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The Metallurgy of the Brass Craft Industry of Muslim Mindanao

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Abstract

The production of the brass craft articles in Maguindanao and Tugaya, Lanao del Sur was studied and documented. Actual production of castings was observed and artisans were interviewed. Chemical composition analysis of raw materials as well as metallographic analysis of products were conducted.

The centuries old casting and foundry techniques being utilized to produce agongs, kulintangs, and betel nut boxes among others were handed down from one generation to another by the craftsmen. The methods were crude but workable. Most of the raw materials had chemical composition that varied within a wide range: Cu(65-88%); Zn(0-25%); Sn(0-17%); Pb(0-6%). The microstructure of the products also varied from the needle-alpha phase, dendritic alpha solid solution to severely cored structure .

Introduction

The Muslim Mindanao culture features music produced by agongs and kulintangs (Saber,1983). These are percussion instruments made of casted brass. Included also in their traditional material possessions

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are brassware articles like trays, ash trays, lamp stands, jars, plates and decorative items (Madale, 1986).

The brass crafts are produced locally by artisans in Tugaya, Lanao del Sur, which is the acknowledged Maranao metal work center. Seventy percent of its residents are engaged in the brass craft industry making it as a major source of the community income

Brass making is also a traditional backyard industry of the Maguindanaos in Kapimpilan along the Rio Grande in Cotabato City. Natives of the area date the industry as far back as the 15th century (Kalangan, undated). They produce about 30 varieties of traditional products which include kulintang, gador and langguay (ornamental brass), lantaca (decorative canon), kendi (cooking pot), lanoang (jewelry box) and others (Kosain, 1997).

Marketing of the finished products often pass through several middlemen before they reach the market, making the street value several times greater than the manufacturers'. They are sold both locally and at times exported. However, for the producer, the margin of profit is enough only to cover material and labor cost. The Maguindanao group organized a cooperative in 1987 to consolidate the efforts of the producers with a starting capital of P5,000 and 5 full time workers. Monthly gross production value reached as much as P540,000 (Kosain,1997).

The products and design are unique to the Maguindanao and Maranao culture. As such, the brass items can easily be tied up with the tourist industry of the south. If properly enhanced and promoted, it can potentially contribute to the gross national product of the country.

The study investigated the methods of production being employed, the kind of raw materials, and the quality of finished products. Field observation was undertaken as well as interviews. Chemical analysis of raw materials and metallographic analysis of finished products were conducted.

Production Process

The methods of production are crude involving centuries old forging, foundry and casting techniques that were passed from one generation of artisans to another.

A. Foundry practices

The foundry operations in Tugaya and Kapimpilan employ the lost wax process or investment casting method to produce kulintangs, agongs, cannons and containers. It consists of pattern making, mold making, and melting and pouring (Milan ,1975).

Pattern making. Wax patterns are made of candle wax and resin from the sap of the Danglog tree. These are pulverized and mixed according to the required proportions: 1/3 resin and 2/3 paraffin by volume for face and base; 2/3 resin, 1/3 paraffin by volume for design, boss and gating. The mixture is dipped in hot water to soften for kneading. This is flattened manually using wood rollers then cut according to the design requirements. The wax sheets are wrapped around a wooden pattern and joined using kerosene. Figure 1 illustrates the procedure. The decorative design such as the okir is carved on another wax sheet and added as another layer on the face wax. A short side gate or a top gate, which is actually the pouring cup, is also attached to allow for wax removal and for melt pouring. Figure 2 shows the finished wax pattern assembly ready for molding.

Investment shell. The wax pattern is coated by at least two layers of ceramic shell. The "facing" mixture of 1/3 clay and 2/3 charcoal (by volume) is applied gently and lightly on the decorated surface of the wax pattern to a thickness of 1/4-1/2 inch as shown in Figure 3. This is air dried before the second coat of "backing" material, a mixture of coarse sand and clay, is added to a thickness of 1-2 inches. Moisture is removed by sun drying the assembly for 2-3 days (Figure 4a). The wax pattern is removed by firing over charcoal for about 3 hours prior to pouring of the brass melt. Riser and runners are absent. The "gate" serves as the pouring cup as well.

