

Jyoti K. Sinha *Editor*

# Vibration Engineering and Technology of Machinery

Proceedings of VETOMAC X 2014, held  
at the University of Manchester, UK,  
September 9–11, 2014

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# Preface

The 10th International Conference on Vibration Engineering and Technology of Machinery (VETOMAC X) 2014 in Manchester is the 10th instalment in a series of conferences being held in an effort to bring together researchers and engineers working in the field of vibration. This conference is organised by the University of Manchester (in collaboration with the Vibration Institute of India) and held in Manchester, UK, during 9–11, September 2014. The conference aims to provide engineers and researchers a platform for sharing their innovative and creative research findings aimed to benefit the engineering and technology of machinery.

VETOMAC X covered a holistic plethora of relevant topics in vibration and engineering technology including (but surely not limited to); Condition Monitoring, Machinery and Structural Dynamics, Rotor Dynamics, Experimental Techniques, Finite Element Model updating, Industrial case studies, Vibration control and Energy harvesting, Signal processing, etc. The conference concentrated on nearly 100 papers from key researchers and engineers from universities, private and public research centres and industries from more than 20 countries worldwide. The papers were subjected to a unanimous peer review by experts from different fields covered by the conference before being accepted for oral presentation and publication. The full proceeding also includes six invited lectures from renowned experts: Prof. K. Gupta, Mr. W. Hahn, Prof. A.W. Lees, Prof. John Mottershead, Prof. J.S. Rao and Dr. P. Russhard.

The organisers would like to thank the keynote speakers, authors, presenters and session chairs for their participation. Special gratitude must be extended to a number of individuals whose invaluable help enabled the organisation of the VETOMAC X 2014 Conference in Manchester, UK. Sincere gratitude is also expressed to the scientific committee and all the reviewers. The consistent support of the School of Mechanical, Aerospace and Civil Engineering (MACE) of The University of Manchester in every respect in organising VETOMAC X 2014 is gratefully acknowledged.

I particularly wish to thank Prof. Andrew Gibson (Head of School), Prof. Paul Mummery (Line Manager), Ms. Anne McGourlay (Head of School Administration), Mrs. Vera Sokolovski (Web Manager), Ms. Alison Lawton (School Finance

Manager), Miss. Michelle Mallon (Conference Secretary) from School of MACE, my Research Associate and Ph.D. students; Mr. Erfan Asnaashari, Dr. Keri Elbhah, Mr. Ahmed Gubran, Mr. Akilu Kaltungo and Mr. Adrian Nembhard for their day-to-day support. Lastly, I acknowledge my wife Sarita and my son Aarambh as my real strengths throughout.



Manchester, UK

Jyoti K. Sinha

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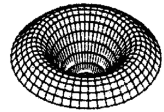


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## History of VETOMAC Series of Conferences

(in collaboration with the Vibration Institute of India)

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- **VETOMAC II, 2002:** Bhabha Atomic Research Centre, Mumbai, India.
- **VETOMAC III, 2004:** Indian Institute of Technology, Kanpur, India.
- **VETOMAC IV, 2007:** University College of Engineering, Osmania University, Hyderabad, India, Bharat Heavy Electricals Limited, Hyderabad, India.
- **VETOMAC V, 2009:** Huazhong University of Science and Technology, Wuhan, China and City University of Hong Kong, China.
- **VETOMAC VI, 2010:** Indian Institute of Technology, New Delhi, India.
- **VETOMAC VII, 2011:** Shanghai Jiao Tong University and City University of Hong Kong, China.
- **VETOMAC VIII, 2012:** Institute of Fluid Flow Machinery, Polish Academy of Sciences, Gdansk, Poland.
- **VETOMAC IX, 2013:** Nanjing University of Aeronautics and Astronautics, Nanjing, China.



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**Part I**  
**Keynote Lectures**

# Ancient Temple Carts—Modifications for Structure and Steering

J.S. Rao and Bigil Kumar

**Abstract** Temple carts from ancient times are used to bring out Deities on festival days in a procession. The origin of these carts and their construction is discussed in this paper together with current design practices befitting with changing times.

**Keywords** Rig-Veda · Hindu gods or extra-terrestrial visitors · Temple carts · Steering · Globally elastic but locally plastic structures

## 1 Introduction

Indian temples have their origins from Rig-Veda times, a period exactly not identifiable from modern historical dating methods, but derived from inference to be at least 4,000 years old. The epic Ramayana contains description of battles with incredible weapons cited as Brahma weapon.

