Safe Rigging Principles and Practices

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By

Shankar Saran

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This book is dedicated most reverentially to
the thousands of labourers, workers and employees
who have laid down their lives in constructing, operating,
and maintaining hazardous industries, especially the steel industry,
and faded away from memory unwept, unhonoured and unsung.
My salutations to them.

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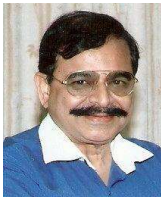
PREFACE



Safety in mechanical handling of heavy loads and safe rigging principles and practices became a subject of great interest to me on joining the integrated steel industry as a *Graduate Engineer Trainee* in the erstwhile Hindustan Steel Limited (now, Steel Authority of India Ltd.) at Rourkela Steel Plant (RSP) on May 31, 1971. Since I was deeply involved with all capital repairs of blast furnaces, it did not take me long to realise that we engineers suffered from a serious knowledge gap of even fundamental aspects like chains, slings, sling angle and hitches, hand-operated gearless pulling and lifting machines, and above all, the safety rules and procedures that are so crucial and indispensable for mechanical engineers engaged in regular dismantling, erection and maintenance of heavy steel plant equipment.

This major knowledge gap had obviously resulted from the fact that these topics were not covered in the curriculum of the mechanical engineering degree course. Hence, as frontline managers, we often faced very embarrassing situations on the shop floor where rigging jobs would pose a variety of challenging problems, but owing to a lack of knowledge one would have to stand like a dumb-bell and allow the rigging job to proceed in a manner as decided by the rigger and "chargeman" in the group who had acquired some rudimentary practical skills in rigging.

It was precisely due to the serious embarrassment created during such situations that the idea of writing a comprehensive book on rigging took root in my mind. Of course, I did realise this task was a Herculean one, especially when I was still at the foot of the hill and wet behind the ears. Nevertheless, I embarked on this challenging project when I was promoted *Safety Engineer* on December 30, 1975, and was approached by the National Safety Council, Bombay to conduct a solo 2-day training programme on *Safety in Material Handling in Thermal Power Projects* for the frontline executives of the National Thermal Power Corporation, Korba from 16-17 July 1981. This programme was conducted in the aftermath of a major accident in which the tall chimney of the power plant under construction had collapsed suddenly leading to several fatalities.

The subject was developed further when I was posted Assistant Manager (Training) in the Training and Development Center of SAIL/RSP in 1982, where I received encouragement from my direct reporting officer, Mr B. C. Pradhan, Superintendent (Training) who assigned me the task of developing a comprehensive training module on *Safety in Material*

Handling as one of the three modules of the multi-skill (rigging, fitting and welding) training initiative that was undertaken for the first time in the SAIL/RSP for enhancing the productivity of employees. My perseverance and quest for continuous self-improvement have paid off, though belatedly, and the seed of an idea that was sown in the early 1970s has reached fruition after serving the steel industry for over 36 years!

This book has been written keeping in mind the fundamentals of safe rigging principles and practices and the practical needs of the frontline executives and supervisors whose routine job involves handling of heavy loads. Starting from the fundamentals of estimating the mass and center of gravity of an object, this book covers important topics like the construction of wire ropes and slings, sling angle, sling hitches, the effect of curvature on stress, snatch blocks, bulldog grips, shackles, eye bolts, chain pulley blocks, lifting beams, spreader beams, hoist rings, and more. Two real-life case studies have been included and analysed in detail on the basis of *H.W. Heinrich's Domino Theory* to illustrate how the lack of knowledge and skill often results in property loss and fatal injuries. Four short real-life case studies have also been included for the sake of variety.

The first programme on *Safety in Material Handling* was designed and conducted by me as Superintendent (Safety) and the head of Safety Engineering Department in Visakhapatnam Steel Plant (VSP) in September 1990 for newly recruited "Khalasis": eight each of Wire Rod Mill, and Light and Medium Merchant Mill. There has been no looking back since then. The course content was continuously improved and enriched in technical content with real-life case studies and film shows. Encouraged by the excellent feedback from the employees, a 3-tier safety training programme titled *Safety in Material Handling* was subsequently started on a regular basis: every Wednesday for "chargemen"; every Thursday for technicians and every Friday for "Khalasis". Over 10,000 regular employees and 1000,000 contractors' workers were covered under these programmes during the period 1990 to 2007. This safety training module turned out to be a "star performer" and its spectacular impact on the accidents arising in the course of material handling/rigging may be appreciated from the fact that whereas there were 59 such accidents in 1990-91, it dropped sharply by 88% in 16 years and was hovering around only 7 by 2006-07 when I retired!

