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Up-Scaling Heat Recovery Unit (HRU) For Fuel Saving and Process Improvement: A Case Study of Silk Reeling Ovens in Karnataka

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Abstract: *Silk reelers in Sidlaghatta taluk, Chikkaballapur District in Karnataka state use traditional ovens called as Italian based ovens (IBO) for cocoon cooking. Solid lengthy pieces of wood are used as a fuel in the oven for heating water in which cocoons are cooked to release the silk thread ends. The oven consists of a simple firebox with a chimney, which operates at a low efficiency of 12-15%. A large amount of heat generated is wasted in the form of hot flue gases, which escape through the chimney. The temperature in the flue gases is above 300^{O}C, thus a lot of heat dissipates from the chimney creating a hot and uncomfortable work environment. Due to the low efficiency of the oven, more wood is consumed and cooking takes a lot more time. As a solution to the problem, a simple system called Heat Recovery Unit (HRU) was designed and retrofitted to the IBO to recover the waste heat from the chimney to pre-heat the water and the same pre-heated water can be used for cooking cocoon in the oven. This in turn increases the efficiency of the oven, reduces operational time and improves the comfort level of workers as less heat is dissipated from the chimney. This system created considerable interest among the end users, and hence a agency was identified and provided with a prototype for commercialization. Using policy support and introducing subsidies more than 400 units were disseminated in the Sidlaghtatta silk reeling cluster.*

Key words: *Biomass oven, cocoon, silk, waste heat, HRU, Preheated water*

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I. Introduction

Silk reeling is an age-old industry in the state of Karnataka. It's beginning can be traced to the 18th century during the regime of Tipu Sultan(1), the ruler of erstwhile Mysore State, who organized a silkworm rearing unit in the southern part of his kingdom. Channapatna in Karnataka state is believed to be one such centre. He sent emissaries to different parts of the world in search of and finally procured yellow multi-voltine race, suited to the climatic conditions of the region, which is surviving till today. Presently India is the second largest silk producer in the world producing raw silk of 28472 MT (2). This industry provides employment to approximately 8 million people in India. Karnataka produces 9823 MT (or) 34% mulberry silk out of the country's total output. Silk reelers use three types of traditional ovens for cocoon cooking in Karnataka namely Cottage basin oven, Charka oven and Italian based cottage oven. About 20,960 cottage basin ovens (of which 800 are Italian type) and 23210 are charka basins operate in Karnataka (3). Cottage oven based reeling involves cooking and reeling which are done separately. Re-reeling of silk is done separately. In Charka oven reeling, both cooking and reeling is done in same oven. There is no re-reeling in charka reeling units. Only in Sidlaghatta cluster, reelers use Italian based cocoon cooking oven. A reconnaissance during the project on dissemination gasifier technology in the silk reeling sector found that only in Sidlaghatta reelers use Italian based silk reeling ovens. This is a very specialized type of unit and consists of one cooking basin and two associated reeling basins. There is no re reeling step in silk yarn processing.

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1.1. IBO and its operation

In the processing of silk reeling, the energy is used for different operations namely Stifling, Cocoon cooking, and Silk drying. Cocoons are first stifled to kill the pupa and to evaporate moisture in the cocoon to extend the storing life, otherwise there is a chance of piercing of the cocoon shell by moths, and silk threads cannot be extracted from such cocoons. The next operation is cocoon cooking in boiling water to dissolve the sericin gum and to locate the loose end of the silk thread. The final operation is silk drying to remove moisture from the silk. For cocoon stifling and cocoon boiling, the solid biomass and crop residues will be used as fuel and for silk drying hot charcoal (bi product of solid biomass getting from cocoon cooking oven) will be used. Figure 1 to 3 gives details on the process of cocoon stifling, cooking and silk drying

1. Cocoon stifling   2. Cocoon cooking   3. Silk drying

In IBO, a single cooking vessel is installed just behind the two reeling basins. The system is called as a table. In each table three workers are engaged, one member is for cocoon cooking and other two members for silk reeling. After the cocoons are cooked in the cooking vessel it is served to the reeling basins. The reeler sits facing the reeling basin but silk is wound to the big reel behind him. The cooking vessel used in the oven contains 12 liters of water and temperature will be maintained at 90 to 92^{o}C. In each table everyday about 20 kg of cocoon is processed in three batches and around 2.5 kg of silk is produced.

