IMPROVEMENT ON TRADITIONAL FOUNDRY TECHNOLOGY OF NEPALI ARTS AND CRAFTS FOR IMPLEMENTING IN ENGINEERING PRODUCTS

Submitted to:
University Grants Commission
Sano Thimi, Bhaktapur, Nepal

Submitted By:
Biraj Singh Thapa(Project Leader)
Tejesh Man Shakya(Activity Leader)
Subash Panta(Supporting Researcher)

MAY 2014

UNIVERSITY GRANTS COMMISSION	PROJECT FINAL DRAFT REPORT

A. DETAILS of PROJECT OWNER

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Role in Project:	Activity Leader	Role in Project:	Supporting Researcher

C. Project Title:	Improvement on traditional foundry technology of Nepali arts and crafts for implementing in engineering products
D. Project Objectives:	1. Outline the means and methods to preserve the tradition of Nepali foundry technology 2. Assessment of new possibilities of job based on foundry technology in institutional manner 3. Propose improvements in foundry technology not only for arts and crafts but also for engineering products including hydro turbines
E. Summary of Project Progresses	The project was initiated with the literature review on the ancient and current foundry practices in Nepalese society. The study was done to know the existing status of foundry technology in the markets of Nepal. As per the proposed plan, we had made visits to three different sites, Traditional Art/Craft Casting Industry, Sand Casting Industry, and Vacuum Casting Industry, all located in Lalitpur. The aim of visit was to know the technology, skill and the level of expertise used in each of these industries. In the next phase of work, an application of traditional technique for engineering purpose was identified. Francis turbine blades were fabricated out of a prototype made by use of Rapid Prototyping Machine at Kathmandu University with different casting techniques. Evaluation of the techniques in each of those industries was done to find the better of the processes between them. The assessment was done based on the blades model and the level of accuracy of the model casted in each of these foundry sites. The fineness among the products was evaluated to validate the product for further consideration. The full Francis runner was then casted using the lost wax technique. Another period of the project work was focused on workshop that brought together experts, entrepreneurs, academicians in the field. The aimed idea behind the workshop was to look into the possibility of applying the foundry technology in Nepal for engineering use. The workshop was most successful in identifying the prospects of the local casting industry for the engineering works. Partnerships of the concerned authorities to bring the local art and the engineering together could well revitalize the casting industry of Nepal and help for its sustainable growth.

F. COST PLAN SUMMARY (In approximate NRS)

Budget Headings	Total	UGC Funding	Institute Contribution
A. Experts Cost	145,000	72,500	72,500
B. Research Cost	127,500	127,500	0
TOTAL	**272500**	**200000**	72,500

G. Attestation by Head of Institution and Official Seal of the Institution

Seal	Signature
Name	**Associate Prof. Dr Hari Prasad Neopane**
Designation	Mechanical Engineering Department, Head
Date:	11 May 2014

Abstract

There is a long history of metal casting in Nepal, though existing traditional casting technology is not being practiced majorly in the field of engineering except in the field of arts and crafts. Nepali sculptors, craftsmen and metal casters have been daily practicing their own foundry technology in Patan as ancestral profession since ancient period till now. But those practices are only limited in the field of arts and crafts and there is abundant probabilities to divert their traditional technology of metal casting in engineering fields as well. The complete traditional and manual process of Nepali foundry technology is being out of favor for young generation of Nepali craftsmen and metal caster. That's why the craftsmen and metal caster prefer to work in advanced foundries of China. The possibilities of new job in Nepal can also prevent Nepali craftsmen and metal casters to migrate in Chinese Foundries. Hence, the project has been worked out on traditional foundry technology of Nepal for improvement and also implement in the engineering products.

This project started with the literature survey on the ancient techniques prevalent in the casting market of Nepal. Site visits to different casting industries in Kathmandu valley was helpful to collect information of exact status of use of technology and problems being faced. Further, methods to apply improved technology for engineering products was devised and demonstrated by model casting of Francis turbine blades. Francis runner blades were fabricated using the local casting techniques. The results helped identify the level of precision that could be obtained from traditional foundry practice that is necessary when fabricating engineering goods. Further, means and methods to make the traditional casting technology more sustainable and diverse were developed with expert consultation and detail explorations by meeting and workshops.

The aim of the project was to start a new thread of research based industrial applications of ancient technology developed in Nepal for metal casting.

Acknowledgement

We extend our sincere appreciation to University Grants Commission for funding this Faculty research project. We would like to express deepest gratitude for their invaluable guidance and suggestions during the period of the project.

We are also indebted to Prof Dr. Bhola Thapa, Registrar and Dean School of Engineering, Prof Dr. Bim Prasad Shrestha, Former HoD and Associate Dean (Research), School of Engineering and Associate Prof. Dr. Hari Prasad Neopane, HoD, Department of Mechanical Engineering, Kathmandu University, Dr. Tara Nath Mainali, Director, Dhalout Karyashala, Mr. Tej Ratna Shakya, Senior Metal Sculptor, Ethnic Works Art and Design, Mr. Durgananda Shakya, Metal Artisan, Durga Handicraft for their encouragement and valuable suggestions during the research work.

We are immensely thankful to Turbine Testing Lab, Kathmandu University for their help during the proceedings of this project. This research would have been incomplete without the assistance of Sailesh Chitrakar, Ravi Koirala, Niroj Maharjan and other researchers at TTL.

Also, we would like to thank all the staffs, friends and workers of University Grants Commission, Kathmandu University and Turbine Testing Lab.

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CHAPTER 1: INTRODUCTION

Rationale

Foundry Technology or Metal Casting Technology is one of the ancient but advanced processes in the field of world art and engineering. From ancient Egypt to post- modern world, Lost Wax Technique and Sand Casting Technique have been most preferable process in Metal Casting for creating arts and designing engineering appliances. As per found evidences in Nepal, since 6th century A.D. Lost Wax Technique is being used in Metal Casting for miniature and monumental sculptures till now. This represents the superior example of art and engineering in Nepal. Since Rana period of Nepal, Metal Casting Process had been started to apply in architecture as interior and exterior design as well as in weaponry and pure engineering design like power house, water pipe-line, bridge construction, rod manufacturing and other engineering appliances.

There is a long history of metal casting in Nepal, though existing traditional casting technology is not being practiced majorly in the field of engineering except in the field of arts and crafts. Nepali sculptors, craftsmen and metal casters have been daily practicing their own foundry technology in Patan as ancestral profession since ancient period till now. But those practices are only limited in the field of arts and crafts and there is abundant probabilities to divert their traditional technology of metal casting in engineering fields as well. The complete traditional and manual process of Nepali foundry technology is being out of favor for young generation of Nepali craftsmen and metal caster. That's why the craftsmen and metal caster prefer to work in advanced foundries of China. The possibilities of new job in Nepal can also prevent Nepali craftsmen and metal casters to migrate in Chinese Foundries. Hence, the research proposal has been worked out on traditional foundry technology of Nepal for improvement and also implement in the engineering products.

Research Questions and Status of Answers

- What are the current foundry practices in Nepal? What is the degree of accuracy of these methods?

✓ *Answer to this research question has been found by market survey*

- What improvements can be made to the existing methods so as to have better accuracy considering the cost factor as well?

✓ *Answer to this question has been found by filed visits, experts' suggestions, consultation with entrepreneurs in the field and workshop.*

- How does the quality of product vary between those manufactured from the traditional method and the improved method?

✓ *Solution was found by comparing the fabricated products with the traditional sand casting technique and the recent vacuum casting method.*

Literature Review and Theoretical aspect

The most commonly used metal casting method is the *cireperdue*, also known as the lost wax process. In this process, the artist creates desired image in wax with the help of simple tools. The wax model then coated with special clay mixture and dried in the sun. The process is repeated several times for 3 to 4 weeks until the mould is thick and hardened. It is then heated and the melted metal is poured into the opening of the mould. The metal piece passes through skilled hands, hammers and chisels before it is ready for market. (SaphalyaAmatya, Art and Culture of Nepal – An Attempt towards Preservation, p.69)

The Nepalese metallurgy and metal art may be even more than two thousand years old. Museums and personal collection in Europe and America have preserved bronze, copper, gold images of the finest order, which were produced in Nepal more than 1500 hundred years ago. In the Kirat period, which proceeds the Lichchhavi period, excellent art and crafts in stone, wood, clay, etc. might have developed. Unfortunately, we do not have any visible record of this art of the period. (C.L. Gajurel& K.K. Vaidya, Traditional Arts and Crafts of Nepal, p.2)

The process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify, is known as casting. With the discovery of various metals, like iron, copper, people started making use of those materials to produce instruments, weapons, ornaments, etc. The history to which this art was started is still a mystery. According to "Mohenjoddo and Harrapa", there was a discovery of a women statue, made of bronze, which is believed to have been made in some 3000 B.C old Sindhu Ghati traditions. Preserved in a national museum at New Delhi, India, this statue is supposed to have used lost wax method of casting, as stated by Angel Michel.