Of course, the most obvious question that arises is: When will such accidents reach the ideal zero target? Appreciating that there is no magic bullet to prevent all accidents overnight, the obvious answer lies in the continuous safety training and re-training of employees and ensuring good supervision on the site. But a more specific remedy lies in adopting safe

rigging principles and practices as a thrust area and establishing a comprehensive *Rigging Management System* as proposed in Chapter Twelve of this book. Such an approach will also help to enlist voluntary compliance of all the employees and the frontline managers with the safe rigging principles and practices at all levels of the organisation's pyramid.

Accidents do not happen. They are CAUSED!

It is nice to see people bubbling with enthusiasm and enjoying every breath of life. Unfortunately, life is short and accidents can make it shorter. And the shortest path to catastrophe and hell is undeniably through the deliberate violation of well-established and time-tested safety rules and procedures. We should never lose sight of the fact that all safety rules and procedures are written with fine nibs crafted from the bones of victims of accidents and dipped in the blood of workmen who died in earlier accidents. Hence, any deliberate violation of the established safety rules and procedures is tantamount to sheer *hara-kiri*. Fatal accidents also cast deep shadows on the bereaved family's happiness. All the laws of the land and all the prescribed safety rules and procedures of the organisation must, therefore, be adhered to and followed to the hilt with an unquestioning obedience. The only silver lining in a gloomy accident scenario is the age-old adage that proclaims: *"Accidents do not happen. They are caused!"* The focus of all accident prevention programmes must, therefore, be on eliminating the root causes of accidents that essentially lie in one's *"Ancestry and Social Environment"* as expounded by H.W. Heinrich in his world-famous *Domino Theory*.

The primary objective of this book is to serve as an aid to all the frontline managers in industries for taking effective countermeasures to liquidate the root causes of accidents arising in the course of rigging activities and reach the ideal zero accident target in the shortest possible time. This is, no doubt, a gargantuan task, but with determination and perseverance, all barriers can be overcome. Just remember that safety has no holidays! Hence, safety efforts too must be directed assiduously round the clock: 24/7.

I sincerely wish all my readers and the frontline managers in industries grand success in this noble endeavour.

FOREWORD

At the outset, I congratulate the author for his painstaking effort over time to write this useful book. It is more than just a technical publication on the subject as it is based on insights and lessons learnt by the author as a practitioner of the principles and practices recommended in the book. I welcome the book and the opportunity to contribute its *Foreword*.

Hopefully, readers would also join me in appreciating that the author is a committed safety professional who realised at an early stage of his career that the scientific and technical knowhow underlying the rigging practices was not imparted in engineering colleges. Consequently, the frontline managers responsible for supervising such operations lacked adequate competence and confidence. Faced with such a dilemma himself, the author committed himself to develop his knowhow through self-study and experience. The author not only kept this promise but carried forward his keen interest much further that has materialised in the form of this book.

I feel readers would appreciate if I share here a few observations based on my professional career of nearly five decades in different positions, including that of the Director General in the Directorate General Factory Advice Service and Labour Institutes (DGFASLI) and the National Safety Council (NSC) of India. Both are premier national organisations in the field of safety, health and welfare of employees covering various industrial sectors.

I was closely involved in studying and addressing safety issues inherent in material handling operations of all varieties as a part of my responsibility to enforce the Dock Workers (Safety, Health & Welfare) legislation in the major ports across the country during my postings at the individual ports and at the Headquarters in Mumbai in different positions including that as the Chief Inspector of Dock Safety. The basic approach comprised safety studies and designing and conducting specialised training courses in different industrial sectors such as the port sector, integrated iron and steel plants, shipbuilding and shipyards, and automobile and engineering factories throughout the country, and through contributions to the National Standards Setting process of the Bureau of Indian Standards as the Chairman/Member of its National Committee on the subject concerned. The following three observations are worth sharing here:

(i) Different safety and health statutes applicable to factories, ports and docks, and construction sectors recognise the hazardous nature of rigging operations and require that all lifting machinery and lifting tackles used in these operations must be proof load tested and

thoroughly examined at the prescribed stages by a "competent person" who is approved for this purpose by the relevant regulatory body based on the person's technical qualifications and experience. My observation is that a competent person usually does not carry out a thorough examination as it requires dismantling and careful visual examination of the key components of the appliance in order to arrive at a reasonable conclusion regarding its safe condition. On the contrary, even if the law requires only a thorough examination annually and no testing is required, the competent person skips the thorough examination and instead carries out a proof load test which could be injurious to the safe operation of the appliance.

