Indian Journal of History of Science, 46.4 (2011) 683-693

Catalogue of forge welded iron cannons in Western Maharashtra*

PP Deshpande, Sachin Joshi and Shivendra Kadgaonkar**

India has a glorious tradition in cannon technology and Western Maharashtra is endowed with number of forts each having several number of cast and forge welded cannons that have not been documented and studied. The Project was aimed at cataloguing of the forge welded as well as cast iron and bronze cannons in Western Maharashtra and analyze the salient features of this treasure from the past. It will help us to know the present condition and state of these metallurgical monuments and will also provide the basis for technical investigations to reveal medieval Indian engineering expertise that was responsible for technological developments.

Cannon is a tubular device designed to fire a heavy projectile over a long distance and its introduction in war fare enlarged the canvass of the traditional battles to a decisive role. The cannons used in India were either forge welded iron cannons or cast bronze cannons (Balasubramaniam, 2007). While bronze casting practice for manufacturing cannon was adopted from the Ottoman Turks, the forge welded canon technology seems to be developed in India (Balasubramaniam, 2005). Such forge welded iron cannons found at Nurwar Mushirabad, Dacca (Bangladesh), Bishnupur, Bijapur, Gulbarga and Thanjavur exemplify the medieval Indian blacksmith's skill in the design engineering and construction of large forge welded iron products. Although the important role played by cannons is known, there are very few technical analysis reports of forge welded cannon technology in India. Panchanan Neogi was the first scholar to draw attention to some of the forge welded cannons of India (Neogi, 1914). S.D. Joshi has published a few investigations on cannon technology with reference to the Mughal period: 1200 AD to 1800 AD (Joshi, 1970). Recently R. Balasubramaniam has published a

* The project was carried out under the sponsorship of National Commission for History of Science between September 1, 2008 to August 30, 2010.

**Department of Metallurgy and Materials Science, College of Engineering, Pune- 411005; email: pravinpd@hotmail.com

survey on cannon Technology in India and addressed several issues regarding forge welding technique (Balasubramaniam, 2007).

During the entire project, we visited one hundred and sixty five forts in Western Maharashtra. One hundred and ninty seven cannons were documented. Out of these cannons, one hundred and eighty two cannons are cast iron cannons and one gun metal. Twelve cannons are massive forge welded iron cannons and two are composite. Also we prepared Auto Cad drawings of all these cannons and weight of massive forge welded iron cannons was calculated.

The detailed break up of cannons is as follows:

Forts	**Cast Cannons**	**Forge welded Cannons**	**Composite Cannons**
Devgiri	40	6	
Janjirā	21	3	
Korlai	5		
Mahimatgaḍ	3		
Rasalgaḍ/ Mandangaḍ/ Palgaḍ	20		
Nāshik		1	1
Ratangaḍ	5		
Revdanda	3		
Sinhgaḍ	4		1
Khānderi	10		
Underi	11		
Satārā	1	1	
Govalkot	1	1	
Padmadurg	42		
Dhule			1 (Gunmetal)
Raigaḍ	3		

Out of this work, we are giving here a short account of forts and forge welded iron cannons in western Maharashtra forts.

Janjirā: Situated in Raigaḍ dist. of Maharashtra originally it was a small wooden structure built by a Koli chief in the late 15th century. It was captured by Pir Khan, a general of Nizamshah of Ahmednagar and later strengthened by

Malik Ambar, the Abyssinian-origin Siddi regent of Ahmednagar kings. From then onward Siddis became independent, owing allegiance to Adilshah and the Mughals. Despite their repeated attempts, the Portuguese, the British and the Marathas failed to subdue the Siddi power and take over this fort. All of Shivaji's attempts to capture Janjirā fort failed due to one reason or the other. As per description given in the old Gazetteer (1883), in the bastions and on the walls are ten guns, three of local and seven of European make. The largest local gun is said to have been brought by the Peshva's army, probably in 1735, and abandoned on its retreat. Of the seven European, guns, three were made in Sweden, one in Spain, one in Holland, and one in France. Swedish brass guns, bears the letters C. R. S., and below the letters are the Royal Arms of Sweden with the date Anno 166' and engraving "Goos-Mich Iohan-Meyer in Stockholm". The Spanish brass gun bears the words "Don Phillipe III Rev D' Espana" with the golden fleece below, and the Spanish arms. The Dutch brass gun has engraving round the breech "Hans Noorden ET Ian Alberte de Grave Amsterdam", and the date 1672.