The Gāyatrī Mantra a highly revered mantra, based on a Vedic Sanskrit verse from a hymn of the Rig-Veda (3.62.10), attributed to the rishi (sage) Viśvāmītra, see Griffith [11].

This is 16th stanza of Upanishads in Devanagari script, a translation into English is provided by several, among them that of Easwaran [10] is “O nourishing Sun, solitary traveler, controller, source of life for all creatures, spread your light and subdue your dazzling splendor so that I may see your blessed Self. Even that very Self am I!”.

Jones [12] on February 2nd 1786 addressed the Asiatic Society of Bengal about the origin of Sanskrit, having similarities with Latin and Greek; commonly used words are: Father, Mother and Horse.

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Ramayana refers to some Vedic Gods like Indra, Agni and Varuna among others, see Didhiti Biswas article in Dodiya [9]. The Rig-Veda and the life of ancient Indians during that period are described by Srinivasa Iyengar [25].

Mohenjo-Daro Harappa (Mound of the Dead) was discovered in 1922. Kenoyer [14] places the settlements of the Indus around 3750 BC. At this site, 37 skeletons were found in contorted positions, in a residential district of the town, see Fig. 1. In all there were just 44 skeletons found at this site.

At the time of Mohenjo-Daro, mankind has not known an atomic weapon. No conventional weapons such as swords or spears were found. No scavenging animals and their skeletons were discovered at this site. This is despite the well recorded and understood destruction of the city of Pompeii in the eruption of Mount Vesuvius in 79 AD, see De Carolis et al. [8]. Just as we ignored completely the battles described in Hindu epics Ramayana and Mahabharata, here too in Mohenjo-Daro the mysterious circumstances were ignored.

The first atomic bomb was detonated on July 16, 1945, in the Trinity test in New Mexico; its creator, Oppenheimer [20] remarked later “it brought to mind words from the Bhagavad Gita: Now I am become Death, the destroyer of worlds.”

According to Dales [5], the evidence given earlier suggesting that Mohenjo-Daro was destroyed by armed invaders was a quick conclusion drawn.

Suggestions were made that this might be the site where Ramayana epic battles took place. Ramayana describes in the battle that Brahma Astra was used which generated brightness more than 1,000 Suns, trees were up in flames; more significantly the epic describes people who survived the battle were losing hair and nails started to fall out—typical effects of radiation observed after the present day atomic explosions, see Tsoukalos [26]. Childress [4] discusses Vimanika Sasthras (flying



**Fig. 1** Skeletons at Mohenjo-Daro attributed to Massacre theory

machine technologies) described 6,000 years ago in Sanskrit texts indicating that this technology existed in the olden days. The texts describe three giant cities orbiting the earth with gleaming metal and iron with them going to war with each other. Tsoukalos and others are proponents of the idea that ancient astronauts interacted with ancient humans. What is it our ancestors are describing in the ancient Sanskrit scripts, some type of technology that was witnessed; they didn't understand nuts and bolts aspects of this technology, yet they created divine representation; the practices that they have developed are so effective, they remain in force even today in India.

Davenport [7] spent 12 years in studying at the site; according to him Mohenjo-Daro corresponds exactly to Nagasaki. An epicenter about 50 yards wide where everything was crystallized, fused or melted was found. Sixty yards from the center the bricks are melted on one side indicating a blast. At this site even today the radiation levels are high suggesting that there was an atomic attack; see Childress, History Channel Video [4].

According to recent findings based on radio-metric dates from Bhirrana (Hararyana) the origin of the Indus Valley Civilization emerged in the 8th millennium BC in the Ghaggar-Hakra and Baluchistan area, see Khandekar [15].

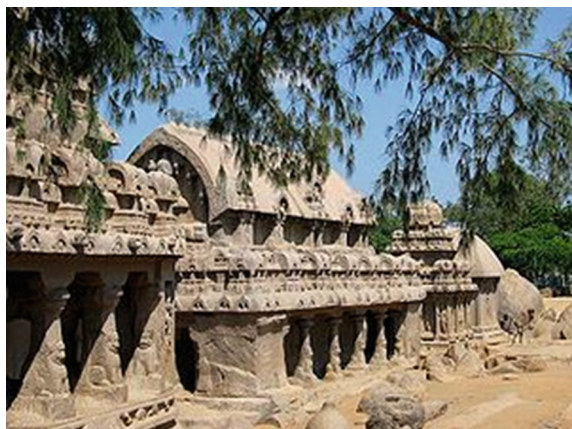
Rig Veda cites chariots in many places: The chariot carrying the God is moving through the air with very swift motion; (Rig Veda V. 77.3). It is hard to overtake (Rig Veda. V.35.7), see Griffith [11]. Parts of *Ratha* are mentioned in Vedas.