What is more surprising is that the managers in the maintenance departments of the enterprise concerned, though technically qualified and responsible for proper maintenance of the appliance themselves, do not insist on the competent person to carry out a thorough examination jointly with them. There are, of course, good exceptions, particularly in those enterprises that have approved internal competent persons. In my view, there is a general belief among the competent persons and the maintenance departments that a proof load test is a good substitute for a thorough examination. It is a wrongly held belief. There are instances of failures of lifting machines within hours of a proof load test having been carried out. A thorough examination requires much greater time, technical expertise, skill and serious application of the mind and therefore yields a much more reliable conclusion. Furthermore, neither the competent persons devote enough time, effort and other resources to keep abreast with the latest technical standards, nor there is any proper institutional support system for this purpose in our country.

(ii) Each rigging operation constitutes an entirely different technical system consisting of a lifting machine, lifting tackles, loose gear, the load and its attachments, etc. Even if the individual parts of the technical system have been properly tested and maintained in a safe condition, the safety of the overall technical system can only be ensured by technically competent, experienced and committed supervisors and skilled workmen. They have to be supported by a ready reckoner of technical information such as safe working loads, weights of loads lifted, stress induced in the sling legs, etc. It is, therefore, necessary that the supervisory staff and the workmen are given regular training and re-training. I am glad that this book is targeting these key categories of employees and also provides a wealth of information which can be readily used by them on the shop floor.

(iii) Good technical systems for safety require the support of a good safety management system established as per the relevant national standard across the organisation. A special safety management sub-system targeting the rigging operations must be made a distinct part of the overall safety management system in the organisation.

Readers will find it interesting that the author has used an innovative way to highlight the safety management principle that good safety performance in any enterprise requires full commitment and support of the top management. He cites the example of the prestigious Panama Canal project of the US that was completed in 1914 after remaining suspended for two years and attributes its success to the meticulous planning and commitment of the top management to the safety, health and welfare of the workforce.

The ancient history of material handling referred to in the book is fascinating. While it invariably brings back to memory the awe-inspiring "Wonders" created through the use of primitive material handling techniques, one wonders whether anyone spares a thought to empathise with the labour force for the huge loss of lives, torture and suffering inflicted on them by brutal methods of work. It comes as a great relief when we think of the modern methods of material handling using powerful lifting machines and tackles and well-developed rigging practices based on scientific principles that not only minimise the need of heavy manual work but also help to achieve total safety by the application of modern safety management principles and practices.

A book like this should be welcomed by anyone concerned with safe and efficient handling of materials as it is particularly targeted to meet the day-to-day needs of the frontline and middle-level supervisory staff and the riggers, signalmen and crane operators. The book is anchored in the Indian work culture and industrial work environment coming as it does from an Indian author with distinguished and rich practical experience of over three and half decades in the subject area.

I wish the endeavour great success.

K.C. Gupta
Ex-Director General
Directorate General Factory Advice Service and Labour Institutes
Ministry of Labour, Government of India, and
Ex-Director General, National Safety Council, Mumbai, India

OBJECTIVES

The basic objective of this book is to enable all the frontline managers, supervisors and riggers acquire a good understanding of the science and art involved in the rigging activities and to develop in them the confidence to carry out any rigging activity safely. It will also help them in proper understanding and appreciation of the following aspects of rigging:

(i) The complexities and hazards involved in all rigging activities.

(ii) The role and responsibilities of a team leader, rigger, signalman and crane operator in carrying out any rigging activity with utmost safety.

(iii) How to determine the mass and C.G. of an object; how to ensure the stability of a load, and how to life any load on an even keel.

(iv) The constructional features of wire ropes; their properties and characteristics; effect of curvature on the stress in a wire rope or sling; inspection of slings; methods for proper storage of wire ropes, etc.

(v) The constructional features of different types of slings; types of hitches and their applications, and how to calculate the stress in the legs of slings at different sling angles and for different configurations.

