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KAḌAK BIJLĪ – THE FORGE-WELDED IRON CANNON AT JHANSI FORT

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The forge-welded iron cannon by name *Kaḍak Bijlī*, located at Jhansi Fort, is described here. It measures 5.5 m in length and weighs about 5 tons. The barrel of the cannon has been constructed by hooping two iron rings over 11 longitudinal iron staves. The iron rings were hooped over such that the second layer of rings closed the gaps between the first layer of rings. Valuable information about its design and construction is available in the damaged rear portion of the cannon. The unique design of the firing mechanism in the rear portion indicates the intricate engineering of the cannon. The damaged portion reveals that the thickness of iron staves increased on progressing into the barrel of the cannon. Further, the inner rings maintain their thickness nearly constant while the external rings become progressively thicker, thereby providing the apparent tapered appearance to the barrel of the cannon.

Keywords: Construction, Design, Forge-welding, Jhansi Fort, Iron cannon.

INTRODUCTION

There are several wonderful forge-welded iron cannons still remaining in numerous forts spread across the length and breadth of the Indian sub-continent. Forge welding was the local Indian technology of manufacturing cannons in contrast to casting that was refined by the Europeans.Indians, by the medieval times, had mastered the manufacture of large iron cannons by the forge welding method [2]. Other examples are the iron beams at Konark and Puri temples [3]. Iron, for use in forge welding, was obtained by the reduction of iron ore with charcoal (direct reduction process). Iron extraction was performed in traditional bloomery furnaces. It is important to study and catalogue the forge welded iron cannons in medieval Indian forts.

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In this communication, one of the forge-welded iron cannons located in the Jhansi Fort in Central India will be addressed. This cannon must be considered important from an engineering perspective because some part of the back and front portions of the cannon have been partly dismantled. Therefore, the constructional details of the cannon are clearly discernible. The other forge-welded cannons, studied thus far [4-8], were standing in their complete form, and it was only possible to speculate on the construction of the cannon, based on their overall appearance. Therefore, this particular cannon, by name *Kaḍak Bijlī*, provides an opportunity to understand the construction of pre-modern Indian forge-welded iron cannons.

History

The Jhansi fort is one of the most strategically situated forts of central India. Due to its shape like a star, the fort is also known as Star Fort. It is built on an elevated rock rising out of the plain that is popularly known as Bangara Pahari. Situated almost about 75 ft above the ground level, it covers an area of 49 acres, among which the fort itself occupies an area of 15 acres. The fort possesses a huge fortification wall and a moat on two sides. There are twenty two bastions, of which sixteen are big. A sloping road from the south leads directly upto the main gate and leads into the interior of the fort. Three phases of constructions can be identified, among which Bundellas and the Marathas were the main architects, followed by the British, who performed minor additions and alterations to the fort. The British were responsible for the present main entrance, which was earlier located on the north-east part of the fort. They also repaired the parapet walls of the south-eastern and south-western corner bastions of the fort. The fort may be divided into three main parts, Baradari, Shankar Garh and Panch Mahal. Besides these, there are few more important structures, which are also of great value. The city wall has ten gates, Khanderao, Datia, Unnao, Orchha, Baragaon, Lakshmi, Sagar, Sainyar, Bhander and Jhirna. The first eight still have wooden doors and of the remaining two, the former is completely closed, but the latter is open. There are also four prominent windows in the walls, which are locally known as Ganpatgir-ki-Khirki, Alighor-ki-Khirki, Sujankhan-ki-Khirki and Sagar-Khirki. Further details of the Jhansi fort are provided elsewhere [9].

