CHAPTER 7

CONCLUSIONS

7.1 Contribution of the Thesis

Agra exists on the world map because it is home to that glorious epitome of architectural splendor; the Taj Mahal. The Taj a world heritage site and has been a jewel in Agra’s fabled history and is today the harbinger of numerous employment opportunities for the natives. However, there is a dark side to this story; what is hailed, as the symbol of love has become the nemesis of all industrial set up in and around Agra. Agra was once known for its large no of cast iron factories in India. More than 300 Foundries and allied industries were running earlier. Coke was burnt in the Cupolas to melt the iron, Burning of the coke during the melting process caused pollution. Cast iron foundries facilitated the establishment of industries manufacturing diesel generator (DG) sets and parts of DG sets were exported to England,and Middle East. Thus, Agra gained lot of industrial importance and the business was flourishing. While the business was in full swing, environmentalist Mr. M.C. Mehta filed a petition in Supreme Court to close the polluting foundries to save the World historical monument, the Taj. After a number of hearings in the Supreme Court, considering the reports from appointed committees and research organizations, finally Supreme Court issued the notification of closure of foundries in the year 1996. In concurrence to the orders, the polluting foundries of Agra were closed by 31st December 1997 which created a social and economical disturbance in Agra. This disturbance forced Government of India to take some steps and a number of research organizations such as Tata Corf, NML Jamshedpur etc. were called in 1997 to explore the ways to alternative melting technology, which has low pollution and is within CPCB laid norms. The melting techniques proposed by these organizations were of high cost. Therefore, these alternatives were not adopted by the foundries. Due to these unfruitful measures taken by Government of India, the problem continued. In view of the Supreme Court’s verdict on MC Mehta’s case, various alternatives were suggested by
Varadarajan committee and Mahajan committee, for the survival of small-scale foundries of Agra. One of the suggestions made was shifting the polluting industries to an area outside the TTZ and government had allotted plots to several industrial units. But not many industries shifted out of Agra because of the heavy involvement of finances and non-availability of land as per the choice of the foundry owners. The second suggestion made was the use of natural gas operated gas fired cupola. The other notable recommendation was setting up of green belt development plan around the Taj Mahal to save it from the effect of pollution.

A number of foundries did nothing about relocating or switching to natural gas. According to the representatives of Agra Foundries Association, the basic equipment for the gas fired cupola costs between 45 to 55 lacs which is beyond the scope of large number of the small scale units. Also there was a serious problem of gas supply by Gas Authority of India Limited (GAIL). It has been reported that a number of foundries have deposited the requisite money to GAIL for the supply of gas connection but have not been able to get the gas connection till date. Also fixing up suitable scrubber, cyclone or bag filter along with the dry or wet arrester to reduce the particulate emission level was costing a lot.

This ban created a need for the use of advanced scientific design of the furnace and a suitable fuel having low pollution contents very well within the limits laid by CPCB. This solution should not only satisfy the environmentalist by protecting the grand Taj Mahal, but also regain the lost pride of Agra for its foundry works without affecting human health. Noticing the problems faced by foundries in general and Agra in particular the study was mainly concentrated on cast iron foundries of Agra. In this thesis an attempt has been made to find such an alternative melting technique which enables to rehabilitate the foundries without affecting the grandeur of historical monuments particularly, the Taj Mahal. When this method is adopted by the foundries of Agra, the past glory of the foundry industry in the city is again restored. The problem of excessive pollution has assumed a national character and foundries in West Bengal, Gujarat and Maharashtra
are also facing closure. It is further expected that if suitable steps are not taken, all foundries using coke-fired cupolas across the country will have to be closed due to restrictions by the CPCB and increase in public awareness. Therefore, the alternate melting technique adopted in this research can be planned to be adopted in other parts of the country, so that they may not face the critical situation as faced by the foundries of Agra, and solution of coexistence of foundries, human being and historical monuments is evolved systematically. For this, a detailed survey of production, growth, consumption and export orientation of castings in India and abroad with special attention to Agra is discussed. Foundry clusters in India their foundry products and the melting technique adopted have been observed. After conducting a regressive survey of Agra foundries an alternative amongst the possible alternatives has been suggested. Possibility of using the alternative fuel for minimizing the pollutants and cost has also been tried. Experiments were carried out on the selected alternative with suitable modifications and alternative fuel and its blending with other fuel for cost reduction. The experimental results were analysed and validated using state-of-the-art computing techniques. While proposing the alternative melting technique, the affordability and ease of adaptability is also considered.

