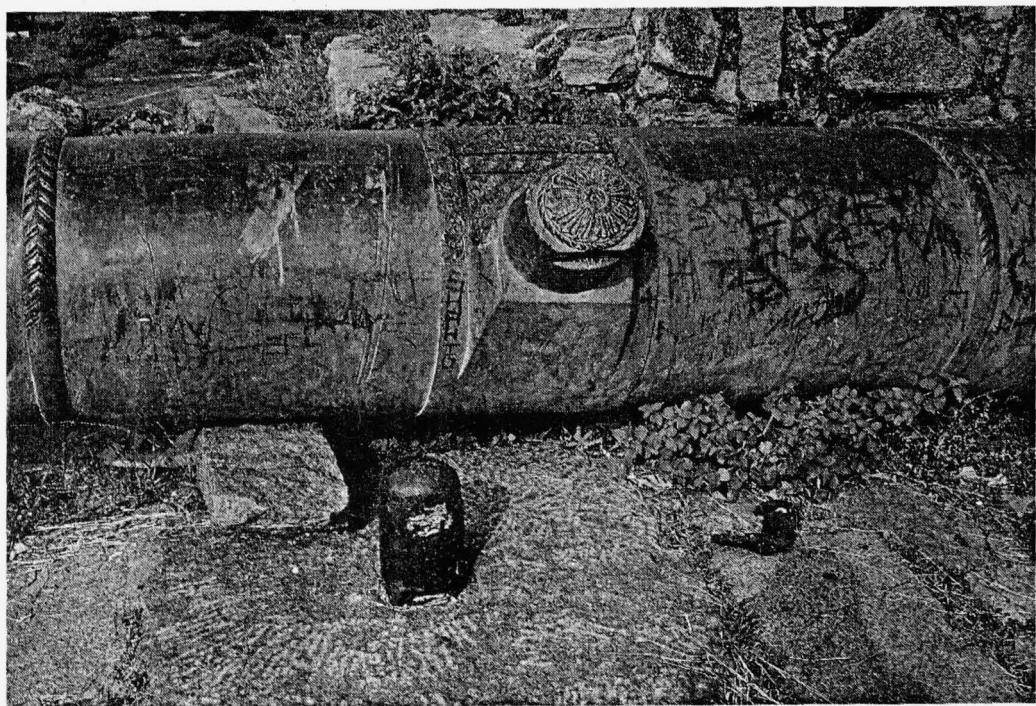


Fig. 6: Middle trunion portion of the cannon. Notice the intricate design of the trunion. A swivel connected the trunions and rested on the iron pivot. The pivot can also be seen.

to understand how the cannon was actually used. The cylindrical bottom of the cannon in the trunion locations is smooth. Notice the ingenious engineering design where the trunions join the main barrel (Fig. 6). The cannon was placed on a swivel, constructed usually of wrought iron. This swivel rested on an iron pivot. The pivot can be noticed in Fig. 6. The cannon could then be turned around to face different directions by swiveling over the iron pivot. The different positions in which the cannon was placed is still indicated by the remnants of the swivel marks on the stone surface, which appear to emanate as straight lines from the iron pivot (see Fig. 6).

Moreover, there must have been a provision in front of the cannon for resting the cannon and also for aiding its movement for positioning purposes. This is usually a wooden arrangement moving on a grooved surface on the platform⁴. In this way, the cannon's direction of fire and height could be adjusted. These features are not visible because the surface of the bastion has been repaired and the older arrangement is not visible. Further details about the movement of cannons placed on bastions are available in the article by Deloche⁴. The rear portion of the cannon is shown in Fig. 7. The tapered truncated cone design of the back end of the cannon must be noted. The decorated region in the back portion is 62 cm long with a diameter of 66 cm at the end of the barrel



Fig. 7: Rear portion of the cannon.

location and 27 cm diameter at the extreme end. This section is called cascable in ordnance technology. Interestingly, there are a total of 16 iron rods located at equidistance around the circumference of the back plate and inserted in to the rear end of the barrel. The ends of the rods are visible (see Fig. 8, where locations of three rods have been arrowed). The rods are arranged at regular intervals such that the angular distance between each of them is 22.5°. The locations of the iron bars have been indicated in the schematic of the engineering design of the cannon along the circumference of the backside (see Fig. 5). The end portion of the iron rods is clearly distinguishable due to its different color. The shadow cast by the wall on the backside of the cannon makes photography of the backside difficult in nature light. These iron rods are related to the manufacturing methodology of the cannon. They also strengthen the rear of the barrel (for more details, see ref. 16).