IBO is operated for three hours in every batch, and during most of this time the water temperature in the cocoon cooking vessel is maintained to around 90 to 92^{o}C, which is a very challenging task. In the interval of one to one and half hours, approximately two litres of contaminated water in the cooking vessel will be replaced with fresh water to maintain cleanliness in the water and protect silk quality. Adding fresh water to the cooking vessel will reduce the remaining water temperature in the vessel, hence extra fuel is required to increase the temperature of water to reach up to 90 to 92^{o}C. After completion of batch (3 hours) of operation, the contaminated water in the cooking vessel is drained out and replaced with fresh water to start the next batch of operation. The fresh water has to be heated up 90 to 92^{o}C by feeding extra fuel.

II. Methodology

An energy audit was conducted initially to understand the heat utilization in the silk reeling ovens. Results indicated that the operating efficiency of the oven was in the range of 12 -15%. Inefficient design, no upgradation of technology, and badly built combustion chamber means more wood needs to be burnt to heat the cooking vessel and boil the water faster. But the results are in the reverse direction, it is often observed that temperature in the flue gases is above 300 degree Celsius, thus lot of heat energy is lost to the atmosphere which accounts to oven inefficiency, excessive fuel consumption and also creates a hot and uncomfortable working environment in the work place.

2.1 Findings of energy audit

The energy audit study results of the cocoon cooking oven shows that 26.4% (4)of the heat goes through the chimney, 12.1% of heat goes through the fire box opening, and remaining 49.2% of heat is lost through the surface, thermal mass, ash and char. The remaining heat loss is unaccounted loss. Apart from the efficiency mentioned earlier, a large amount of heat generated is currently wasted in the form of hot flue gases, which escape through the chimney. Heat is also lost through radiation by the oven and through discarded char and ash. This radiated heat makes the working conditions uncomfortable by further raising the temperature in the working area. The various heat streams of traditional cocoon cooking oven are shown schematically in the form of sankey diagram in Figure 4.

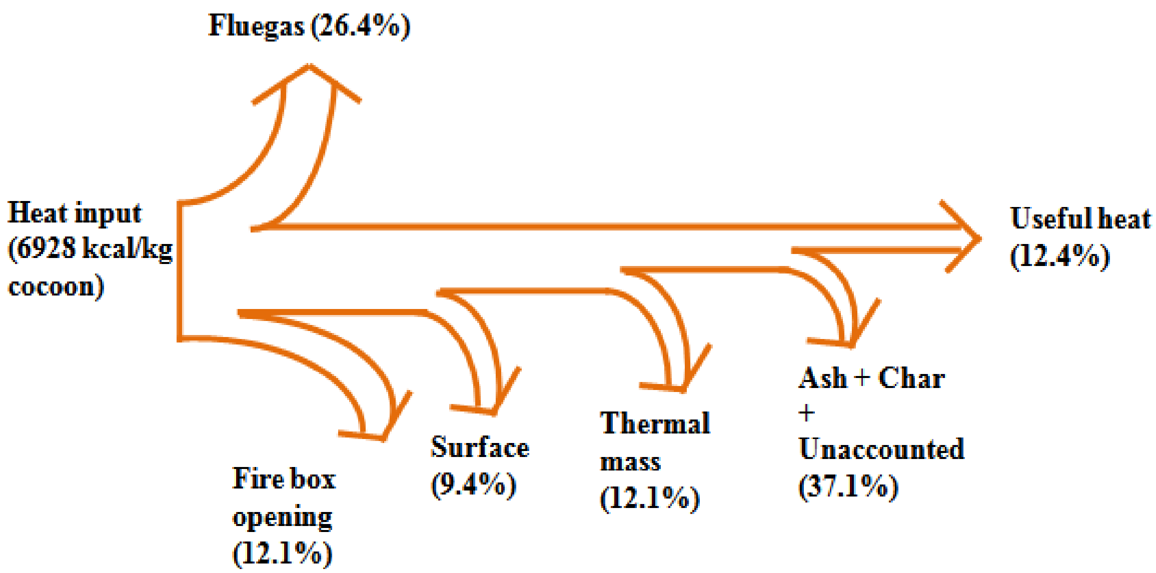
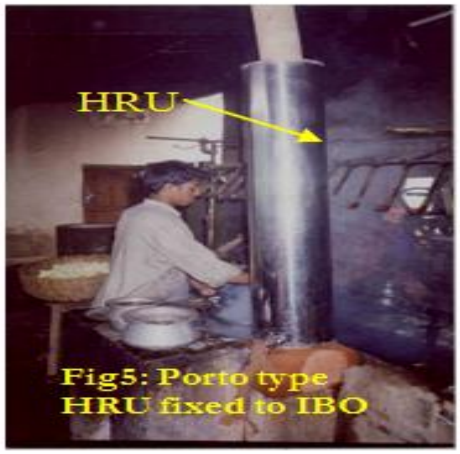