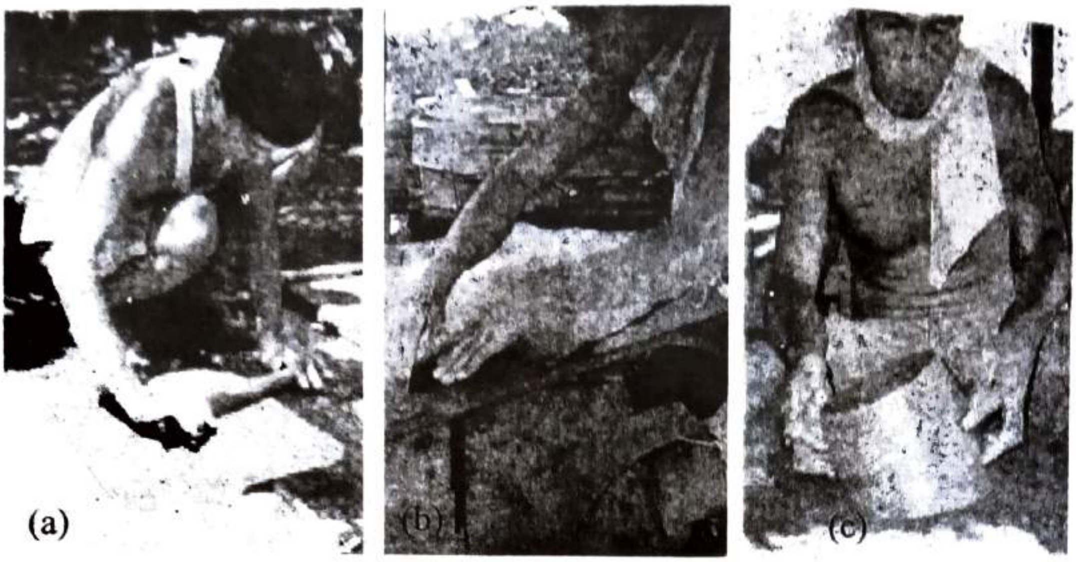

Figure 1. *Pattern preparation. (a) wax pattern sheet rolling, (b) cutting, (c) forming*

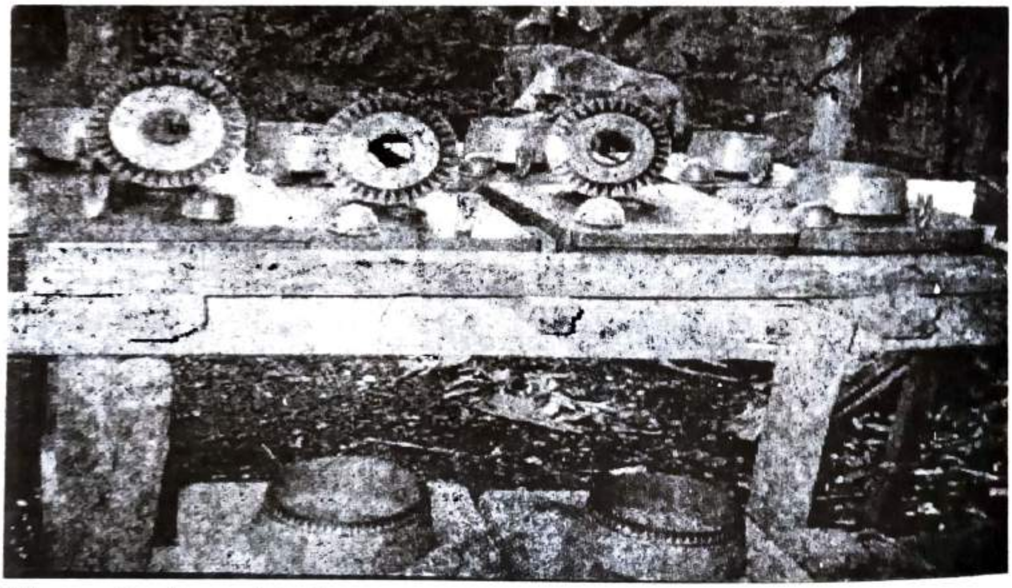

Figure 2. *Assembled wax patterns.*

Melting and pouring operations. Brass scraps are charged in a home-made crucible (Figure4b), made of 2/3 clay and 1/3 powdered charcoal. The filled crucible is placed inside a crucible furnace that was dug, usually in an elevated area as shown in Figure 5a. Charcoal is used as fuel and is placed all around the crucible. Melting period takes about 10-12 hours. Borax or paraffin is sometimes added as a flux towards the end.