The excellent designs on the surface must be noted (Fig. 9). These designs and the inscriptions on the top surface appear to have been embossed (i.e. cast in position).

MATERIAL OF CONSTRUCTION

Two small pieces were chiseled off from the front and back ends. These samples were analyzed for their chemical composition using a Jobin Yvon JY-38S Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) at ARCI, Hyderabad. It must be understood that these samples would provide surface compositions and not composition of the interior of the cannon. Surface composition analyses of copper alloys may be sometimes misleading due to dealloying phenomenon (i.e. selective leaching of the baser alloying element from copper alloys, for example dezincification).

The results of the compositional analysis are provided in Table 1. Both the samples revealed similar compositions. It was surprising to observe that Zn

Table 1: Composition of the metal analyzed from samples obtained from the front and back portions of the cannon.

	Elements analyzed & concentration in %							
	Ni	Fe	Pb	Sn	Al	Mn	C	S
Front	0.07	0.17	12.2	1.8	0.04	0.005	0.13	0.047
Back	0.1	0.09	8.8	2.03	-ND-	0.005	0.03	0.017



Fig. 8: Ends of iron rods (arrowed) noticed on the outer circumference of the end plate joining the rear of the barrel.



Fig. 9: Notice the excellent design that has been embossed on the surface at the muzzle end.

was not present in the first analysis. Therefore, the samples were again specifically analyzed for this element. It was noted that Zn was present only in small amounts and the maximum detected amount was 0.4 wt. %. Considering the limited compositional analyses from the material of construction of the *Fath Raihbār* cannon, it can be concluded that it is primarily a bronze (copper alloyed with tin). Typically, gun metal (an alloy of copper containing about 10 % tin) was used for casting European cannons. Compositional analyses of samples obtained from the interior of the cannon by drilling would provide a better idea of the bronze composition actually used.

There are reports in the literature of the use of *haft-josh* while referring to cannons in the Mughal period¹. Abu'l Fazl in *Aṣ-ṣin-i-Akbarī* identifies *haft-josh* as an alloy of six metals which he quotes is also sometimes referred to as *taliqun* and 'is considered by some the same as common copper'¹⁷. Analysis of composition of *Fath Raihbār* indicates that the material was essentially copper alloyed with a small amount of tin and with a relatively larger amount of lead. Lead does not mix in copper and is present as a distinct phase. The presence of lead improves fluidity of copper. The present analysis of the cannon material is in tune with what has been quoted in the literature.

The significant amount of lead in both the samples must be noted (Table 1). Lead has been added to aid fluidity of the molten metal to facilitate casting. Given the enormous size of the cannon and the volume of material required for casting, the flowability of the material would have been an important consideration and therefore the use of bronze with relatively high lead content is understandable. Most of the other elements are present in small amounts.

CONSTRUCTION METHODOLOGY

Only bronze was used in the entire construction of *Fath Raihbār*. How was the cannon cast? There are two possibilities. First, it could have been cast solid and later the material in the inner core drilled away. Alternatively, the barrel could have been cast hollow. There is no existing literature from the Mughal period that provides the detailed method of construction of bronze cannons. This is not surprising because the manufacture of such strategic war items must have been a closely-guarded trade secret, mostly handed down families. Therefore, the manufacturing methodology must be deciphered based on careful study of existing cannons.

Historians have provided clues about cannon manufacture based on careful study of Mughal paintings. Khan¹⁸ hypothesized that the stone chamber and powder chamber in cannons of Babur (1526-1530) were “joined together by dovetailing device reinforced with a metallic strip.” Images of cannons used by Akbar show that in these “the powder chamber cast separately was fixed to the barrel by dovetailing device”¹⁸. Habib¹⁹ suggests that in the case of Akbar’s cannons fabricated in several pieces, the pipes were joined “on the principle of *kareez* pipes, thicker on one side and thinner on the other” and that the joints were “strengthened with rings hammered into place over the joint.” Mughal paintings of Aurangzeb indicate that his cannons were designed such that the powder chamber was cast separately and fixed to the main barrel by a dovetailing device¹. There is need to undertake a detailed technical study of Mughal cannons to supplement the learned historians’ perspectives.