Metal

Scientists have basically divided matter as physical and chemical. Physically, matter remains as solid, liquid and gas whereas chemically, it is pure or impure. Impure substances can be heated to obtain pure substances. E.g. salt water from ocean can be heated to extract salt.

Pure substances are classified as elements and compounds. A mixture of two or more elements is referred to as compounds. Element is differentiated into three categories: metal, non metals and metalloid.

Till date, 90 elements have been discovered. Besides, dozens have been invented in labs. Mendeleev, a Russian Scientist, in 1969, generated a periodic table considering elements properties and atomic weight. Only 62 elements were known at the time. The latest periodic table developed by scientists has 112 elements in them. The table is placed in order based on elements properties and atomic number. Elements have been a designated by a symbol. E.g. Na for sodium, Ca for calcium, and so on. Of the 112 discovered elements, 70 are metals whereas rests are non metals and metalloids. E.g. of Metals are lithium, beryllium, magnesium, zinc, copper.

Metals and Non Metals

All metals, except mercury, remain solid at room temperature whereas all non metals remain as solid, liquid and gas. Metals are glossy and have high density. Most of the non metals, except Iodine and Graphite are, non shiny and also they have low density. Metals are conductor of heat and electricity whereas none metals vice versa. Metals have a high melting and boiling point than non metals. Metals in contact with oxygen can rust whereas non metals do not. E.g. of Non metals is helium, oxygen, etc.

Metalloid

Metalloids have properties both of metals and non metals. E. g. of Metalloids is Beryllium, Germanium and Arsenic. Arsenic and antimony are non malleable and non ductile but are good conductor of electricity.

Alloy metal

Alloy Metal is a mixture of two or more metals, non metals and metalloids. For e.g. brass is made of copper and zinc whereas bronze is a mixture of copper and tin. Alloy metal mixed with iron results ferrous alloy whereas non ferrous alloy is without iron. For e.g., steel is made of 98% iron and 2 % carbon, similarly, stainless steel is made of Iron, carbon and chromium. The use of alloy metal is made to cope with hardness, high melting point of metals. The combination of red copper and white zinc results in brass which is much harder and shiny than copper. The melting temperatures of glass and zinc are 372^{o} and 232^{o} Celsius respectively. But the mixture made of these two components has a melting temperature of 180^{o} Celsius.

Metal Ores in Nepal

Metals are mainly extracted from their ores where they are in impure state. The refining process of impure metals to pure ones is referred to as metallurgy. Till date, 80 metal ores have been discovered in Nepal but the growth from these metals has only limited to cement industries. History tells that Ratna Malla made first use of copper currency by extracting copper from Makwanpur. In Nepal, Iron ores have been found in Phulchowki, Ramechhap, Janakpur, Tanahu, Gandaki and Copper ores in Solukhumbu, Everest region, Makwanpur, Dhading and Udayapur. Similarly, traces of gold ore in Swoyambhu, bismuth ore in Bhimphedi, glass ore in Ganesh himal, Rasuwa and zinc ore in Gulmi, Lumbini region have been discovered. Likewise, magnesium, calcium and talcum ores have also been found.

Types of casting

Casting in Nepali Language is known as “Thanjya”. The craftsman who casts is called “Thakami”. There are different types of casting performed by the craftsmen. Lost wax casting in Nepali Language is named “Si Lhoka Yayegu Thanjya”. One of the different casting processes is sand casting. This process is extensively used in making utensils, fabricating machine parts and creating metal sculptures. A sand mold is prepared from the prototype fabricated by the carvings on wood or any other possible fabricating hard materials.

Another process of casting is Die casting which is mostly used for fabricating machine parts. This process can produce desired shape of die and the metal can be poured in the die to gain needed shape. After settling, the die is taken out and the metal takes the shape of the die.

Lost wax casting

This is considered to be the oldest casting processes in Nepal. Hollow, elliptical and irregular bodies can be casted with this process, which was developed in the 6th century A.D. in Nepal. Besides Kathmandu, this process is famous in Palpa, Tansen, Chainpur for making utensils and statues. Because of its originality and unique style of casting developed by Nepalese, it can be considered an indigenous technology of Nepal. Lalitpur has a long history of producing magnificent sculpture from this process. Most of the locals in this region are involved in this sector. In this process, first of all desired wax model is prepared. Then wax model is covered by a kind of ceramic clay (high temperature resist clay) with the mixture of cow-dung and paddy-husk, which is called mould. Then the mould is heated until the wax is drained out and the moisture is removed out. The molten metal is then poured into the cavity left by the wax. Then the mould is gently broken up thus desired metal object to view. The basic explanation of this process that traditionally applying in Nepal is carried out as following:

a. Wax model

Firstly, honey is extracted from bees' hive and the hive is heated to make raw bee wax, which is molt with mixture of resin (to maintain its strength in normal room temperature as per season) and ghee (to make malleable) for preparing workable wax. After cooling and preparation of the workable wax, that is heated until getting malleable and makes desired shape and form by the aid of several hand tools. The resulting shape and form is known as wax model. After preparation of wax model that needs sprues and vents as channel for de-waxing and pouring molten metal passing through all empty cavity.

b. Casting mould

Wax model, after added sprue and vent system is covered by two kinds of ceramic clay, which resist high temperature around 700°C, called Casting Mould. First and second layers are coated by dipping wax model into the slurry prepared by Masin-Cha (a greenish-gray coloured fine, soft and smooth clay that can get after digging the earth around 12 ft deep) with soaked in required water and mixture of 50% cow-dung. Then after, wet slurry of mould should place to dry by using natural air cooling system or any other air cooling system to apply third and fourth layers of mould that is covered by Mhas-Cha (a yellow coloured clay, also used by local Ceramist at Bhaktapur and Thimi, which can get after digging the earth around 6 ft deep) with required water and mixture of 25% paddy-husk and place to dry by

natural sun heating system or any other heating system to make stronger the mould. If necessary or the wax model is about large size, the mould should be reinforced by iron wire.

c. De-waxing

The prepared casting mould is burned by Propane Gas or Kerosene Torch-Fire around 50°C-60°C until the wax is not removed out from the mould or directly burned out the wax inside the Kiln. If not directly burned out the wax inside the Kiln, less than 50 % of wax is retrieved by this process, rest tends to disappear because the wax is lost in this procedure, and the process is termed as lost wax casting.

d. Metal Casting

The casting mold is then placed into the home made updraft Kiln by using traditional material such as terracotta brick cemented by mould making yellow ceramic clay and plastered by mixture of yellow ceramic clay and paddy-husk as heat insulator. It is then baked to around 600°C - 700°C temperature by using fire-wood around 3 hours to 8 hours (depends on the size of the mould). Meanwhile, desired scrap metal (copper 1084°C or brass 930°C or bronze 913°C or silver 961°C or gold 1063°C) is melted into the crucible made out of graphite based ceramic clay in the home made furnace by using iron drum insulated inside by refractory fire brick with use of hard coal vacuum air pressured by electric blower. Nowadays, instead of hard coal kerosene, diesel and also rarely electric mediums are used to melt metals. After melting, the metal is poured into the empty cavity of baked casting mould. It is then allowed to cool after which the shell of mould is broke open and desired metal object is made out. Then the unnecessary sprues and vents are cut out by manual hack-saw or electric cutting tool. The casted metal object is chased by various files and sand papers and if necessary or found any casting defects like shrinkage, bubbles, small and big holes are refilled by Gas Welding (Calcium Carbide and Oxygen). Also the metal object is engraved with desired designs by various chisels as finishing elements.

The aesthetic value of Nepali foundry based metal sculptures has made it popular all over the world. Most of Buddhist and Hindu metal sculptures are exported to USA, UK, Germany, France, Canada, Taiwan, China, Tibet, Spain, India, etc. Because of its possible market and reputation as a family profession of Shakya, Federation of Handicrafts Association of Nepal and Department of Small and Cottage Industry of Nepal Government have been making

various efforts to train and transfer these technical skills and craftsmanship to other populations. This sector has great ability to generate employment opportunities as well as foreign currency, thus this form of Nepali art and craft requires a long lasting vision of all those concerned to bear fruitful results in the years to come. (Shakya M.R, Nepalma Hastakalako Dhalan Garne Prawidhi- Sankhipta Chinari, p. 5-7)

Casting practices in Nepal

The tradition of casting in Nepal dates back to Lichchavvi period (300-800 C.E). The custom is still being practiced especially among the Shakya families for creating various sculptures, utensils making. But now-a-days besides Shakya families, other Newari communities as well as other migrated communities from out of valley have also being practiced this local foundry technology for Nepali arts and crafts. The expertise of Newari metal sculptors and craftsmen in the field to create these masterpieces is very much remarkable. However the techniques have not been updated parallel to the latest advancements.

