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Entrepreneurship: Innovation through Root Cause Analysis for Process Problem Solving–*A Case Study*

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Introduction

Energy Conservation efforts plays the central role in evaluating the efficacy and cost of climate change policies. Ultimately, total greenhouse gas (GHG) emissions are the product of population, economic activity per capita meaning manufacturing or production of goods and services, energy use per unit of economic activity, and the carbon intensity of energy used. Although greenhouse gas emissions can be limited by reducing economic activity, this option obviously has little appeal. Much attention has therefore been placed on the role of improvements of the existing technologies and the development of new technologies. These two parameters can play a major role in reducing carbon emissions and in lowering the cost of those reductions. In addition, the influence of technological changes on the emission levels, concentration, and cost of reducing GHGs will tend to overwhelm other factors like labour productivity improvement, materials productivity, capacity utilisation improvement etc., especially in the longer term. Understanding the process of technological change is therefore of utmost importance. Nonetheless, the task of measuring, modelling, and ultimately influencing the path of technological development is fraught with Complexity and uncertainty as are the technologies themselves.

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In one of the studies sponsored by the Petroleum Conservation Research Association (PCRA) under ministry of petroleum and Natural Gas, Govt. of India, the cluster of glass manufacturing industries in Firozabad was selected for developing and demonstrating some such technology solutions which are very simple and do not need any High-tech or cost intensive options.

The aim was also to develop low cost technological solutions and best practices to be adopted at the workstations of glass and bangle sector, which was highly energy intensive by nature.

About Firozabad Glass cluster

Situated about 40 km eastwards from the Taj Mahal city of Agra, is a very unique and exciting world altogether different from the international glamour of the Taj, but producing equally beautiful products. The glass industry in the town has a 300 years old history and accounts for about 70% of all the glass tableware produced in India, in the unorganized sector and about 90% of the bangles made in India. These industries were using coal as the main source of fuel, which polluted the air quality, especially in terms of particulate matter and sulphur oxides. Many studies also identified that this had indeed caused damage to the white marble of Taj Mahal. Upon a government initiated process, the honourable Supreme Court of India asked the industries to either switch over to the fuel sources from coal /Coke to natural gas which is considered as clean fuel, or get ready for permanent closure. The industry was desperately looking for technical assistance to improve their environmental and energy performance efforts at their premises. Most of the units have since switched over to natural gas as a fuel.

Observations

While a large number of areas needing improvements were identified, it was decided to select a few very critical areas accounting for the major portion of carbon emission in the entire route of manufacturing glass bangles.

A thorough process study was undertaken and critical analysis of the processes and methods was carried out.

The two major areas needing immediate attention emerged as;

1. Frequent failure of pots (used for melting glass)
2. Inefficient and traditional design of furnaces (Talli bhatti and Sikai bhatti) used for intermediate stage processing of glass.

Frequent failure of pots (used for melting glass)

During the discussions with the owners, they were really concerned about the frequency of failure of pots. Whenever a pot fails, it adds to about 2 and half hours addition in the batch processing cycle times. The average cycle time is a typical 16 hours.

A pot furnace is a cylindrical structure, which accommodates between 10 to 12 of such pots. The pots are like tea cups without handles to hold. Each has a diameter of about 3 and half feet and a height of 24″ to 30″.

While heating the raw material (a basic mixture of siliceous sand and chemicals) in these pots, sometimes the pots fail and the whole raw material either flows out (if in liquid form) or is lost (if still under process), depending upon the stage of the batch.

It takes only about a maximum of 25 minutes for the highly skilled team to replace the failed pot with a new pot. However, the process of removing and replacing a new pot involves opening up of one window of the pot furnace. Each window provides access to one pot. fig. 1 and fig. 2 depict the exposure of high temperature zone to the environment. The inside temperature being of the order of about 14500C to 16000C, starts loosing heat at a very high rate to the atmosphere. In this process, the system looses enough heat, which requires about 2 hours and 30 minutes stabilising again. This amount of lost heat is considerable, affecting the profitability of the unit. fig. 3 shows the positioning of a new pot as a replacement.

Fig. 1 The door broken open

Fig. 2 Gaping opening of the section.