(vi) The constructional features and applications of various types of rigging tackles like hooks, rope clamps, snatch blocks, shackles, eye bolts, hoist rings, turnbuckles, blocks and tackles, and special beams like lifting beams, spreader beams, and equalising beams.

(vii) The theoretical aspects of lifting machines like chain pulley blocks, power winches, gearless pulling and lifting machines, pulley blocks and tackles, screw jacks and the safety precautions to be taken when using these machines.

(viii) The safety rules applicable to team leaders, riggers, crane operators and signalmen, and the general safety rules to be adhered to when rigging any heavy load.

(ix) The statutory provisions in the Factories Act, 1948 and A.P. Factories Rules, 1950 pertaining to lifting machines.

(x) The importance of strict compliance with the prescribed safety rules and procedures that is emphasised through several true-life case studies involving fatalities, serious injuries and property loss.

(xi) Understanding the rigging principles and practices involved in rigging any heavy load so as to be able to draw out a proper “lift plan”.

(xii) The necessity of establishing a *Rigging Management System* in the organisation so as to enlist voluntary compliance with the safe rigging principles and practices by all the employees, frontline managers, and senior management personnel at all levels of the organisation’s pyramid structure.

DISCLAIMER

(i) Any rigging activity is potentially hazardous and complex, and the requirement of safety varies widely depending on a large number of factors like the size, weight and shape of the load; the design, capacity, condition and quality of the lifting equipment and tackles used, and the hazards posed by the surrounding environment. The rigging team must, therefore, possess the necessary knowledge and skills to identify the specific safety hazards associated with the rigging job in hand and take appropriate measures for executing the job safely. The responsibility for safe execution of the rigging job lies squarely with the rigging team, and the author shall in no way be liable for any accident arising out of and in the course of any rigging activity as no warranty is given by him.

(ii) The scientific rigging principles and safe rigging practices gave herein are based on the author's knowledge and practical experience, and may not be exhaustive enough to include all the unsafe conditions and practices that may be encountered on the site in various industries.

(iii) The manufacturer's recommendations in respect of its rigging tackles and equipment are generally considered as final and binding and must be adhered to strictly by all the users.

(iv) All the drawings and sketches given in this book are only for the purpose of illustration and may differ in shape, size and proportion from the actual products manufactured and made available for use on the site. The reference to any particular manufacturer's name or depiction of their products does not imply its endorsement by the author.

(v) All references to statutory provisions made herein are with respect to the Factories Act, 1948 and Andhra Pradesh Factories Rules, 1950 of India. Readers may refer to the relevant legislation in their own countries for due compliance.

(vi) This book does not dwell on the detailed metallurgical composition, manufacturing processes or the metallurgical properties of the various lifting equipment and tackles used for rigging. The relevant manufacturer's technical literature or the relevant national and international standards may be referred to for such information.

(vii) This book does not cover vacuum lifting devices, magnet lifting devices, marine and aerial applications and other related topics of rigging, since these are beyond the scope of this book.

ACKNOWLEDGEMENT

It is man's folly and pride that makes him exclaim: *"I've done it!"* The truth is that any successful venture is an outcome of the collective efforts and valuable contribution of several noble personalities—some visible and some invisible in the wings. This comprehensive book on *Safe Rigging Principles and Practices* is also the result of an assortment of collective efforts and good wishes of many distinguished personalities and eminent organisations.

Though many pages of this book were written in the late 1970s, when I was a young Safety Engineer in the SAIL/RSP, it could be completed and finalised only after a lapse of almost 36 years in 2012! Its publication, however, kept lingering due to several unexpected roadblocks. I wish to express my sincere gratitude to all the distinguished personalities and eminent organisations for assisting me in my endeavour and giving me permission to reproduce copyrighted technical information, data and images that have helped to enrich and add value to the contents of this book. All these documents have been acknowledged with details in the "References" given at the end of the chapter concerned.

My heartfelt thanks are due to Ms P.J. Achamma and Ms Leenamma Nair, both former Jr. Staff Officers, SAIL/RSP and to Ms K. Kameswaramma and Ms A.V.A.S. Lakshmi, both former Jr. Staff Officers, RINL/VSP for their untiring efforts in providing secretarial assistance for this book. I also appreciate the spontaneous cooperation of my college friend, Mr Kamal Kishore, who has since settled in the USA, for providing valuable links to the Silver Bridge collapse. I also value the help extended by my college friend from the University of Reading, UK, Mr Mehmet Elci, in facilitating certain copyright permissions from Germany. Both Mr PSN Murthy former Manager (Library), RINL/VSP and Mr H. Zoyeb, CEO of M. Raj & Co., Visakhapatnam, have also done me a great favour by providing me with very useful technical literature for reference.