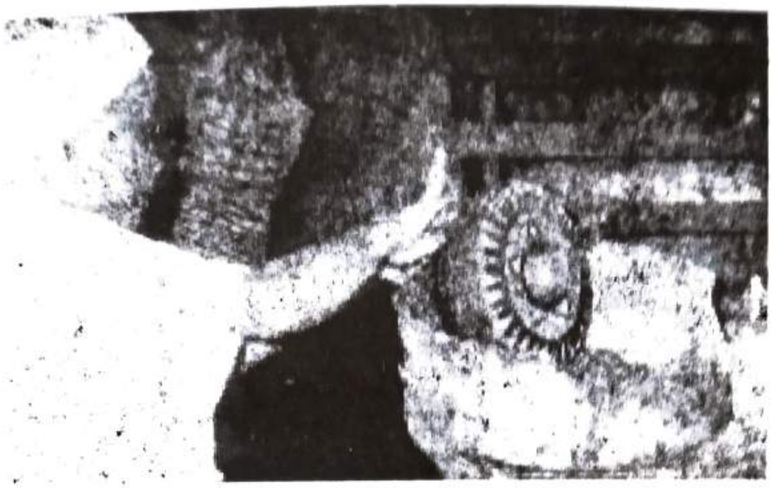

Figure 3. *Application of facing mixture*

Pouring temperature is determined by inserting a metal bar into the melt to test the viscosity. (If the melt does not stick into the bar, then it is ready.) Color , a bright reddish yellow, is also used as a sign of proper pouring temperature. This inadequate method generally leads to misruns and early solidification even before the mold is completely filled.

Figure 5b shows the products being cleaned.

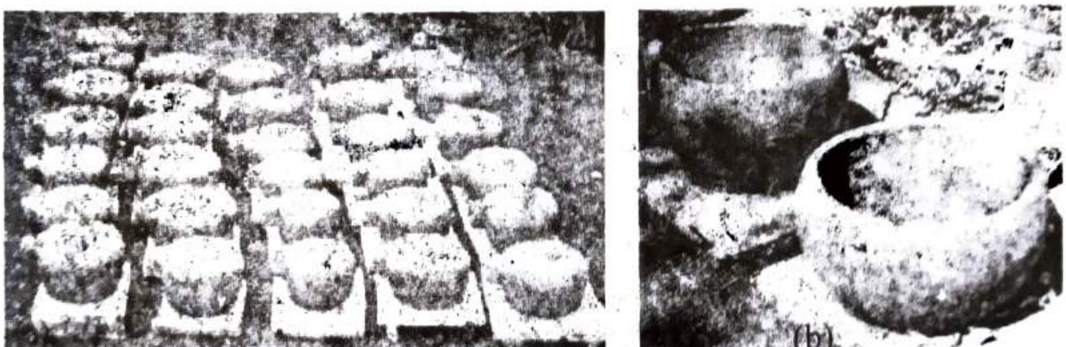

Figure 4. *(a) Sundrying of molds; (b) homemade crucibles for melting scraps.*

B. Forging

The production of the trays, ash trays, lamp stands, and cther decorative items utilizes a modified forging and shallow drawing process. It is termed by the local operators as "stamping." Commercially available brass plates (Seminar paper,1977) are fastened by wires in sets of 2's to 5's and hammered on a pattern or die to acquire the desired shape. The decorative designs are manually engraved utilizing tools that were fashioned by the engravers. Skills and creativity are key to the operations.