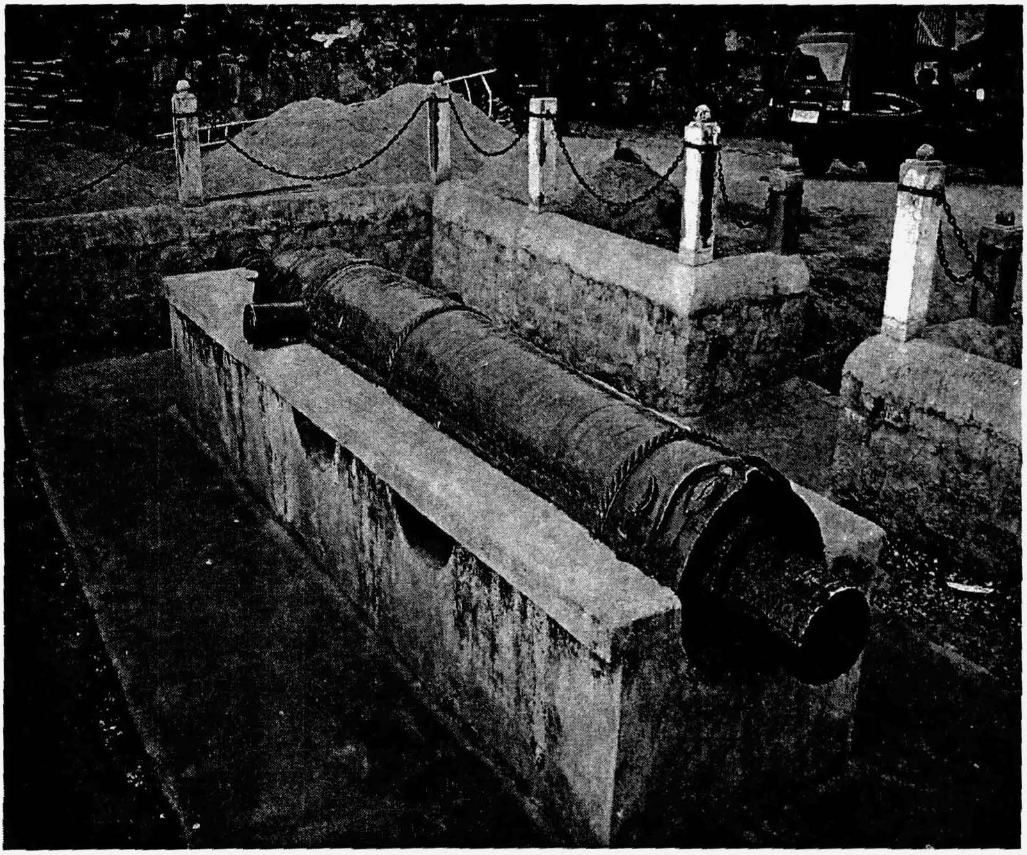

Fig. 1: Overall view of the *Kaḍak Bijlī* cannon located immediately to the left of the current main entrance to the Jhansi Fort.

There are two large forge-welded iron cannons located in the Jhansi fort. Both these cannons are known by their names. The *Kaḍak Bijlī* cannon is located immediately on the left, when one enters the Jhansi Fort , through its present entrance (Fig. 1). The other cannon is located near the Gaṇeśa Temple slightly in the interior of the fort and is called *Bhavānī Śaṅkar* [9]. There is no inscription on the *Kaḍak Bijlī* cannon unlike the *Bhavānī Śaṅkar* cannon. However, there is a plain surface on the top of the decorative ring on which the trunions have been attached. This must have previously contained an inscription (Fig. 2). The inscription is not visible because it appears to have been deliberately erased, probably by the British when they took over the Jhansi Fort. It must be possible to reveal the traces of the original inscription by special non-destructive techniques.

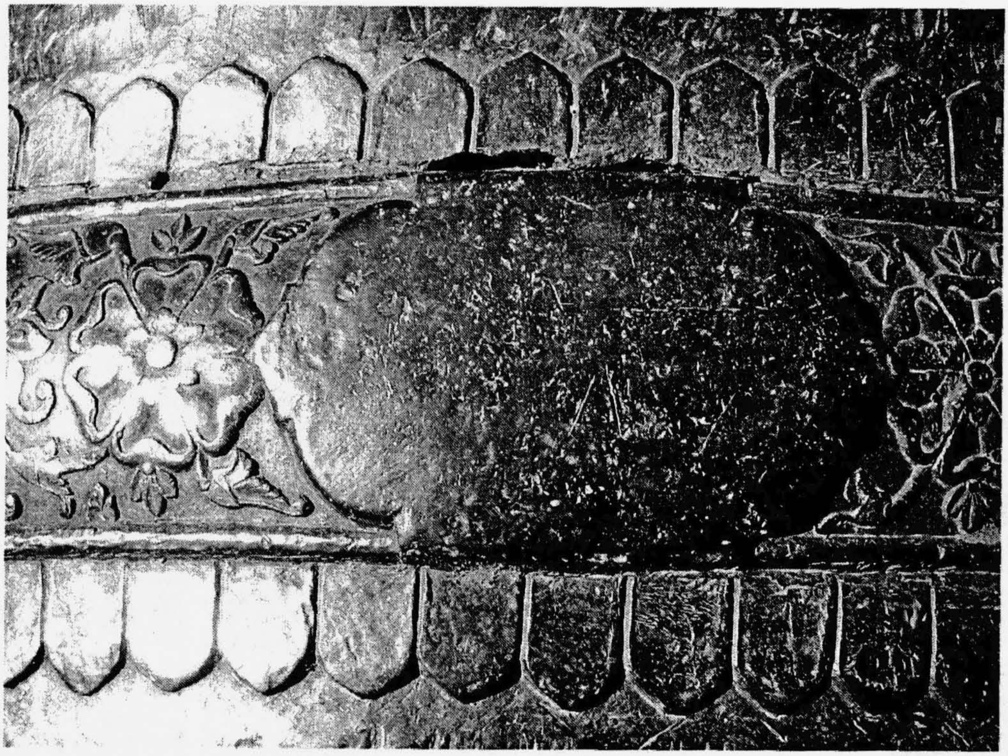

Fig. 2: Specially prepared surface on the ring that holds the trunions. This must have originally contained an inscription.

The notice put up by the Archaelogical Survey of India near the cannon reads as follows, "The great cannon of Gangadhar Rao's period is still visible in the eastern side of the rampart. It used to lighten from its nozzle at the time of operation which is curved like a lion's mouth and as such it received this name. Gulam Gaus Khan terrorized the enemies with this cannon."

