A NEW HAMMER PROPOSAL FOR COCOA POWDER PRODUCTION USING DFX TECHNIQUES

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ABSTRACT

Cocoa processing involves powder milling and sieving. For this application industrial companies uses, for example, vertical Raymond mills. Cocoa powder is abrasive which wear all internal mill components. To minimize wear effects maintenance people needs to replace frequently some components. Furthermore, each maintenance stop exposes all internal mill chamber to external contamination of cocoa batches. Besides contamination problems, higher number of maintenance stops leads to higher product costs and shorter plant productivity. The main parts of the whole equipment are usually made from cast and steel of high quality. In the recent years some higher wear resistant materials as cemented carbide, were made available. The aim of this paper is to propose a new alternative hammer using this technological leap as well as Design For (DFX) techniques.

Keywords: *Raymond Mills, DFM, DFA, DFE.*

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1. INTRODUCTION

Mill parts manufacturers are looking for higher productivity and performance, while end-users want harder and stronger parts with the benefits of longer wear life (Conner, 1997). To achieve optimum performance, part manufacturers must link advances in materials technology with smart part design to meet the demands of their costumers.

Chocolate production needs cocoa powder with specific mesh to attend the production requirements (available in http://www.indeca.com.br/choco.htm, Mars 2009). Cocoa processing powder is found in some regions around the world. In Brazil, the main region is located in the south of Bahia – Ilheus region. To obtain the specific size powder it is necessary some kind of mills. In south of Bahia region, vertical Raymond mills are frequently used. This kind of equipment processes a large amount of non-flammable and non-explosive materials with humidity lower than 6% in mining, construction, chemical industry and metallurgy. The fineness of the finished product can be adjusted in according to the final customer needs (available in http://www.tradeboss.com, Mars 2009).

The main parts of the whole equipment are made from high quality cast and steel. It is known that these materials suffer high wear level in contact with powder to be processed (available in http://www.raymondmill.biz/Raymond_mill.html, Mars 2009). As a consequence, it is necessary to replace some internal components in order to maintain the equipment in well working condition. To carry out this task well trained work team is called for and enough parts in stock are necessary. On the other hand, the higher the number of maintenance procedures the lower the process productivity. In the cocoa industry, it is very important to decrease the number of stops needed to open the mills. Each time an internal chamber is opened means a contamination possibility.

One of the most important components with high wear level is the hammer for powder grinding. The hammer depicted in Fig.1 is made by carbon steel body with brazed cemented carbide insert. The cemented carbide insert is a material made by tungsten carbide and cobalt (Brookes, 1996; Fernandes, 2002; International ASM, 1995; Schatt and Wieters, 1997; Silva et al., 2001). The brazing alloy is a copper shim with a silver alloy in both sides. From the hammer producer point of view, the production of this piece implies different production lines: one for steel and other for cemented carbide with a problem associated with brazing process.

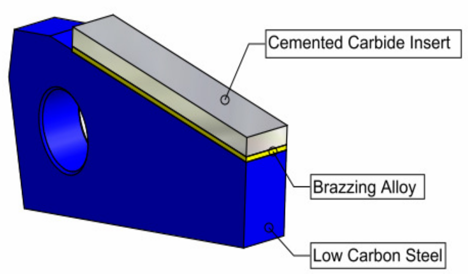

Figure 1. Current hammer for vertical Raymond mill (source: Durit Brasil Ltda).

Based upon on DFX techniques, namely: Design For Assembly - DFA; Design For Environment - DFE and Design For Manufacturing - DFM, this paper proposes an original design, monolithic piece with same geometry manufactured with a single one material with higher wear resistance and produced by just one production line. As a result, the producer eliminates two components and the assembly problems as a consequence. Besides that, it is expected time reducing on logistic processes as well as reducing stock control problems with better delivery time and quality control.

From the costumer point of view, hammers made with single material are safer than the currently adopted hammers, since they might fail in consequence of brazing problems. The reduction in maintenance procedures, logistic work (stock control and purchase orders) raises the plant productivity. The hammer current design made by three components is more difficult to recycle than a piece made by just one component.

The paper is structured as follows: Section Two lays down the necessary theoretical background. The proposed process and how tools are integrated to each other are described in details in Section Three. Section Four presents the application of A-TRM to a case study. Key conclusions and further development are presented in Section Five.

2. LITERATURE REVIEW

It is presented below the main topics which support the design procedures used herein.