Figure 5. *(a) Charging of crucible in the furnace. (b) Cleaning of castings*

Raw Materials

A. Sources

Artisans and operators source their raw materials from the community and the nearby cities like Iligan, Marawi and Cotabato.

The resin from the sap of the Danglog tree are gathered from the locality and sold to artisans (Milan, 1975).

Sand and clay for molds and crucibles are found in abundance along the shores of Lake Lanao and Rio Grande. Tugaya sand is red sand which is ideal for mold making (Madale, 1986). Bamboo and wood charcoal, kerosene, paraffin wax or candles, and oil come from commercial establishments while brass scraps are bought from engineering and machine shops or hardware stores. Supplies, however, are erratic.

B. Analysis of brass raw materials.

The chemical analysis of the brass scraps being utilized by the manufacturers were analyzed using NSC's 750 Atom Comp Vacuum Emission Spectrometer. Table 1 summarizes the results of the analysis for various operators in Tugaya and from Kapimpilan.

Table 1. *Chemical analysis of brass scraps.*

Elements	Stamped sample	Casting sample 1	Casting sample 2	Kulintang sample
Cu	73.310	68.181	65.448	88.132
Zn	25.03	18.445	12.13	0
Sn	0	11.79	16.65	4.548
Pb	0	0.035	3.444	6.168
Fe	0	0	0.159	0.370
Ni	0.031	0.043	0.206	0.520
Al	1.548	1.408	1.956	0
Si	0.084	0.095	0.059	
Mn	0	0	0	0.020
S				0.058
P				0.007

Based on the analysis, the stamped sample can be classified as cartridge or yellow brass according to Table 2. This is the material being utilized to produce trays and other forged or stamped articles. The absence of other elements indicates that the raw material is a commercially available brass plate, the composition of which is more controlled than scrap. There is, however, a noticeable variation in composition for casting samples 2 and 3 which is expected since they come from scrap materials of engineering and machine shops. The composition is closer to the leaded-tin bronze rather than brass. The sample from Kapimpilan is also classified as leaded-tin bronze (Heine,1976). This also confirms Maceda's (1983) study.

***Table 2.** Brass and bronze classification.(Source: Heine, R.W., et al. Principles of Metal Casting 2nd ed.)*

Class	Addition elements
Brass:	
Leaded semi-red	8-17 % zinc, tin < 6%, lead over 0.5%
Yellow	Over 17% zinc, tin < 6%, total aluminum, manganese, nickel, iron, or silicon < 2%, lead < 0.5%
Tin	Over 6 % tin, zinc more than tin
Bronze	
Tin	2-20% tin, zinc less than tin, Pb < 0.5%
Leaded tin	Up to 20% tin, zinc less than tin, lead over 0.5%, and less than 6%

Tin, aside from its corrosion resistance property, also provides the ability to produce musical tones (Heine,1976). Copper alloys with 15-25% tin are sometimes called bell metals, after its primary application (Rubin,1977). Kulintangs and agongs are musical instruments and generally utilize high tin bronzes.

Inspite of the presence of other alloying elements or impurities, control of composition is not given due attention by the operators. Dross is simply scraped off. This may be because the final physical properties of the product are not crucial to its function. The utilization of low grade copper alloy scrap had been known for quite sometime in order to produce complex brasses. However, this was practiced only on a limited scale in order to use scrap (Ellis,1948).

Metallographic Analysis of Products

Metallographic examinations of products were conducted using at least 3 etchants, either solely or in combination of the other to reveal the microstructures: ammonium hydroxide in 3% H_2O_2, ammonium persulfate, and ferric chloride in ethanol.

A. Forged product

Figure 6 shows the microstructure of a sample material used for the stamping process. The presence of a few elongated grains and the nearly equixed grains shows that the metal had undergone cold working and annealing. The brass plate, being a commercial plate, must have undergone the annealing process. The estimated grain size is 0.025- 0.030 mm which is likely to produce a smooth surface (Metals Handbook,1972). Fine grained alloys are used for shallow drawing or forming operations (Allen,1969).

