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AZDĀHA PAIKĀR - THE COMPOSITE IRON-BRONZE CANNON AT MUSĀ BURJ OF GOLCONDA FORT

R. BALASUBRAMANIAM*

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A composite iron-bronze Mughal cannon, *Azdāha Paikār* located on the Musā Burj of the Golconda fort outer rampart, belonging to the period of Aurangzeb is described. The history of the cannon has been first outlined based on the inscriptions available on the surface of the cannon. The engineering design of the cannon has been highlighted along with details of its construction. The manufacturing methodology of the cannon has finally been discussed based on observed metallurgical features. The cannon was manufactured by casting bronze on an iron assembly consisting of shrunk-fit rings over cylindrical iron barrel.

Keywords: Aurangzeb,Bronze,Cannon,Casting,Engineering, Golconda iron, Manufacturing methodology.

INTRODUCTION

The history of gunpowder and firearms, and development in cannon technology in the Indian sub-continent has been recently reviewed from a historical perspective by Khan [1]. The learned scholar has collected information about the existing cannons primarily from literature sources. It is important to undertake a first-hand study of the medieval Indian cannons because they provide valuable information about the general state of technology, apart from the material and manufacturing technology employed to construct the cannons. There is an imperative need to study the cannons from a metallurgical perspective.

Analysis of historical development of bronze and wrought-iron cannon technologies of the Indian sub-continent reveals that the nature of firearms in the Mughal, Maratha and Deccan states remained almost the same throughout the seventeenth and first half of the eighteenth century, similar to what was evolved at the end of Akbar's reign (1556-1605) [1]. One notable failure was the

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

non-adoption of cast iron technology for cannon and cannon ball manufacture by the Indian states, which resulted in the ultimate domination of India by European colonial powers.

In spite of stagnation in cannon technology, there were two notable innovations that were implemented during this period. These were the use of light cannons resting on swivels fired from the backs of camels (*śaturnal* meaning "camel barrel") and the strengthening of wrought iron cannon barrels by casting them over with bronze (which we may define as a composite cannon) [1]. The second innovation may have been an attempt to economize on the use of copper (a relatively expensive metal then and even now) without weakening the barrel. European visitors admired these composite cannons, particularly the excellent joint between the iron and bronze sections. One commentator notes that, "nothing but the different color of the two metals indicated the joining" [2]. The Maratha and Rajput cannon-makers also appear to have manufactured composite cannons in the eighteenth century [1].

According to Khan [1], the earliest surviving composite cannon is located at Narwar fort. The inscriptions on this cannon reveal its name *Fathjang* and that it was manufactured in the year Samvat 1753 (1696 AD) for use by Raja Jai Singh Sawai, a Rajput chief in the services of the Mughal Empire [3]. A recent study of the *Azdāha Paikār* cannon, located on the Musā Burj of the Golconda outer rampart, indicated that this indeed was a composite cannon. The name of the cannon translates as "Dragon Body". Such fancy names were often given to cannons in the Mughal period. The inscriptions on the cannon provide the year of manufacture as 1674, thereby proving that it is older than the composite cannon at Narwar. In the present communication, this cannon would be described in detail, paying special attention to metallurgical and technical aspects. Another aim of the paper is to highlight the skill of the medieval Indian metal workers (iron smiths and bronze casters) in manufacturing composite cannons. By composite, it is implied that both iron and bronze were utilized in significant quantities in the construction of the cannon. It is worth noting here that iron rods were frequently used to strengthen the rear of the barrel of Mughal bronze cannons. Such a cannon will not be called a composite cannon because the entire cannon was cast in bronze.

History

The *Azdāha Paikār* cannon is now located on the Musā Burj (Fig. 1) on the outer rampart of the Golconda fort. This *burj* (bastion) falls within the military cantonment located at the bottom of the Golconda fort. Therefore, this cannon can be accessed only with the permission of the army authorities.

Fig 1: The *Azdāha Paikār* cannon located on the Musā Burj of the Golconda Fort Rampart.