Fig 4: Sankey diagram showing heat streams of a traditional cocoon cooking oven

A large amount of heat generated is currently wasted in the form of hot flue gases, which escape through the chimney; hence considered the concept of recovering the waste heat from chimney flues gases to utilize to preheat the water. Hence a technology was developed to utilize the waste heat/flue gas from the chimney.

III. Need for intervention

As explained earlier, the main challenge in silk reeling is maintaining the water temperature at 91-92^{O}C in the cocoon cooking vessel. If the water temperature is higher then the quality of silk is affected and if it is lower the ceresin gum will not dissolve from the cocoon to release the silk thread. Every time the cocoon is cooked the worker has to add wood into the oven to increase the water temperature or add cold water to reduce the water temperature. During the completion of every batch, the cooker will have to replace the contaminated water by fresh water in to the cooking vessel and further heat the water to 91^{O}C to start the next batch of operations. During the start of every batch, the reelers have to wait up to 20 to 30 minutes to heat the water. During this time the cooker will add more wood in to oven to heat the water very fast. Besides this the workers will have bear the heat dissipated from the oven chimney and especially in summer it is very difficult to work.



3.1 Intervention

The emphasis of the intervention was to develop a low cost appropriate technology with an aim of improving energy efficiency, working environment, productivity and product quality. A simple tube-in-tube type heat exchanger or HRU was placed in the path of the flue gas to recover heat from the hot flue gases for preheating water used in Italian cocoon cooking ovens. The initial model of the HRU was designed with a galvanized iron sheet to reduce the cost but this affected the silk quality due to release of rust from the welded joints. Usually brass is used as welding material and therefore welded joints are prone to corrosion when in contact with hot water. The HRU material was therefore changed to stainless steel, which does not affect the silk quality. Two modifications were introduced based on user feedback such as water holding capacity and height of HRU.

The HRU design does not disturb the existing reeling and oven design and avoids additional financial burden to the owner. Simply the HRU was placed in the flue gas path to recover heat from the hot flue gases for preheating the water. The diameter and length of the HRU were adjusted after taking feedback from the workers and owners. The simple design of HRU makes fabrication easy. The HRU contains 2 circular tubes, inner and outer tube. The inner tube helps to extract flue gases from the oven and the outer tube helps in storing water. The outer tube is closed at the top and bottom using circular plates. A tap is provided at the bottom for hot water collection and at the top 2 inlets are provided one for filling water and another to act as air vent.

IV. Results of intervention

It was observed that the temperature of pre-heated water inside the HRU increased to about 75 to 80^{o}C during a single batch of operation (about 1.5 hours) and hot water was available almost at the required temperature immediately for the next batch of operation.

4.1 Performance (operational, economic and other benifits)

The table below shows that 20 kgs of cocoons were used for processing in both the traditional and HRU based Italian based ovens. It was observed that in the Italian based Oven with HRU 20% fuel (wood) savings was observed as compared to traditional Italian oven and savings in terms of money worked out to Rs. 32/-. The payback period works out to around 5-6 months. Apart from the quantified benefits of fuel savings, the processing rate of silk production was increased and reduction in temperature in the working environment due to the presence of layer of water between chimney and the workers.