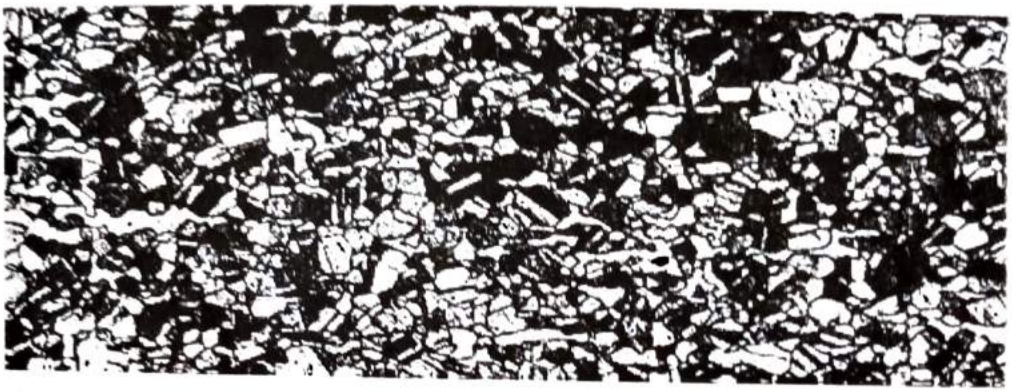

Figure 6. *Stamped tray décor sample, 100x. Etchant:* NH_4OH *with 3%* H_2O_2.

A. Casted product

Microstructures. Figures 7 and 8 present samples taken from a casting producer. Figure 11 exhibits the needle-shaped alpha phase which would generally denote that the material contains manganese and/or aluminum (Metals Handbook,1972). Figure 12, on the other hand, shows a eutectic phase in alpha matrix of the Cu-Zn-Sn alloy (Beraha,1977).