Padmadurg (Murud Peta): The Lotus Fort, also called the Kansa fort, commanding the entrance to the Rajpuri creek, was built by the great Maratha ruler King Shivaji in about 1693 on a rock in the centre of the bay about two miles north-west of Janjirā [About 1693 Kasa or Kansa is mentioned as one of the newly built forts of the Marathas. Elliot, VII. 355.]. Guns of various calibre lie about the fort and some are mounted on wooden gun-carriages in the towers. The water-supply is obtained from a large cistern which fills in rains and lasts through the dry season [Mr. F. B. O'Shea, Superintendent of Post Offices, Konkan Division.].

Mulher: The Mulher Fort in Satana, on a hill about two miles (3.21 km.) south of the Mulher town was built by the Bagul dynasty, who ruled the region from 1308 to 1619. The region was named Bagul-gaḍ because of the rule of Bagul dynasty, which afterwards came to be known as Baglan. In 1638 Mughals invaded Baglan and conquered it, after which the fort was named as Aurangabad. This attack ended the prosperous Hindu rule in Baglan. Mulher had been the Capital of Baglan for all this time. In 1671, Marathas first attacked the Mulher fort, but the Killedar could repulse the attack. Then in February 1672, Marathas first captured Salher fort and then attacked the Mulher fort too. In this campaign, Shivaji Maharaj conquered the forts like Salher, Mulher etc. in the Maratha Kingdom. Afterwards, the fort of Mulher was again conquered by the Mughals.

At third gate of the fort there are three guns known as Fateh-i-lashkar, Ramprasad, and Shivprasad, each seven feet long. There was a fourth gun called Markandeya Toph which the British Government is said to have broken and sold.

Cannons

Auto Cad drawing and weight analysis of a few of the cannons have been attempted.

Figs. 1 to 5 show photographs with Auto Cad Drawings and weights of some of the cannons.