The practice of the casting among the Newari population sticks to the present day. Certain elements of the technique have been lost, notably the extraordinarily fine and delicate stone settings, and the production of the present cannot be compared in skill with the great metal sculptures of the pre-medieval and medieval periods. (Refojo, 2006) But the art and craft of producing exquisite metal icons still remains among the Shakyas of Patan who to this day continue to provide fine metal work to visiting foreign tourists and to the Buddhists of the world.

The first recorded evidence of copper and bronze objects being produced in Nepal can be traced back to the early Lichchhavi period (A.D. 500-800). Casted pieces such as statues were found at Chandeshwori temple in Banepa and at Sankhu. These objects appear to date back to A.D. 6th century. Likewise, records from the Chinese traveler, Yuan Chuang, who passed through Nepal during the seventh century, described his appreciation and admiration of Nepalese metal craftsmanship. So impressed were the Chinese in the artistry of Nepal's metal industry, the Chinese emperor Kublai Khan invited one of Nepal's famous artists,"Araniko", to help renovate Chinese metal structures in the year A.D. 1274. Evidence of Araniko's work can still be seen in the form of Boddhisattva, Lokeswara, Tara and the renowned white Nepalese pagoda that still remain standing in China. (Friedman, 2000)

Metal statuary represents the highest form of Nepalese arts. The growth of the metal industry has mostly been marked in the medieval period. Yet the tradition has been long carried by the Newar communities residing in Nepal. The Newar craftsmanship to manipulate metals and produce exquisite sculptures has a major hand in giving Nepal its well known reputation in the field of arts and crafts. The sculptured portraits of its nobles, the life-size statues of its kings, the dignified bas-reliefs of its saints, and the noble conceptions of its gods, executed in hammered brass or cast copper shows their profound knowledge of artistic principles in the sector.

The contribution of the Newar metal sculptors of the Kathmandu valley to the Himalayan art traditions has been long-lasting and profound. (Alsop, 2005). Some elements in their working style set their designs apart from the rest of the worlds. They obtain their result by the combination of two distinct technical processes. The smaller work is cast in the well known cire-perdue manner, literally, the “lost wax” and technically the “waste mould” method of casting. Parts of their larger conceptions, such as the head and hands, are also executed in the same way, but the body and lower portions of seated figures are constructed by being beaten up into the desired form with the hammer. The use of pure copper metal, and post card finishing work in which the copper is almost glided by the use of mercury, and so on are few aspects that are practiced only among the Newari casting communities. Also the distinction of their design with the rest of the world is also characterized by the use of technique named, repousse, in which they manipulate sheet copper, which requires strenuous hammering followed by delicate engraving. Their ability to execute these processes gives an indication of their master mind and touch of their master hand. Newar craftsmen capacity to visualize the design and then execute processes of riveting, embossing and melting to finally give it a desired shape is a sign of their knowledge in doing of their work which is unparallel to anyone.

CHAPTER 2: METHODOLOGY

The study consisted of historical research and developmental research on related topic. Therefore, it has been designed as per both historical and developmental approach.

This project was commenced from photo documentation, interviewing with concerned experts, reading books, observation of products and concluded with final printed report and public presentation. Details of Research methods to be followed as follows:

Table 1. Details of Research Methods

S.N	R&D stage	Goal	Activities	Remarks
1	Development of theoretical foundation	Detail study of various foundry techniques (including traditional and modern)	Literature survey	Activity Completed
		Identify foundry practices followed in Nepal	Visit to various foundry industries	Activity Completed
2	Propose an improved method for foundry	Improved method compromising cost and precision in manufacturing	List detail steps for requirements for industry set up along with the procedures to perform foundry	Completed
3	Scope of Implementation	Feedback and Improvement	Workshops to spread the findings from the research	Completed
			Collect comments from experts and people involved directly and indirectly with foundry	Completed

			As per the suggestions make necessary changes	Completed
4	Product Fabrication	Casting of a Francis Turbine runner	Cast one item with high precision	Completed

Table 2. Detailed Work Schedule and Activity Plan (Revised)

S.N.	Stage	Activities	Detail activity plan	Deadline / Date	Responsible
1	Project Coordination	Task appointment	Completed (April 2013)	Achieved	Biraj S. Thapa
		Establish project communication strategy	Completed (April 2013)	Achieved	Biraj S. Thapa
		Establish Project infrastructure	Completed (April 2013)	Achieved	Biraj S. Thapa
		Start research activity	**First milestone (31 April 2013)**	**Reached**	**Project Team**
2	Development of theoretical foundation	Literature survey of various books	Completed (June 2013)	Achieved	Tejesh M. Shakya
		Visit to various foundry industries	Completed (June 2013)	Achieved	
			1. Home based Casting Facility for traditional crafts in Nepal	Achieved	Tejesh M. Shakya Biraj Singh Thapa
			2. Vacuum type of specialized lost wax casting	Achieved	Tejesh M. Shakya

			method in Nepal for traditional crafts in Nepal		Biraj Singh Thapa
			3. Dhalout Karyashala	Achieved	Tejesh M. Shakya Biraj Singh Thapa
			4. Casting facility locally available around Kathmandu University	Achieved	Subash Panta Biraj S. Thapa
		Submit Project Inception Report to UGC	**Second Mile Stone(5 July 2013)**	Reached	**Project Team**
3	Identification of improved method for Traditional foundry	List detail steps for requirements for industry set up along with the procedures to perform foundry	Completed (April 2014)	Achieved	Tejesh M. Shakya
			Completed (April 2014)	Achieved	Subash Panta
4	Product Fabrication	Cast one unit of Francis turbine designed by Kathmandu University	Completed(January 2014)	Achieved	Biraj S. Thapa
				Achieved	Tejesh M. Shakya

5	Discussion and Sharing	Workshops to spread the findings from the research	**Participants in Workshop**	Achieved	Tejesh M. Shakya Biraj S. Thapa Subash Panta
			1. Arts & Crafts organizations: 5		
			2. Casting Manufacturers: 10		
			3. Academicians: 5		
			4. Potential Entrepreneurs: 3		
			5. Government officials: 3		
		Collect comments from experts and people involved directly and indirectly with foundry	Develop Draft report of findings(May 2014)	Achieved	Subash Panta
			Circulate to the concerned ones(May 2014)	Achieved	Tejesh M. Shakya
		As per the suggestions make necessary changes	Follow-up feedback and corrections(May 2014)	Achieved	Subash Panta
		Submit Draft Report to UGC	**Third Mile Stone(12 May 2014)**	**Reached**	**Project Team**

6	Completion of Project	Draft and Review of final report	Comments from UGC experts after progress and or final presentation	**To be planned**	**Project Team**
		Submit Final Report to UGC	**Fourth Mile Stone**	**To be planned**	**Project Team**

Table 3. Budget Revised Project Budget in NRS

SN	Budget Heading	Unit	# of Units in Year	Unit Rate	Total	UGC Funding	Contribution	% of Contribution	Payment after 15 % Tax from UGC
A	**Expert Services Costs**								
A.1	Project Leader (B.S. Thapa)	Per Day	30	2,000	60,000	**30,000**	30,000	50	**25500**
A.2	Activity Leader (T. M. Shakya)	Per Day	40	1,500	60,000	**30,000**	30,000	50	**25500**
A.4	Supporting Researcher (S. Panta)	Per Day	50	500	25,000	**12,500**	12,500	50	**10625**
A	**Subtotal Expert Services Costs**				145,000	72,500	72,500	**50**	**61,625**
B	**Direct Research Cost**								
B.1	Secondary data Collection	Total			5,000	**5,000**			**4250**
B.2	Field visits and Primary observation	Total			20,000	**20,000**			**17000**
B.3	Workshop for details explorations	Total			20,000	**20,000**			**17000**
B.4	Additional Equipment for casting an Engineering products	Total			45,000	**45,000**			**38250**

B.5	Casting of Engineering Products	Total			30,000	**30,000**			**25500**
B.6	Miscellaneous Costs	Total			7,500	**7,500**			**6375**
B	**Direct Research Cost**				127,500	127,500			**1,08,375**
	Total Project Budget				**2,72,500**	**2,00,000**	**72500**	**27**	**1,70,000**

CHAPTER 3: ANALYSIS AND INTERPRETATION

Application of Foundry Technology in fabrication of engineering products

The main aim of this research was to identify and improve the traditional local foundry technique for engineering product fabrication. And it was most successful in its intention to identify the use of traditional foundry technique in engineering market. As an engineering application, Francis blades were casted using two different casting techniques.

One of them was the **sand casting** process. This is one of the most simple, common and inexpensive of all the casting processes. In this process, a sand mold is prepared from the prototype fabricated by the carvings on wood or any other possible fabricating hard materials. In our case, the pattern used is a blade prototype fabricated by the use of Rapid prototyping machine at KU. Molten metal (Mild-Steel) is poured as per the pattern. The metal is then allowed to cool, finally after which we get the desired casted product. Because of its simplicity and quick processing time, this method is relatively cheap. Almost any time of metal can be casted with this process. However, it is difficult to obtain fine surface finish using this process. Also, the process in most cases, gives rise to problem of blow holes and shrinkage as also seen in our fabricated product.

