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Effect of Microstructure of Babbitt Alloy on Frictional Behavior

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Abstract - **This paper aims to investigate the effect of casting method of Babbitt alloy on frictional behavior through tip test technique. Backward extrusion carried out on two groups of specimens manufactured by two different methods; Gravity Die Casting (GDC) and Reheocasting (RC) at constant reduction area for both groups. First group included various punch nose and extruded at room temperature, while second group extruded at three different temperatures with constant punch nose. Also thixo-backward extrusion as a new technique was carried out. Results show that the radial tip distance of specimens of RC was larger than its value for specimens of GDC and clearly increases with the increasing of punch nose especially at punch nose 4mm. But when forming temperature increases the radial tip increases at GDC greater than RC for the same reduction area and punch nose. This means that friction condition larger with RC than GDC. Thixo-backward extrusion indicate that its friction condition and microstructure closed to GDC but its extrusion load was too least compared with other methods.**

Keywords; Backward extrusion, tip test, Babbit alloy, Friction

INTRODUCTION

The friction between the work piece and forming tool is an important factor in metal forming processes. Ring compression test is the well known method in determining the friction condition in bulk forming. Tip test method was proposed by Im et al [1] to investigate friction condition based on backward extrusion process using an aluminum alloy 6061-O and they found that the relationship between the radial tip distance and shear friction factor is linear through FEM simulation. According to tip test technique the level of friction increases when radial tip distance and the maximum load increases.

Kang et al [2] investigated the effect of material properties on frictional behavior by tip test ant they concluded that the increasing of strain-hardening value effected in raise the ratio of shear friction factor between the die and punch interface. Im et al [3] used tip test for various materials and found that the contact of workpiece-die interface lead to friction more than contact of workpiece-punch interface and strain-hardening of the material have important role in this result. Jung et al [4] studied the effect of surface roughness of the punch and dies on friction effect and they found that the tip test can be used to determine the effect of relative surface characteristics on friction behavior and material flow. Chauviere et al[5] used aluminum alloys of 2024-O and 6061-O to investigate tip test with four lubricants VG32,VG100, grease and corn oil and they concluded that the surface roughness of the tool is very important factor in determine the level of friction condition. Ajiboye et al[6] derived dimensionless parameters based on Buckingham π theorem and the data obtained from the tip test experiment through dimensional analysis and they found that the prediction of friction behavior can be obtained by tip distance parameter is the best compared to the load. Jung et al [7] investigated the effect of flow stress on the sensitivity of the downsized tip test and they found that the soft material had shear friction factor and contact area relatively larger than those of harder material. Jung and Im [8] presented equation for shear friction factor prediction related counter punch interface m_{fd} using tip test technique. The current study aims to investigate the effect of microstructure obtained from two different casting method of Babbitt alloy, size nose of punch and temperature on friction behavior in backward extrusion using tip test technique. In addition thixo-backward extrusion was investigated, too.

EXPERIMENTAL PROCEDURE

Material used in this study is 84%Pb, 10%Sb, and 6%Sn Babbitt ASTM B23 alloy 13, was produced by two casting techniques with chemical composition as shown in table(1).

Table (1) Chemical analysis of ASTM B23/13

Element	Sn%	Sb%	Cu%	Fe%	As%	Bi%	Zn%	Al%	Cd%	Pb%
Standard	5.5-6.5	9.5-10.5	Max. 0.5	Max.0.1	Max.0.25	Max.0.1	Max.0.005	Max. 0.005	Max. 0.05	Rem.
Actual	6.03	9.75	0.037	0.01	0.21	0.09	0.009	0.002	0.012	Rem.

