Journal of Manufacturing Engineering, September, 2013, Vol. 8, Issue. 3, pp 145-148

STUDIES ON PANCHA LOHA - AN INSIGHT INTO BHARADWAJA'S VYMANIKA ŚASTRA

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ABSTRACT

There are references to ancient aircraft materials and processing methods in ancient Indian scientific works like Samarangana Sutradhara and Bharadwaja's Vymanika Sastra. Vymanika Sastra (Science of Aeronautics) presents details regarding unique property specific advanced materials for an ancient aircraft in archaic Sanskrit. A few attempts have been made to decipher and follow details given in this treatise to repeat the experiments and recreate some of the property - specific materials. The purpose of this research is to repeat the making of one such material described in the text, reproduce those conditions and check whether there is validity of the claimed properties. An attempt was made to reproduce a copper based golden yellow, soft, light and strong alloy, 'Panchaloha' as mentioned in the scripture. The methodology adopted, analysis of the microstructures of the samples prepared and certain properties of Panchaloha obtained, are described in this paper.

Key words: *Vymanika Sastra, ancient material, Panchaloha, property-specific material and copper alloy*

1. Introduction

Vymanika Śastra, a part of the unknown work, 'Yantra Sarvasva'(encyclopedia of machines) authored by Maharshi Bharadwaja consists of nearly 6000 lines in lucid Sanskrit dealing with the construction of an aircraft in about 600 aphorisms embedded in 8 chapters. It gives a detailed description of an aircraft, seasonal food and clothing prescriptions for pilots, concepts and techniques provided on board in an aircraft, parts of an aircraft, core materials and alloys for structural purpose, property–specific materials, classification of aircraft and their construction, etc.

Bharadwaja's Vymanika Śastra enumerates the various metallurgical processes that include ore identification, selection and mineral extraction, purification and smelting to obtain materials with unique properties. For this purpose, various types of furnaces, crucibles and bellows were employed. There are about 36 unique and property – specific composite materials mentioned in Bharadwaja's Vymanika Śastra that are essential for the construction of machines in an aircraft. Thus a peep into Bharadwaja's Vymanika Śastra entrenches the fact of requirement of numerous materials for the construction of an aircraft.

2. Literature Review

The study of G. R. Josyer's published work "Vymanika Śastra"[1] and "Brihad Vimana Śastra"[2] edited by Swami Brahmamuni Parivrajaka Gurukul Kandgi of Haridwar – published by Dayanand Bhavan, New Delhi (19) led to the present investigation.

Ancient Indian aviation has been exhaustively studied by Prof. D K Kanjilal, whose work 'Vimana in Ancient India'[3] makes extensive references to Indian epics, Vedas in great detail and describes usage of vimanas in the prehistoric era.

The earliest research in the development of some of the specific property materials was undertaken by Naren Sheth [4] of Mumbai, who has successfully developed laboratory samples of 'Chumbakamani' 'Paragrandhika–Drava' and 'Panchadhara Loha' with able assistance from IIT Bombay, BARC and TIFR. Dr. Maheshwar Sharon's report throws light on the equivalence of these materials to those developed by modern Science during the later part of the 20th century.

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The content of this manuscript has been presented in 3rd International Conference on Recent Advances in Material Processing Technology (RAMPT'13)

In 1988, Dr. David Childress, an eminent scholar from USA, published the first edition of his book 'Vimana – Aircraft Of Ancient India and 'Atlantis',[5] in which he has reproduced completely 'Vymanika Śastra'(Josyer's English version).

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One of the milestones in the pursuit of Vymanika Śastra was the development of 'Tamogarbha Loha, Pancha Loha and Araara Loha' – presumably a copper alloy by the Centre for Studies in Ancient Indian Sciences of B M Birla Science Centre, Hyderabad[6].

The task force sponsored by INSA comprising of Dongre, P G College, ITBHU, Varanasi, P Ramachandra Rao, Director, NML, Jamshedpur, and others has developed 'Prakashastambhana Loha' [8] which is a silico–phosphate glass having selective transmittance to infrared light as described in Amshubodhini [9], an allied text of Bharadwaja's Vymanika Śastra dealing with the properties of Solar rays. A plane coated with this unique material supposedly cannot be detected using radar.