Pallavas (600–900 AD) are amongst the earlier patrons who built rock-cut chariot-shaped temples of Mahabalipuram: They are called locally as *Ratha* (Chariot) and the Gopuram (superstructure) called *Vimanas*, see Fig. 2.

In Tanjore Brihadeshvara Temple (1009 AD), Fig. 3, there is an elaborate mural as given in Fig. 4; see Mohamed and Iqbal [19].

Lord Siva on his chariot with his eight arms wielding different weapons is driven by Lord Brahma. The *Ther* is Earth with the Sun and Moon as wheels. Nandi, Siva's *vahana* is pulling the chariot. Brahma is smiling at Siva looking at his

**Fig. 2** Five *Rathas* of Mamallapuram (Mahabalipuram) (630–638 AD)





**Fig. 3** Brihadeshvara Temple



**Fig. 4** Destruction of Demons by Lord Siva as Tirupurantaka on his chariot with eight arms



inability to destroy the three demons with his bow and arrow, being closely watched by other Gods. Siva observing Brahma's smile turns the bow backwards and opens his third eye to destroy the asuras. This mural is recalling what our ancestors saw during Rig-Veda and Ramayana periods.

**Fig. 5** First temple with a Wheel (1117–1135 AD)



This mural clue that Gods were flying but not resident on earth is taken by Vikrama Chola (1117–1135 AD) who built the first temple in Thukkachi with a wheel, see Fig. 5. This was followed by Rajaraja Chola II who built the Airavatesvara temple (1146 AD), see Fig. 6 which has a horse-drawn chariot carved on the front of the mandapam. This trend followed in Konark in Odisha and Hampi.

Konark Sun Temple (1278 AD) was conceived as a gigantic chariot of the Sun God, Fig. 7 shows one of these wheels. The next step seems to be taking the Gods as they are known in the scriptures to flying chariots, see Fig. 8 as depicted by History Channel. Rig-Veda also describes battles using Vimanas, as depicted in History Channel and described best by our ancestors in Fig. 9; that's the reason why the superstructures of temples are called Vimanas.

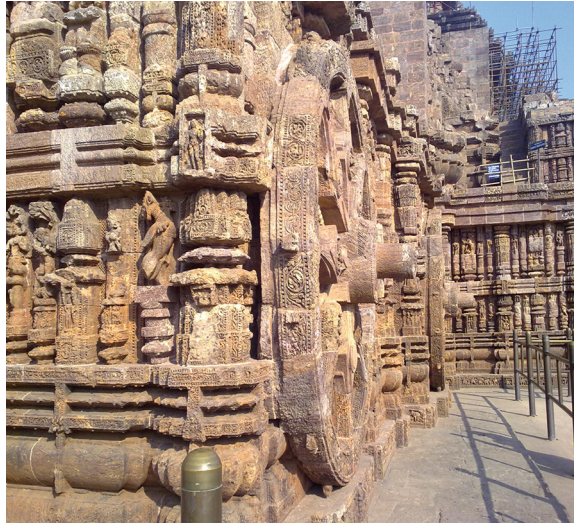
Stone chariots were built in Konark (1278 AD), see Fig. 10. Vijayanagara Kings built several temples in Hampi and one stone chariot in Vittala temple in 16th century, see Fig. 11.

It is difficult to date when the practice of chariots taking Gods on festival days began; it is probably during the Vijayanagara period in 16th century. *Ther* itself is considered as the manifestation of the temple housing a God. Those pulling the *Ther* consider to be rewarded by divine blessing. In to days practice, Rathotsava is