The date of the cannon is not known with certainty. The other cannon located in the Jhansi Fort, i.e. *Bhavānī Śaṅkar* is dated to 1724 AD based on an inscription on its top surface. The *Kaḍak Bijlī* cannon could also date from this period because it is similar in design to *Bhavānī Śaṅkar* cannon, which was constructed during the period of Maratha rule [9]. The *Kaḍak Bijlī* cannon appears to have witnessed lots of action during the mid-19th century and this must be reason for the ASI placard to state that the cannon belonged to the time period of Gangadhar Rao (about 1850 AD). The present notice put up by the ASI, therefore, needs to be modified.

DESIGN

The cannon is a muzzle loading type of cannon. In this type, the cannon ball and the gun powder are loaded from the front of the cannon. Two trunions provided in the middle of the cannon must have been used for manoeuvring the cannon. The complete dimensions of the iron cannon are provided in the engineering drawing of Fig. 3. A reconstruction of the original cannon is provided in the bottom of Fig. 3. Close observation of the surface of the cannon reveals fine hammer markings all over the surface. Interestingly, from the front location onwards up to the rear end of the cannon barrel, the cannon barrel exhibits a increasing taper of its diameter (Fig. 1).

The total length of the cannon from the front to the extreme rear of the cannon is approximately 550 cm. The cannon is partly damaged in the front and rear portions. If the material used in these sections is included, the weight of the cannon, estimated based on the measured dimensions, must have been approximately 5270 kgs.

The iron cannon is half buried on a concrete platform, such that the lower portion of the cannon is completely buried inside. It would be a good

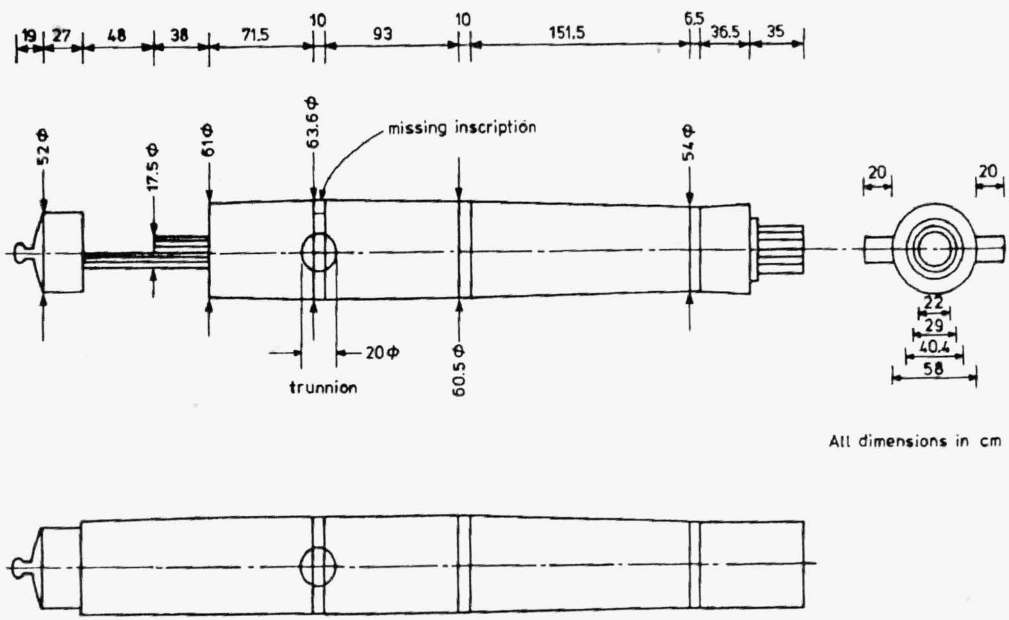

Fig. 3: Engineering drawing of the cannon showing the prominent dimensions.

idea to remove the cannon from the concrete platform. Another suitable arrangement must be planned such that most of the cannon is made visible. This will also help minimize corrosion of the cannon in the buried portion

Let us explore the design of the cannon. Prominent details along the length of the cannon would be addressed. The section from the front end of the cannon to the first decorative ring can be considered as the first section. The second section can be assumed to be the location from the first decorative ring to the ring supporting the protruding trunions. The third section can be the location from the ring supporting the trunions to the rear rim of the barrel of the cannon. The last section is the rear end of the cannon.

In the front portion, part of the cannon is damaged. The outlines of a lion carved on the outer surface can be clearly made out in the portion that still