2.1. INTEGRATED DESIGN TECHNIQUES

Generally, designers who work at conceptual phase pay no attention in production requirements or assembly problems (Whitney, 1988). This behavior is being changed over time thanks to the Design-for-Techniques and the team approach. With a first draft project all team members discuss the initial idea with intensive inter-action with the different knowledgement areas looking for a better project with lower production and assembly costs. DFA can be defined as a process for improving product design for easy and low-cost assembly while DFM is concerned with the cost and difficulty of product manufacturing (Junior, 2005). The major aim of DFA technique is to simplify the final product with lower assembly cost. By its turns, the major aim of the DFM technique is to find the best production process eliminating, for example, unnecessary steps. To carry out any of these techniques is necessary to analyze the part as a whole and with contribution of different people (manufacturer engineers, materials engineers, designers, quality engineers, just to name a few of them).

In recent years, a new technique has been developed as an answer for scrap control and working life increment. Design for Environment, DFE, aims at preventing pollution and caring natural, no renewable resources (available in http://faculty.washington.edu, Mars 2009). DFE might be sought as an umbrella term which describes techniques used to incorporate environmental demands into products and services before production phase (available in http://www.epa.gov/dfe, Mars 2009). An overlook for new materials with better properties allowing higher life times with a reasonable cost/benefit value is a key issue for successfully implementing this technique. DFE encompasses design for recycling, design for energy efficiency and hazardous minimization.

2.2. RAYMOND MILLS

The whole Raymond grinding mill machine is collocated with jaw crusher, elevator, hopper, electromagnetic vibrating feeder, main unit, classifier, collector, cloth duster and high-pressure blower. Its schematic presentation is shown in Fig.2.

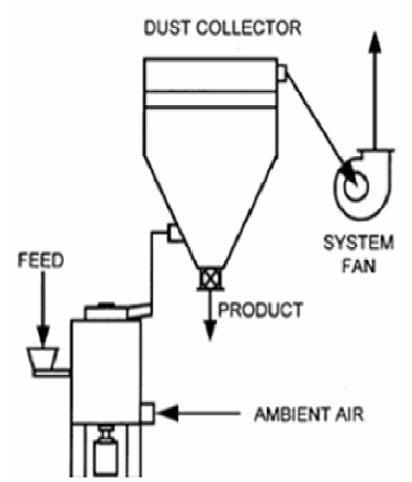

Figure 2. Schematic Raymond process presentation (available in http://www.airpreheatercompany.com, Mars 2009).

The working principle of a Raymond Mill is as follows: load the stuff (cocoa powder, for instance) for grinding evenly and continuously into the grinding chamber of the main frame. Due to the centrifugal force in rotation, the hammer swings go outward and presses closely upon external wall. The stuff is carried to the space between the hammer and external wall. When the hammer rolls, the stuff is thus grinded. After being grinded, the stuff is to be routed to the classifier along wind belt of the blower and the rough powder will be put back to the grinder for regrinding. The fine powder flows into the cyclone collector together with air flow and is expelled from the powder output pipe as a final product. In the grinding chamber, since the stuff contains moisture to some extent, the heat generated during grinding makes the moisture evaporate; since the pipeline joints are not airtight, the external air is sucked in and the circulation air mass increases. In order to enable the grinder to work in negative pressure, the increased air flow is guided to the duster and sequentially to the atmosphere after purification (available in http://www.raymondmill.biz/Raymond_mill.html, Mars 2009). Figure 3 shows the internal overview of a vertical Raymond mill.

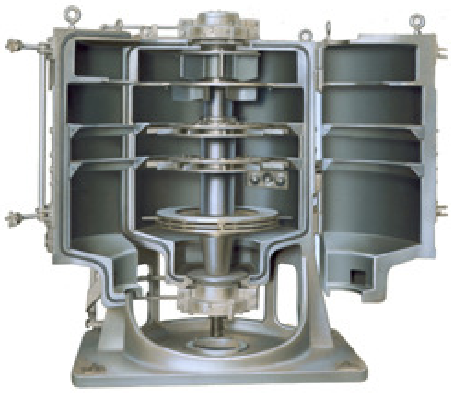

Figure 3. Raymond mill internal view (available in http://www.airpreheatercompany.com, Mars 2009).