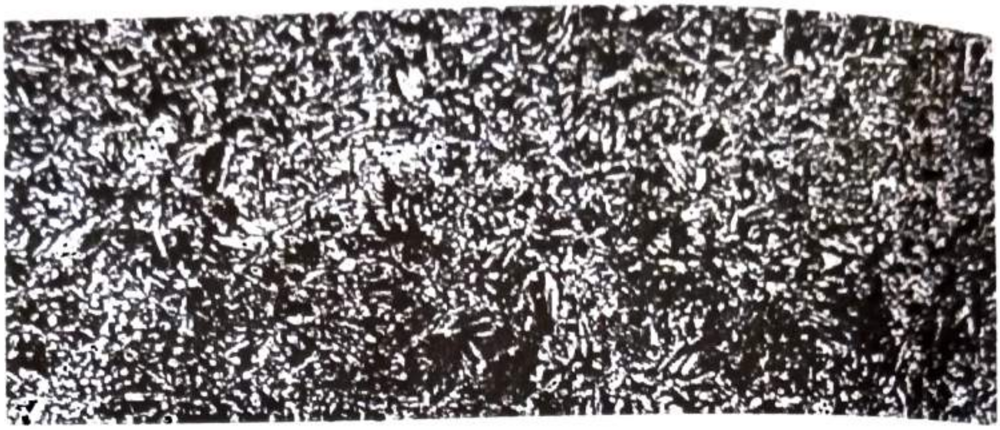

Figure 7. *Casted cup, 100x. Etchant: NH_4OH with 3% H_2O_2.*

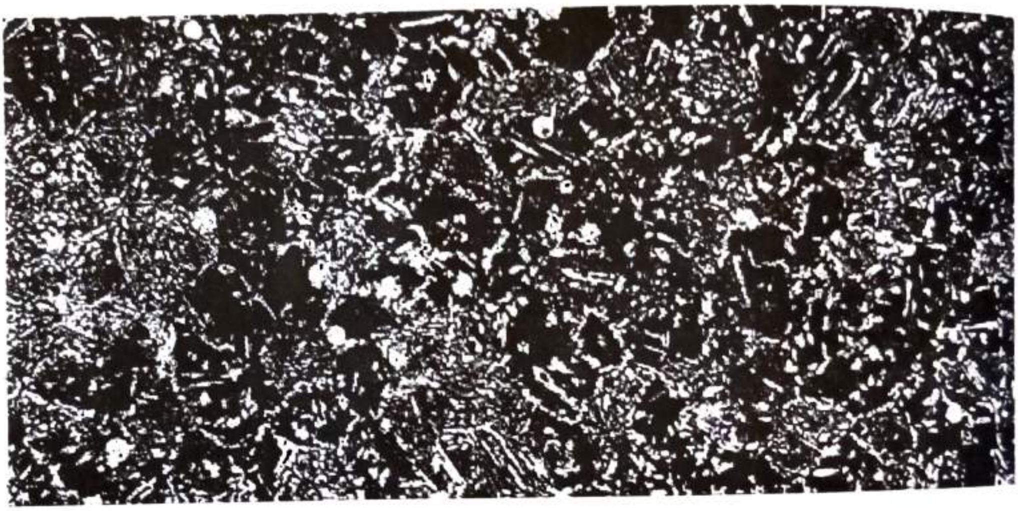

Figure 8. *Bell handle, 100x, Etchant: NH_4OH with 3% H_2O_2.*

Figures 9-11 show samples from the 3rd producer. Figure 9 has dendritic alpha solid solution with coring. This is a characterestic of bronze with high tin content. It occurs because of the long solidification range of tin in copper. It also promotes severe coring (Heine,1976) as demonstrated in the photomicrograph. The coring behavior would present difficulty in risering. Figure 10 shows the delta phase appearing as white islands.

Figure 11 shows what appears to be a dealuminized (Metals Handbook,1972) alloy of aluminum-bronze. Samples of raw materials from the operator indicate nearly 2% aluminum.

Samples from the kulintang parts in Figure 12 also exhibit coring.

The variations of microstructure from the same producer indicate the wide range of copper alloy compositions of the raw materials in the operations.

Figure 9. *Kettle décor, 100x, Etchant: NH_4OH with 3% H_2O_2 and ammonium persulfate*

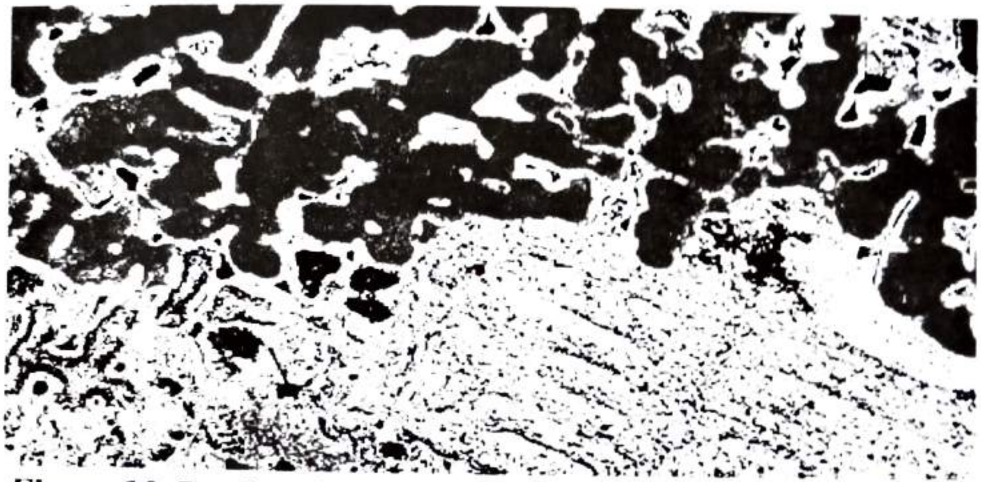

Figure 10. *Betelnut box, 100x, Etchant: NH_4OH with 3% H_2O_2 and ammoniumpersulfate.*