7.2 RESULTS

After performing a large number of experiments, using the parameters influencing melting of the charge in the rotary furnace it has been observed that the use of circular ring burner in place of conventional burner results in 40% to 51.22% fuel saving at different levels of blending ranging from 10% to 50%. But at 50% blending fuel cost is high and the flame temperature is lower, so, at 10% blending about 40% fuel saving is observed. It has been further observed maximum melting rate and lowest fuel consumption is obtained when the furnace was rotated at 1 r.p.m. with 10% excess air, 400°C preheat air and 10% blending of biodiesel with LDO. A substantial amount equal to the Rs.43,12,400/- is saved by using the modified furnace working with specified parameters in place of
**conventional rotary furnace.** Modified furnace having circular ring shaped burner, heat exchanger, a chimney with a baffling system rotating at 1 r.p.m can produce 2000 kg. of castings from 10 heats instead of 4 heats in case of conventional furnace due to increase in melting rate. This may increase the **profit to as much as 250%**. It has also been observed that during the melting process carbon losses are found. An intersting study for carbon losses has been conducted for grey cast iron and SG iron production and concluded that 20% loss of carbon is found. So, it is suggested that during the melting process **20% additional carbon is required in the charge as per the requirement of carbon percentage in the castings.** By adopting the modified furnace, high melting temperature can be obtained that enables to produce high quality S.G. Iron. The grey cast iron and S.G iron produced has the desired mechanical properties viz., tensile strength, percentage elongation and hardness obtained by varying percentage of carbon, which is also evident by the element compositions in sample castings of grey cast iron and S.G iron and producing long grey flakes or nodules. The detailed microstructure studies of samples produced during experiments using ‘Biovis Materials Plus’ image analysis system also confirm the production of **graphite ranging between 16-19%** with maximum flake area, well distibuted **graphite flakes of different sizes covering up to area of 20% and having good machinability.** It has been found that inclusions of sulphide and oxide during the solidification process are totally avoided in the newly modified furnace. The problem faced by Agra foundries regarding the hardness and difficulty in machining of casting is solved by producing the casting with modified furnace.

The problem of air pollution which was the root cause for the closure of the Agra foundries to save the Taj Mehal, is also dealt in details. Many experiments at varying levels of input parameters were conducted using blends of bio-diesel with LDO and natural gas. It is observed that by adopting modified rotary furnace for iron melting the air polluting elements i.e., sulphur dioxide (SO$_2$), nitrogen dioxide (NO$_2$), SPM and carbon monoxide (CO) are found at levels much below the norms laid by CPCB. When the optimum input parameters of melting to achieve high melting rate were
considered, the pollutants are totally controlled. While using natural gas the pollutants are found lower than in the case of bio-diesel blended with LDO.

In today's scenario of competition, industrialist wishes to have a soft analysis or a model that could simulate the actual working furnace to visualize the efficiency and the applicability. The modeling and simulation is also used for checking the impact of one or more parameter over others. In this thesis, the results of experiments were used in determining the value of input parameters for optimizing the outputs using the state-of-the-art soft computing techniques. Three models viz., regression model, ANN model and Neuro fuzzy model are presented for modeling and simulation of the furnace, considering seven influential parameters.

The results of experiments were used for the purpose of modeling and optimization of furnace parameters. State-of-the-art soft computing technique were employed for determining the value of input parameters viz., percentage of excess air, speed of rotation, degree of air preheat and melting time for optimizing each of the outputs i.e. melting rate, flame temperature and fuel consumption. The experimental observations of all the seven parameters influencing the melting process have been used to develop three models using the concept of artificial intelligence using Levenberg-Marquart (LM) approximation in artificial neural network (ANN). The models accepts four input parameters and generates three output parameters viz., fuel consumption, melting rate and flame temperature. Model developed gives estimated values very close to experimental value with a variation less than 5%. Similarly, from Regression model and Neuro Fuzzy model estimated values obtained are very close to experimental value with a variation less than 5%. The input parameters were then optimized using the Guided Evolutionary Simulated Annealing (GESA). Neural Network model (trained using a series of experimental results), serves as fitness function and applied here as input to GESA. It is observed that the optimal process parameters and melting rate closely resemble with the experimental values. GESA determined the optimal process parameters while maximizing the melting rate. Similar results are obtained while Neuro fuzzy model is used as fitness
function. Interactive ANN was also used for optimizing the parameters in forward and reverse direction.