Fig. 3 A study of the earlier failed pots

Fig. 4 types of failure of pots

Fig. 5 types of failure of pots

Fig. 6 types of failure of pots

Data collection and analysis

Luckily enough, the unit had a system in place for recording the change of failed pots.The unit owners reported that the maximum pot life was about 75 days. However, to avoid any chance variations, it was decided to consider data for at least six months, i.e. double the period of reported maximum life. The data for 6 preceding months (4-5-2008 TO 13-10-2008: 165 days) was analysed for one industrial unit viz: M/s Durga Glass Works, was gathered (Table-1) for two pot furnaces the company was using, and analysed as follows.

The following table provides the life of the pot in terms of no. of days (column 1), No. of pots failed in Pot furnace 1 (column 2) and No. of pots failed in Pot furnace 2 (column 3).

Table1. Comparative TBF of pots in Furnace No. 1 (12 pots) and Furnace No. 2 (11 pots)- Observation period: (4-5-2008 TO 13-10-2008: 165 days):

TBF (Time between failures) Days	No. of Failures	
	Pot Furnace No. 1	Pot Furnace No. 2
1	0	3
2	3	2
3	1	3
4	0	2
5	0	2
6	2	4
7	8	10
8	3	7
9	3	7
10	8	8
11	2	8
12	6	8
13	9	4
14	2	13
15	4	8
16	4	3
17	3	3
18	5	3
19	1	0
20	3	3
21	3	7
22	3	1
23	4	0
24	4	2
25	1	3
26	1	1
27	2	0
28	1	4
29	1	0
30	1	1

31	3	1
32	1	1
33	0	0
34	2	2
35	1	1
36	0	0
37	0	0
38	1	0
39	1	0
40	0	0
41	0	1
42	2	0
43	1	1
44	0	0
45	0	0
46	0	0
47	0	0
48	0	1
49	0	0
50	0	1
51	1	0
52	0	1
53	1	0
54	0	0
55	0	0
56	0	0
57	0	0
58	1	0
59	0	0
60	0	0
61	0	0
62	0	0
63	1	0
64	1	0
65	0	0
66	0	0
67	0	0

68	0	0
69	0	0
70	0	0
71	0	0
72	0	0
73	0	0
74	0	0
75	1	0
Total failed pots	106	130

Considering the number of pots in the furnace, the furnace no. 2 performed even worse, at about 40 % higher rate of failure. The above data is graphically shown in Charts 1 (Furnace 1) and Chart 2 (Furnace 2). On the X axis is the position of pot in the furnace and on Y axis are the total no. of failures of pots in the observation period.