The history of Golconda fort has been dealt in detail while addressing two forge welded iron cannons located on its outer rampart [4,5]. As *Azdāha Paikār* was manufactured during Aurangzeb's reign, the point of historical interest is the siege and subsequent capture of Golconda fort by Aurangzeb [6] (1658-1707). Aurangzeb first sent his son Shah Alam to launch an attack on Golconda in July 1685. The fort was not captured by the Mughals at that time because the last Qutb Shahi king, Abu-'l Hasan submitted to the terms dictated by the Mughals. However, he could not keep up his words. Therefore, after capturing Bijapur on 12 September 1686, the Mughals reached Golconda on 28 January 1687 and laid siege on the fort beginning 7 February 1687. Aurangzeb personally commanded the operations and was encamped on the north west of the fort. In spite of the siege, the fort could not he captured. Finally, the Mughals entered and captured Golconda fort by bribing one Sardar Khan who opened the western gate on 21 September 1687 at 3:00 am. A rich booty of 4 crores of rupees in cash in addition to gold, silver and jewelry was secured. Once Aurangzeb captured Golconda, he strengthened the outer rampart by stationing some of the massive guns that he had brought along for bombarding the fort. The cannon addressed in this paper was one such cannon.

The *Azdāha Paikār* cannon is specifically mentioned in *Ma'asir-i-Ālamgiri*, written in 1710-11 [7], while describing the siege of Golconda by Aurangzeb. Two other cannons, which were used in the bombardment of the fort during the second Mughal siege in 1687, were the *Fath Raihbār* [8] and *Duś man Kob* [9] cannons. These cannons are at present located on the Petla Burj and Sampolia Burj, respectively.

Inscriptions on bronze cannons of the Mughal period mention the emperor under whose rule the cannon was cast, the name of the cannon, the engineer responsible for the cannon's construction, the weight of gunpowder and weight of shot to be used.

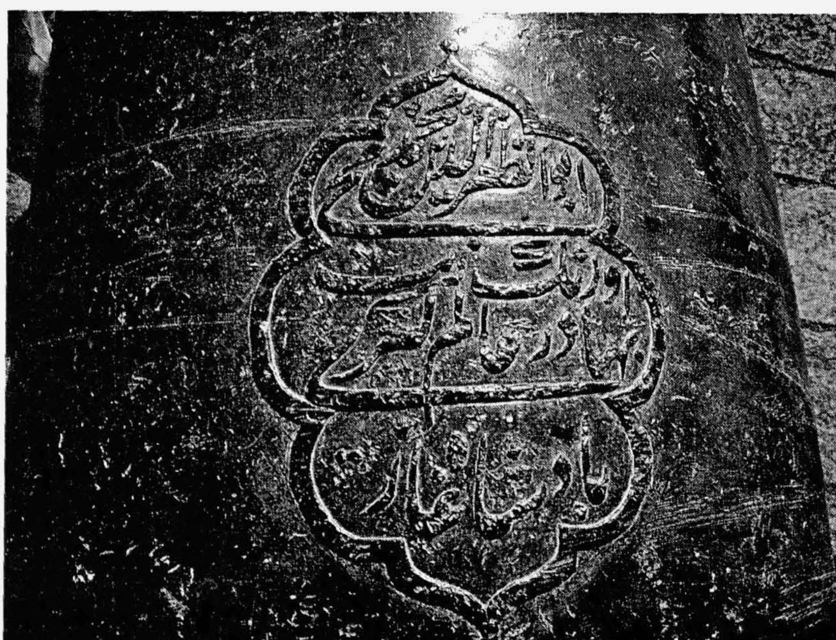
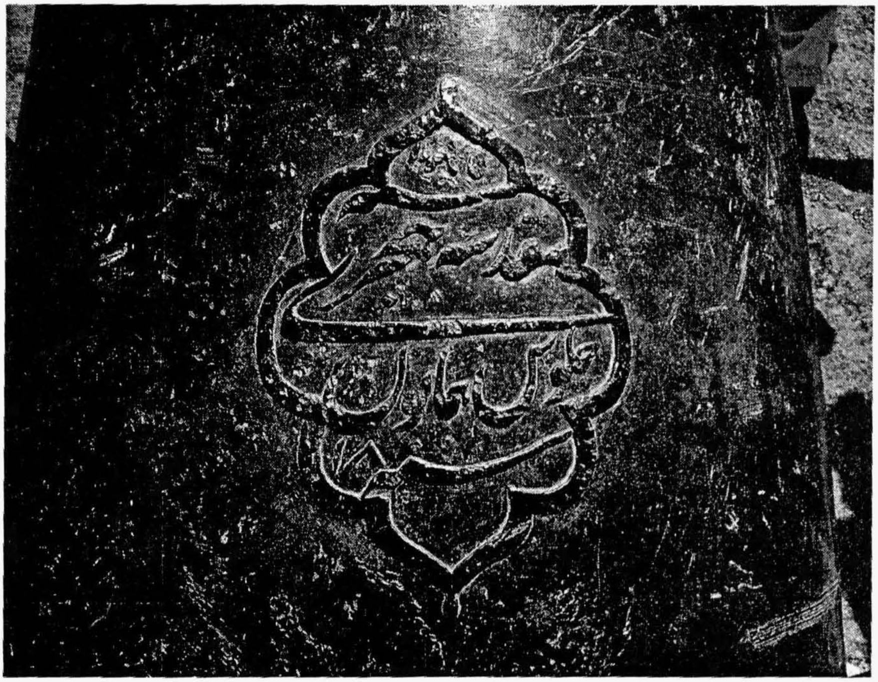