The other of the techniques used is the **Vacuum Casting** Technique, the advanced technology of Lost Wax Casting Process. Relatively new, this technique has only been used to cast small sized products, such as jewelry and miniature sculpture, in Nepal. Vacuum molding (V-process) is a variation of the sand casting process for most ferrous and non-ferrous metals, in which gypsum based powder is held in the flask with a vacuum. In vacuum casting process, first a rubber mold is made out of the pattern. Then a wax model is made, which is further used to cast the metal product. The process requires multiple making of different molds, thus proving a very expensive method. But the advantage to using this process is its mold, which can be reused to replicate the product several times. However, the disadvantage to this method is time consumption. The process requires several hours to cast a single product whereas sand casting can do the same task within a very short time. Nevertheless, the surface finish obtained is very smooth, thus eliminating costs for further finishing processes.

After casting from both the techniques, we have been able to identify each process's merits and demerits. Sand casting is relatively inexpensive, simple but produces products with low

quality surface finish whereas vacuum casting is time consuming, much expensive but produces fine surface finish. Sand casting method requires post fabrication finishing processes to obtain the required surface quality. Vacuum casting should be used to hold products to extremely close tolerance and produce best quality surface finish. When fabricating engineering products, efficiency is a major concern. So, during engineering product formation, costs have to be compromised sometimes to produce highly efficient products.

Table: Costs of Casted Blades from different techniques.

BLADE	Quantity	Price(in Rs)	Price (in Rs.)
Sand casting process	2	283	565
Vacuum Casting Process	1	6000	6000
Total			6565

With time and cost taken into consideration, a full Francis runner was casted using the lost wax casting method.

Casting of the full FRANCIS RUNNER

Available Vacuum Casting Equipments in Nepal can produce tiny and miniature products like jewelry and tiny sculpture or tiny engineering products. Therefore, the researching team became obligatory to choose another options of casting technology to fabricate a full model of the Francis runner as an Engineering Product, which has been cast applying Italian Lost Wax Casting Process at the Foundry of Ethnic Works Art and Design in Patan in different stages as follows:.

a. Prototype Development:

First of all, the pattern for the runner is developed using the Rapid Prototyping Machine at Turbine testing Lab, Kathmandu University.

b. Reproduction Mould and Wax Casting:

Then Silicone Rubber Mould is prepared for casting wax pattern of Francis Runner. After casting of wax pattern, it has added required srpues and vents as channels for molten metal during metal casting passing through.

c. Metal Casting Mould:

Then, wax pattern is surrounded by temporary casing made out from GI-Sheet and sealed the casing tightly by wax slip to not to leak the liquid moulding material during pour into the casing. After then, prepared gypsum based moulding powder that includes 50% of gypsum and 50% of refractory grog is put on to the water and prepared the slurry, which later pour on to the wax pattern of Francis Runner inside the casing. After 15 minutes slurry is set as solid and removes the casing.

d. De-waxing and Metal Casting:

Then casting mould is ready to bake into the improved fuel saving kiln (made out of fire proof blanket and stoneware body) with the multi-fuel firing system. Within half an hour the wax pattern inside the mould is burned out and continuously baked the mould around 8 hours to 12 hours to eliminate all moistures of the mould at the temperature around 600°C - 700°C. In meanwhile, Brass (alloy composition of 60% copper & 40% zinc) scrap is melted in the crucible made out of graphite based ceramic body inside improved fuel saving furnace (made out of fire proof blanket and stoneware body) with multi-fuel firing system at the temperature of 930°C. Here, multi-fuel firing system is locally developed in 2006 A.D. by Foundry Based Metal Sculptor Tejesh Man Shakya, in which propane gas or kerosene or diesel or hard-coal could be used for firing metal melting furnace and propane gas or fire wood or fire briquette could be used for firing mould baking kiln. After 2 hours the brass is molt as liquid metal and then baked mould is taken out from the kiln to put into the iron bucket with reinforcement of sand to not to leak from gypsum based mould of Francis Runner while pouring molten brass. After then, the hot crucible with molten brass is taken out from the furnace with the help of ladle and poured into the gate of the mould passing through runner to whole empty cavity of desired shape and lift up from the riser of the mould. Then, the mould is sunk into the bucket with cold water to make cool the molten brass for solidifying. In half an hour, the mold is broke open and desired brass form of Francis Runner has seen. Then unnecessary parts like

sprues and vents attached with Runner are cut out by using cutting wheel through electric grinder.

e. Chasing and finishing:

The result of casting by applying Italian lost wax casting process, an improved foundry technology, is satisfactory but forecasted defects of metal casting is seem such as minor problem of shrinkage, which later filled up by gas welding and made plain by grinding and machining in lathe.

In this way, a full Francis Runner has been prepared as an engineering product with the improved Foundry Technology using in Metal art and craft products and tested for generating 2kw electricity at Turbine Testing Lab, Kathmandu University. This also proves that if potential Hydropower Entrepreneurs of Nepal dared to invest to establish Metal Casting Foundry in Nepal with facility of contemporary Foundry Technologies or locally improved Foundry Technologies can make possible to cast required Hydropower turbine in Nepal by Nepali Engineers and Nepali metal craftsmen further step of developing Hydropower sector of Nepal for generating sufficient electricity in Nepal.

Industrial Requirements for Performing Foundry and identification of improved method

Time to time, Nepali Traditional Foundry Technology has been improved as required by Nepali metal sculptors and craftsmen by themselves or by the technical help of mechanical engineers. It could be sufficient improvement for the products of arts and crafts in Nepal since they have still large market and having competition very hardly international market. But also numerous Nepali metal craftsmen are migrating slowly but surely to China to work in Chinese Foundry due to the insufficient earnings from metal arts and crafts in Nepal, which causes for lacking the high qualified skilled craftsmen (majorly from Shakya and other Newari Communities) in Nepali Foundry and only middle and low qualified skilled craftsmen are continuing working in Nepali Foundry. Even, the improvements on traditional technology are insufficient for having competition with international standard and maintain the quality required to engineering products in Nepal. There could be raised some questions and answers regarding local foundry technology for implementing in engineering products as following:

a. Why not properly implement the local Foundry Technology in Engineering Product in Nepal ……?

- The terminology “Engineering” is only introduced in Nepal after establishment of Tribhuvan University. Before that there isn’t use any proper word in Nepali equivalent to engineering in Nepal.
- Engineering is discriminated from own ancient Nepali craft technology.
- Own ancient Nepali craft technology is being very less practiced in engineering products Inaccessible of ultra-modern foundry technologies.
- Engineering consists to science and mathematics. But in terms of Fine Arts, that consist aesthetics and philosophy.
- Engineering always demands accuracy with minimum tolerance. But Fine Arts command trial and error.

b. Why need improvement on Traditional Foundry Technology of Nepal ……?

- To get accurate result of metal casting :

  Metal casting itself is complicated and risky job all over the world. Sometimes, the result of metal casting carried out negative and need to be facing with unexpected problems. Therefore, to get possible accurate results in metal casting, there still need improvement on Nepali Foundry Technology.

- To minimize casting defects:

  While casting of metal arts and crafts, there seems plenty of casting defects such as rough surface, scabs or buckles, blow-holes, pinholes, sand spots, swell, hot tears, cold cracks, cold-shots or surface laps, lifts and shifts, sponginess, displaced cores, misplaced cores, pour-short, gas porosity, run-outs, metal penetration, fins, internal air pockets, dross or sand inclusion, mis-runs, seams, distortion, drawing, drops, crushes, cuts, washes, shrinkage etc. These casting defects maximize the production cost as well as time for maintaining. Thus, to minimize these casting defects there still need improvement on Nepali Traditional Foundry Technology.

- To save time or to adopt fast process:

  Nepali Traditional Foundry Technology is very time consumable job. It takes minimum two weeks or preparing small size of the casting mold. Due to time

consuming, it is not possible to product any metal art and craft in short period. Therefore, it needs to adopt fast process of lost wax casting to save the time as well.

- To increase efficient productivity:

  If it is possible to cast any metal objects without much time consume and with minimum casting defects, the cost of production will minimize that helps to increase efficient productivity in the sector of Metal Casting.

- To generate international standard local employment :

  In fact, Nepali craftsmen are recognized with highly skilled human resource in the world. But due to lack of contemporary technologies and preferring own ancient technologies in Nepali Foundry Industry, highly skilled craftsmen losing their earnings since losing efficient productivity and needed to migrate in Chinese Foundry. If necessary improvement on Traditional Foundry Technology of Nepal can take place, it is still possible to generate international standard local employment as well as possible to generate new kind of similar business or industry related to engineering products.