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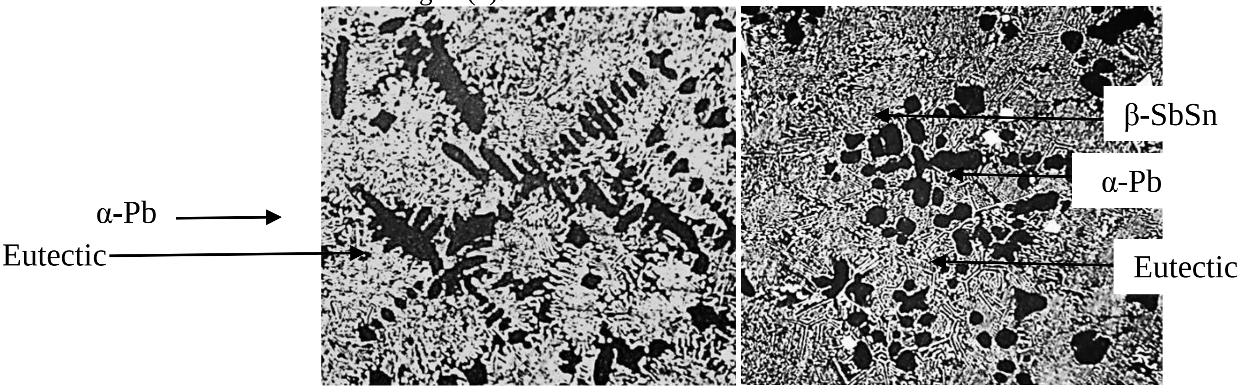
Two casting methods include Gravity Die Casting (GDC) and Rheocasting (RC) were adopted in this study. Microstructure of those methods were illustrated in figure(1).



(a) (b)

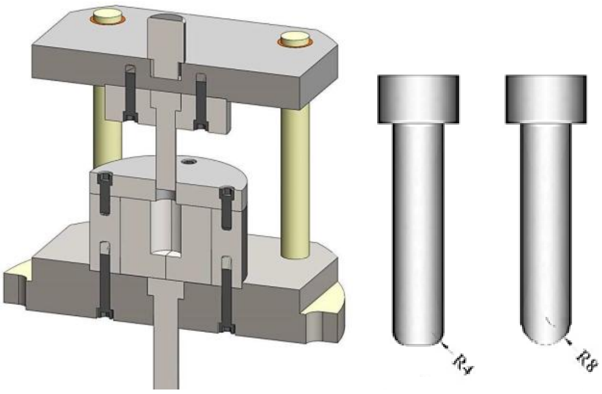
Fig. (1) Microstructure of billet a- GDC b- RC

Results of tensile test for two types of castings and hardness are illustrated in table (2)

Table (2) Mechanical properties of two types of alloy

Property / Material	σ_c MPa	σ_y MPa	El%	HB Kgf/mm^2
Nominal	107	23	5	19
GDC	111	50	18	20
RC	123	76	14	25

Backward extrusion rig includes die and punches of three punch nose radii (0 , 4 , 8). Fig.(2) illustrates this die and punches. All specimens formed at reduction area of 40%.



(a) (b)
Fig. (2) Backward extrusion rig a) Die assembly b) Punches

The billet was reheated to forming temperature using induction system. Two "K" type thermocouples were inserted to monitor the temperature evolution: the first one into the center of the billet and the second one into the die at less than 5 mm from the billet surface as shown in Figure (3).

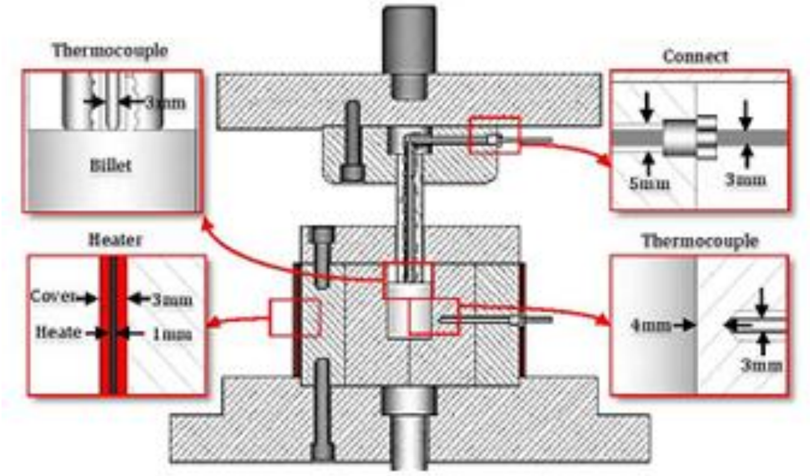


Fig. (3) Geometry of heater and thermocouple

The geometry of product in the backward extrusion of 30mm stroke and examined in this work at is illustrated in fig. (4).