Fig 2: Inscriptions on the top surface, sequence from the muzzle end: (a) First



(b) Second

(c) Third

(d) Fourth, and

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

ابو المظفر محمد محي الدين اورنگ زيب بهادر عالم گير بادشاه غازي

سنه ١٨ جلوس والا سنه ١٠٨٥ مقدسه هجري

توپ اژدها پيكر

عمل محمد علي عرب

گله يك من بوزن شاه جهاني و باروت سيزده آثار يك نيم پاو بوزن شاه جهاني

Fig. 3: Reading of the inscriptions on the top surfaces by Yazdani [8].

The inscriptions found on the top surface of the cannon have been provided in Fig. 2[(a),(b),(c),(d) and (e)]. The complete reading of the inscriptions by Yazdani [8] is shown in Fig.3. The translation of the inscriptions is as follows[8]:

> "Abu-l-Muzaffar Muhammad Muhiu-d-din Aurangzeb Bahādur Ālamgir, Badshāhi Ghazi (the victorious king)
>
> Eighteenth year of the auspicious reign (corresponding to) 1085 A.H. (1674 A.D.)
>
> *Azdāha Paikār* (Dragon Body) gun
>
> Made by Muhammad Ali Arab
>
> Charge: one *maund* according to the Shāhjahānī weight; Gunpowder: thirteen and one eighth *seers* according to the Shāhjahānī weight".

In the above translation, 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* [10]. Therefore the weight of the gunpowder (11.0 kgs) and shot (33.5 kgs) used in this cannon are precisely known. Notice that 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 made of copper, bronze (hollow as well as solid), brass, wrought iron and lead [1].

Another interesting piece of history available from the inscriptions is the name of chief engineer, Muhammad Ali Arab. Interestingly, he is the same engineer who supervise3d the manufacture of three other Mughal cannons belonging to Aurangzeb's reign that are currently locaed 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 [9], the *Fath Raihbār* "Guide to Victory" (located on the Peṭlā Burj and manufactured in 1672 [8,11] and the *Atish Bar* "Raining Fire" (located on a bastion at the foot of Bala Hisar hill towards the south-west and manufactured in 1679 [9]. While the *Fath Raihbār* cannon finds mention in the list of cannons used by Aurangzeb in the siege of Golconda[7], the other two cannons are not mentioned. This implies that they were transported to Golconda after its capture.