Careful observation of the surface of the cannon at the rear end of *Fath Raihbār* did not reveal any visible physical joints. Moreover, the presence of iron rods inserted into the rear of the cannon was observed, as noted earlier. It is certain that the iron rods would strengthen the location at the rear portion of the barrel. The total depth up to which these iron rods proceed into the cannon is not known. The end portion of the barrel had to support large forces due to the thrust provided by burning of gunpowder. The engineering design at the rear end would have provided additional toughness to the cannon, especially at the powder chamber location. It is interesting to note that a total of 8 iron rods spaced 45° apart are present along the outer circumference of the rear place connecting to the barrel in the *Azdāha Paikār* cannon¹⁶. The same engineer manufactured this cannon. The lower number of rods used in this composite (iron-bronze) cannon indicates that the cannon maker was aware that the composite cannon would withstand a greater force than the bronze cannon.

Another reason for the presence of the iron rods could be they were used to join the moulds of the barrel and cascable, with each being made separately. In this regard, it is relevant to look at the European method of casting large bronze cannons during Aurangzeb’s period, as there was technology diffusion in bronze cannon technology between Europe and India¹. The moulds of the barrel and cascable were made separately. The moulds were joined together and later the molten metal was poured in the entire mould assembly.

Casting the large barrel of the cannon with provision for protruding trunions would have required enormous skill. Founding or casting consists of pouring molten metal into a mould and allowing it to cool. Let us briefly review the possible casting procedure based on known bronze cannon casting technology in medieval period²⁰.

Pattern Preparation

The model of the barrel was created on a tapered wooden spindle of a size similar to the cannon to be cast. An extension was provided at the muzzle end to form a “feeding head,” which served as a reservoir of molten metal. The wooden spindle was greased and tightly wound with rope to approach the form of the barrel to within a margin of one inch.

Above this rope-covered spindle, the actual shape of the barrel was provided using layers of clayey paste. Each layer was thoroughly dried before application of the next layer. In this manner, a model that closely resembled the required size and shape was readied. This model was covered with a layer of molten wax. The surface was smoothened and the necessary design and decorative bands were delineated. Wooden blocks shaped like the trunions were attached by iron pegs in to the spindle. The model dimensions were made greater (by about 2.5%) than those of the final design in order to allow for contraction of the bronze on cooling.

Mould Preparation

The mould was prepared using layers of a semi-liquid mixture of clay, sand and water. The composition, shapes and sizes of the ingredients of the mixture were carefully designed so that the mixture would flow freely over the minutest of details of the pattern. Each layer was dried before the next layer was applied. The ultimate thickness of the layers depended upon the size of the gun to be cast, being about 3 inches for a cannon of bore diameter 4 inches. The outside of the mould was ribbed, so that reinforcing staves and hoops could be fit over the mould.

The trunion patterns were first removed from the mould. Then, the pattern was removed from the mould. This consisted of first pulling out the tapered spindle, and then unwinding the rope. Finally, the mould was positioned

vertically with the muzzle on the top. Using fire at the bottom, the wax on the pattern was melted. This made it easier to remove the clay part of the pattern without damaging the mould. The ends of the trunnion holes were squared off and covered by tiles.

The mould of the barrel had to be first made open at both ends to enable the pattern to be removed. Therefore, a separate patterns and moulds had to be prepared for the barrel and the cascable. The cascable mould was then attached to the barrel mould. Once the complete mould was ready, it was placed bottom end down in a pit, adjacent to the furnaces. It was surrounded by tightly rammed earth along its entire length. The molten metal was then run into the mould using the “dead head” (i.e. feeding head). After approximately twenty-four hours after the pouring the molten metal, the mould and casting would have cooled sufficiently, to enable their being dug out and removed from the pit. On further cooling, the reinforcing staves and hoops fit on top of the mould could be removed. The mould was then broken from the casting. The casting was first cleared of rough unwanted protrusions, using hammer and chisel. The dead head was then sawn off. Notice that each mould could be used only once.

Ornamentation

Embossed (i.e. raised) decorations are frequently encountered in Mughal ordinances. These were so elaborate that many of the cannons can be considered as works of art (see Fig. 9): Embossing required skillful execution. A pattern of the embossed features had to be first carved in wax, then carefully attached to the main pattern. When the mould was heated to melt the wax, cavities of the required shape were left behind, later filled by molten metal. The production of decorations was expensive and time-consuming because it required the employment of highly skilled artists. Embossed decorations also interfered with surface finishing operations because where they occurred the piece could not be turned, but had to be planned. Of course, finally, if the cannon failed to perform, the cost of the expensive embossing would be a big waste.