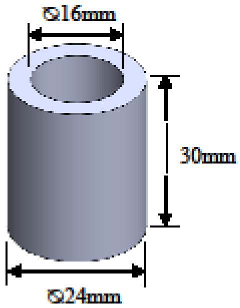


Fig. (4) Geometry of extruded specimens

THIXO-BACKWARD EXTRUSIO

Thixo-backward extrusion was carried out on this alloy at (230°C) when material at semi-solid state.

Backward extrusion and thixo-backward extrusion specimens were cut to vertical sections as shown in Figure (5). Two zones of specimen were examined: the wall and bottom. Each zone of specimen was examined, at 1,2,3, and 4mm from the inner edge.

The procedure of preparation includes wet grinding with emery paper followed by polishing process using alumina suspension with particle size of 0.3µm, and then specimens were cleaned with water and ethanol, and then dried. Then etching curried out with etchant consisting of 75% acetic acid, and 25% hydro peroxide.

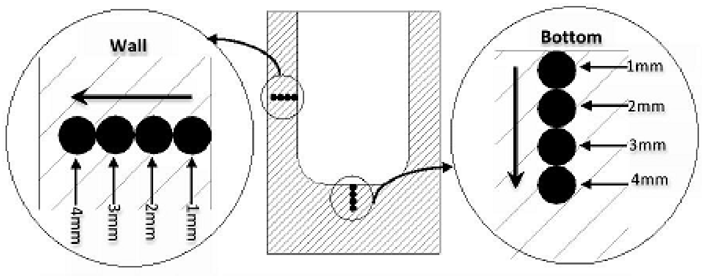


Fig.(5); Zones of specimen for microstructure examination

RESULTS AND DISCUSSION

Table (3) shows the values of radial tip for specimens produced by two casting methods GDC and RC that formed in backward extrusion with three nose radius at room temperature. While table (4) indicates the values of tip distance for two methods casting at three temperature. It is obvious that the values of radial tip of RC samples are higher than GDC for three different nose of punches at room temperature and sample of punch nose (4mm) gave the greatest value. Frictional condition can be estimated through radial tip according to principle of tip test that the friction increases when radial tip increases. It is noticed that the microstructure of the casting strongly affected in the value of tip distance at room temperature and when temperature is raised. Fig.(1) shows the microstructure of two types of billets that revealed dendritic shape of GDC and equaixed grain of RC. The dendritic shape of microstructure affected

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in decrease the friction between billet and die interface also between billet and punch interface through deformation in the backward extrusion greater than equaixed grain shape of microstructure, while this result reversed when temperature is raised (fig.s 7,8,9). Figures (10,11,12) indicate that grain size of GDC is nearly twice the grain size of RC method especially with nose punch (4mm) as shown in fig. (12). Also, it is clear that the values of grain size for punches of noses (0,8mm) closed to each other but with nose of (4mm) the grain size decreased. The nose of punch affected in grain size and friction is changed with variation punch nose and resulted in change of tip distance as shown in table (3). When grain size is fine it means that the surface area of grains increase and lead to increase in contact area between the grains and wall of die in addition to increasing of dislocation density through the forming process. The variation of grain size at different profile of punch for products of two casting method after forming appears (fig.s 7,8,9), especially at contact surfaces between punch and billet.