2.3. CURRENT HAMMER CONSTRUCTION PROBLEMS

Nowadays, Raymond mill´s hammers are made by hard metal alloys with brazed carbon steel. Hard metal alloys are a typical example of a composite material constituted of a hard phase, tungsten carbide, together with a metal which plays the role of binder. Cobalt is the most frequently used metal (Brookes, 1996; Fernandes, 2002; International ASM, 1995; Schatt and Wieters, 1997; Silva et al., 2001). This material package has a similar mechanical behavior of the concrete: extremely hard and durable in compression, but relatively weak in tension. This composite exhibits high hardness and stands elevated strength levels. Furthermore, hardness and strength can be easily adjusted by varying the alloy´s composition. For instance, the higher the tungsten carbide content the harder is the alloy (Brookes, 1996; International ASM, 1995; Schatt and Wieters, 1997).

Ironically, the dimensional consistency of carbide at high temperatures, in combination with its weakness for tensile stress, is what leads to cracking in the brazing process. In general, cemented carbide brazing is done between 923,15K to 1033,15K. At those temperatures, the expansion rate of steel is several times greater than carbide. During the cooling stage, the melted solder begins to solidify at a relatively high temperature when the steel body is still in a highly expanded state relative to the carbide edge. As the steel cools further and contracts, it imposes a pulling action on the carbide, inducing tensile pre-stress or microscopic cracks that will propagate once the component is in operation (Beard, 1989).

The conventional method of bonding tungsten carbide to a steel support member is generally limited to small sizes of carbide, as there is danger of the carbide cracking because of the difference in the coefficient of thermal expansion between the steel and the carbide. For example, in brazing with silver solder, a temperature of approximately 978,1K is employed so that the brazed parts must be cooled from 978,15K to the room temperature. The coefficient of thermal expansion of carbon steel is approximately $11,8X10^{-6}K^{-1}$ while that of cemented carbide is approximately $5,9X10^{-6}K^{-1}$ or only about half of that of steel. The difference in contraction of the steel and the cemented carbide in cooling from about 978,15K to room temperature is in the order of $5,9X10^{-6}X675$ or 0.00398 mm per mm of component length (http://www.freepatentsonline.com/3599316.html, Mars 2009). Thus, for example, if a platelike tungsten carbide facing member is brazed onto a platelike steel support member, the latter expands more during the heating accompanying the operation than the former. As the assembly bonds together and cools, the steel support member tends to shrink to a greater extent than the tungsten carbide so that the facing has a tendency to bow and become slightly convex on the tungsten carbide side, Fig.4.

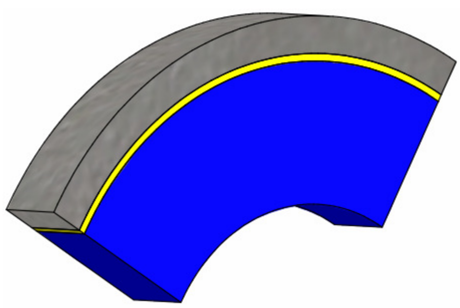

Figure 4. Cemented carbide pre-stress schematic representation after brazing. Blue: carbon steel; yellow: cooper shim with brazing alloy in both sides and dark: plate like cemented carbide insert.

The convexity of the tungsten carbide facing is an indication of internal stresses set up in the facing. The high residual stresses set up in the assembly during cooling effectively weaken the joint strength causing fracture, distortion, and difficulties in machining or grinding to final tolerances. To minimize the brazing cracking problem, a sandwich of very ductile metal (cooper shim with brazing alloy in both sides) is placed between the carbide and steel. This buffer helps to accommodate most of the stresses imposed by the contracting steel – the copper shim deforms during the cooling cycle relieving the stresses. After completion of the brazing operation, the assembly must be kept on programmed furnace to cooling by controlled rate (Brookes, 1996).

3. PROPOSAL FOR A NEW HAMMER CONSTRUCTION CONSIDERING DFA, DFM, AND DFE CONCEPTS

The conventional route to produce cocoa hammers is represented in Fig.5. It is clear that the amount of activities to obtain the final part is too big. Besides that, to guarantee the final quality of brazed hammer it is necessary to certify the brazing process and the operator who drives it. All process involves two different lines: hard metal and steel lines.