It is probable that Muḥammad Ali Arab continued the profession of his father Muḥammad Hussain Arab. Two cannons executed by Muḥammad Hussain Arab are currently in the Parenda fort [12]. Interestingly, one of these cannons is also called *Azdāha Paikār* (photograph of this cannon appears in the article by Deloche in this volume [13]) and this cannon was manufactured in 1660. The other cannon *Malik Maidan* "Battle King" was manufactured in 1663.

Among the cannons fabricated by Muḥammad Ali Arab, the author has personally studied the *Azdāha Paikār* and the *Fath Raihbār* cannons. As will be discussed shortly, the *Azdāha Paikār* composite cannon is an excellent piece of artillery, skillfully engineered and manufactured. The *Fath Raihbār* is an all-bronze cannon [11]. The *Qila Kusha* and *Atish Bar* cannons need to be studied to understand their nature. The engineering skill of Muḥammad Ali Arab must be appreciated, as he was skilled in casting massive bronze cannons as well as composite cannons. It is reasonable to conclude that the technology for making composite cannons had evolved to a fairly sophisticated level by the end of 17th century. Interestingly, a new term for an artillerist *deg-andaz* appears along with the usual designation *topcī* during this time [1]. Research needs to be conducted to first identify and catalogue other composite cannons of the Mughal period.

Engineering Design

The *Azdāha Paikār* cannon is located at top of the Musā Burj, which is a tall bastion. The Musa Burj consists of three storeys and the height of the lower portion of the bastion is 18 meters from the bottom of the ditch [14]. Notice the heavy segmental recoil wall built at a very short distance from the back of the cannon (Fig. 1). This is a common feature noticed in Indian forts when cannons were placed on platforms atop bastions [13]. The wall neutralized the recoil of the cannon when it was fired and thereby prevented stressing of the swivel and pivot.

Yazdani first reported its dimensions as being 14'10" in length, 2'4" in diameter near the bore and 9' in circumference at the end [8]. The detailed dimen-

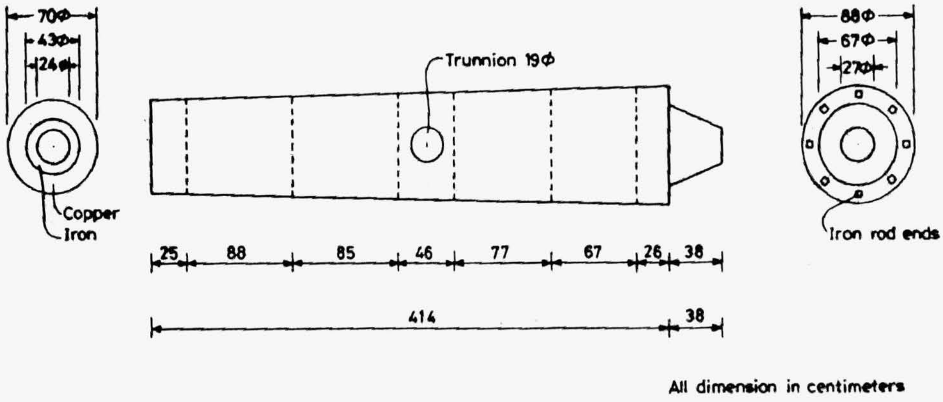


Fig 4: Engineering drawing of the cannon.