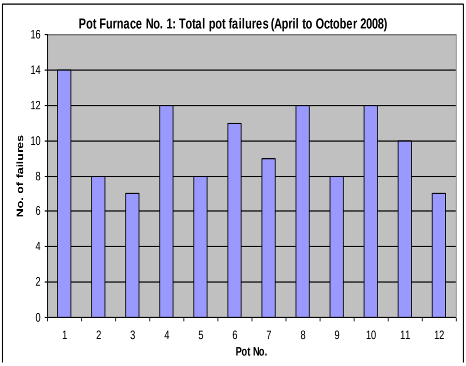

Chart 1

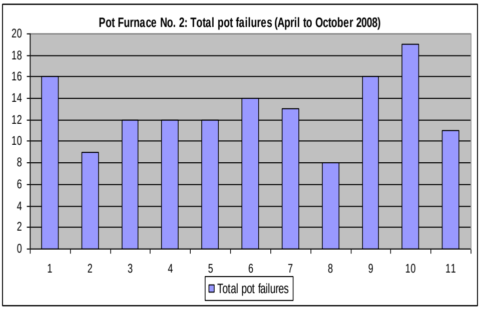

Chart 2

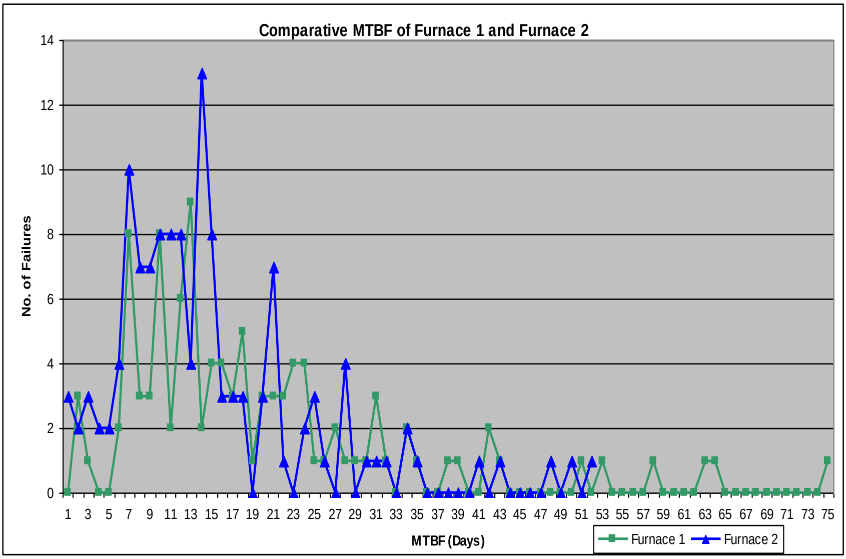

Chart 3 provides a comparative Chart 1 and 2 of pot failures in both the furnaces.

It may be observed that the maximum pot life in furnace 1 was 75 days whereas in furnace 2 it was only 52 days. This helped in concluding that apart from higher failure rate of pots, the pot life also was much shorter in furnace 2 as compared to furnace 1.

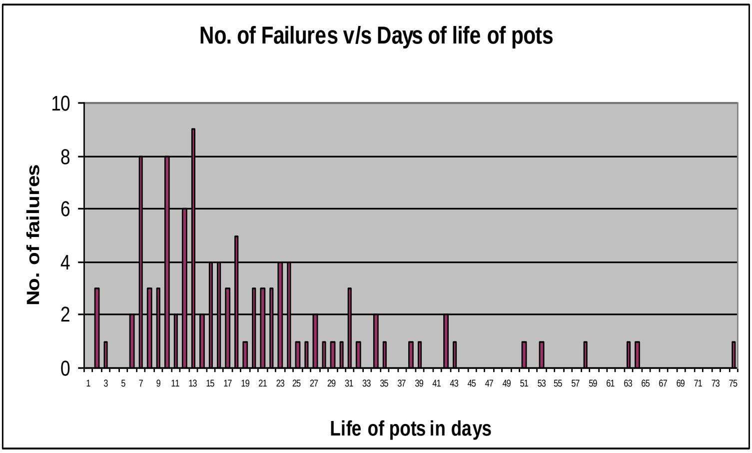

Chart 4. Pot failure frequency for normal and general glasses (Furnace 1)

A further analysis showed that most of the failure of pots was in a time frame of between 5 to 30 days in furnace 1 and 5 to 20 days in furnace 2.

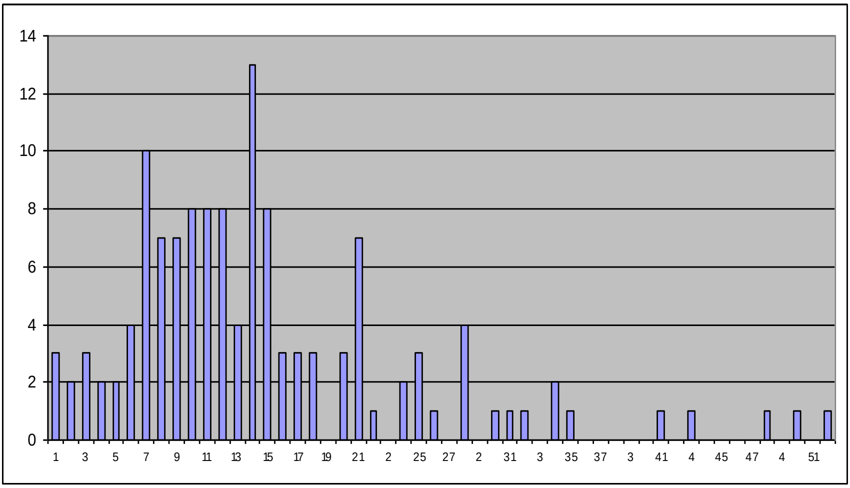

Chart 5. Pot failure frequency for Red Glass. (Furnace 2)

Failure Pattern

The main observations:

1. The frequency of failure of pots in Pot Furnace No. 1 has been much lower than those in Pot Furnace No. 2.
2. In Pot Furnace No. 2, the life of any pot has not gone beyond 52 days, whereas in case of Pot Furnace No. 1 the pots have lived up to a maximum of 75 days.
3. On enquiring about the probable reasons for this happening, it was brought to notice that Pot Furnace No. 2 is always used to produce Red Glass, which has Selenium as an additional ingredient. This is known to attack the pot material by eating it (dissolving) faster. This was corroborated by responses from other units also which are manufacturing Red Glass.