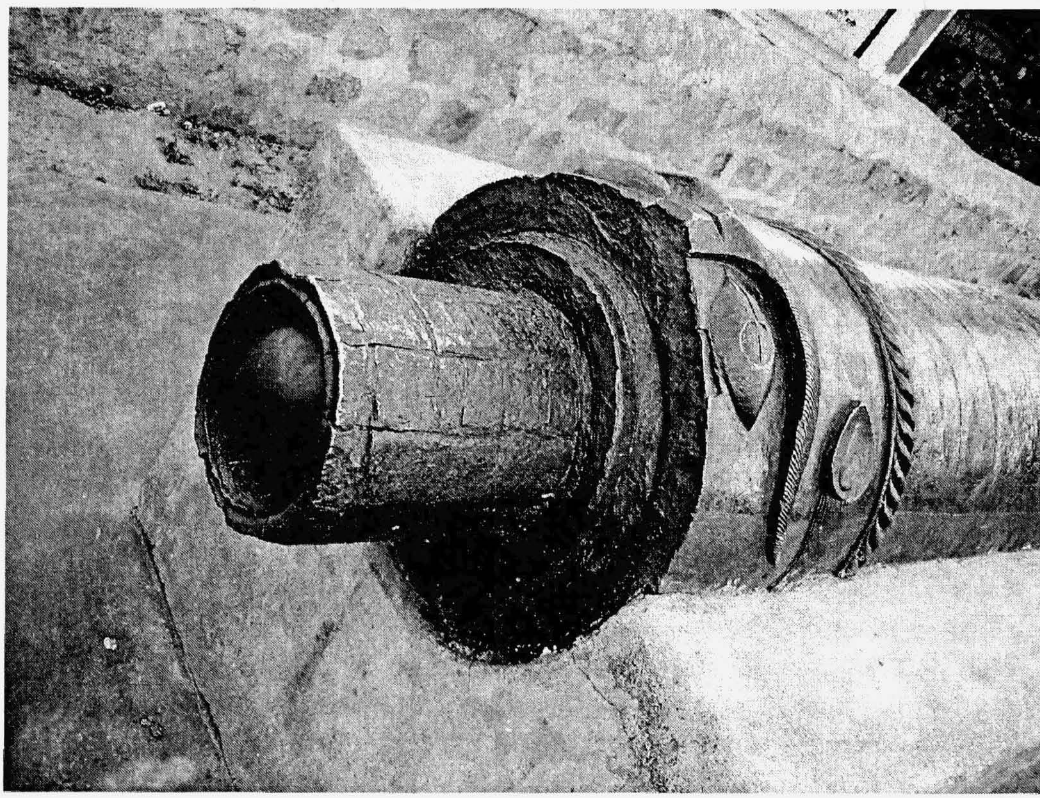

Fig. 4: The damaged front portion of the cannon. The outlines of a lion's face can be made out on the external surface.

remains (see Fig. 4). The damaged portion provides valuable ideas about the construction details of the cannon. The damaged portion reveals that only two forge welding iron rings have been placed one above the other and forged together in order to obtain the cannon's thickness. Therefore, it is clear that although the front faces of medieval iron cannons reveal presence of many rings, the number of rings that actually make up the thickness of the cannon is usually two or three. In the case of *Kaḍak Bijlī*, only two rings have been forged over the iron staves in order to obtain the thickness of the cannon's wall. We do not know about the appearance of the cannon as it would have been in the complete form. However, it can be assumed that an additional outer iron ring must have been provided in the front plane of the cannon, based on the design features of the cannons at Thanjavur [5] and Bishnupur [6].

Another important aspect of fitting of iron rings is obtained from this section. It can be noticed from Fig. 4 that the rings were not directly placed on the top of another, but rather placed such that the outer ring coverd the gap between the inner rings. This kind of design is important to provide toughness to the barrell. Roessler had also proposed such a construction methodology for the shrink fitting of the iron rings in the case of Thanjavur cannon [4]. The forge welding of the iron rings has been performed in an excellent and skillful manner as can be gauged by good fitting of the outer ring over the inner ring, and these rings on the iron staves.

An important feature that is evident in the front plane of the cannon is the presence of iron strips running along the inner diameter of the barrel. This is similar to several other forge-welded iron cannons of medieval India, which have been lined with long iron strips, placed longitudinally along their inner diameter. Interestingly, these strips have not been flattened out on the front plane, like the Thanjavur cannon. These long iron strips are technically known as staves and these were provided to obtain a smooth surface in the inside of the cannon as well as to assist the motion of the projectile. The front portion of the cannon (Fig. 4) indicates that there are a total of 11 plates, each 6.4 to 7 cm wide, that make up the inner diameter of the cannon. The thickness of the plate at the front section is 4 cm. Interestingly, a cannon ball is still struck to front of the barrel (see Fig. 4). The diameter of the ball is 18 cm and therefore its weight is approximately 23.8 kgs (about 50 pounds).

On the front face, the inner diameter of the barrel is 22 cm while the plates are about 4 cm thick. The inner and outer diameters of the first ring are 29 cm and 40.4 cm, respectively. The external diameter of the outer ring is 58 cm. These measurements are based on the rings that are still present in the front region of the cannon.

The first section of the cannon, up to the first decorative ring, occurs at 71.5 cm from the front end. There are six rings, each about 6 cm wide, seen on the outer surface. This is from the damaged end to the location of this raised ring. In the damaged section, the length is 35 cm and therefore, six rings must have been originally placed at this location.

Counting the decorative ring as the thirteenth from the front plane, the iron cannon is further build up by iron rings of progressively larger diameters. There are a total of 22 rings between the first decorative and the second decorative ring. The second decorative ring is similar in design to the first ring and it is located 151.5 cms from the first. While the first decorative ring is 6.4 cm wide, the second decorative ring is 10 cm in width.