- To bring “Fine Arts” and “Engineering” to a common platform:

  Fine Arts never developed as a mainstream education except than low class labour work or middle class handcraftsmanship in Nepal. However, this sector is prominent earnings of foreign currency in Nepal since ancient period to till now. If Engineers and Fine Artists can lead to the Nepali metal craftsmen, that will help to establish a new kind of common platform in Nepal for Nepali Fine Arts and Engineering or could be established new terminology in the world encyclopedia as an “ARTENGINEERING.”

After experimental casting of Francis Blade with accessible different Foundry Technologies in Nepal, the researching team finds out the appropriate contemporary technology for implementation in Engineering Products.

a. Nepali Traditional Lost Wax Casting Process:

One of our own traditional lost wax casting processes, applying the casting mold from local ceramic clay with the mixture of cow-dung and paddy husk, is comparatively high standard technique but very time consumable technique.

b. Italian Traditional Lost Wax casting Process:

It is improved process of ancient lost wax casting technique in Europe and developed in Italy 900 years ago. Comparatively, it is similar to Nepali lost wax casting process and fast process than Nepali process, but expensive process due to extra fuel consumption and imported materials.

c. Ceramic Shell Lost Wax Casting Process:

It is also improved process of lost wax casting technique in West and also similar to Nepali lost wax casting process and fast process than Nepali process, but expensive process due to imported materials. Comparatively, it gives best casting result and less fuel consumption as Nepali Process.

d. Vacuum based lost wax casting process:

It is advanced process of Italian lost wax casting process and gives high quality casting results with close tolerance but it is quite expensive process because it needs ultra modern equipments and accessories for the casting.

e. Sand Casting Process:

It is also traditional metal casting techniques in the world; however it is less use in Nepali Foundry in comparison of lost wax casting process. It is fast and cheap technology but not comparative high quality technique than lost wax casting technique.

Among these all mentioned above technologies, the researching team find most appropriate technology for producing Engineering Appliances is “Vacuum Based Lost Wax Casting Process” due to its high quality finishing surface during casting, closer tolerance of the product and fast process.

Workshop on "ENGINEERING WITH TRADITIONAL TECHNOLOGY"

On 4 May a one day workshop with the topic "**Engineering with Traditional Technology**" was conducted at Turbine Testing lab auditorium at Kathmandu University. The program was organized with the fund of University Grants Commission project and assistance of Turbine testing Lab. The program was supported by Department of Mechanical Engineering. Faculty members, art and craft experts, entrepreneurs in the casting field, and students of Department of Mechanical Engineering attended the program which covered the theme "Use of traditional technique in engineering". The workshop was aimed to bring different field experts into a common platform and work out the ideal point of meet for art and engineering.

Associate Prof. Dr Hari Prasad Neopane formally started the program with the welcome speech and gave a brief overview on the program. The brief inaugural program was addressed by Bhola Thapa, Registrar and Dean, School of Engineering, Kathmandu University. He highlighted about the long history of Nepali arts and crafts and the need to upgrade it for economic prosperity of Nepalese people. He highlighted the need of art and engineering to bond together in contributing to the development of the society. The technical sessions, that followed, included six different presentations including the technique to cast the Full Francis Runner by Hridaya Man Nakarmi. He gave a brief idea of foundry practices in industry at De-matrix Engineering Services Ltd. Also art and craft experts presented their views on how the field can serve for engineering purposes. Dr. Shin from KOICA shared the knowledge and experience of Korean development. He explained how Korea elevated itself from the chains of poverty and deprivation to modern sophisticated nation by building on its foundation of old technology and combining it with contemporary innovations. The final speaker for the session was Mr. Tejesh Man Shakya, Assistant Professor at Center for Art and Design, School of Arts, who exhibited how traditional sculptures are manufactured in Nepal, and shared his idea on how such techniques may be applied in modern engineering.

In a brief closing session Prof. Dr. Bim Prasad Shrestha, Associate Dean, School of Engineering, awarded certificates to the participants. He extended vote of thanks to the facilitators and participants and shared a belief that the Workshop would have commendable impact in future activities in casting industries at large.

The list of the faculties, art and craft experts, entrepreneurs, manufacturers is listed in Appendix-I.

CHAPTER 4: CONCLUSION AND RECOMMENDATION

Nepal has a very long history in the casting sector, however very less work has been done to upgrade its technique and broaden its purpose. This has held back the industry to a considerable extent. The growth of the sector initiates with its adaptation to the latest advancements. Also identification of more applications of casting process in the fabrication of engineering products is important. The recognition of purpose of casting in engineering sector is a major outcome of this project.

The project was successful in identifying the possible areas where traditional foundry technology could be used for engineering purposes. The fabrication of the Francis Runner showed the prospect of the casting market to grow up for engineering uses. The visit to the industries presented us with the existing working scenario of the casting industry in Nepal. The field visits showed the prospect of the casting market to flourish, which is an encouraging sign. Yet, the techniques and methods have to be simplified so as to take this industry to a broad way level.

Further, consultation and feedbacks from the market was encouraging in terms of filling the void between art and engineering. Related experts, businessmen, academicians expressed their view on how the field could be regenerated to reap more benefits. Thus, the casting industry of Nepal demands immediate attention of all those concerned to take this industry to a new height.

After some experimental casting of similar Francis blade developed by rapid prototype machine by applying different foundry technologies, the researching team has found different casting result with different quality level of different cast blade. With analyzing all results, the researching team has also concluded the best quality produced from the vacuum casting plant. Therefore, the researching team recommends for establishing large size vacuum casting plant that suits to manufacture all size of Engineering Products as well as Art and Craft Products in Nepal.

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[10] (2000). In M. S. Friedman, *Nepalese Casted Vessels, Decanters and Bowls* (pp. 5-11). Pilgrims Publishing.

Appendix-I: Workshop Participants' List

S.N.	Name	Designation	Subject/Category	Institution
1	Prof Dr. Bhola Thapa	Faculty	Mechanical Engineering	Kathmandu University
2.	Associate Prof. Dr. Hari Prasad Neopanae	Faculty	Mechanical Engineering	Kathmandu University
3.	Prof. Dr. Bhim Prasad Shrestha	Faculty	Mechanical Engineering	Kathmandu University
4.	Dr Myong Hoon Shin	Technical Instructor	Mechanical Engineering	Technical Training Centre(KOICA)
5.	Mr. Kirti Man Shakya	Faculty/Designer/Sculptor	Design Studio	Centre for Art and Design Kathmandu University Hattiban, Lalitpur
6.	Mr. Mahendra Shakya	Faculty/ Traditional Foundry based Metal Sculptor	South Asian Art Studies Buddhist Studies	Centre for Art and Design Kathmandu University Hattiban, Lalitpur Lumbini Buddhist University Baneshwar, Kathmandu
7.	Hridaya Man Nakarmi	Director	Mechanical Engineering	De-Matrix Engineering Services Pvt. Ltd.
7.	Mr. Purna Kaji Shakya	Assistant Professor/Sculptor	Sculpture	Nepal Fine Arts Campus Tribhuwan University Bhotahiti, Kathmandu
8.	Mr. Prakash Ratna Shakya	Faculty/Sculptor	Sculpture	Sirjana College of Fine Arts Tribhuwan University Lazimpat.
5.	Mr. Prem Bahadur Shakya	Member/Traditional Foundry based Metal Sculptor	Buddhist Sculpture	Federation of Handicraft Associations of Nepal Thapathali.
9.	Mr. Rajan Shakya	Member/Traditional Foundry based Metal Sculptor	Buddhist Sculpture	Lalitpur Handicraft Association Patandhoka, Lalitpur
10.	Mr. Durgananda Shakya	Vacuum Foundry based Metal Artisan	Buddhist Sculpture	Durga Handicraft Satdobato, Lalitpur

Besides, researchers from Turbine Testing Lab, students of Department of Mechanical Engineering also attended the program.

