AN IMPROVED POTTERY KILN

RURAL ENERGY & INFRASTRUCTURE SECTION

Mahatma Gandhi Institute of Rural Industrialization

A project being executed by:
Indian Institute of Technology, Delhi

Sponsors: Khadi & Village Industries Commission
Government of India

An Improved Pottery Kiln

Introduction

Pottery has always had a special place in Indian society since ancient times. Starting from the unbaked clay pots, the unglazed terracotta pottery to the glazed pottery used in Modern homes, there is a wide variety of pottery used even today. A large percentage of this pottery is being produced by the unorganized sector, in small scale, employing very primitive technology. As a result they have higher production costs, lower profit, inferior quality & higher level of pollution.

One aspect of pottery production which has particularly stayed at a very traditional level is the firing of pottery in kilns. The kilns used in the small scale industries are highly inefficient, consuming large fuel quantities as compared to the actual energy requirement for the process. On the contrary, the kilns used in the organized sector are much better from the point of view of energy efficiency, but far too expensive for small potters to afford and are also more suited for larger scale of production. Moreover, most of the modern kilns use fossil fuels, viz., oil or gas while the traditional kilns primarily use locally available fuels such as wood, charcoal or coal. There is, therefore, a need to improve upon the traditional furnaces without change of fuel or a substantial increase in the capital cost. Rather it is preferable to have a design which can save the capital cost as well as the running cost. This booklet gives the details of one such improved design of an updraught kiln, which has resulted in over 40% saving in fuel-wood as compared to the traditional kiln and also consumes less material in construction saving the construction cost as well.

Traditional Pottery Kilns

In India, a large variety of kilns are in use for firing of pottery depending upon the types of products such as clayware, stoneware and bone china crockery etc.. and the scale of production. Small scale units use batch kilns like bonfire or pit kilns, updraught kilns ands downdraught kilns.

Most of the potters making traditional earthernware use bonfire kilns which are not only highly inefficient in terms of energy and highly polluting, but also result in breakage of upto 50% of the fired ware. Updraught kilns are the most commonly used for unglazed artistic pottery to avoid excessive breakage and to have better control on the firing cycle. Updraught kilns have the advantages of low cost and simple construction with much better retention of heat and higher temperatures as compared to bonfire kilns. Downdraught kilns are more suitable for glazed pottery which requires higher and more uniform temperatures inside the kiln. They have better heat retention with higher temperatures as compared to updraught kilns but have higher constructional cost. All these kilns use coal or firewood as fuel.

Firing Process

Pottery is fired after the initial drying in sun or open, which removes a large part of the moisture in the product. Firing of pottery consists of various stages, namely, smoking, slow firing, rapid firing and soaking. In smoking, the heating is very slow, and temperatures are below 150°C. As the name suggests, the fuel is allowed to burn without a large flame, at very low rates. This is the phase during which the remaining moisture in the pottery is allowed to evaporate. The low heating rates ensure no cracks by preventing violent eruptions of water vapour from the pottery. In slow firing, volatile matter other than moisture is removed at temperatures of 450-500^{o}C, at moderate rates of heating. After all the volatile matter is gone, rapid firing is done at a high rate so as to raise the temperature of the wares rapidly to the maximum required values. In soaking, firing is done at a rate sufficient to maintain the temperature of the wares at the highest value over a period of time. The total duration of firing normally ranges from about 5-6 hours to about 40-48 hours depending on the requirements of the pottery being processed, type of kiln and the fuel used for firing.

Energy Budgeting in a Typical Kiln

The energy released by the combustion of fuel in a pottery kiln gets distributed with only a small fraction getting absorbed by the pottery. In traditional kilns, the walls are made very thick, which absorb a large part of the energy, which is essentially a loss. Also, the fuel is burnt directly on the floor, causing very high losses to the ground. A large part of the energy is lost due to high temperature of the flue gases exiting the kiln. Figure 1a gives the breakup of energy consumed in a traditional updraught kiln used at Kumharpara in Kondagaon, district Bastar, Chhattisgarh. Here highest loss is to the ground followed by the loss due to the energy stored in the kiln wall, which is 18” thick. Figure 1b gives the energy budget of another updraught kiln used in Gramoday Sangh at Bhadrawati, Maharashtra. This kiln had even thicker walls which stored 45% of the energy released during the operation of the kiln. The losses through the flue gases are nearly the same in both. Other losses include the convection and radiation losses from the wall exterior and the flames.