I am also greatly indebted to my rationalist friend, philosopher and guide, Mr TPN Pillai, former Assistant Manager (Civil), SAIL/RSP who encouraged me to take up cartooning as a very creative and effective medium of constructive criticism. The few cartoons in this book are a result of his encouragement and inspiration.

I am also deeply obliged to Mr K.C. Gupta, former Director General of the Directorate General Factory Advice Service and Labour Institutes, Government of India, Mumbai, and the National Safety Council, Mumbai for kindly consenting to contribute the *Foreword* to this book.

I am also thankful to Dr Preeti Bhatt, Associate Professor of Humanities and Social Sciences, Malaviya National Institute of Technology, Jaipur, for proofreading the book and to my batchmate in the SAIL/RSP, Mr A.K. Shrivastava, for introducing me to Dr Preeti Bhatt. Very valuable technical advice and guidance has also been rendered by Prof. Bhanu Prakash, Department of Marine Engineering, Andhra University, Visakhapatnam, for which I thank him profusely.

I am also very grateful to my youngest son, Mr Ashish Saran, for flying all the way to the US and coordinating with the National Safety Council, Chicago for getting valuable technical literature and copyright permissions on my behalf.

Last but not the least, I am deeply indebted to Dr Kalpana Sharan, my sister-in-law, who translated the text of the fatal accident on Gyda Offshore Oilfield Platform from Norwegian into English, and to Dr Sudhir Saran, my elder brother, under whose umbrella I enjoyed my stay of 3½ years in the UK and pursued the MSc course (2010-11) in Renewable Energy at the University of Reading and happily passed with distinction. It was only then that I could complete my marathon project of writing this book in the salubrious environment and warm comfort of his home in Staines-upon-Thames.

Nevertheless, all said and done, it is my firm conviction that without the invisible blessings, guidance and approval of the *Absolute Reality*, such a challenging and complex task could have never been accomplished by an ordinary mortal like me.

Flashback of Victories


1


2

[1] Author (second from right) receiving the ***Steel Minister's Trophy*** from Mr S.R. Jain, Chairman, SAIL at Bhilai Steel Plant, awarded to the VSP for the first time in the very first year of its commissioning in 1990 for the best safety performance among all the integrated steel plants in India

[2] Author with the eight safety awards received by him on behalf of the VSP during his six-year tenure as the head of Safety Engineering Department (1989-1995)

3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[3] Author (right) with the VSP team receiving the First prize awarded by the Confederation of Indian Industry (S.R.) in Chennai on February 17, 2006, for the best technical presentation on SHE

[4] Author (left) receiving the ***Golden Peacock*** trophy from the Governor of Himachal Pradesh on June 11, 2006, in Palampur, awarded to the VSP for the first time by the Institute of Directors for the best environment management system established in India

5

6

[5] Author (second from right) receiving the ***Safety Innovation Award*** bagged by the VSP for the first time and awarded by the Institution of Engineers (India), New Delhi, on September 6, 2006

[6] Author (right) receiving the ***Outstanding National Citizen Award*** on January 4, 2007, from the National Citizens Guild, New Delhi, for his personal contributions in the fields of safety and environment

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[7] Author (right) receiving another safety prize on behalf of the VSP from Mr Arvind Pande, Chairman (SAIL) at Bhilai Steel Plant in September 1995

CHAPTER ONE
1.0 INTRODUCTION

1.1 Material handling: Yesterday

Primitive man had to depend entirely on his own muscular strength for hauling heavy loads. By and by, his creative instinct helped him in developing several manual skills which he used advantageously for hunting his prey and building his dwelling place. Prehistoric remains near Lake Rudolf in Kenya indicate that simple pebble-tools, usually flint stones deliberately flaked at their edges, were used by our early ancestors (Fig. 1-1) 2½ million years back for skinning and chopping the meat of animals. Hand axe, spears and several other hunting tools came much later.

