LEAD TIME REDUCTION IN CUPELLATION PROCESS IN FIRE ASSAYING

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Abstract—Fire assaying, a technique that has been around for centuries, is still the most generally accepted method which is used to determine the purity of gold. In Indian jewellery industries (including big market players like Tanishq), the lead time for receiving the sample from the customer department and declaring the result (purity of gold) is very large which forces the company to outsource the testing activity, which increases the overall cost. One of the key processes in Fire assaying is the cupellation process.. During the study some bottle neck areas were identified and this paper presents the solutions to overcome the same and increase the productivity. In the proposed method individual loading of cupels have been eliminated and bulk loading is introduced using bullion blocks. For this purpose, indigenous equipment multi-loader, an exclusive fork and base plate have been designed. All the modelling has been done using NX 5 CAD/CAM software. This will enable the operators to process 21 samples in one stroke and thus reducing the loading and unloading time considerably.

Key word: Fire assaying, cupellation, multi-loader, bullion block, cupels.

I. INTRODUCTION

This paper presents how the total time of an assaying process in a jewellery industry, where determining the purity of gold which the industry is going to use for their product, can be reduced by improving designs and adding some extra features to the existing tools used in cupellation process. Although if a company incorporates this new design may have to change a bit of their algorithm of working, but reduction of total time, reduced exposure of worker to high temperature and hence high efficiency and better productivity is all estimated by this paper. Assaying process consists of many steps: 1) Planning the samples available for assaying, 2) Preheating cupels, 3) Batch setting, 4) Cupellation Process, 5) Hammering, rolling, annealing and strip making, 6) Acid Dissolution Process, 7) Final weighment and purity Calculation. All these processes in brief will be explained in section II. Section III explains the difficulties faced in the current procedure of this process. Section IV gives a detail of the new design solution. Advantages of the new design is explained in section V

II. ASSAYING PROCESS

In assaying process the samples to be tested for their purity from different department or customers are collected in the assaying lab. While the samples are sent for Batch Setting process, cupels are subjected to preheating in the muffle furnace at the temperature of 1150^{o}C to ensure the uniform melting of samples as they are loaded inside the furnace. In batch setting traditionally 10 samples along with 2 reference samples are weighed and are arranged in particular order. 12 silver beads are added to each gold sample by 2 to 3 times of their weight (0.5gm approx.). Lead foils are cut into square shape and gold samples, silver sheets and copper strips are folded in it. The function of silver and copper is to enhance the solubility of impurities present in the gold during the cupellation process. The function of lead is to absorb the oxides formed by the impurities. In cupellation process all the 12 samples are loaded inside the furnace on the preheated cupels without disturbing their order. Samples melt at the temperature of 1150°C during melting of samples furnace is made to open for some time to allow the passage of oxygen for the formation of oxides. At the end of the process when all the oxides are absorbed by the lead which is then absorbed by the cupels, only gold and silver remains in the sample. Next they are hammered in order to form a thin disc. They are rolled to form a strip which is then punched accordingly for their identification. The samples are then kept in drying furnace and are annealed for 5 minutes. After annealing the samples are rolled such that their identification punch mark remains on front. They are sent for acid dissolution process where they are first treated with 22Be nitric acid which dissolves all the silver in the solution and then by 32Be nitric acid for further purification. The samples are then washed and dried and hence pure gold is obtained. In final weighment and purity calculation the final weight of pure gold obtained is compared with the initial weight of the sample collected and hence the purity is determined.

III. Problems Faced In This Process

In this process, it takes around 3 minutes to load the cupels for preheating, 3 minutes to load the samples on preheated cuples and 3 minutes to unload the samples from the furnace at the temperature of 1150°C, hence the operator is exposed to such a high temperature and poisonous fumes for 9 minutes (3 minutes at a stretch). As 12 samples have to be kept and unloaded one by one in the same order, there are chances of possible mixing of samples or dropping down of molten sample while taking them out. Disturbing the order due to human error is another drawback in this process.

IV. The Design Solution

The above bottle necks lead to develop a new design to load the samples. The new method not only allows loading all the samples in a single stroke but also increases the number of samples to 21.The new design incorporates the use of 21 HB magnesia bullion block, thereby eliminating the use of cupels.

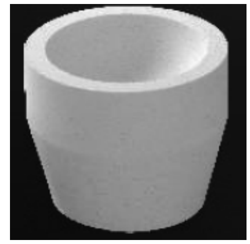

Fig. 1: Eliminating the use of Magnesia Cupel

The use of magnesia bullion block also increases the capacity to absorb lead (than cupel) which is very important for cupellation process [1]. 21 single cupel have a volume of 50cm3 whereas a 21HB bullion block has a volume of 214cm3 (for 21 samples), thereby increasing the efficiency to absorb lead.