Good performance of the furnace alone cannot be the criterion for adoption of the melting technique by the small-scale foundries, cost of the melting also plays an important role. The cost of melting is influenced by the capital cost, operating cost including the maintenance and labor cost. The cost of melting, which is of crucial importance has been dealt in detail. Therefore, the economics of four possible alternatives of melting viz., LDO-fired coke-less Cupola furnace, gas-fired Cupola furnace, coke-fired Cupola and bio-diesel fired Rotary furnace had been studied. Economic analysis has shown that modified bio-diesel fired Rotary furnace is most suitable as the cost of the casting produced is lowest. Considering the initial cost of furnace, it is observed that if the amount to be invested for purchase of gas fired cupola in place of modified rotary furnace is deposited in bank, a substantial amount per annum can be earned. Also, melting with modified rotary furnace requires less skilled manpower and utilization of the furnace is very high as number of heats per day and number of days of melting can be increased or decreased according to the requirement. This facility is not available in cupola (gas fired or coke fired). So, modified rotary furnace is most suitable on account of reasons above including cost of installation and operation.

Hence, it has been concluded that a modified rotary furnace fired with blends of bio-diesel and LDO is an energy efficient, eco-friendly, affordable and proposed for small-scale foundries of India and Agra in particular based on technical and economic considerations.

Results from the experimentation were analyzed and validated using statistical analysis. Regression analysis had been done to study the effect of “rotational speed, melting time, preheat air temperature, excess air and flame temperature on fuel consumption”. Test of significance (student ‘T’ test) was used to test the hypothesis in all the above cases. It has been found that all the hypothesis favour our results. The affordability and ease of adaptability is also considered while proposing the alternate melting
technique for small-scale foundries. The statistical analysis is discussed in detail in appendix C.

Present research will also be of great use if its outcome could help the government and concerned authorities to develop guidelines that are more specific. This thesis is based on the self-designed, developed and modified rotary furnace, using innovative features.

### 7.2.1 Innovative Features

1. Installation of compact heat exchanger (for increasing the efficiency by considerable heat recovery) and chimney with a baffling system (to arrest most of the pollutants from the waste gases and with basic refractory lining) in the rotary furnace.

2. Specially designed circular ring burner with six holes on its periphery to save substantial percentage of fuel as compared to conventional burner.

3. 20% of excess carbon must be added in the charge to get theoretically required carbon percentage in the casting.

4. Low cost small sized Rotary furnace can be effectively used for the production of S.G. iron in a clean and eco-friendly environment.

5. Slow rotation of the furnace causes homogeneity resulting to better heat transfer hence resulting into good quality castings in an eco-friendly environment.

### 7.2.2 Applications Potential

The Research work has a very good long term or immediate application potentials;
7.2.2.1 Long Term

i. Government should make new policies for ensuring availability of bio-fuels at cheap rates that can make the bio-fuel fired rotary furnace to act as panacea of ailing small-scale foundries.

ii. If the natural gas is available to the foundries in abundance and a certain amount of subsidy is given to them, then the gas-fired Rotary furnace will be a boon in this field of application.

7.2.2.2 Immediate

i. Revival of the foundries in Agra keeping the view of low finance conditions and fulfilling the CPCB pollution norms.

ii. Suitable for small foundry owners who cannot invest much to install units like Laser and Induction furnaces.

iii. The possibility of the development of the high temperature of the melt, which will make the Agra foundries possible to produce the ductile iron castings at competitive rates.

iv. The quality of the castings at the competitive price can cater to the needs of the global market.

v. Production of castings in a clean and healthy environment.

vi. To rejuvenate the Iron foundries to produce their castings again in TTZ.
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