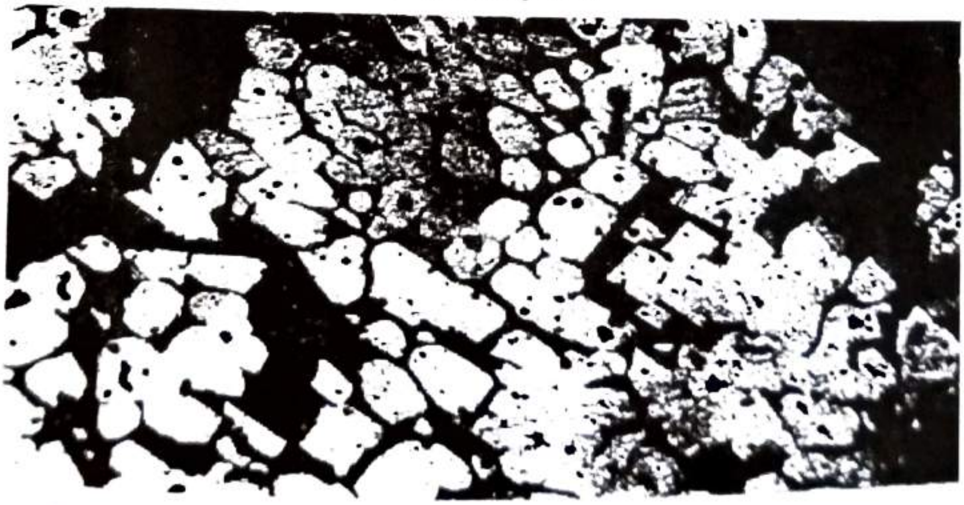

Figure 11. *Bell ring, 100x, Etchant: Ferric chloride.*

Figure 12. Kulintang sample with cored structure. Etchant: Ferric chloride

Casting defects. The photomicrographs in Figs. 13 reveal casting defects such as cracks and microporosities. These defects are due to a number of reasons such as, the absence of proper gating and riser; lack of fluxing agents that will allow degassing and incomplete moisture removal from the molding materials during the sun drying process. The casting practice as noted does not use risers, gates, and fluxes.

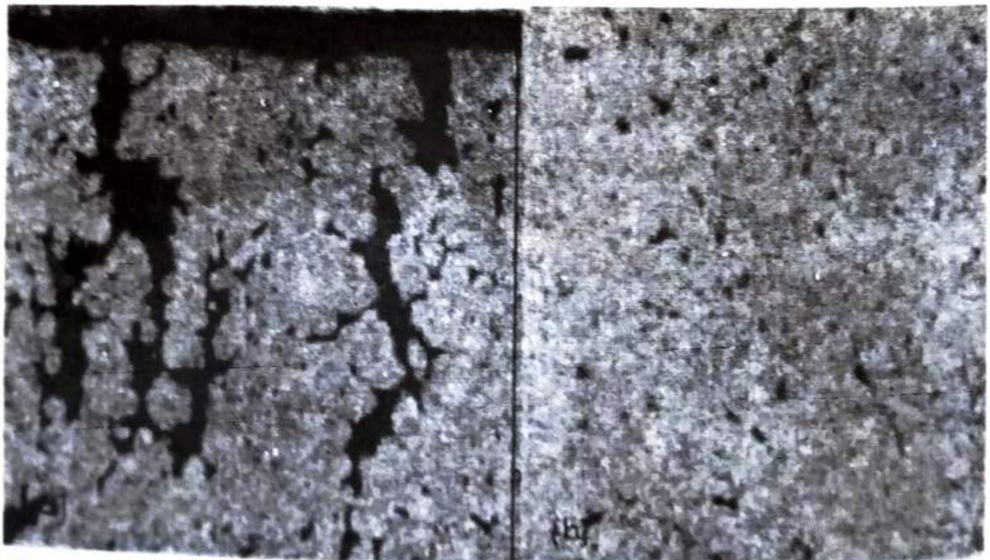

Figure 13. Kulingtan sample showing (a) cracks near the edge, and (b) microporosities. Etchant: Ferric chloride.

Conclusion

The complex nature of the scrap copper alloy being utilized in the brass and bronze foundry processes had produced wide variations in the microstructures of the castings. The study also pointed out the lack of composition control in the operations, while the absence of mold accessories and fluxes created various casting defects.

Recommendations

Studies involving the utilization of appropriate foundry techniques should be conducted in order to improve the processes and operations.

Acknowledgement

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