The 21HB bullion block enables to load 21 samples without disturbing the arrangement to samples. To load the bullion block an exclusive fork has been designed. As the Bullion block available in the market is beveled on all sides, the fork has been developed to fit the bullion block firmly length wise when lifted up. The bullion block is loaded in the furnace length wise.

The detailed view of bullion block is given below:

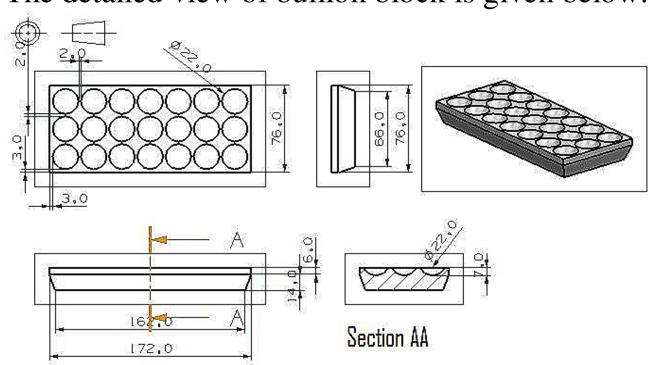

Fig.2: Detailed design if bullion block (in mm) [2]

The fork is so designed that it does not allow the bullion block to tilt of shake. This helps the operator to firmly unload the bullion block after the cupellation process without disturbing the position of the sample. Fork has the beveled face of thickness 5mm. The handle is 350mm, which allows the operator to be at the safe distance while loading and unloading. AISI 446 annealed

Stainless steel [3] is used to manufacture the fork. The detailed dimensions are given in the following drafting.

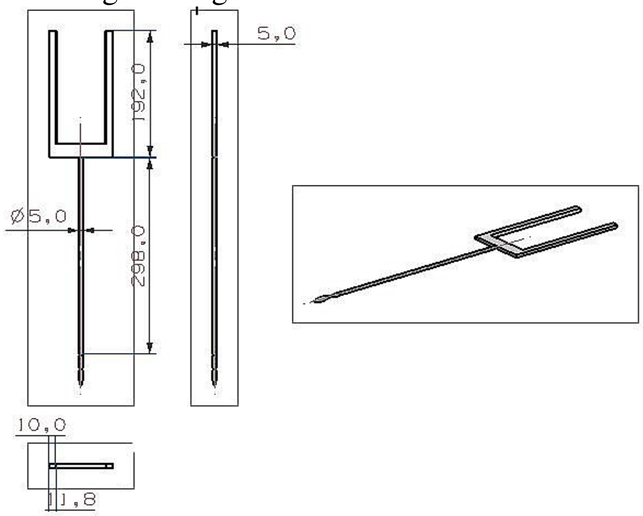

Fig. 3: Detailed design of Fork (in mm)

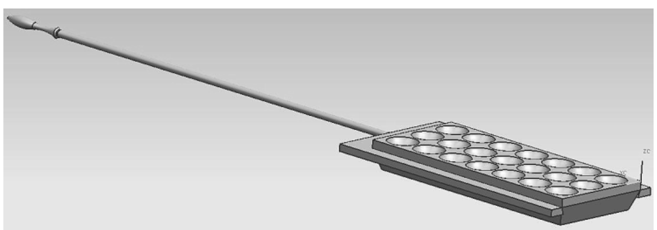

Fig. 4: Bullion block lifted using the exclusive fork designed.

In order to load all the samples in single stroke, a multi loader is designed. For multi loader to align correctly over the bullion block, a base plate is also designed.

The base plate will be fixed to the ceramic doom in the furnace and is made on the same material as that of the ceramic doom in order to withstand the high temperature of the furnace. The base plate is 7mm high and positions the bullion block in the cavity, so as to restrict any movement of the bullion block during the process. The base plate also consists to two guides 5mm each, to position the multi loader in the correct alignment with the bullion block. Here utmost care has been taken to design the base plate because a slight difference in alignment in position bullion block and multi loader will result in improper loading of the samples (disturbing the predefined position). The detailed view is given in the following drafting.