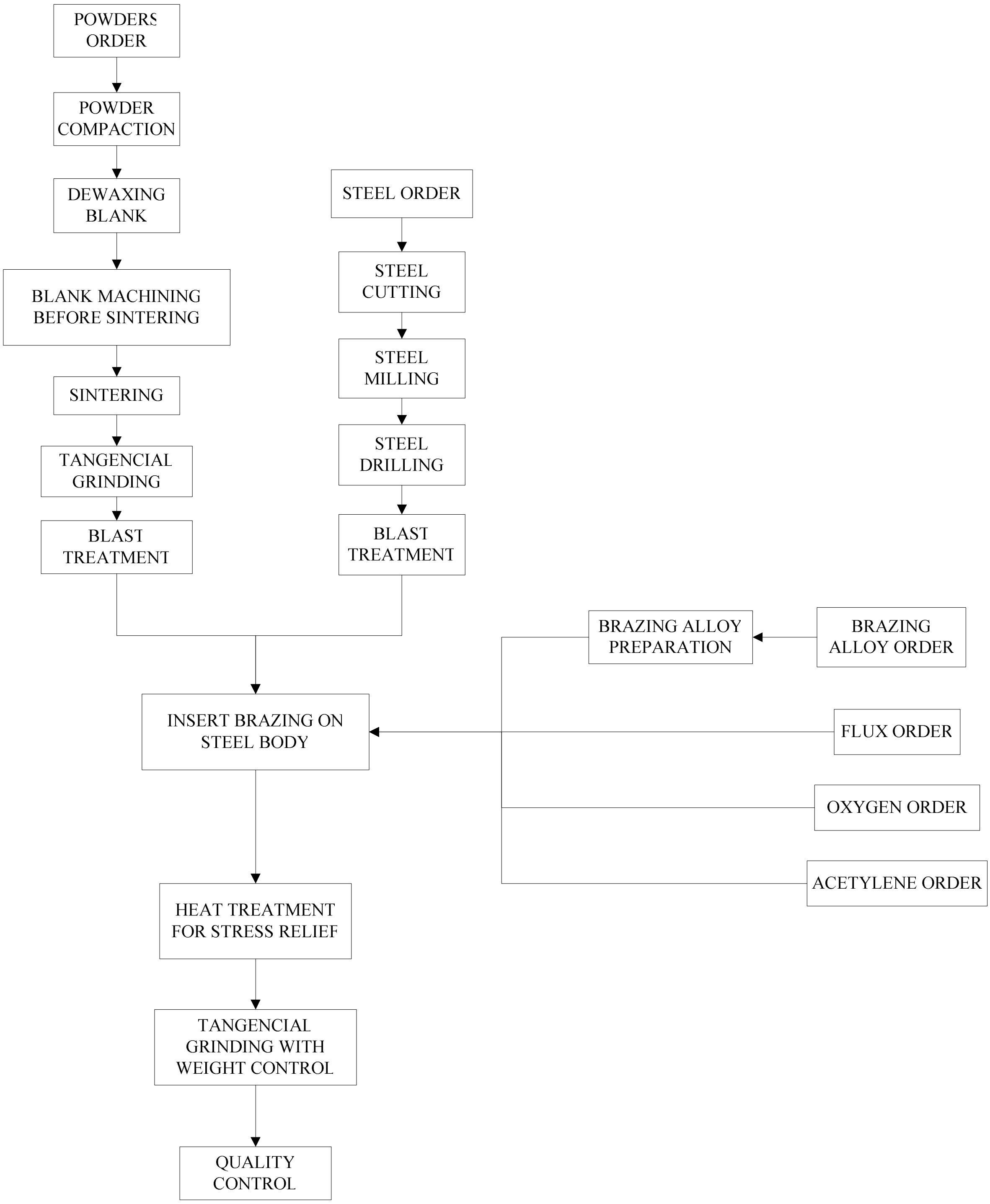

Figure 5. Actual Durit´s cocoa hammer production route involving cemented carbide and steel lines.

The final goal of the project is to delivery a part made just with one material, as shown in Fig.7, decreasing the total amount of production steps – Fig.6.

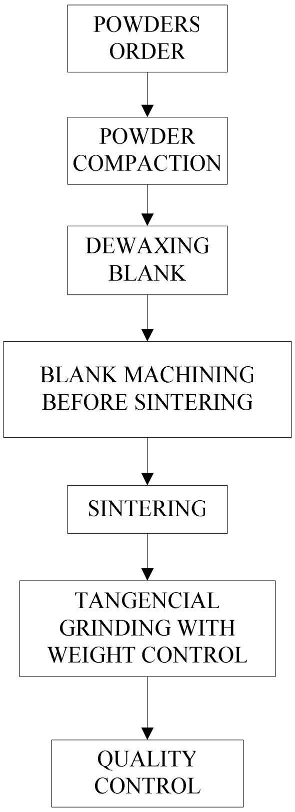

Figure 6. New proposal for hammer production with just one material.