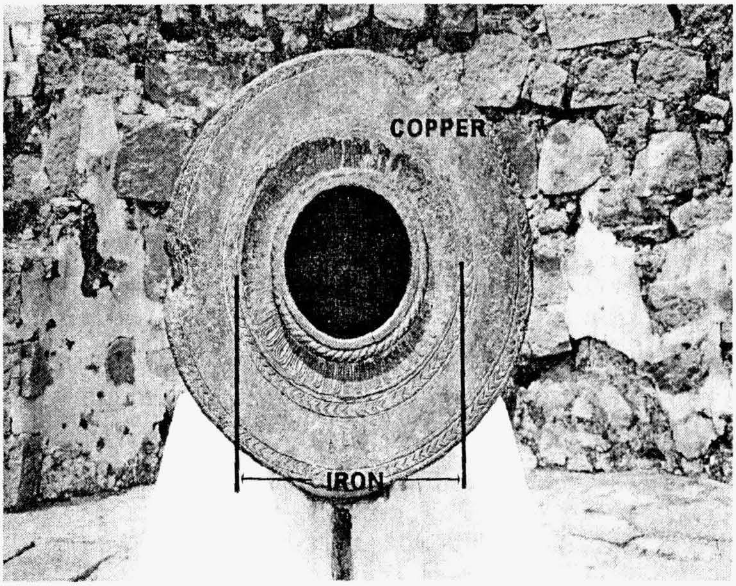


Fig. 5: Front face of the cannon. The iron section is marked in the picture because it is difficult to demarcate the iron and copper portions in black and white reproduction.

sions of the cannon were carefully measured during the study of the cannon in April 2002 and Nov 2003. The engineering drawing of the cannon (Fig. 4) shows the significant dimensions. The *Azdāha Paikār* is almost similar in size (length and diameter) to the all-bronze *Fath Raihbār* cannon [11].

The front face of the cannon (Fig 5) readily indicates that the inner bore of *Azdāha Paikār* is composed of iron barrel. A thick iron ring has been shrunk fit over the barrel. The bronze casting surrounds this iron assembly. The two different metals used in the fabrication (iron and copper) are distinguishable by their different colouration. While the iron interior appears brown, the bronze exterior is green due to patina formation. The iron and bronze portions have been marked in Fig. 1 because the difference in color will not be readily apparent in black and white reproduction.

It must be noted that the inner iron barrel is not composed of longitudinally laid iron strips (i.e. staves) as observed in case of wrought iron cannons [4,5]. The inner barrel has been constructed by curling over an iron plate, possibly over a cylindrical mandrel. The end positions of the iron plate where they meet are noticeable at the bottom (around the 5'o clock position in Fig. 5). Close observation of the bore further indicates that two iron cylinders (with the second one tightly fit over the first one) formed the innermost barrel. In Fig. 5, the innermost cylinder is seen without any decoration and the cylinder fit over this is decoratively engraved to resemble a twisted rope, viewing from the front. The iron ring that was shrunk fit over the cylindrical barrel is clearly distinguishable on the front face (Fig. 5). Notice that the surface of this ring has also been engraved with decorations. The ring exhibits a small concavity due to this engraving. Such iron rings must have been consecutively shrunk fit over the barrel, probably covering the complete length of the barrel. This is the design noticed in conventional forge welded wrought iron cannons. Therefore, the probable scheme employed for constructing the inner iron portion of the barrel is known, based on details available from the front face.

Based on measurements, the inner diameter of the barrel (i.e. bore) is 24 cm. The front face further indicates that the thickness of inner iron cylinder is 1.3 cm, the second iron cylinder 1.3 cm and that of the iron rings used for shrink fitting is 7.0 cm. The overall diameter of the front face is 70 cm, which is approximately just less than three times the bore diameter. The length of the

Fig. 6: One of the trunions located in the middle of the cannon.

cylindrical barrel, excluding the back portion, is 414 cm. The back portion adds another 38 cm, thereby providing the overall length of the cannon as 452 cm. Assuming the shrunk fit iron assembly to proceed till the end of the barrel, the weight of the iron assembly (iron barrel and shrunk fit rings) has been estimated to be 3.28 tons (almost 98 Shāhjahānī *maunds*).

The body of the cannon shows a taper. The diameter of the cannon at the location just behind the trunion is 78.4 cm while that at the end of the barrel is 88 cm. The complete length of the cannon is 452 cm. Two trunions (each 19 cm in diameter and 19 cm in length) are located almost at the center of the cannon (Fig. 6), considering the overall length of the cannon including the back portion. Notice the excellent design that has been engraved on the surface at the location of the trunions (Fig. 7). The design and construction of the bot-

Fig. 7: The excellent design in the middle portion of the cannon.

tom of the cannon at the location of trunions is not clear because this portion has been embedded in the support basement (see Fig. 1). It is important to remove the *Azdāha Paikār* cannon from this basement and set it up like it used to originally operate (by means of a forked swivel resting on an iron pivot). Deloche has described the operation of swivel cannons [13].