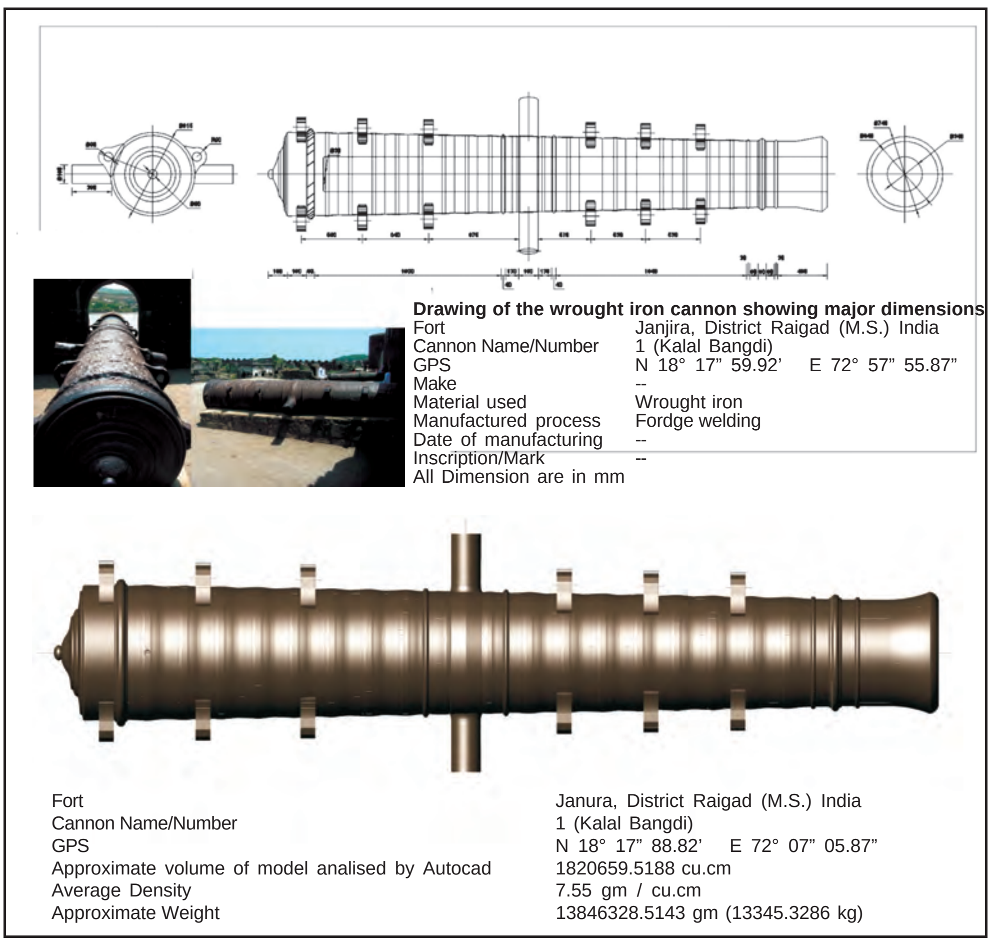
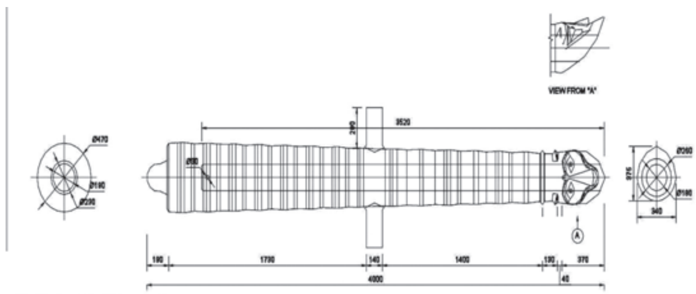


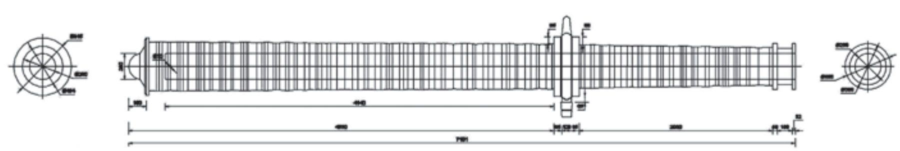
Fig. 1. Kalal Bangdi Cannon at Janjira fort, Maharashtra, weight: 13946Kg (Approx. 15.37 tons)



Drawing of the wrought iron cannon showing major dimensions

Fort	Janjira, District Raigad (M.S.) India
Cannon Name/Number	2 (Chavari)
GPS	N 18° 18" 0.08' E 72° 57" 55.84"
Make	--
Material used	Wrought iron
Manufactured process	Forge welding
Date of manufacturing	--
Inscription/Mark	--
All Dimension are in mm	

Fig. 2. Chavari cannon at Janjira fort, Raigad district,weight:3012 Kg (Approx. 3.32tons)

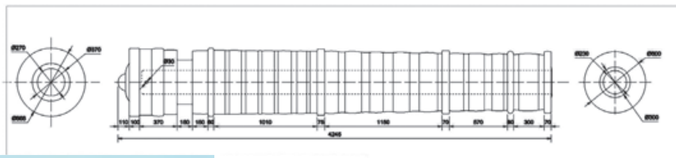


Drawing of the wrought iron cannon showing major dimensions

Fort	Janjira, District Raigad (M.S.) India
Cannon Name/Number	3 (Landa Kasam)
GPS	N 18° 18" 0.20' E 72° 57" 55.83"
Make	-
Material used	Wrought iron
Manufactured process	Forge welding
Date of manufacturing	-
Inscription/Mark	-
All Dimension are in mm	