Appendix-II: Pictures to reflect project activities

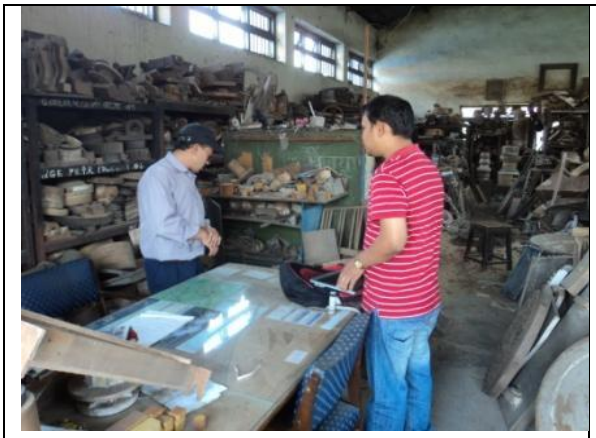

Fig. 1 Pattern Shop at Dhalaut Karyashala

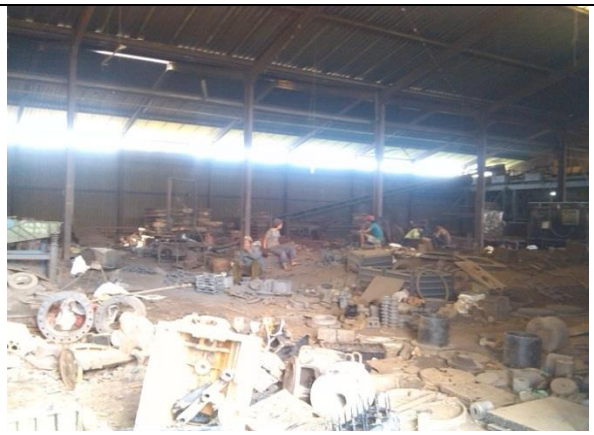

Fig. 2 Casting facility at Dhalaut Karyashala

Fig. 3 Crucible for melting Metals at Dhalaut Karyashala

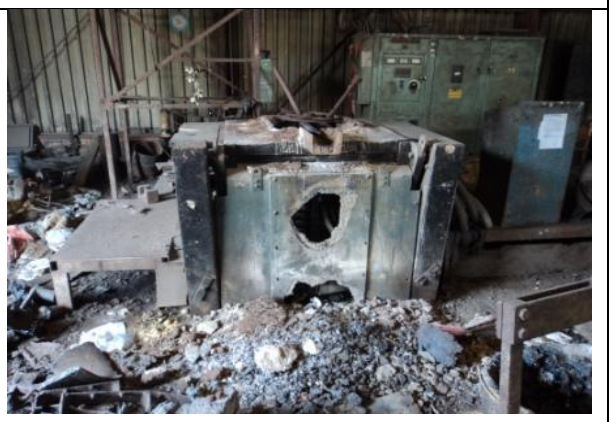

Fig. 4 Electric Furnace for melting Metals at Dhalaut Karyashala

Fig 5. Wax Injection machine for

Fig 6. Suction machine (left) & Electric

Casting wax into the rubber mould	Kiln (right) for Vacuum Casting
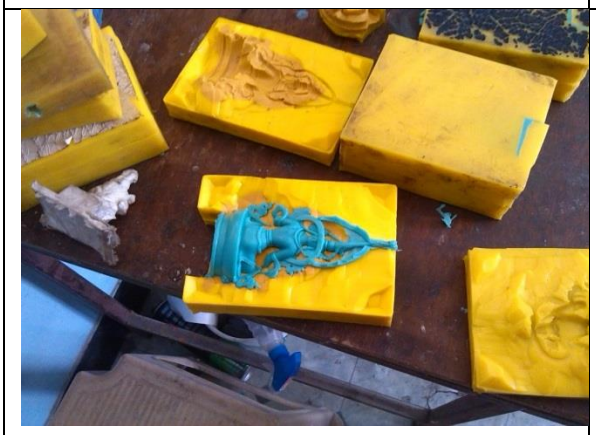	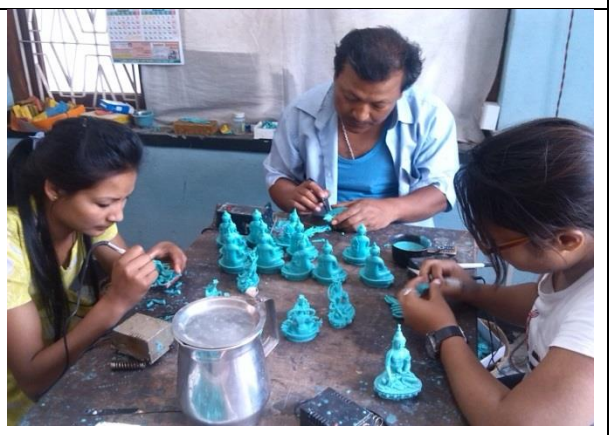
Fig. 7 Silicone Rubber Mold for Wax Casting	**Fig. 8 Craftsmen intensive traditional craft manufacturing**
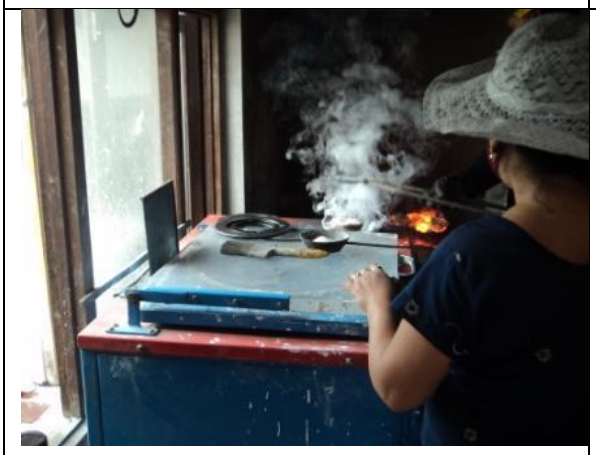	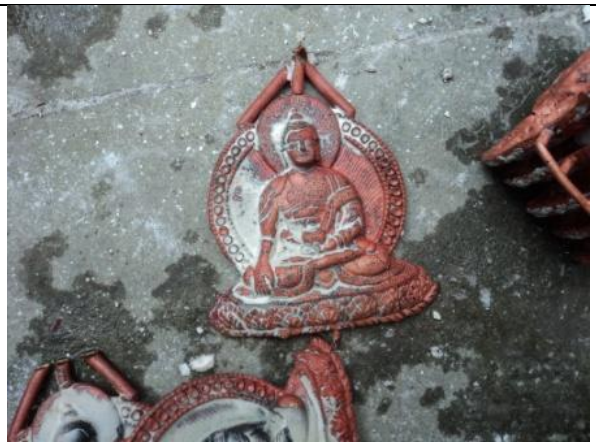
Fig. 9 Pouring molten metal into the Mold inside Suction Machine for Vacuum Casting	**Fig. 10 Copper image of Buddha from Vacuum Casting Process**
	
Fig. 11 Home based traditional wax modeling process	**Fig. 12 Home based traditional wax modeling process**

Fig. 13 Home based traditional wax modeling Process

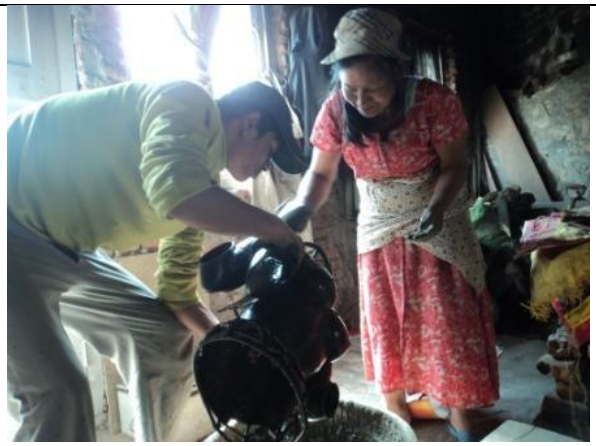

Fig. 14 Home based traditional molding process

Fig. 15 Home based traditional molding process

Fig. 16 Home based traditional mold baking kiln (left) & developed metal melting Furnace (right)

Fig. 17 Pouring molten metal into the traditional mold

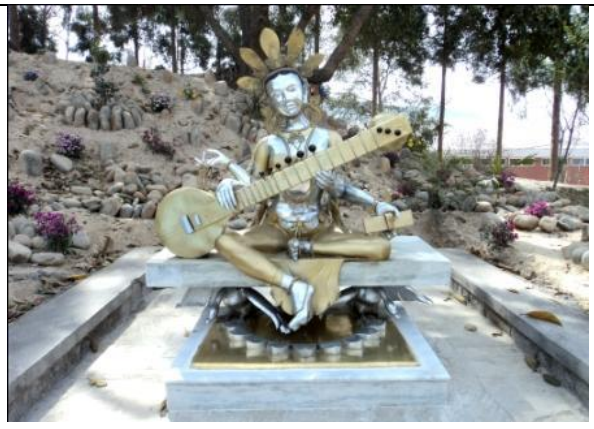

Fig. 18 Saraswati, Cast in Nickel Silver & Brass using Lost Wax Process

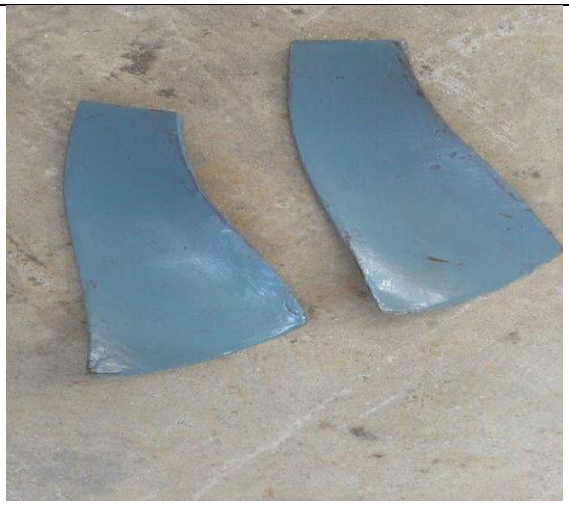

Fig. 19 Francis Blade Model casted in Dhalot Karyashala (Sand Casting Technique)