The unique feature in addressing knowledge of ancient Indian origin is in the methodology adopted, distinctly different from the approach of modern scientific approach. A close synthesis of Sanskrit scholars, bridge builders and modern scientists is a prerequisite in this pursuit as the coded and veiled expressions in Sanskrit verses need decoding and interpretations with reference to context. Once they are deciphered and the menu is composed, it becomes the task of the modern Scientist to carry out experiments in the laboratory and characterize the materials prepared. A few aspects in this regard need to be highlighted at this juncture.

1. During those times, coke/charcoal was used as a fuel. Also, since the furnace was in the open, the efficiency was low. As a result, the maximum temperature that could be achieved in the ancient times was around 1000- 1050oC in open fire burning. Hence, even to melt copper (M.P. 1089oC), forced fire burning had to be adopted.

2. Owing to limitation in the maximum temperature attained, ancient scientists probably could not completely melt the material. For example, in the making of the Delhi Iron Pillar, analysis indicates that once iron reached the molten semisolid state, it was piled and forged to weld together layers of the metal.

3. Dissolution of one component into another lowers the melting point of the mixture. For the same reason, melting procedures adopted probably were in the serial order of increasing melting points so that each higher melting component dissolved in the lower melting component.

4. There was neither accurate measuring equipments nor did they have units of measurement to indicate temperature levels attained. Most descriptions are qualitative. In Bharadwaja's Vymanika Śastra, the unit of temperature mentioned is 'kakshya'. However, the exact interpretation of 'kakshya' is not yet known but it appears to be a non – linear scale of temperature.

5. There is vast difference with regard to the choice of materials and the method employed by the Scientists of the ancient times and those today. In ancient times, scientists made use of naturally available materials and hence the impurities (trace elements) present in it remained. In the modern world, synthetic substitutes/equivalents that are devoid of trace elements are used. It has now been proved experimentally that the presence of trace elements has profound influence on the final properties of the material synthesized. Hence it can be concluded that the material obtained using synthetic equivalents and the material obtained using natural materials will be different and definitely show variation in properties.

The best approach to check the veracity of the claims made in the text is to reproduce at least some of the materials mentioned therein. One material from the text Panchaloha (leaded brass) has been selected and deciphered for this purpose and attempts made to reproduce the same.

3. Experimental Work

The deciphering of terminologies for the Pancha loha was done and an attempt was made to reproduce it whose composition is given in Table 1.

Table 1: Composition of Pancha Loha

Pancha Loha		
Sanskrit name	Modern chemical equivalent	Proportion
Arkam	Copper	12 parts
Aanjanikam	Lead Sulphide	3 parts
Kshwinkam	Zinc	8 parts
Temperature : 102 kakshyas*		

***Kakshya** – Non-linear scale of temperature (It varies between approx. 3.54^{o}C for high temperatures and 12^{o}C for low temperatures.)

3.1 Method adopted for Trial # 1, 2 and 3

It was assumed that coal fired pit furnace was employed in those times for melting purposes. Hence a coal fired blower type furnace was allowed to attain a temperature of 900°C and A1(~1 kg) SiC crucible was kept inside the furnace. First copper (99.99%, ASTM B-115:2000) was placed in the A1 crucible and allowed to melt completely. Then zinc was added in partial amounts to the molten copper while stirring continuously using graphite rod to obtain homogeneity. Once zinc melted in copper completely, PbS (99.5%) was added in small amounts and stirred continuously till all the charge [Table 2] added completely melted. The molten material is held at a temperature of about 1200°C for 5 minutes. The material was then cast into a metal mold and allowed to solidify.

Table 2: Raw materials added in Trials 1, 2 and 3

Pancha Loha	Trial # 1	Trial # 2	Trial # 3
Raw Materials	Proportion as mentioned in the text	Weight in grams	Weight in grams
Copper	12 parts	120	180.9
Lead Sulphide	3 parts	30	45
Zinc	8 parts	80	120.6

4. Results

Chemical composition was checked using EDAX (Quanta-2000 with EDAX-Genesis, SEIFEI, Netherland) and density measurements were made using Densitec (ORMA BC 1000, Italy) on the basis of Archimedes principle. Electrical conductivity was measured using 15x 6 x 1 mm^3 specimens using eddy current conductivity meter (AS 3000 DL, GE Inspection Technologies, England, 2005). All these properties are listed in Table 3.