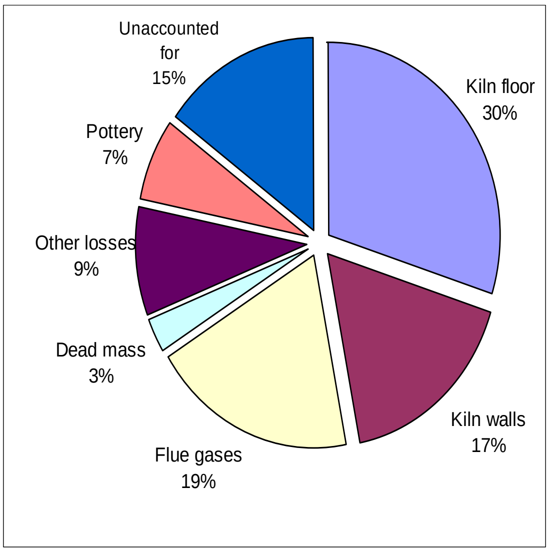

Fig 1(a) : Energy budget in Kondagaon kiln

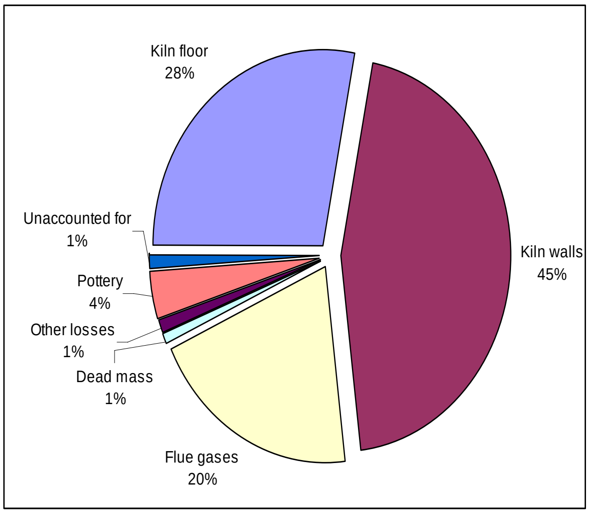

Fig 1 (b) : Energy Budget in Bhadrawati Kiln

The energy absorbed by the floor and the kiln walls is many folds higher than that absorbed by the pottery, because the walls and floor are several times heavier than the payload of pottery: The traditional Kondagaon kiln, for example, fires about 1000 kg of payload in a single firing, while the mass of the walls alone would be around 7500 kg of brickwork. A comparable mass of soil and bricks below the floor are also getting heated.

The Improved Updraught Kiln

The new kiln was developed with the prime objective of decreasing the energy losses due to storage in walls and heat conduction to the ground. The energy absorbed by the walls and floor can be reduced by decreasing the mass of the wall and floor coming in contact with high temperature, thereby preventing bulk of the mass from getting heated to high temperatures. This can be achieved by providing a low-cost insulation between the first layer of bricks facing the fire, and the remaining part of the wall or the floor. Several traditional kilns use ash as the insulator.

In the new design, the insulation is provided by the air gaps in the floor as well as the wall. The wall is constructed using a rat-trap bonded structure, which provides substantial air gaps in the wall as shown in figure 2. Figure 2(a) gives a schematic of the rat-trap bond and figures 2(b) and (c) show the construction of an actual kiln wall using this structure.

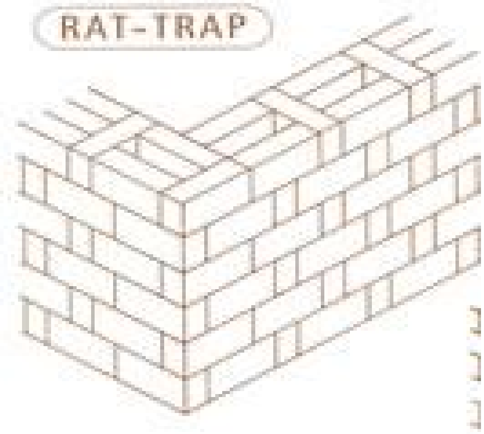

Figure 2a. Schematic of Rat Trap Bonding

Figure 2b. Kiln floor during construction

Figure 2c. Kiln wall during construction

Here the inner layers of the wall are constructed using the rat-trap bond. The air gap after the innermost row of bricks isolates the rest of the brick structure from the hot inner layer, thereby preventing a large part of the wall from absorbing energy. The rat-trap bonded structure has a thickness of 9", corresponding to the length of a brick. The width of the brick is 3", hence the structure gives air gaps of 9"X3"X3" separated by 3" brick width in the entire wall. This construction reduces the mass of the wall in direct thermal contact with the hot gases. While air gap prevents heat transfer due to conduction, non-continuous gaps keep the convective heat transfer in these gaps low. To increase the strength of the wall, a solid layer of 3" thickness is provided on the outerside of the wall. The total thickness of the wall in this kiln is 12".