The distance from the second decorative ring upto the ring on which the trunions are located is 93 cm. There are further 11 rings (of about 7.5 to 9 cm width) from the second decorative ring upto the ring on which the cylindrical trunions are located. Therefore, excluding the trunion-containing decorative ring, this section of the cannon is made up of 47 rings on the external surface (or 47×2 for the entire barrel cross section as there are two rings that make up the thickness of the barrel). The location discussed above can be considered as the second section of the cannon.

The width of the iron rings progressively increases from 6 cm to 9 cm on going up the cannon. The iron ring that supports the two trunions is 10 cm in width (Fig. 5). The excellent design inscribed on this particular ring must be noted (see also Fig. 2). The trunions are placed diametrically opposite to each other and each of these solid cylindrical masses are 28 cm long and 20 cm in diameter. These have been intelligently forge welded on to the iron ring. The iron ring containing these holding supports is counted as the 48th from the front.

The third section can be considered from the iron ring containing the trunions till the end of the tapered cylindrical bore of the cannon. A part of the

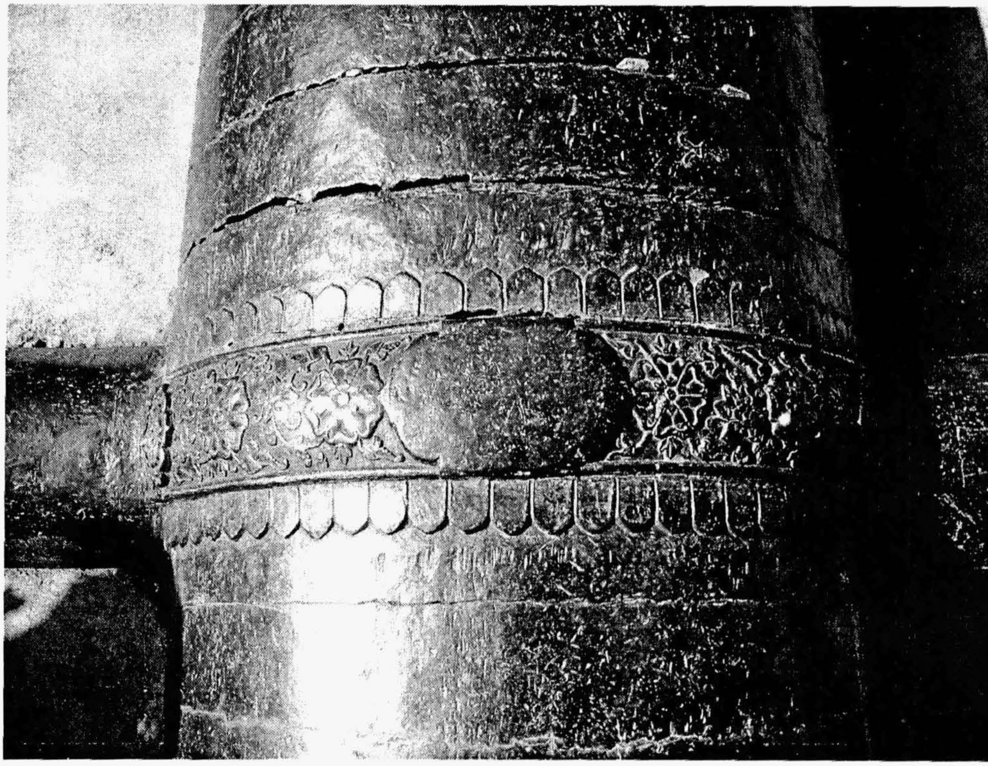

Fig. 5: Details of the decorative iron ring to which the trunions are attached.

section has been damaged (Fig. 6). A total of 9 iron rings are still present in the undamaged portion of this section. Their width ranges between 7.5 and 8.5 cm. The rear portion of the cannon has been damaged and it is open at the end. The distance from the remaining rear ring to the end of the barrel is 86 cm. Assuming that the average of width of rings that were oringially present at this location to be 8 cm, there must have been originally 11 rings at this location, thereby giving a total of 20 rings on the external surface from the ring with trunions upto the rear of the cannon. It is also seen, from the cross sectional view of the damaged back portion (Fig. 7), that only two rings have been used in order to make the thickness of the cannon wall.

A total of 68 iron rings were estimated counting from the front to the end of the barrel. As it is known from the front face (see Fig. 4) and the rear damaged section (see Fig. 7) that two rings were shrunk fit over each other to produce the thickness of the gun, a minimum of 136 iron rings have been used in constructing the tapered cylindrical barrel of the iron cannon.