**Fig. 6** Airavatesvara Temple and spoked chariot wheel



**Fig. 7** Konark Sun Temple



**Fig. 8** Battles from flying chariots



**Fig. 9** Vedic battles in Sky from vimanas





**Fig. 10** Konark Temple chariot (1278 AD)



**Fig. 11** Stone chariot in Hampi (16th century)

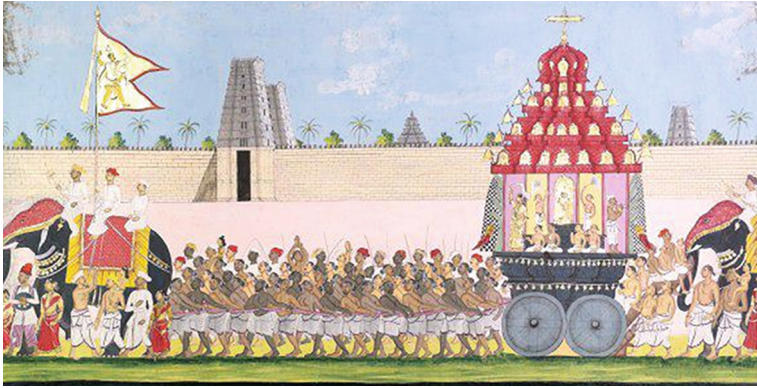


an important social gathering enhancing living in harmony. An ancient Rathotsava is depicted in Fig. 12; see Dallapiccola [6].

A special section of Vedas deal with the construction of temples and *Rathas*. Silpa Shastra deals with *Ther* construction (Maha Viswakarmiyam) script of which is put on palm leaves between 8 and 10th AD is shown in Fig. 13 see Umaphathy [27].

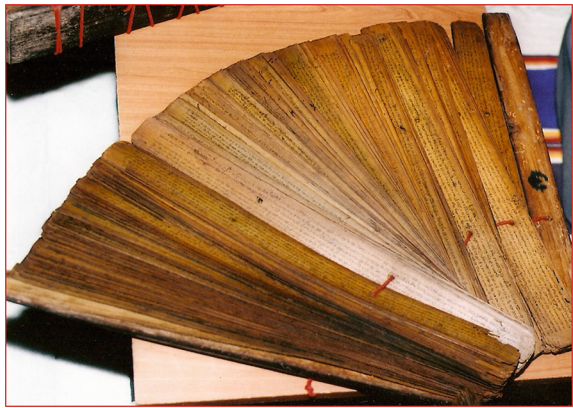
Shastras (Rules) to design the *Thers* are probably developed as early as 8th century AD; 1. Viswakarma *Rathalaksanam*, 2. Kumara Tantra, 3. Maha Viswakarmiyam and 4. Karanagama [13] see, Acharya [1, 2] and Mankad [18]. The *Ther* used in Brihadeshvara temple in Tanjore is shown in Fig. 14. In general a *Ther* should have a *Simmasanam* (Crown Chair) for the Deity, a *Devasanam* (Seat of Devas) a *Narasanam* (Seat for priests), different *Boothabars* from which the Crown Chair is reached, see Fig. 15.

The *Ther* has a superstructure like a Vamana; see Fig. 16; but this is not essentially a load bearing structure but has all decorations befitting a festive mood.



**Fig. 12** Ancient Rathotsava and procession

**Fig. 13** Silpa Shastras on palm leaves



**Fig. 14** Tanjore Temple car



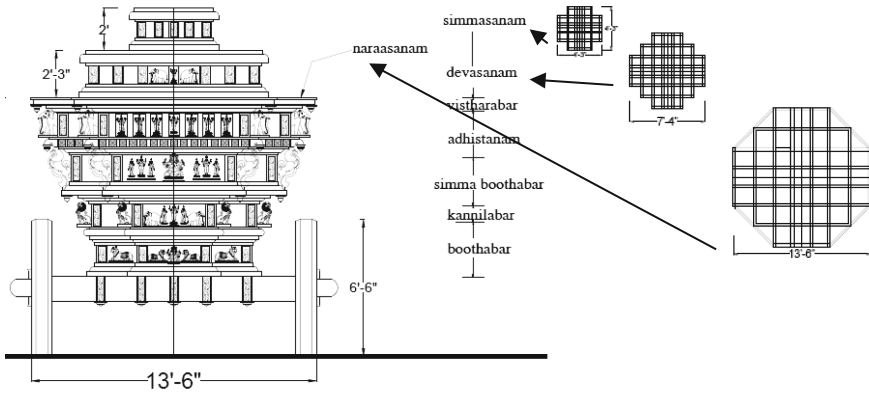


Fig. 15 A typical temple Ratha (car)



Fig. 16 Tanjore Temple car in procession

These *Thers* do not have any steering system or a braking system. The *Thers* are pulled by devotees and being very heavy about 300 tons in the case of Tiruvarur temple; move inch by inch. Steering, sometimes breaking is achieved by using wedges placed by trained volunteers. The state of Tamilnadu alone has nearly 500 such *Thers* in different temples; each of these *Thers* cost around 600,000 US\$.

A review of the ancient *Thers* is given by Rao, Bhonsle and Kumar [23].

Here the modern approach to determine the stresses, a simple steering linkage and weight reduction through topology optimization is presented.