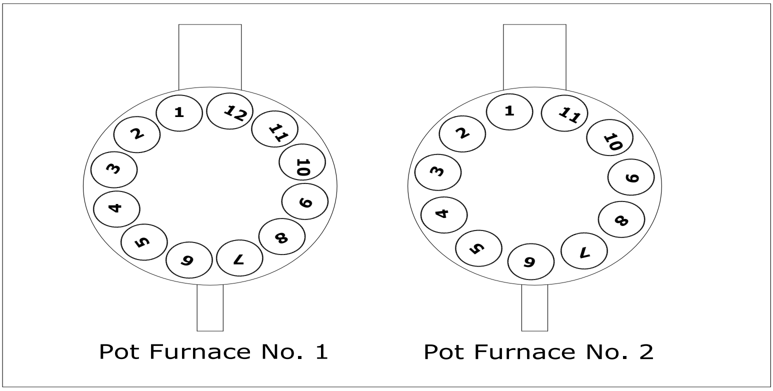

Fig 7. The layout of the pots in the two furnaces

The data gathered was further grouped according to the position of the failed pots. It was observed that most of the failures were in the zone highlighted by the elliptical zones, as in Fig. 8.

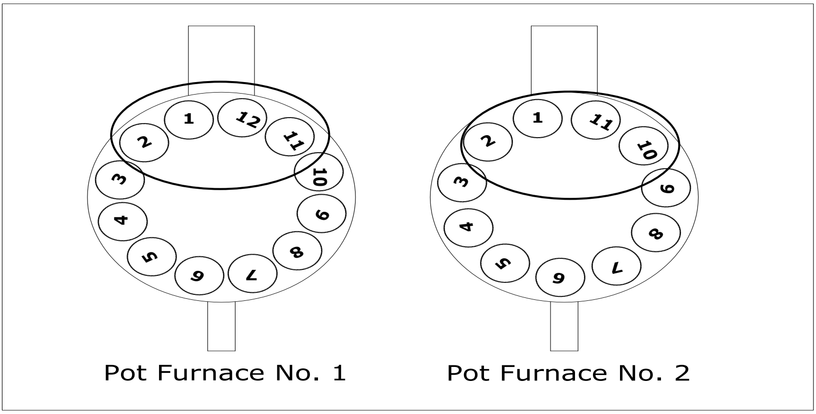

Fig. 8

Understanding the pot making

With a view to understand the process of making the pots, a visit was made to one of the suppliers of the pots. The pot manufacturer was not in a position to provide any details about the composition of the raw material used for the pots, except that he was bringing the raw material from a place named Katni in Madhya Pradesh, known for it’s Lime industry.

Chemical composition of raw material of the pots

Having understood the reasons for higher failure rates of pots as chemical composition of the raw material, it was decided to go deeper in to the chemistry of the raw material, with a hope that perhaps the chemical composition of the raw material of the pot could throw some light. A sample of the material was sent to a laboratory. The following results were reported by the laboratory (Table 2).

Table 2. Results of raw material analysis

Sl.No.	**Parameters**	**Test Results (%)**
1	LOI	7.52
2	SiO2	67.28
3	I R	NIL
4	Al2O3	19.88
5	Fe203	1.00
6	CaO	0.68
7	SO3	0.14
8	MgO	0.60

From the chemical analysis report, it was observed that the major component of the raw material was Silica (SiO_2), standing at 67.28%.

This was indeed an eye opener and a shock. It was realised that Silica is also the raw material for making glass, and that the pot itself contained a major portion of Silica, hence it was natural for the borax power to eat in to the pot material. Added to this, Selenium also was reported to have a high affinity to silica. The reasons for higher pot failure rates in furnace no. 2 became clear. Having realised the fact that the raw material of the pot itself was the cause of the failure, a search for an alternate material was taken up. A series of discussions with the ceramics experts were held, and some suggested materials were put forth. However, the prohibitively high costs of such materials did not attract interest of the owners of various factories.