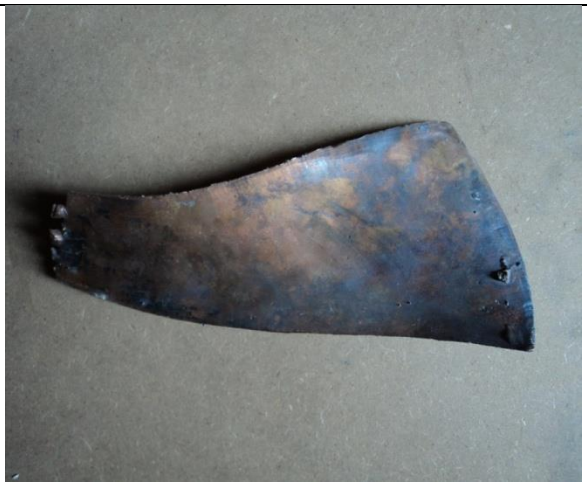

Fig. 20 Francis Blade Model casted in Durga Handicraft (Vacuum Casting Technique)

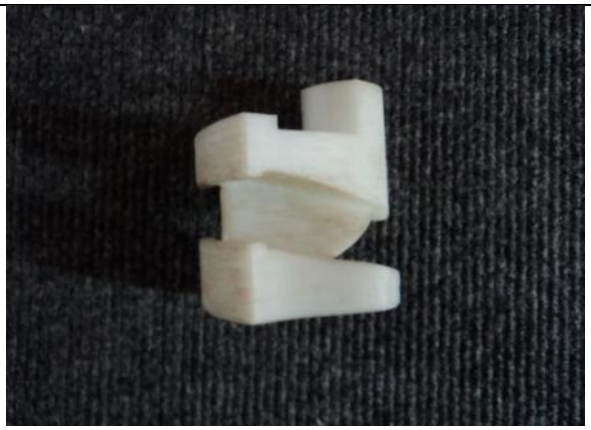

Fig. 21 Section of Francis Runner developed from Rapid Prototype Machine

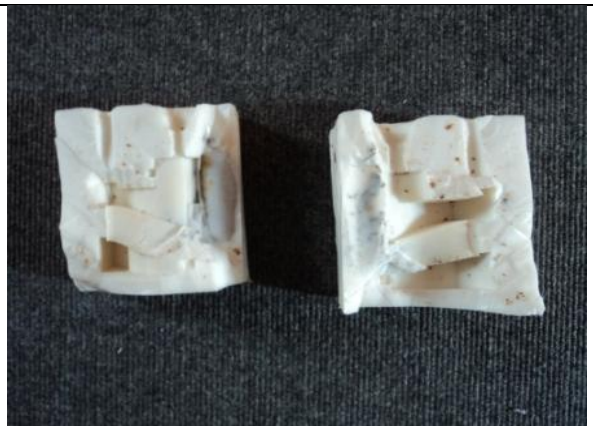

Fig. 22 Silicone Rubber Mould of Section of Francis Runner

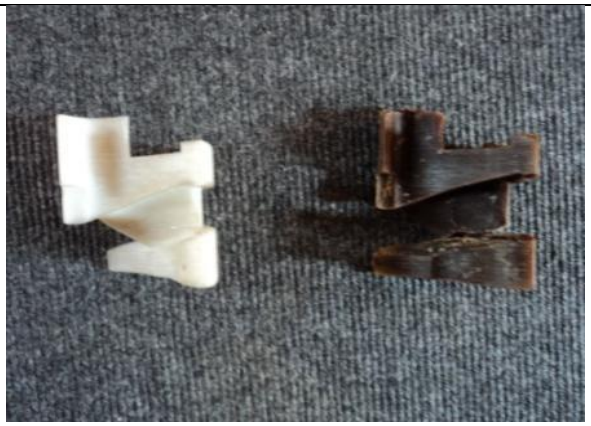

Fig. 23 Cast piece of wax (Right) from Silicone Rubber Mould of Section of Francis Runner

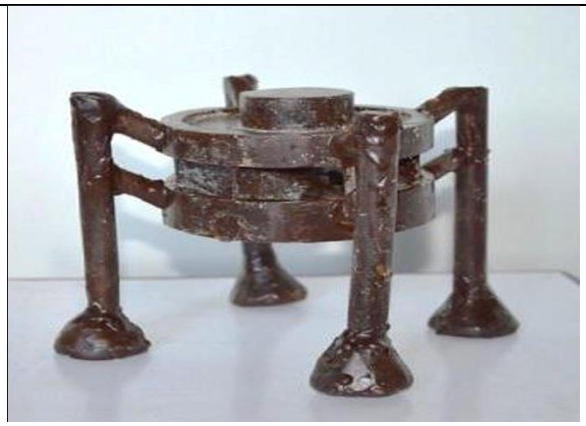

Fig. 24 Wax Francis Runner with added Sprues and Vents

Fig. 25 Casting Mould of Francis Runner prepared from slurry of gypsum based powder for Italian Lost wax casting

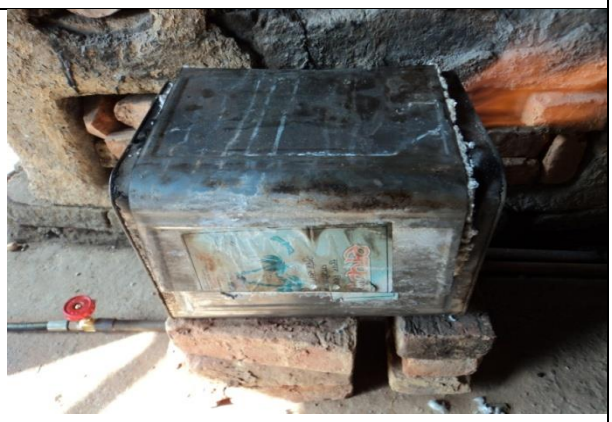

Fig. 26 Locally improved home based gas kiln by Tejesh Man Shakya in 2006 A.D. for mould baking

Fig. 27 Locally improved home based multi-fuel furnace by Tejesh Man Shakya in 2006 A.D. for metal melting