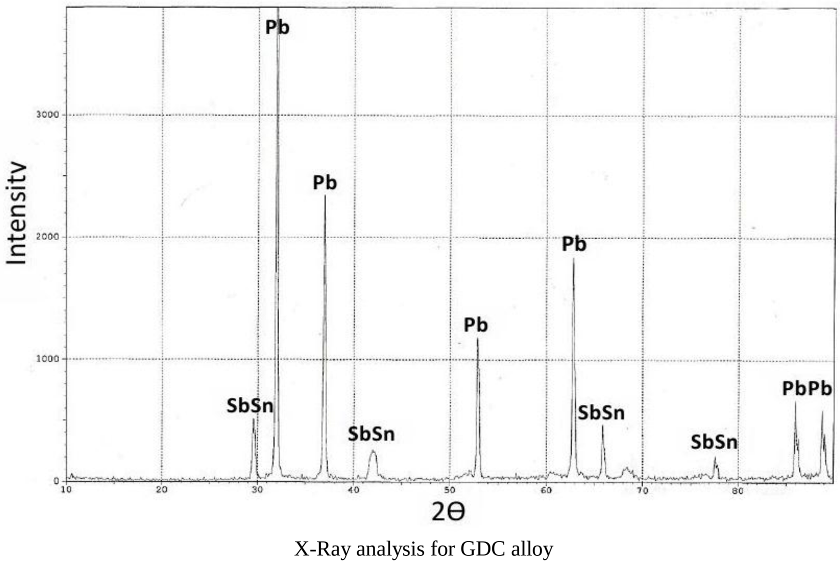
At high forming temperature the value of tip distance changed (table 4). It can be noticed that GDC method gives higher values of tip distance than those of (RC) especially at (100ºC). This means that the large grain size suffers slow deformation at this temperature and causes high friction through deformation. Generally two microstructures give larger tip distance at room temperature than other high temperatures and explanation of this case is the retardation to deformation at room temperature where it is less at high temperature for this alloy.

Thixo-backward extrusion which used with punch of profile (4mm) and the same reduction area was carried out at (230ºC) (semi-solid zone). The microstructure of product of this process was similar to GDC but more homogenous across the section indicated (fig.13). The measurement of tip distance that this value closed to values of GDC at 60ºC,80ºC but the main advantage was least value of maximum extrusion force (1.8KN) compared to the (35KN) at (100ºC) and (73KN) at room temp. (20ºC) for the sample of GDC. The main feature observed for thixo backward extrusion was uniform grain size approximately (fig. 14) while grain size for other (GDC) products, that increased gradually from inner to outside.

The max. load of backward extrusion process coincides with the principle of tip test concept at room temperature that the maximum load increases when radial tip increased at the same punch as shown in (table 3). The maximum load decreases when temperature increased in spite of increasing in radial tip distance (table 4) because of lowering of flow stress at high temperature.

Table (3) Radial tip value of GDC and NRC billets
At different nose of punch

Type of product	Nose radius of punch (mm)	Radial tip(d) (µm)	Max. load (KN)
NRC	0	369	80
NRC	4	918	89
NRC	8	419	98
GDC	0	167	73
GDC	4	686	83
GDC	8	211	90



X-Ray analysis for GDC alloy

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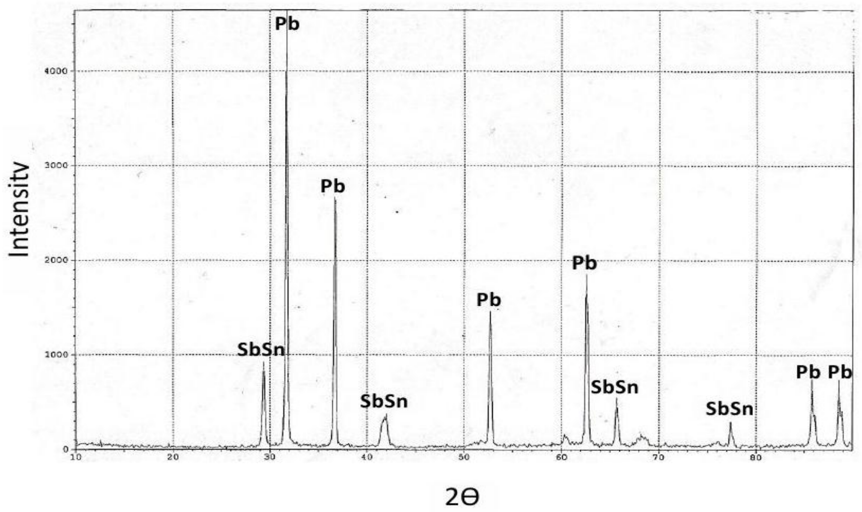