Fig. 8: Design of the rear portion of the cannon.

The lower portion of the cannon barrel is shown in Fig. 8. The touch (or fuse) hole can be noticed on the top. The tapered truncated cone design of the back end of the cannon must be noted. The decorative back portion is 38 cm long, with a diameter of 66 cm at the end of the barrel location and 29 cm diameter at the exterior end. This section is called cascable in ordnance technology. The cascable will be discussed in greater detail in the next section.

Utilizing the measured dimensions of the cannon, the weight of the remaining portions, assuming it to be composed primarily of copper, is 13.72 tons (approximately 410 Shāhjahānī *maunds*). Therefore, the overall weight of the cannon is 17.00 tons. This roughly corresponds to 508 *maunds* as per Shāhjahānī weights.

Some interesting observation regarding the dimensions may be noted here. In terms of modern inches, the total length is 178 inches. In terms of Indian units, 0.75 of the modern inch equaled the *aṅgulam*. According to this, the length is 238 *aṅgulam*. According to the Indian scale, 12 *aṅgulam* equaled

1 *vitasti* and 2 *vitasti* equaled 1 *hasta* or *aratni.* Further, 4 *hasta* resulted in 1 *daṇḍa* [15]. Therefore the length of the cannon approximately converts to 20 *vitasti* or 10 *hasta* or 2.5 *daṇḍa.*

Manufacturing Methodology

The basic construction methodology is casting of bronze over shrunk-fit iron barrel. Both these aspects would be discussed below.

Constructing a cylindrical iron barrel out of a plate and, that too, of relatively long length would have necessitated the use of a mandrel. It is also likely that several short iron cylinders were joined to produce the long barrel, rather than fabricate one long cylinder. The inner barrel was shrunk fit with another cylindrical barrel, as per the evidence available from the front face. These iron barrels were held in place and strengthened by shrink fitting (i.e. hooping) iron rings over the barrel, like seen in forge-welded wrought iron cannons. The number of iron rings used in the construction of the barrel cannot be ascertained by just visual observation of the front face. This would require careful non-destructive evaluation techniques.

The next aspect concerning manufacturing technology is casting of bronze over the iron assembly. Molten bronze was poured over the shrunk-fit cylindrical iron barrel. When one considers the massive amount of bronze used in the casting (approximately 14 tons), the engineering skill and planning required to undertake such a massive casting must be appreciated. Efficient furnaces must have provided the large quantity of molten metal. Whether large number of small furnaces or small number of large furnaces were used for supplying the molten metal is not known with certainty. Of course, it is certain that several furnaces must have been worked in tandem to melt the metal required for pouring because it would not have been possible for a single furnace to provide the entire molten metal. The entire casting of the barrel must have been performed at one go. The planning and execution of the casting, therefore, is an intelligent operation. It must also be emphasized that an enormous amount of skilled labour was required to prepare the pattern, coat this with wax, carve the necessary designs on the wax, attach the arrangement for obtaining the necessary trunions shape and finally prepare the mould. Each of these processes is as important and as intricate as the pouring of molten metal. Once the casting operation was completed, several other operations had to be performed before the cannon was finally serviceable (for more details on bronze cannon casting technology, see ref. no. 11.