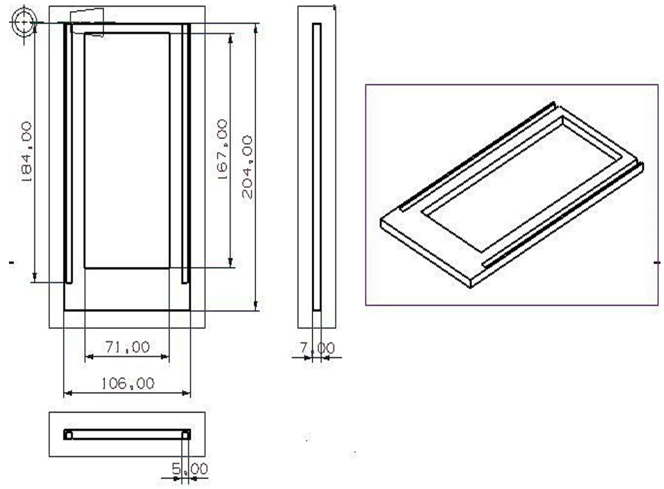

Fig.5: Base plate (in mm)

The multi loader is designed in three parts viz. the base part, the middle plate ant the top part. The base part has legs (to fit in the guides in the base plate) and 21 holes, and guide to insert the middle plate. The middle plate is 1.5mm thick. The top part also has 21 holes and projections which restricts the movement of the samples and allows it to fall only at the correct cavity in the bullion block. The detailed view of all three parts is given below:

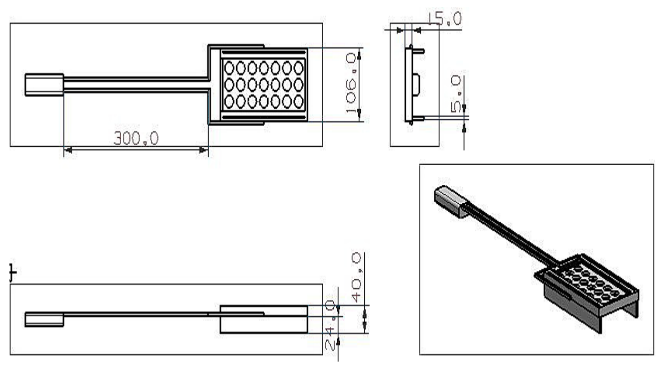

Fig. 6: Base part of multi loader (in mm)

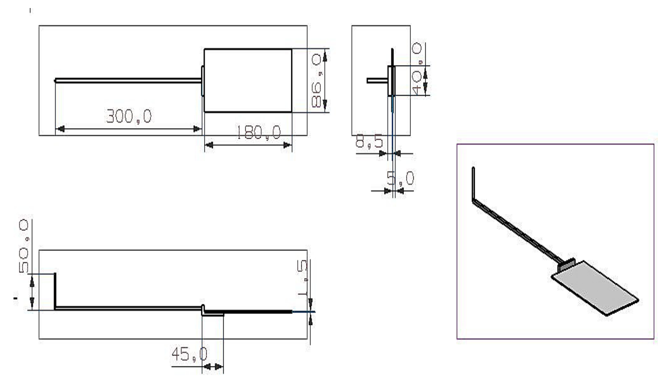

Fig. 7: Middle plate of multi loader (in mm)

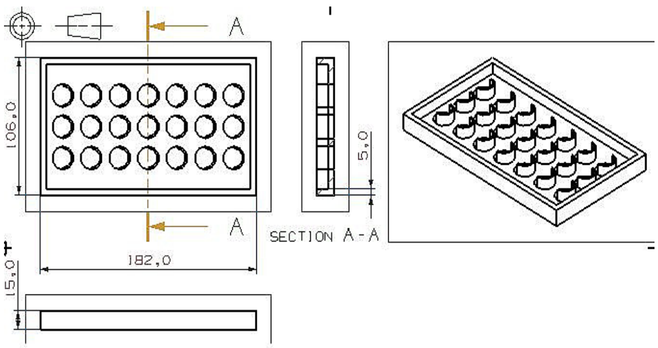

Fig. 8: Top part of multi loader (in mm)

The base part and the top part are made of UNS F23131 cast iron [4] and are welded together. The middle plate is made up of tin sheet and is inserted in the guides in the base part. The legs in the base part guide the multi loader to fit in the correct position in the base plate. The 21 samples are put in the middle plate from the holes on the top part. The middle plate is moved by pulling a handle which makes the samples fall in the bullion block. The handle is 300mm which enables the operator to be at the safe distance during loading. The detailed view of multi loader is given below:

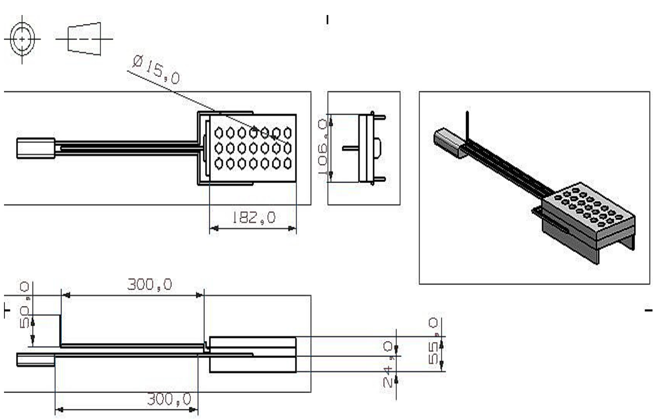

Fig.9: Multi loader (in mm)

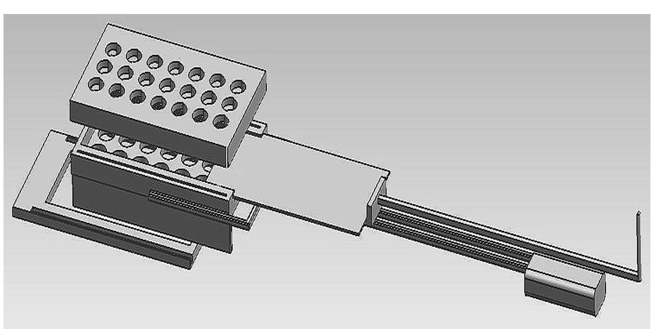

Fig.10: Exploded view of multi loader with base plate

In brief the cupellation process with the new design is given below:

- The ceramic base plate is fixed in the ceramic doom.
- The bullion block is loaded for preheating using the fork.
- The samples are loaded onto the multi loader in the correct order.
- The multi loader is pushed in the furnace and is aligned in the correct position by the help of guides in the base plate. Middle plate is slowly pulled outside which makes the samples fall in the correct position in the bullion block. The multi loader is removed.
- The bullion block with the melted samples is unloaded from the furnace using the fork

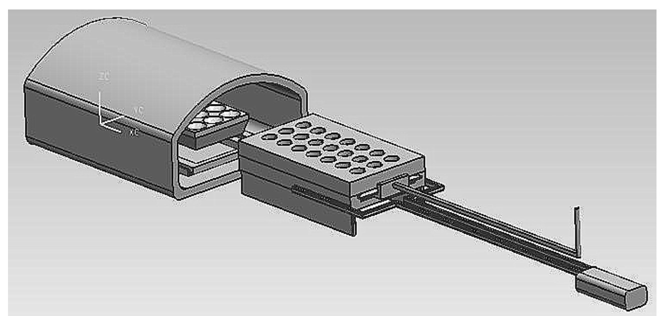

Fig.11: Exploded view completes new design with the ceramic doom.

V. ADVANTAGE OF NEW DESIGN

- Can load 21 samples at a time (instead of only 12 as in the existing method).
- The time for the cupellation process is considerably reduced by the use of multi loader.
- There is minimum error in loading and unloading of samples.
- The operator is not exposed to high furnace temperature and toxic fumes for long durations thereby improving the working environment.
- There is no high investment cost in adopting the new design.

Existing Method*	
Time taken for 12 Samples (in minutes)	
Loading of cupels for preheating	3
Loading of Samples	3
Unloading of samples	3

Table 1: Time taken in cupellation process in existing method.

* The existing method time (Table 1) is taken from, “Jewellery division, Titan Industries Limited, Hosur, India.”

Proposed Method	
Time (max.) taken for 21 samples (in minutes)	
Loading of Bullion block for preheating	0.5
Loading of samples	1.5
Unloading of samples	0.5

Table 2: Time taken in proposed method.

Table 2 shows the advantage in terms of reducing the process time and increase in the number of samples in new method over the existing method shown in Table 2.

VI. References

[1] T.H. Rehren, 'Crucibles as reaction vessels' in P.T. Craddock and J. Lang (eds), Mining and Metal Production through the Ages, 207-15 London: British Museum Press

[2]http://www.infomine.com/suppliers/PublicDoc/RepresentacionesMineras/MaborBrochure.pdf” Mabor brochure.pdf”

[3] Callister, William D. “Callister’s Material Science,” pg 283, 2007

[4] Callister, William D. “Callister’s Material Science,” pg 287, 2007