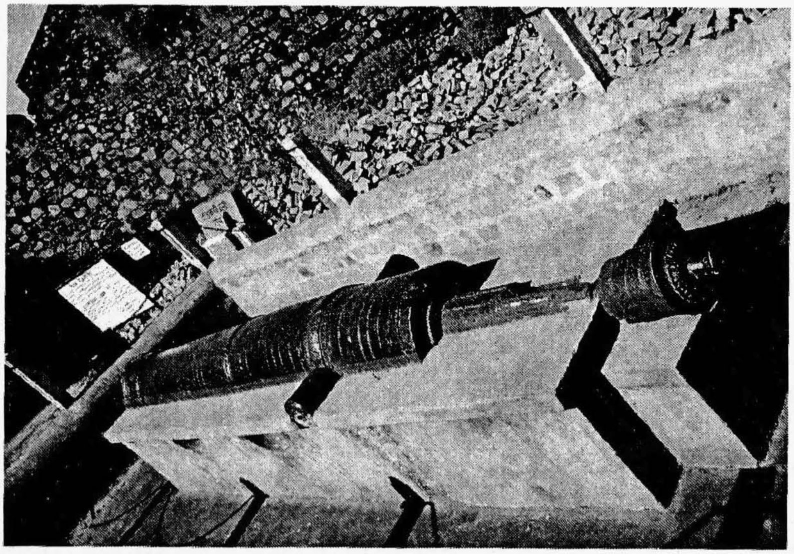

Fig. 6: Damaged back portion of the cannon.

Fig. 7: The damaged portion in the back of the cannon viewed from the rear of the cannon.

The thickness of the cannon consists of only two rings throughout the barrel. The iron rings used in the back of the cannon are of progressively larger width. The diameter of the cannon at different locations has been indicated in the engineering drawing of the cannon in Fig. 3.

The final section of the cannon is the rear end. This is an important location because this section has to withstand the impact of the exploding gun-fire. Its constructional details are worth noting in detail because this would also provide strong clues about the manufacturing methodology of the cannon in the rear section. Two different views of the end section are seen in Figs. 7 and 8. The end portion of the cannon in the damaged section reveals very interesting details. The iron staves from the front end of the cannon progress all the way up to the rear section, where they were connected to the rear block.

A very interesting design feature as to how the gun powder was loaded is available from Fig. 8. It appears that the gun powder was loaded in another cylindrical barrel of smaller diameter. This cylinder is of smaller diameter (10 cm) compared to the inner bore of the cannon. This hollow cylinder is made up

Fig. 8: The damaged portion in the back of the cannon viewed from the front of the cannon.

of six plates each about 6.5 cm wide. The inner diameter of this cylinder is 10 cm and protudes 22 cm from the rear portion onto the barrel of the cannon. The gun powder was probably filled up in this smaller cylinder and lighted using the fuse hole placed on the top of the rear section. Therefore, this smaller cylindrical barrel should proceed up to the location of the fuse hole (see Fig. 9).

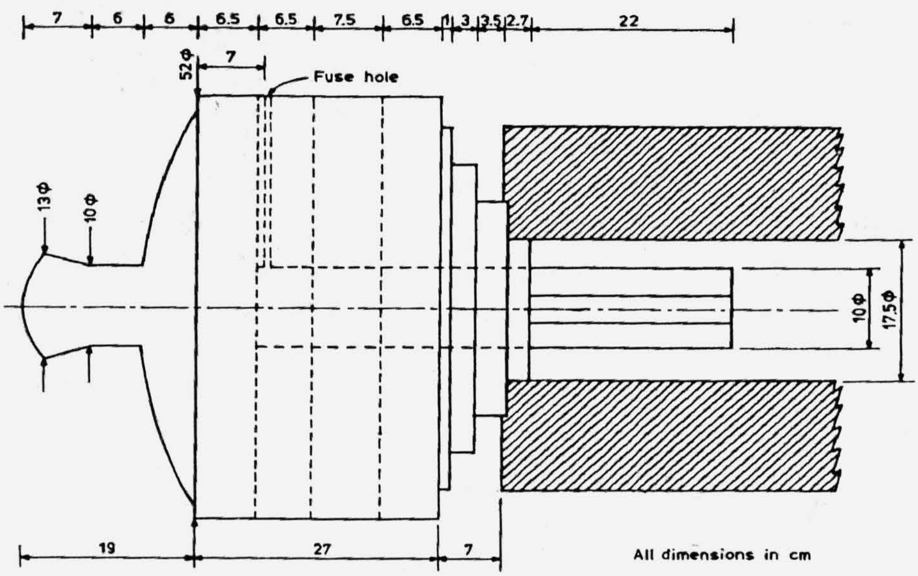

Fig. 9: Reconstruction of the rear end of the cannon. Notice that the cylinder in which the gun powder was filled progresses all the way up to the fuse hole location.

The end supporting circular block of iron at the end of the bore is approximately 55 cm in length. The rear section is again made of rings and a total of 4 rings can be counted on the external face of the extreme rear portion (see Fig. 10). The rear end (Fig. 10) shows that the number of rings has been successively reduced in order to finally reach the solid iron cylinder at the extreme end of the cannon. A reconstruction of the cross section of the rear end is depicted schematically in Fig. 9. The extreme rear of the cannon shows a small projection (see Fig. 10) and this would have aided lifting and handling of the cannon, using either ropes or chains.