The excellent designs on the cannon surface (on the front, back and top surfaces) must be noted (see Figs. 6 and 7). Some of the simple designs have been carved out by removing metal from the surface using hammer and cold chisel. Careful surface observations indicate that the intricate designs (Fig. 7) and inscriptions (Fig. 2) have been embossed (i.e. raised). This implies that

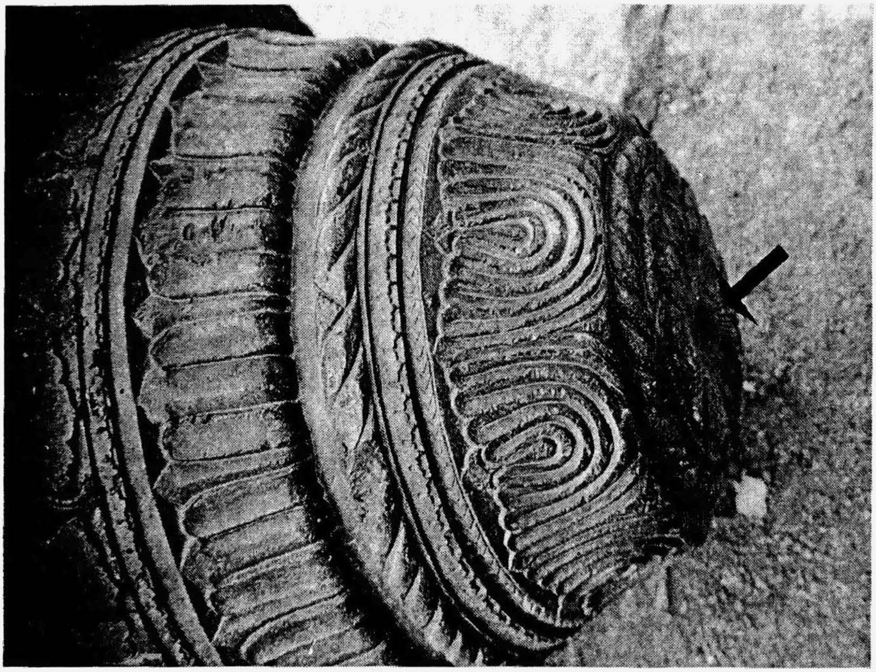


Fig 9: A thick iron rod is noticed at the center of the extreme end of the cannon. This location has been marked with an arrow because it is difficult to demarcate iron and copper portions in black and white reproduction.

these designs and inscriptions were incorporated in the mould before casting. Details of the embossing operation are described in ref. no.11. The final smoothening (or polishing) operation must have involved rotation of the cannon on its longitudinal axis (long axis) based on the nature of the polishing marks seen on the surface. These marks travel around the outer circumference of the barrel in relatively straight lines. Whether this operation was performed with the cannon lying horizontally or vertically is not known. It would have been easier with the cannon in the horizontal position.

Some interesting technical aspects of cannon manufacturing technology are available at the rear of the cannon. The presence of a relatively thick iron rod is noted in the center at the extreme end of the cannon (Fig. 9). This must be related, in some manner, to the inner iron assembly of the barrel because the all-bronze *Fath Raihbār* cannon does not contain such a central iron rod [11]. Secondly, eight iron rods are observed along the circumference of the plate that joins the rear end of the barrel. The ends of the rods are visible (see Fig. 10, where one such rod has been arrowed). The rods are arranged at regular intervals such that the angular distance between each of them is 45°. 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. 4). The end portion of the iron rods is clearly distinguishable due to its different color on visible observation. The shadow cast by the wall on the backside of the cannon makes photography of the backside difficult in natural light.