The first man-made machine is believed to be the spear thrower—a short, notched baton in which the butt of the spear rested before being hurled at the prey (Fig. 1-2). It worked on the principle of the lever and increased the effective length of the throwing arm. Even today, spear-throwers are in use by the Aborigines of Australia. However, the wheel is considered to be man's greatest invention as it brought about magical transformations in his lifestyle and constantly improved his quality of life. Unfortunately, its origin is shrouded in mystery. The earliest historical evidence of a solid wooden wheel is on a Sumerian tablet dated 3250 B.C.

The Sumerians are considered to be the world's first civilisation which existed 5000 years ago between the rivers Tigris and Euphrates and known to the Greeks as Mesopotamia. The Egyptians came to use the potter's wheel only by 2500 B.C., but they never developed this into a wheeled cart until 1000 years later. In Europe the situation was reversed. The wheeled cart appeared around 3000 B.C. and wheel-made pottery came after 1000 B.C.

The first wheel with spokes appeared in eastern Iran around 2000 B.C. It was Leonardo da Vinci who designed the first flared wheel in A.D. 1500. Pneumatic tyres (Fig. 1-3) are a recent invention and came on the road in 1907. It was this same creative pursuit of man that also gave the world some of its most spectacular monuments 4500 years ago: the pyramids of Giza and the Great Sphinx—a legacy of the great Egyptian civilization having roots in the valley of the Nile.

The Sphinx (Fig. 1-4) is 240 ft long and 660 ft high and is carved from an outcrop of rocks without the aid of iron tools (copper and gold were discovered in Asia around 6000 B.C. and bronze by 3000 B.C.). The largest and the first Great Pyramid of Giza is 480 ft. high; covers 13 acres

of land and contains nearly 6 million tons of stone! The second, the Pyramid of Chephren also known as the Pyramid of Khafre, is the second largest of the ancient Egyptian Pyramids of Giza and the tomb of the fourth dynasty Pharaoh Khafre (Chephren) (Fig. 1-4). It contains huge limestone blocks weighing 15 tons each!

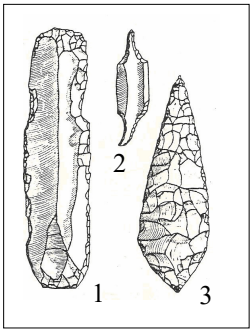


Fig. 1-1: Early hand tools made of flint [1, 2]

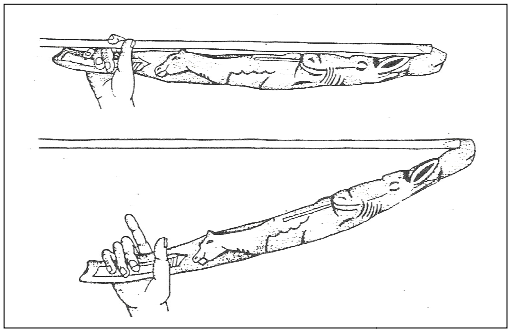
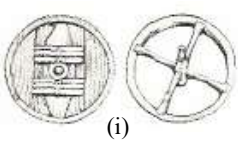


Fig. 1-2: Spear thrower [1, 2]

Legend [Fig. 1-1]: (1) Scraper used to clean off fat and ligament from animal skins (2) Double-ended awl made from flakes of flint and used to pierce holes in the skins for sewing (3) Fine leaf-shaped spearheads made from flint in southern France and Spain 20,000 years ago

HOW THE WHEEL BEGAN

Few inventions have been more important or have origins more obscure than the wheel. The first recorded wheel, made of solid wood, appears on a Sumerian tablet of about 3250 B.C. A thousand years passed before copper rims were added, and the first spoked wheel did not appear until around 2000 B.C. in eastern Iran.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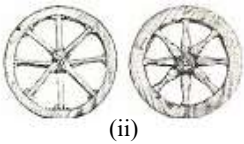
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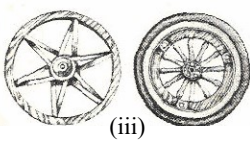
(iii)

(i) An early three-piece wheel (left) and an Egyptian spoked wheel of 1500 B.C. (ii) A Greek wheel of about 400 B.C. (left) and a Roman spoked wheel of A.D. 100 (iii) Leonardo da Vinci designed the flared wheel (left) in the 15th century; the pneumatic treaded tyre dates from 1907.

Fig. 1-3: How the wheel began [1, 2]