In order to obtain a lower-bound estimate of the total number of rings used in constructing the cannon, the ring assemblies in the rear of the cannon must be also taken into account. The minimum number of rings used in this rear construction, as per the outline described above (see schematic in Fig. 9) is

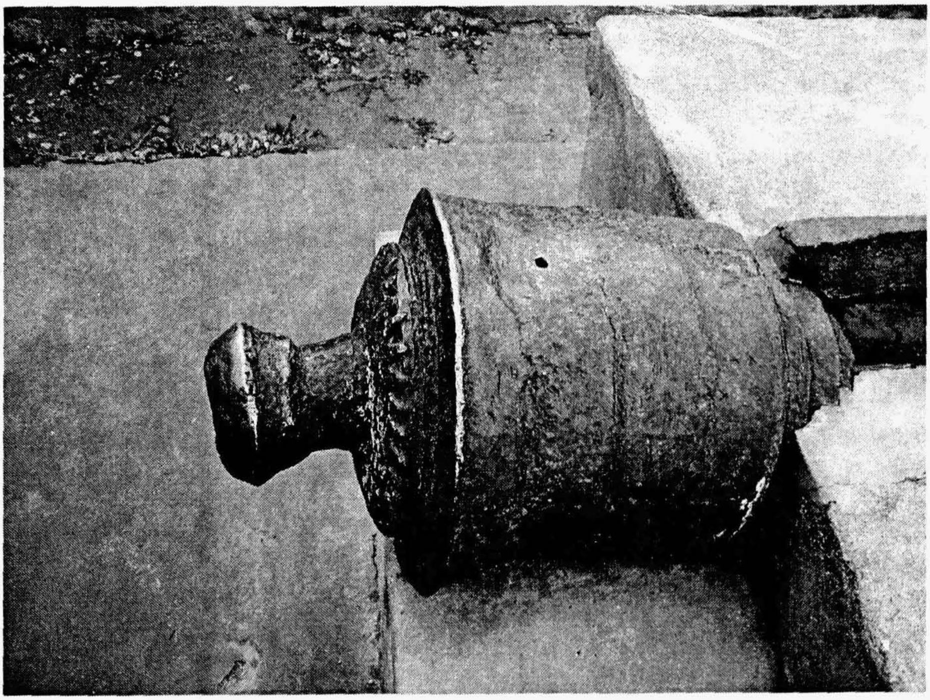

Fig. 10: Rear end of the cannon.

12 rings. Therefore the minimum number of rings used in the construction of the entire cannon is 12+136 = 148 rings.

The engineering genius and blacksmithy skills of the medieval Indians, who forged this wonderful piece of wrought iron cannon, must be appreciated. Apart from the strict dimensional tolerances that were required in the fabrication of the individual rings (with their varying diameter, thickness and width depending upon their location along the gun barrel), it would have required tremendous skill in designing and manufacturing this cannon. The whole operation must have been conducted in the hot working range, further emphasizing the difficulties and skill in handling of the cannon during its manufacture.

Construction

Ideas about the construction methodology of the cannon can be first gleaned from the front face of the cannon. There are a total of 11 plates, each of them 7 to 6.5 cm wide and 4 cm in thickenss, which make up the inner bore of the cannon. On progressing deeper into the barrel of the cannon, these iron staves become thicker. The thickness of the iron staves in the rear was 6 cm (see Figs. 7 and 8).

Another important conclusion that can be drawn from the observation of the front end of the cannon is that two successively larger diameter iron rings have been used to construct the thickness of the cannon. Let us compare the ring diameters at the front portion and at the rear portion, just before the damaged portion. The external ring is approximately 58 cm in outer diameter and 40 cm in inner diameter, as can be made out from the front damaged portion. The inner diameter of the inner ring is 29 cm, while the outer diameter 40 cm. Now moving to the damaged portion in the back, let us look at the dimensions of the inner and external ring. The external ring has an outer diameter of 61 cm (based on the measured perimeter) while the inner diameter is 37.5 cm. The external diameter of the inner ring is the same as the internal diameter of the outer ring (i.e. 37.5 cm) and its inner diameter (touching the iron staves) is 29 cm. Therefore, the thickness of the inner rings has decreased while that of the external ring has increased compared to that seen in the front. This helps us to conclude that as one progresses deeper into the barrel, the inner ring almost maintains its thickness while the external rings become progressively thicker, thereby providing the apparent tapered appearance to the barrel of the cannon.

The procedure by which the thickness of the cannon was built up can be stated with some certainty. The manufacture of the main barrel of the wrought iron cannon would would have required shrink fitting of these rings over a removable central mandrel on which the iron staves must have been longitudinally placed.

Another interesting feature noticed in the damaged front and back portions is that the straight iron staves, which were placed on the inner portion of the cannon bore, continue all the way up to the end of the cylindrical barrel. A very important observation is that the thickness of the iron staves in the rear portion is 6 cm and this is greater than the thickness of iron staves (4 cm) on the front cross section. At the end, the iron staves have been intelligently connected to the rear portion of the cannon, as can be made out from Fig. 8. The inner diameter of the iron staves in the damaged portion is 17.5 cm and this is only slightly smaller than the inner diameter of 22 cm noticed on the front face.

This shows the excellent design maintained in the fabrication of the cannon. This also indicates that while the main barrel shows a increasing diameter on moving from the front to the rear, the inner barrel diameter exhibits increase in diameter from the back to the front.