At this stage, our earlier works in iron and steel foundries helped at this stage. The foundries normally use graphite crucibles for handling molten cast iron and steel. These are also exposed to similar temperatures of 1500^0C to 1600^0C. A set of 2 such small size crucibles were brought from the nearby town of Agra. Fig. 9 shows the graphite crucibles used by the foundry industry. At this stage, the team did not have much information regarding the chemistry of the crucibles or it's probable chemical reactions with various ingredients of glass. Nevertheless, it was decided to try it out for glass making.

Fig. 9

A request was made to the management of M/s Durga Glass Works to help in making a trial furnace to accommodate the smaller crucibles, so that sample glass can be made and the usability of the crucibles can be tested. The management demonstrated it's keen interest and came forward to help. A prototype furnace was constructed as shown stage wise in fig. s 10 through 14.

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 14

Fig 10-14 displays the construction of prototype furnace

Findings

A total of 10 samples of 5 Kgs. lots were produced in the graphite crucible. The quality control department of the company certified each lot. After this experiment, the people on the shop floor of the company, who had 20 to 30 years of experience in glass making, expressed their ultimate satisfaction and said that the crucible material has proved itself and the crucibles will last a very very long time, thereby solving the problem of frequent failures of pots.

Environmental Impact of the Pot Failures

Not only that it adds to the cost of manufacturing, the frequent failures of these pots has its own share of impact on the environment by way of disposal of broken pots, which have very sharp edges and also the corresponding Carbon Foot Print due to excessive use of natural gas, which could have otherwise been used for more productive and value adding purposes.

Concerns of the short life of pots

1. With every failure of a pot, the company loses 500 kgs. of molten glass, as the liquid glass leaks through the cracks and flows in to the sump. This needs additional handling and reprocessing.
2. The opening of the door of the furnace to replace the failed pot exposes the inside of the furnace to atmosphere and the furnace looses considerable amount of heat due to radiation at high temperatures. The corresponding temperature drop inside the furnace is of the order of about 250^{0}C. This takes an additional cycle time of 2 and half hours to bring the furnace to its original state before the failure. The corresponding loss of gas is of the order of 185 SCM (Standard Cubic Meters) of natural gas per pot.
3. The total loss of natural gas per pot failure was estimated at about 320 Standard Cubic Metres (SCM).

The Carbon Foot Print

Considering that the weighted average pot life as 20 days, and that the town has a total of about 1100 pots in operation every day of the year, daily pot consumption in Firozabad were estimated to be about 1100/20 OR say about 55 pots per day. If we consider the low life of Red Glass pots, the figures may as well be about 65 pots per day.

As detailed data for all the glass bangle factories in Firozabad was not available, it was estimated that the average consumption of pots can be safely assumed at about 60 pots per day. This was corroborated by the suppliers of the pots.

This works out to a whopping figure of about 19,200 (320 SCM/pot * 60 pots/day) * 365 or 7,008,000 SCM of gas per annum.

Considering the density of Natural gas as 0.7 Kg. per cubic meter (Methane), this amounts to about 4,900 Metric Tonnes per annum.

Again, considering that 16 Kgs. of CH_4 gives 44 Kgs. of CO_2, this results in to about (44/16)*4,900 OR = 13,490 Metric Tonnes of Carbon Dioxide. At about Rs. 30,000 per tone, the waste of natural gas itself is about Rs. 14,70,00,000 per annum. All this can add to the economy of the town, if only the solution is implemented., and that is a great Carbon Foot Print.

Future course

Having realised that the experimental runs with an alternate material is indeed feasible; the future pots need to be made with the material of the graphite crucibles. Alternatively, even a better glass resistant ceramic material need to be identified or developed.

Next step

A visit to the manufacturers of graphite crucibles in Rajahmundry in Andhra Pradesh was undertaken and discussions with the manufacturers were held. Some of the owners of the units in Firozabad have expressed their interest in using the same.

As this is the first time that any such experimentation was undertaken, the owners of the factories have their own apprehensions whether larger size graphite crucible would perform equally well and whether they are in fact available. The team discussed with some of the crucible manufacturers and it was clarified that the required sizes of the pots can be developed.

Considering the amount of Carbon Foot Print, it is necessary that the policy makers design appropriate and suitable incentive schemes to promote use of such modified materials for pot making.