Fort	Janura, District Raigad (M.S.) India
Cannon Name/Number	3 (Landa Kasam)
GPS	N 18° 18" 0.20' E 72° 57" 55.83"
Approximate volume of model analised by Autocad	882871.4287 cu.cm
Average Density	7.66 gm / cu.cm
Approximate Weight	6762795.1483 gm (6762.7952 kg)

Fig. 3. Landa Kasam Cannon at Janjira fort, Maharashtra, weight: 6762 Kg (Approx. 7.45 tons)

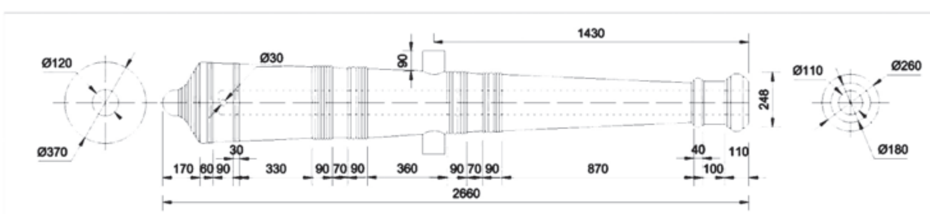


Drawing of the cast iron cannon showing major dimensions

Fort	Hargad, District Nashik (M.S.) India
Cannon Name/Number	1 (Durga Prasad)
GPS	
Make	--
Material used	Wrought iron
Manufactured process	Forge welding
Date of manufacturing	--
Inscription/Mark	--
All Dimension are in mm	

Fort	Hargad, District Nashik (M.S.) India
Cannon Name/Number	1 (Durga Prasad)
GPS	
Approximate volume of model analised by Autocad	988904.6042208 cu.cm
Average Density	7.66 gm / cu.cm
Approximate Weight	7575009.2683 gm (7575.0095 kg)

Fig. 4. Durga Prasad cannon at Mulher fort, Nashik, weight: 7575 Kg (Approx. 8.35 tons)



Drawing of the cast iron cannon showing major dimensions

Fort	Mulher, District Nashik (M.S.) India
Cannon Name/Number	2 (Shiva Prasad)
GPS	
Make	--
Material used	Cast iron + Wrought iron
Manufactured process	Casting + Forge welding
Date of manufacturing	--
Inscription/Mark	--
All Dimension are in mm	

Fig. 5. Shiva Prasad (composite) cannon in Mulher fort, Nashik, Maharashtra

It reveals that Shiva Prasad cannon was made basically by casting. But an assembly of wrought iron rings was used either to repair the damaged mouth portion or reinforce the entire cross section of the cannon. Hence it can be termed as composite cannon.

Manufacturing Technology of Forge Welded Iron Cannons in Medieval India

Forge welding practice in Ancient India: The melting point of pure iron is 1540°C. In the ancient Indian furnaces that were used to extract iron from its ore, it was not possible to attain such higher temperatures required for melting of iron. Therefore, the reduction of iron was performed in the solid state at a temperature of about 1100–1200°C in bloomery furnace. The end product of reduction of iron ore was an iron bloom which was utilized to fabricate commercial objects (Deshpande, 2008, 2011, Prakash, 2001, Tripathi, 2010). This technique is known as solid state reduction process or bloomery process. Indian black smiths in ancient India perfected this technique and fabricated large number of articles ranging from agricultural tools to massive structures like Delhi iron pillar. The same tradition was continued up to medieval period in India and cannons were constructed using forge welding technique. Although medieval Indian blacksmiths successfully used casting in the manufacture of intricate bronze objects, available evidence indicates that few practiced iron-casting techniques. The blacksmiths' lack of interest in casting was likely due not only to the high temperatures required for casting, but also to their mastery over the forge welding to produce large iron objects (Balasubramaniam,2007).