Figure 3: Kiln floor during construction

Similarly, the losses from the floor were reduced by making channels of brick structure on the floor. First a continuous layer of bricks is laid on the floor. On top of this, channels are constructed with alternating rows of bricks and air-gap as shown in figure 3. Above this, another continuous layer of bricks is provided to make the floor of the kiln. This construction reduces the contact between the floor of the kiln where fuel is fired and the ground, hence reducing the losses substantially. Figure 4 shows the completed kiln during firing.

Figure 4: Improved kiln during firing

The reduction in the thickness of the wall, results in significant savings. However, if care is not taken, the reduced thickness can cause development of cracks at the firemouths. This is owing to the traditional practice of firing wood at the firemouths. The part of the wall directly above the firemouths is subjected to very high temperature practically all through the firing, and as soon as the firing is complete, it experiences sudden cooling. This compounded with rat-trap structure of the wall which is both insulating and structurally weaker, experiences higher temperature gradients and hence cracks up. This problem can be fully overcome by providing a lining of fireclay bricks at the firemouth roof. In addition, three steel belts are tightened around the circumference of the kiln at three heights, from the firemouth to the top as shown in figure 5.

Figure 5: Belt to improve structural strength of kiln

Savings

The improved design gives savings in both the capital cost and the running cost of the kiln. The reduction in capital cost is owing to the reduction in thickness of the wall and increased porosity leading to reduction in the number of bricks required for the construction of the wall. The flooring in the new design needs 3 layers of bricks as against a single layer used in traditional kilns.

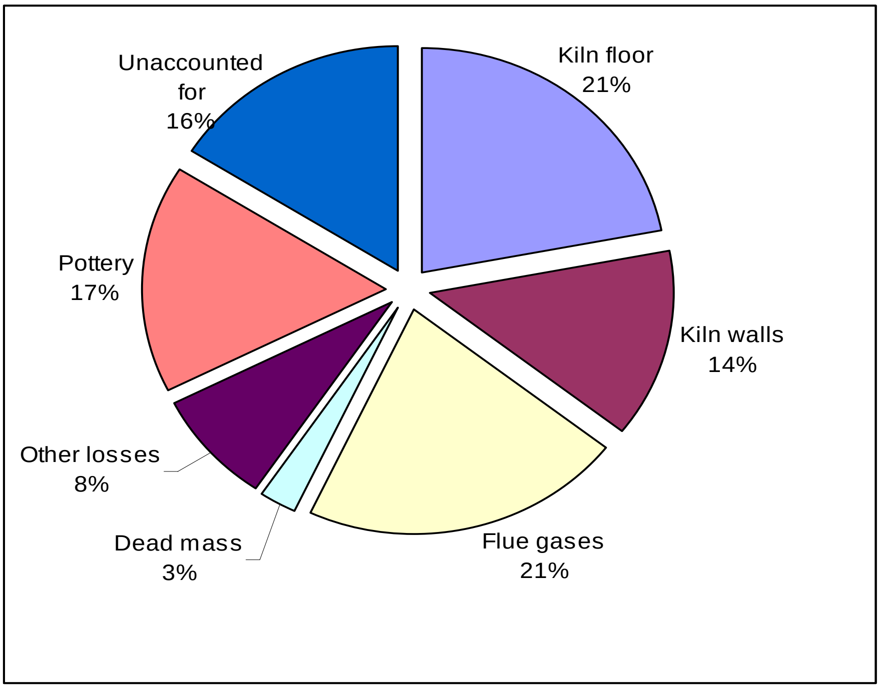

Figure 6. Energy budget of improved kiln

However, the substantial reduction in the mass of the wall more than offsets the increased number of bricks for the floor. For a typical cylindrical updraught kiln of 6' inner diameter and 6' height, the savings in the number of bricks is 32%, amounting to about 1000 bricks, leading to corresponding reduction in construction cost.

The typical fuel consumption in the new kiln has been found to be about 350 kg of wood per 1000 kg of pottery, as compared to about 720 kg of wood per 1000 kg of pottery in the traditional kiln of the same size. The savings in repeated firings have been found to range between 40-60%.

Figure 6 shows the break-up of the energy supplied to the new kiln. It can be seen that the proportion of energy going to the pottery has substantially increased from 7.5% to 16.5%, while those lost to wall and floor have decreased from 47% to 35.5%. Here, it is worth noting that this fraction is out of about 50% fuel as compared to the traditional kiln: i.e., in real terms, the amount of energy absorbed by the walls and floor have decreased from 47% to 0.5 × 35.5 = 17.75%: less than half of the original amount of energy, while that received by the pottery is 0.5 ×16.5 = 8.75%, increasing from 7.5%. Since all these measurements were made in the field with limited instrumentation, the unaccounted for energy is a substantial fraction of the total energy supplied.

For further information, please contact

Director
Mahatma Gandhi Institute of Rural Industrialization
JBCRI Campus, Maganwadi
Wardha, Maharastra
Phone no: 07152-240328
Fax: 07152-240328