Interestingly, the decorative designs did not make the slightest difference in the ballistic performance of the cannons. Therefore, in the later period, the necessary markings were engraved on the cannon once the cannon was tested and approved.

It may be noted here that some of the bronze cannons had provisions for lifting handles provided near the trunnion location (i.e. at the center of gravity). One example of a bronze cannon with lifting handles is shown in Fig. 10.

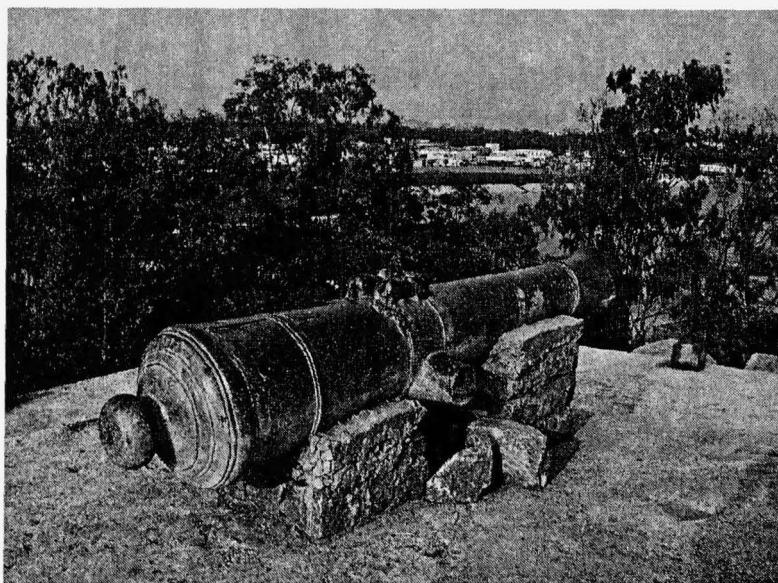


Fig. 10: Bronze cannon atop the *Fateh Darwāzāh* of the Golconda Fort Rampart. This shows the provision of lifting handles in the trunion region.

This cannon is now located on the top of the *Fateh Darwāzāh* of Golconda fort rampart. The handles had to be first carved in wax like the embossed decorations. This was a complicated procedure. The lifting handles were not popular because it was much easier to lift the cannon using a sling arrangement with one end thrown round the cascable and the other round the muzzle.

Machining

After casting the cannon, the rough hole in the center had to be bored to the specified diameter. It was important for the core to remain firm during the casting process because the axis of the hole had to be coincident with the axis of the cannon. Boring could only partly rectify this major fault. Turning was done by holding the tool, fixed to a lathe, in the hand, a slow and laborious business. The lathe for such an operation must have been driven literally by horse-power (i.e. by circular rotation of a horizontal wheel operated by horses and translating this motion to rotational motion of a cylinder). We know about

the existence of such a device (for example, *yarghu*¹⁹ - a wheel turned by ox to smoothen inside of barrels of sixteen handguns in small amount of time) during the time of Akbar²¹.

CONCLUSIONS

The massive bronze cannon by name *Fath Raihbār* “Guide to Victory”, located on the Petla Burj of the Golconda fort outer rampart, has been studied. The dimensions of the cannon have been measured. The total length of the cannon is 486 cm. The diameter of the muzzle is 70, bore 26 cm and end of the barrel 84 cm. The total weight of the cannon is 16.59 tons. The engineering aspects of the cannon have been addressed. The composition of the material of construction of the cannon has been determined. The average composition was Cu-1.9%Sn-10.5%Pb based on two analyses, thereby indicating that the material was leaded bronze. The presence of a relatively large percentage of lead must have facilitated casting. Sixteen iron rods, spaced at regular intervals along the outer circumference of the end plate, have been inserted into the rear of the barrel. Their relation to the manufacturing metho-dology is not known. This must have provided additional strength at the powder chamber location. The possible bronze cannon manufacturing technology has been briefly reviewed. The *Fath Raihbār* cannon is a wonderful example of the Mughal cannon manufacturing technology and provides a good idea of the cannon technology prevalent during the time of Aurangzeb (1658-1707).

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