For the new design, the following guidelines have been used:

- DFA: minimize the number of parts – a straightforward analysis carried out by the Boothroyd Dewhusrt (Junior, 2005) criterion points out the minimum number of parts is one;
- DFM: ease the assembly and manufacturing operations: all manufacturing steps from the previous process were replaced by a three major step process: machining before sintering, sintering and grinding;
- DFE: use materials that are environmentally/recycling acceptable (available in http://www.kennametal.com/carbiderecycling/index.jhtml, Mars 2009) and allowed by Food and Drug Administration (available in http://www.cfsan.fda.gov/~rdb/fnea0016.html, Mars 2009): cobalt and tungsten carbide.

With the new concept it is possible eliminate the steel production line with reducing mill cutting inserts as well as drills and oil allowing machine availability to other works and contributing for lower product cost production. One of the continuing challenges in metal machining is lubricant elimination because they are pollutant (Almeida et al., 2005. Belmonte et al., 2004) as well as it has high cost. The brazing process elimination is important to guarantee a safe product. It´s elimination avoids a specific line production which takes time and a well trained employee.

Based on this study, a hard metal manufacturer and a Raymond Mill end user accepted to develop a prototype for real test on a batch campaign.

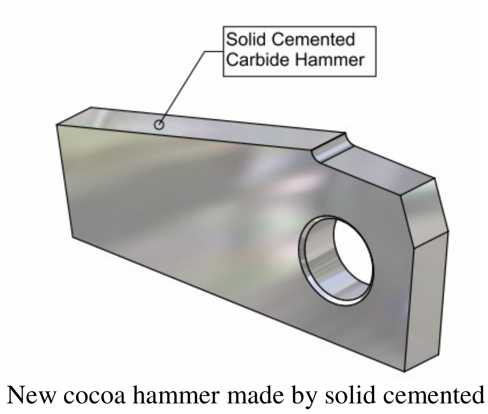

Figure 7. New cocoa hammer made by solid cemented carbide.

To produce the hammer it will be used a cemented carbide grade from Durit Brasil Ltda with 10% cobalt content and medium tungsten carbide grain size as shown in Fig.8.

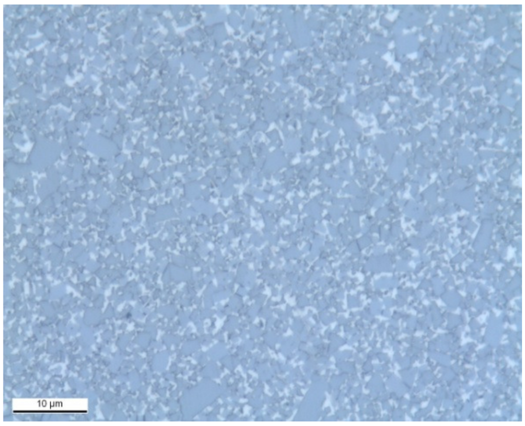

Figure 8. Microstructure of 10% cobalt content grade (source: Durit Brasil Ltda).

4. CONCLUSIONS

The new design will allow to the end-user increment on the productivity with lower un-production time due to hammers lower maintenance requirements. As a consequence of steel part elimination the hammer manufacturer will assist to a steel scrap decreasing. The same is valid for the brazing alloy. With the steel part elimination, insert cutting tool, oils and drills are eliminated as well. Oil elimination plays an important point to environment protection.

The end user will receive a component which allows more working time without replacement increasing the plant productivity: lower purchase orders, lower time for stock control, lower maintenance times, lower probability of internal chamber contamination and easier part recycling in consequence of part made with just one material.

5 FUTURE WORK

After final performance results on the end user, it is possible to change cemented carbide grade improving hardness and wear resistance. There are more companies working with powders using hammers made by steel and brazed cemented carbide. After tests and getting a contract for similar pieces, it will possible to confirm the economic feasibility and the reliability development of a new press tool to obtain the part with lower production steps.

6. ACKNOWLEDGMENTS

Durit Brasil Ltda for having accepted to produce hammer prototypes for real test on the costumer.

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8. RESPONSABILITY NOTES

The authors are the only responsible for the printed material included in this paper.