All these cannons documented here are muzzle loading type i.e. the gun powder and the projectile object are loaded from the muzzle or front end. The outer appearance of all these cannons indicates that individual pre fabricated iron rings were forge welded in order to create the complete cannon structure. The rings exhibit good continuity and the skill of the medieval black smith must be appreciated because these rings have been so skillfully forge welded that the entire surface of the cannon appears smooth due to the excellent closure of gaps between the individual iron rings. The iron rings appear to have been joined by hooping and later by forge welding. The manufacturing technology of cannon can therefore be classified under forge welding of pre-forged iron rings, hooped over longitudinally placed iron staves with correct positioning and alignment. Based on the design of the similar forge-welded-iron cannons (Balasubramaniam 2007), the solid portion of the rear of the cannon should extend up to the fuse hole location. This portion appears to have been constructed of rings over a central solid cylindrical shaft that were successively forged over each other. It appears that the medieval engineers were familiar with the idea of structural design for improved fracture toughness because the solid structure created with successively larger diameter rings would have possessed a better impact resistance compared to a single solid piece of wrought iron. The barrel must have been fabricated separately from the chamber. Initially, the long iron strips were placed on a mandrel in order to provide it support and to aid manufacturing operations that followed. Pre-fabricated iron rings were expanded and then shrunk fit over the long iron strips. The rings of the first layer were brought from the front end. After the first layer was forge welded, the other layers were subsequently built up. Near the trunion and front end extra rings are observed. These additional ring assemblies would have provided further strengthening to the cannon. These outer rings appear to have been forge welded over the layers of rings. The total number of rings that make up the thickness of the barrel cannot be easily distinguished by visual observations alone. It is reasonable to assume that there are layers of rings building thickness of barrel, based on the design of other similar cannons at Thanjavur and Bishnupur (Balasubramaniam, 2004, 2007). Although handling clamps are visible on the cannon, it is difficult to visualize how these massive cannons were transported. One of the remarkable observations concerning all these cannons is that they are almost devoid of significant rusting. The surface possesses a reddish golden hue and the surface is reflective indicating the relatively thin layer present on the surface. This might be attributed to the high phosphorus present in the wrought iron and forge welding technology used for making of the cannon (Balasubramaniam, 2004). It must be noted that no special maintenance procedures are currently applied. Despite of its neglect, these cannons reveal only pitting corrosion. Under similar conditions, modern mild steel would have corroded severely. Thus the atmospheric corrosion resistance of these cannons is excellent and can be compared with Delhi iron pillar. Therefore, these massive forge welded iron cannons demonstrate a marvel of medieval Indian metallurgical skill.

Technical Investigations of Non-ferrous Metal Cannon

Metallurgical investigations of a non-ferrous metal cannon in I. V. K. Rajwade Sanshodhan Mandal, Dhule (MS) India are also carried out and reported here. Fig. 6 shows photograph of this cannon.

Fig. 6. A cannon in I. V. K. Rajwade Sanshodhan Mandal, Dhule (MS) India

Wet Chemical Analysis: It reveals that the alloy having following composition was used to make this cannon.

Element	Wt %
Copper	87.2
Tin	8.6
Zinc	3
Lead	1.2

This chemical analysis shows use of gun metal for making of the cannon.

Metallographical Analysis: Low magnification microphotograph of the sample from the surface of the cannon is shown in the Fig.7.