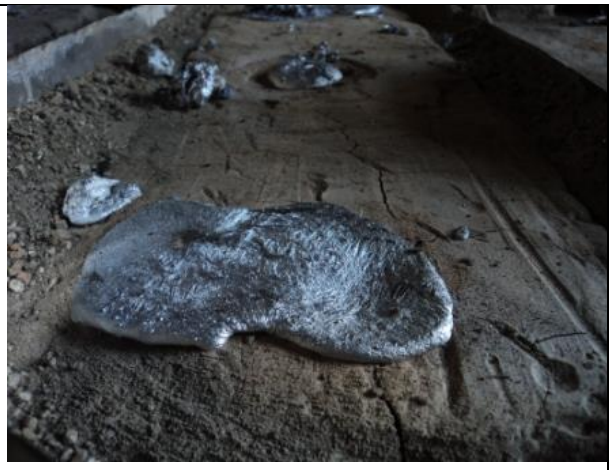

Fig. 28 After pouring the brass into the gypsum based mould of Francis Runner

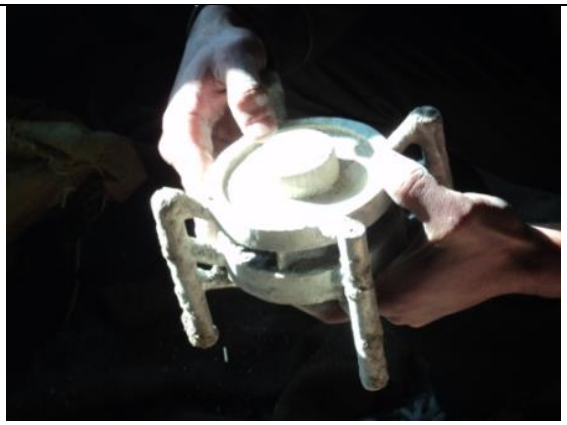

Fig. 29 After break open gypsum based mould of Francis Runner

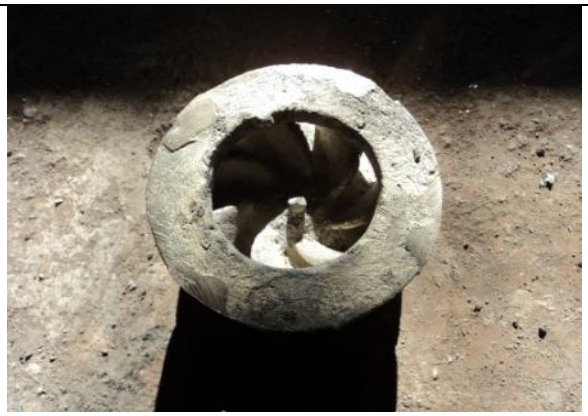

Fig. 30 After cutting sprues and vents of cast brass Francis Runner

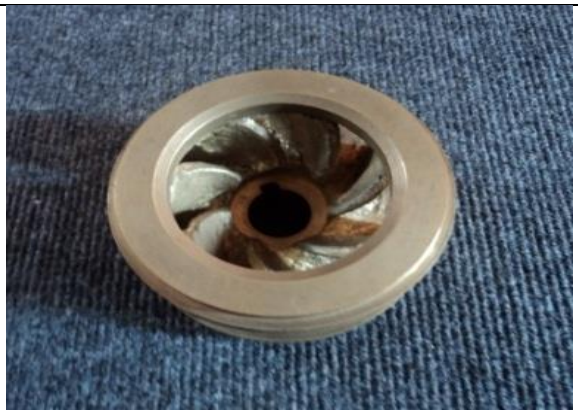

Fig. 31 Final fabricated cast brass Francis Runner after chasing and finishing

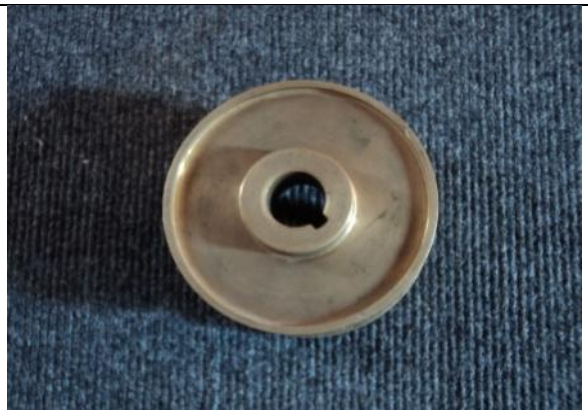

Fig. 32 Final fabricated cast brass Francis Runner after chasing and finishing

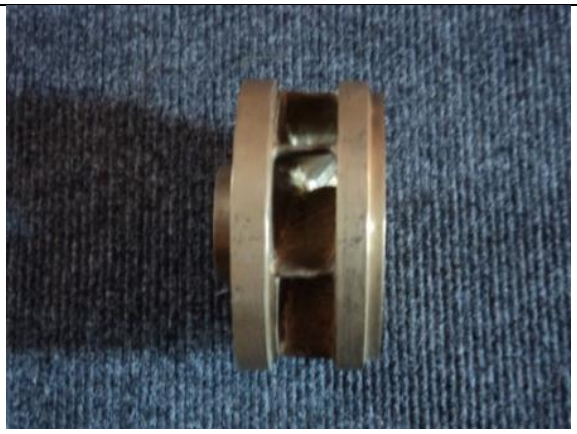

Fig. 33 Final fabricated cast brass Francis Runner after chasing and finishing

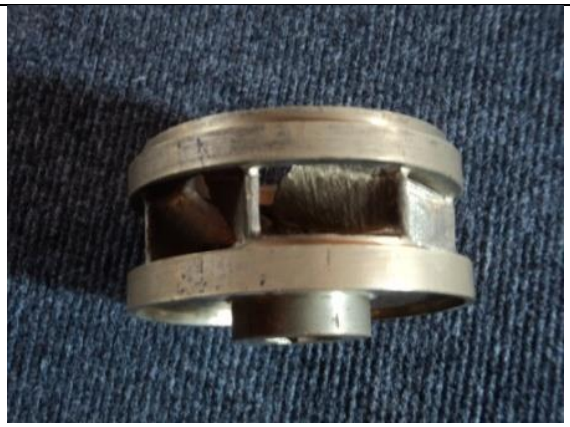

Fig. 34 Final fabricated cast brass Francis Runner after chasing and finishing

Fig. 35 Locally improved Petroleum Kiln with Traditional Materials for Mould Baking by Tej Ratna Shakya in collaboration of Mechanical Engineer Nira Prasad Hyoju at Foundry of Gharelu Moortikala Udyog 1986 A.D.

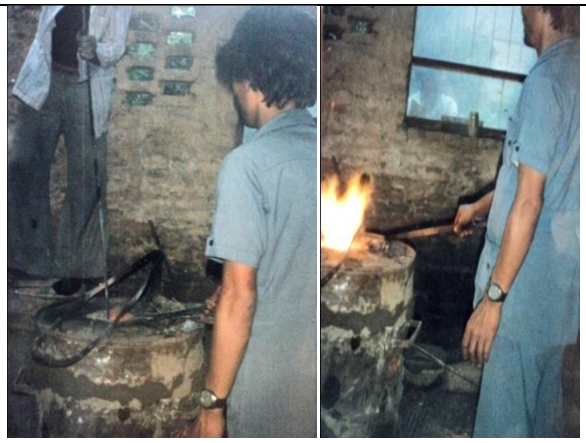

Fig. 36 Locally improved Petroleum Furnace for Melting Metal by Tej Ratna Shakya in collaboration of Mechanical Engineer Nira Prasad Hyoju at Foundry of Gharelu Moortikala Udyog 1986 A.D.

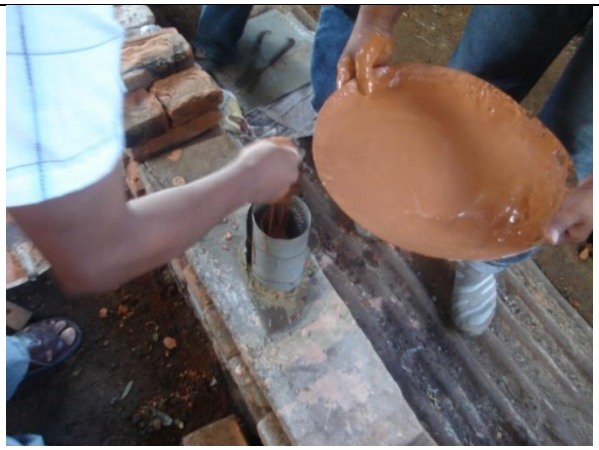

Fig. 37 Preparing Gypsum based Mould - 1st locally organized workshop on Italian Lost Wax Casting Method at Foundry of Ethnic Fine Art November 2006

Fig. 38 Ceramic Shell Mould for Lost Wax Casting Process - Locally experimented Foreign Foundry Technology at Foundry of Ethnic works Art & Design January 2012

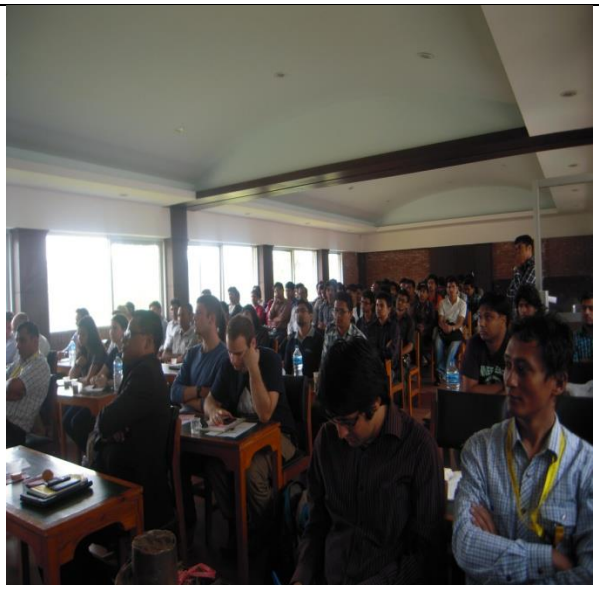

Fig. 39 Participants at the Workshop

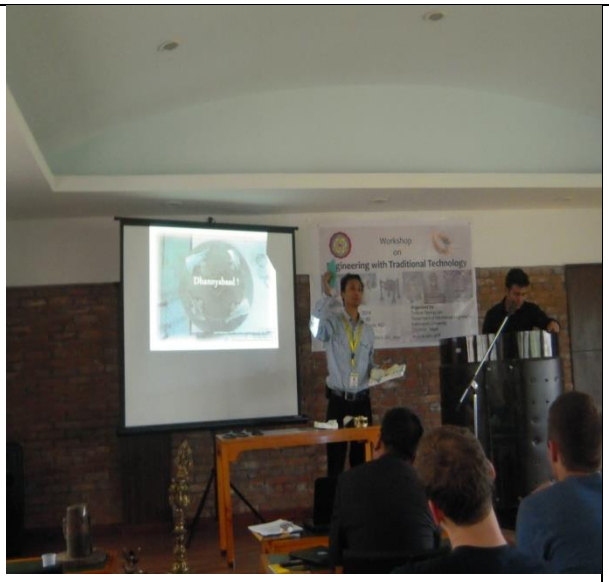

Fig 40. Tejesh Man Shakya explaining the technical aspects of the project

Fig 41. Participants discussing with the product exhibited in the workshop