Table 3: Properties of Pancha Loha

Trial #	Chemical Composition	Electrical Conductivity Sm^{-1}	Electrical Conductivity (IACS)	Density g /cm^3
1	Cu 82.31%; Zn 10.83%; Pb 6.34%; S 0.19%; K 0.33%	1.867 x 10^7	32.19%	8.35
2	Cu 82.45%; Zn 9.75%; Pb 7.24%; S 0.23%; K 0.34%	1.514 x 10^7	26.1%	8.41
3	Cu 83.56%; Zn 9.14%; Pb 6.93%; S 0.19%; K 0.18%	1.508 x 10^7	26%	8.38

The samples were prepared for metallographic examination in the standard way and the microstructure was examined using SEM (Quanta-2000 with EDAX-Genesis, SEIFEI, Netherland) as in Figures 1,2 and 3.

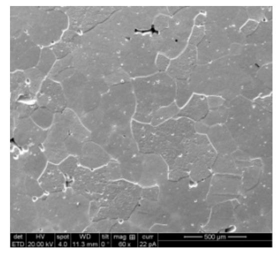

Fig. 1 SEM micrograph of *Panchaloha* obtained in Trial # 1

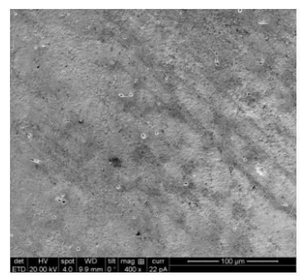

Fig.2 SEM micrograph of *Panchaloha* obtained in Trial # 2

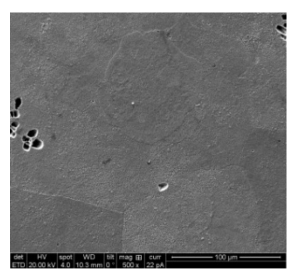

Fig. 3 SEM Micrograph of *Panchaloha* obtained in Trial # 3

5. Discussion

From figure 1, 2 and 3, alpha grains are seen as matrix and zinc is dissolved in copper. Lead being insoluble in copper remained as elemental lead. It is important to note that lead was a very common ingredient in many alloys made at that time. In the microstructure, lead phase could not be identified clearly. However, EDAX analysis indicates quite a high percentage of lead in the material obtained (6% - 8%) and hence is a leaded brass. Further analysis is required to find as to the form in which lead is present in the alloy.

Fine pores were observed in the micro structure due to evolution of sulfur gas (due to addition of Lead sulfide). There is an evidence of coarse grain structure in Trial # 1 and 3. The uniformly distributed pores will probably decrease the apparent density of the material. Also, as there is increase in the percentage of lead in the sample, density also slightly increases.

The lead content was 6.34 – 6.93 % and hence is expected to have good machinability. The electrical conductivity values were quite low and hence conformed to the term ‘cool’ metal as described in Bharadwaja’s Vymanika Sastra.

In those times, since study of microstructure was not possible, the material prepared was evaluated based on some of its mechanical properties. Attempts were made to synthesize light materials from the known natural materials (both organic and inorganic) available at that time. During those times presence of light metals like magnesium, aluminium etc. was not known. It is interesting to note at this juncture they tried to prepare property-specific materials like sound proof, heat resistant, corrosion resistant materials etc by making use of known available raw materials. Thus it will not be proper to evaluate the materials obtained then with the modern day light materials but their attempts must be appreciated keeping in mind the availability of known raw materials which were only a few and also lack of sophisticated technology for production as well as testing at that time.

The challenging aspects of this research are:

i. Decoding – all the terms cannot be decoded due to the non existence of the source books in the modern world.
ii. Non availability of some of the natural raw materials – Some raw materials mentioned in the original text is not presently available in today’s world.
iii. Methodology – The exact procedure to be used for melting. However by looking at the contemporary objects one can draw inferences regarding the methodology adopted.
iv. Even though materials can be synthesized using chemical equivalents, it may not exhibit the same properties as given in the text due to the lack of knowledge about trace elements.

6. Conclusion

This research is a step towards integration of ancient and modern science and technology. It is expected that the present experiments will lead to a greater clarification about the work reported in ancient literature. It will certainly lend some credibility to claims made in the Vedic literature. With this research, the material prepared has shown decrease in density (6% less than the theoretical) and is found to be highly corrosion resistant. Further experiments may yield a highly corrosion resistant porous material with much less density and thus may prove to be vital for aviation and allied industries.

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