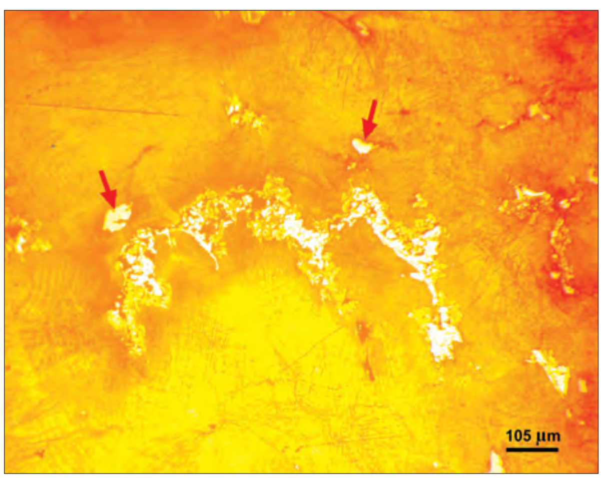


Fig. 7. Photomicrograph of gun metal cannon, X 95

White islands of ($\alpha + \delta$) eutectoid in the matrix are seen in the fig. 7. The α-phase shows evidence for coring and it is visible in the form of darker etching around grain boundaries. This implies that the metal used for making the cannon was cast. Cored α grains contain slip bands. These can be attributed to the cutting of the sample from the surface of the cannon. Particles marked with arrows may be lead oxide inclusions.

Casting of Gun Metal Cannons

Two different casting techniques had been in practice in the medieval period. In one of the methods, core was used to place in the centre of mould and molten alloy was poured over. This procedure was employed for casting relatively large cannons. In the other technique core was used to place in the sleeve of the mould and positioned using chaplets and molten alloy was supplied into the mould. These chaplets were made of wrought iron. The presence of these rods can be seen on the surface by different coloration. No such coloration was found in the present case. Therefore, it can be argued that the cannon was cast by keeping the core in the centre of mould. By analyzing the composition of the cannon at the front and back locations, the pour direction during casting can be determined (Balasubramaniam, 2005). To sum up, Gun metal was used for making of the cannon and the cannon was made by casting. Alloy composition for making cannon seems to be carefully designed. To improve fracture toughness of the alloy tin addition was kept within limits.

Conclusion

The manufacturing technology of cannon can be classified under forge welding of pre-forged iron rings, hooped over longitudinally placed iron staves with correct positioning and alignment. It appears that the medieval engineers were familiar with the idea of structural design for improved fracture toughness because the solid structure created with successively larger diameter rings would have possessed a better impact resistance compared to a single solid piece of wrought iron. High phosphorus present in the wrought iron and forge welding technique might be responsible for excellent corrosion resistance. Gun metal was used in casting non ferrous cannons. To improve fracture toughness of the alloy, tin addition was kept within limits.

Bibliography

Balasubramaniam, R, *The saga of Indian cannon*, Aryan books International, New Delhi, 2007.

Balasubramaniam, R, 'Development of Cannon Technology in India', *IJHS*, 40.4(2005), pp. 503-538.

Balasubramaniam, R, et al. 'A marvel of medieval Indian metallurgy: Thanjavur's Forge welded iron cannon', *Journal of Metals*, Jan 2004, pp. 17-23.

Deshpande, P.P., Dhokey, N. B., 'Metallographical investigations of iron objects in ancient Vidharbha region of Maharashtra' , *Trans. Indian Inst. Met.*, 61.2, (April 2008), pp 1-3.

Deshpande, P.P, Shinde, V.S., Mohanty,R.K., ' Metallographical studies of a steel chisel found at Mahurjhari , Vidarbha, Maharashtra' , *Current Science* , 99. 5,(September 2011), pp. 636-39.

Deshpande, P.P., Joshi, S.V., Mohanty, R.K., Dhoky, N.B., and More, M.A., 'Metallo graphical investigations of iron objects found in the megalithic burials in Vidarbha regions of Maharashtra', *Puratattva*, No .38 , 2008 , pp. 244-250.

Joshi, S.D., *History of Metal Founding on the Indian sub-continent since Ancient Times*, Joshi Publishers, Ranchi, 1970, pp. 58-79.

Neogi, P, *Iron in Ancient India*, The Indian Association for the cultivation of science, Calcutta,1914, pp 32-40.

Prakash, B., 'Ferrous Metallurgy in Ancient India', *Metallurgy in India - NML Golden Jubilee*, Vol., 2001, pp. 52-91

Tripathi, Vibha, *History of Iron Technology in India*, Rupa and Infinity Foundation series, New Delhi, 2008, pp. 29-103.