X-Ray analysis for NRC alloy

Fig. (6) X-Ray analysis of two samples

Table (4) Radial tip value of GDC and NRC billets

At different temperature

Type of product	Temperature °C	Radial tip (µm)	Max. load (KN)
NRC	60	124	60
NRC	80	157	48
NRC	100	185	38
GDC	60	242	54
GDC	80	258	43
GDC	100	585	35
TBE	230	233	1.8

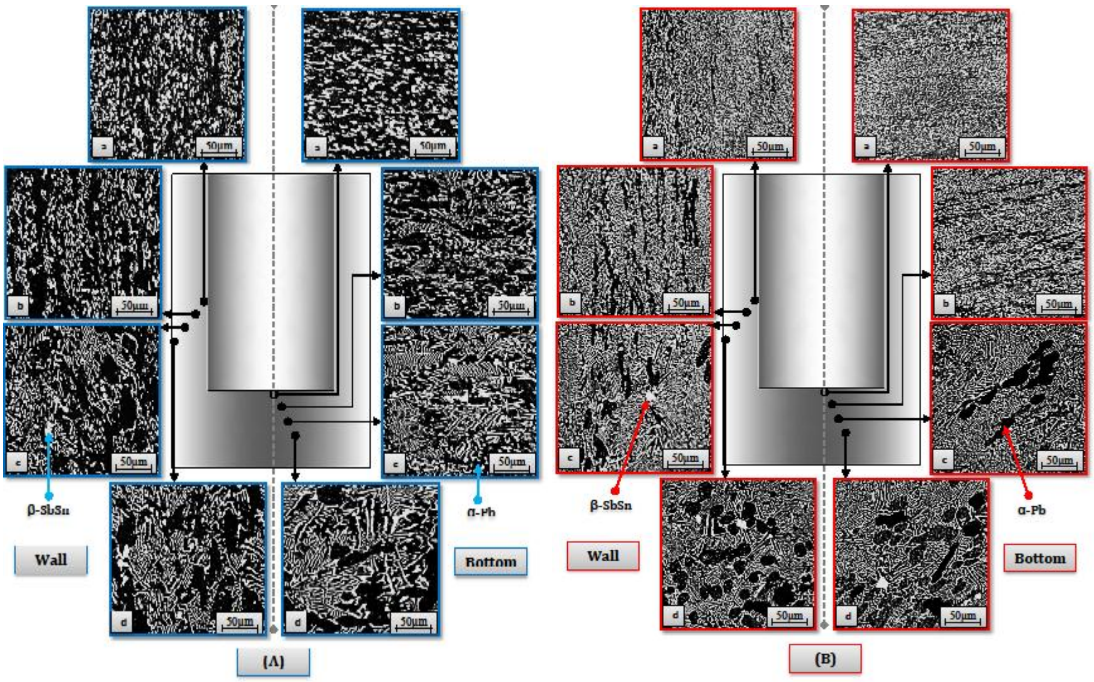

Figure (7); The Microstructure of billet at different positions – nose punch (0) A) GDC B) RC