Table1. Comparison in fuel savings in IBO without HRU and IBO with HRU

SN	Description	Traditional Italian oven	Italian based oven with HRU
	Cocoon processing (Kg/day)	20	**20**
I	**Fuel savings**		
	Fuel consumed (Kg/day)	58.4	**46.4**
	% of fuel savings in HRU based oven	-	**20.5**
	Savings of fuel by using HRU based oven (kg/day to process 20 kg cocoons)	-	**12**
II	**Time savings**		
	Total operational time to process 20 kg cocoon (Hours/day)	11	**10**

	Savings in operational time compared to the traditional oven (Hours/day)	-	**1.0**
III	Money savings		
	Savings of money in HRU based oven after processing of 20 kg of cocoons (Rs)	-	**32**
IV	**Working Environment**		
	Heat dissipation (radiation) from the chimney	High	Reduced considerably
V	**Total cost of only HRU (Rs.)**	**4,500/-**	
VI	**Payback period (months)**	**5– 6 months**	

Note: 1. In Italian based oven using wood as a fuel,   2. Cost of wood Rs 2.60/kg

Initially TERI designed and demonstrated the HRU (40 liters capacity) in two silk reeling units in Sidlaghatta. Trials were carried out and benefits were quantified. Further, TERI collected the user perception of the HRU, Owners of silk reeling units who expressed immense satisfaction over this innovation and their contentment on account of the fuel saved and time saved thereby increasing their profit margins. Workers commented that there is reduced heat dissipation as well as reduced drudgery due to the time saved and better working environment.

4.2 Commercialization of intervention:

As a introductory, an awareness programme was conducted in the cluster to create awareness on HRU in the silk reelers, and a HRU in working condition was demonstrated in one of the units. After this programme, people showed a lot of interest to adopt HRU for their traditional ovens. Further TERI conducted a meeting with the Department of Sericulture (DOS) officials and reelers to link up HRU with government schemes. DOS officials studied the performance and fuel savings aspect of the HRU and prepared a report on HRU and submitted to the relevant authorities to promote HRU on subsidized rate. TERI has also given the prototype to a local entrepreneur called M/S Raghavendra Enterprises, Sidlaghatta for fabrication and marketing the HRU system in and around Sidlaghatta taluk. At present more than 400 HRUs have been disseminated in Sidlaghatta area.

Fig6: commercial HRU model fixed to IBO

V. Conclusions

In IBOs, significant amount of heat loss can be reduced by retrofitting a simple solution of HRU. This has helped in saving fuel to 20% and 60 minutes time because of the availability of preheated water thus reducing the waiting time between the batches. Fuel savings amounted to a saving of Rs 30 and Rs 35 in the Italian based oven. Also it will be helpful to the workers by reducing heat dissipation as well as reduced drudgery due to the time saved. Besides, the availability of hot water for domestic use is an added advantage to all including the local inhabitants of the region. The technology has been occupied by the silk reeling sector. It has been successfully commercialized and disseminated with policy support though introduction of subsidy. This technology can be initiated in other sectors such as, silk dying, food processing, hotel industries, steam production -etc.

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References

[1]. http://www.karnataka.gov.in/Sericulture/english/Pages/Objectives.aspx - Accessed on 24/06/2018
[2]. http://texmin.nic.in/sites/default/files/note-on-sericulture-March2016.pdf - Accessed on 24/06/2018
[3]. Mahesh G. (2012). Business Analysis of silk reeling units in Chintamani taluk of Chikkaballapura district, Karnataka Project report submitted to University of Agriculture Sciences, Bangalore , Vol 7(2), October. pp 15
[4]. Sanjay Mande, B.R. Pai and V.V.N. Kishore (2001) - Study of stoves used in Silk reeling industry, Asia industrial and institutional Stove compendium, published by Asia Regional Cookstove Program
[5]. Sunil Dhingra, Sanjay Mande, P. Raman, S.N. Srinivas, V.V.N. Kishore (2004), Technology intervention to improve the energy efficiency and productivity of silk reeling sector, Biomass and Bioenergy 26 (2004) 195 – 203.
[6]. http://www.csb.gov.in/- Accessed on 15/05/2018
[7]. http://202.138.101.165/sericulture/Index.aspx - Accessed on 15/05/2018