The skill of the medieval Indian blacksmiths that forged this cannon can be appreciated from the fact that careful reproduction of dimensions must have been required because the various gaps have to be closed successfully. The rings that make up the outer shell of the cannon must have been shrunk fit over the inner iron staves, both in the main bore as well as the rear portion. This would have required careful design considerations to take into account the shrinking of the iron ring over the staves. As noted before, the outer rings have closed the gaps between the inner rings.

The damaged portion at the rear end provides some vital clues to how this section was manufactured. The iron staves that made up the inner bore of the cannon was allowed to meet the rear, where it was clamped by means of the iron rings (see Fig. 8).

The design and manufacture of the cannon in the rear section can be addressed based on the schematic of Fig. 9. A cylindrical hollow structure was fabricated using iron staves and the diameter of this cylinder was smaller than that of the main bore of the cannon. Around this, iron rings were forged in order to make up the rear section. Later this rear portion was joined to the main bore of the cannon by connecting with the iron staves from the cannon bore and over which the iron rings of the main barrel were forged over. This can be clearly discerned from Fig. 8.

The ingenious construction of the cannon utilizing sound engineering principles has to be appreciated. However, it must be realized that construction of the forge-welded cannon must have necessarily been tedious because of the enormous skill (and time) required in precise dimensioning of the various rings. This is important because the rings had to fit tightly over each other, once the rings cool down from the high temperature. The construction of this cannon (and also the other forge welded cannons) would have taken a considerable amount of time. In contrast, cannons that were manufactured by casting would have been much faster to fabricate because of the nature of the casting process itself. This allowed more number of cannons to be fabricated using cast iron technology and therefore, resulted in a military advantage for the people capable of casting cannons. In this regard, it is reasonable to propose that the cast iron technology developed by the colonial European powers was a very vital ingredient of their military successes because they could manufacture large number of artillery pieces in a relatively short period of time. Therefore, although the local Indian forge welding technology was in a refined stage during the medieval period, the lack of adapting to casting technology must have been partially responsible for the military defeat to the European colonial powers. Indian technology did not learn from the west as regards cast iron technology and therefore this lack of adaptation ultimately resulted in India falling into European hands during pre-modern times.

MATERIAL OF CONSTRUCTION

It was not possible to obtain a piece of iron from this iron cannon for metallurgical analysis. Of course, it is obvious that the cannon was not cast and therefore the use of cast iron can be safely discounted. The surface condition of the cannon reveals several interesting details. The color of the cannon appears different depending on the time of observation of the cannon. The surface appears reddish brown in sunlight. The surface is almost free of corrosion. In fact, the amount of rust on the exposed surface was so small that rust could not be collected for analysis. The iron used in the construction must have been obtained by the direct reduction process. It would be useful to obtain samples from this cannon that can be subjected to careful chemical and microstructural analysis.

CONCLUSIONS

The forge welded iron cannon located currently in the Jhansi fort, by name *Kaḍak Bijlī*, has been addressed in this communication. The general design of the cannon has been described. The dimensions of the cannon have been measured. Its length is 5.5 m and it weighs about 5 tons. The damaged locations in the front and rear of the cannon permit understanding of the manufacturing details of the cannon. The main barrel of the cannon was manufactured by forge welding two layers of rings over 11 longitudinally placed iron staves. The ingenious construction at the rear portion of the cannon has been described. A smaller diameter cylinder, made up of iron staves, appears in the rear and this was used for filling the gun powder. The engineering skill of the medieval Indian blacksmiths can be appreciated by understanding the construction of this cannon.

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REFERENCES

1. P. Neogi, *Iron in Ancient India*, Indian Association for Cultivation of Science, Calcutta, 1914, pp. 32-40.
2. I.A. Khan, *Gunpowder and Firearms: Warfare in Medieval India*, Oxford University Press, 2004, pp. 17-58.
3. H.G. Graves, "Further Notes on the Early Use of Iron in India", *J. Iron and Steel Inst.*, 85 (1912) 187-202.
4. K. Roessler, "The Big Cannon Pipe at Tanjavur", *Metal News*, 19.1(1999) 1-4.
5. R. Balasubramaniam, A. Saxena and T.R. Anantharaman, "*Rājagopāla* - The Massive Iron Cannon at Thanjavur in Tamil Nadu, *IJHS*, 40.3 (2005).
6. R. Balasubramaniam, K. Bhattacharya and A.K. Nigam, "*Dal Mardan* - The Medieval Forge-welded Iron Cannon at Bishnupur", *IJHS*, 40.3 (2005).
7. R. Balasubramaniam, M. Surender and S. Sankaran, "The Forge-welded Iron Cannon at Bada Burj of Golconda Fort Rampart", *IJHS*, 40.3 (2005).
8. R. Balasubramaniam, S. Sankaran and M. Surender, "The Forge Welded Iron Cannon near Fateh Burj of Golconda Fort Rampart", *IIJHS*, 40.3 (2005).
9. D. Neff and R. Balasubramaniam, "*Bhavānī Śaṅkar* - The Forge-welded Iron Cannon at Jhansi Fort," *IJHS*, 40.3 (2005).