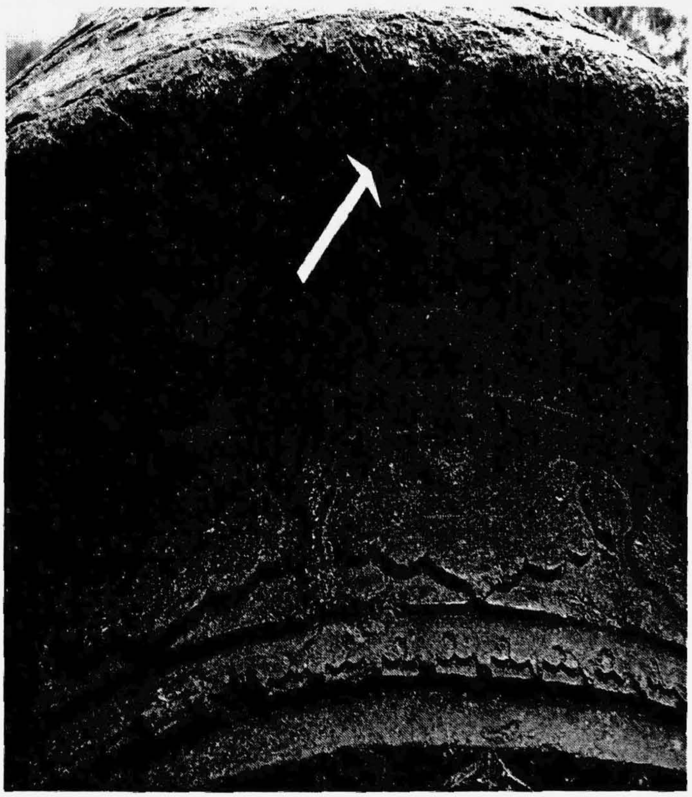


Fig. 10: One of the ends of eight iron rods (arrowed) noticed on the outer circumference of the end plate joining the rear of the barrel.

What is the purpose of these iron rods? This must be related to the technology employed to manufacture of the cannon. Khan [16] hypothesized that the stone chamber and powder chamber in cannons of Bābur (1526-1530) were "joined together by dovetailing device reinforced with a metallic strip." Khan [1] also states that the images of cannons used by Akbar show that in these "the powder chamber cast separately was fixed to the barrel by dovetailing device." Khan mentions that pictorial evidences from Mughal paintings of Aurangzeb also indicate that his cannons were designed such that the powder chamber was cast separately and fixed to the main barrel by a dovetailing device [1]. Irfan Habib [17] 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."

There is no literary evidence outlining the entire cannon manufacturing methodology. This is also not expected because the knowledge of manufacturing large cannons must have been a closely-guarded family trade secret. Therefore, we need to glean information about the possible manufacturing methodology based on first-hand careful observation of Mughal cannons. It may also be relevant to look at the European method of casting large bronze cannons of Aurangzeb's period. 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 (more details about this manufacturing methodology are discussed in ref.no. 11.

Careful observation of the surface of the cannon at the rear end of *Azdāha Paikār* did not reveal any visible physical joints. Would then the presence of iron rods indicate that the moulds for the main barrel and the cascable were made separately and joined together before the casting? It is, however, 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 16 iron rods spaced 22.5° apart are present along the outer circumference of the rear place connecting to the barrel in the all-bronze *Fath Raihbār* cannon [11], also located in Golconda fort. The same engineer manufactured this cannon. Therefore, this implies that similar cannon manufacturing technology was used whether the barrel was of bronze or composite (i.e. bronze cast over the iron barrel) variety. The higher number of rods used in the bronze cannon could indicate that the cannon makers knew that the composite cannon would withstand a greater force than the bronze cannon.

CONCLUSIONS

The design and construction methodology of the composite iron-bronze cannon *Azdāha Paikār*, located on the Musa Burj of Golconda fort outer rampart, are described. The inner portion of the barrel of the cannon was constructed of wrought iron, by shrink fitting iron rings over cylindrical iron barrel. The iron barrel was fabricated by folding over of iron plate. Bronze was cast around this iron assembly (cylinder+shrunk fit rings). The total length of the cannon is 452 cm. The diameter of the bore is 24 cm, muzzle 70 cm and rear end of the barrel 88 cm. The total weight of the cannon is 17.00 tons, out of which 3.28 tons is the weight of the iron assembly. The manufacturing methodology of the cannon has been discussed based on observed metallurgical features. The ends of eight iron rods are noticed at regular intervals along the outer circumference of the end plate connected to the rear of the cannon. Their relation to the manufacturing methodology is not known. This must have provided additional strength at the powder chamber location. The *Azdāha Paikār* is the earliest known composite cannon.

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