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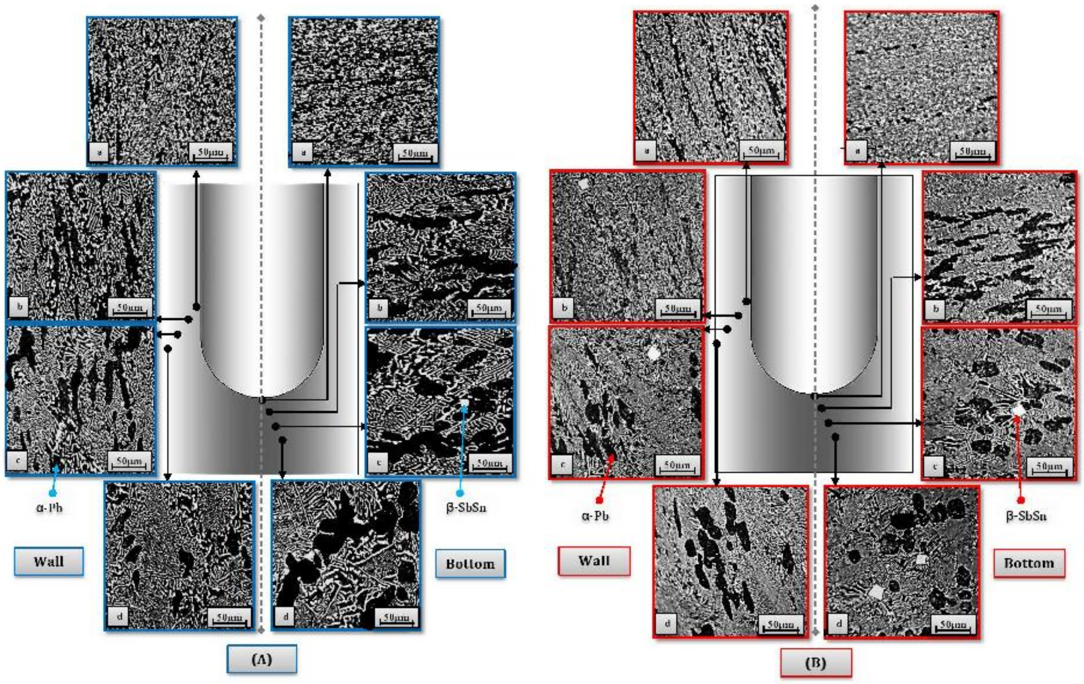

Fig.(8);The Microstructure of billet at different positions – nose punch (8) A) GDC B) RC

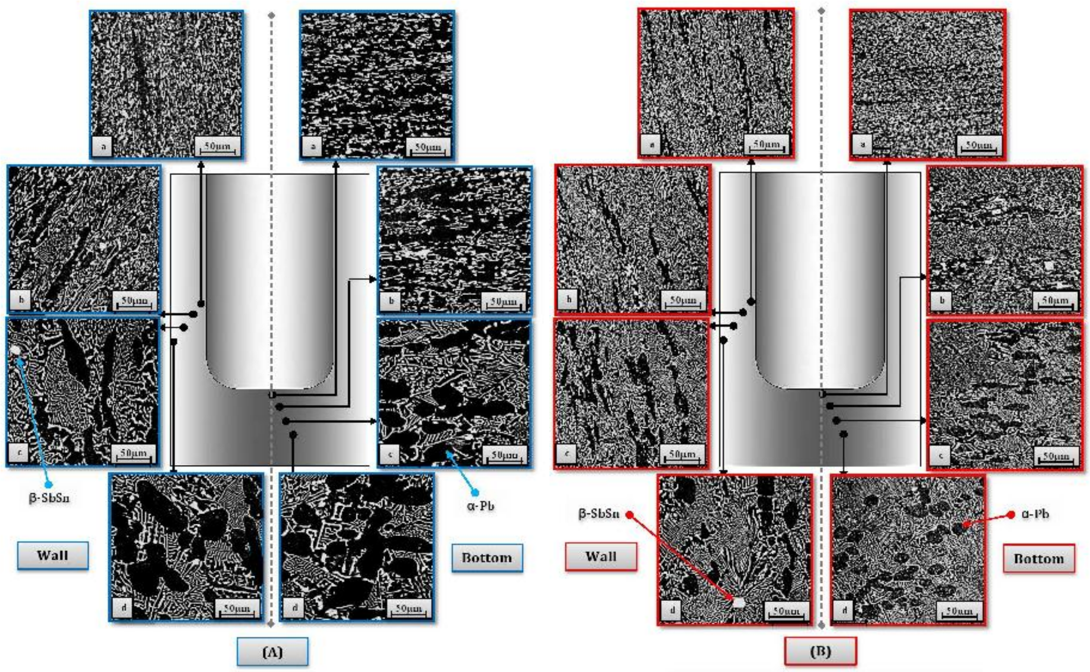

Fig.(9);The Microstructure of billet at different positions – nose punch A) GDC B) RC

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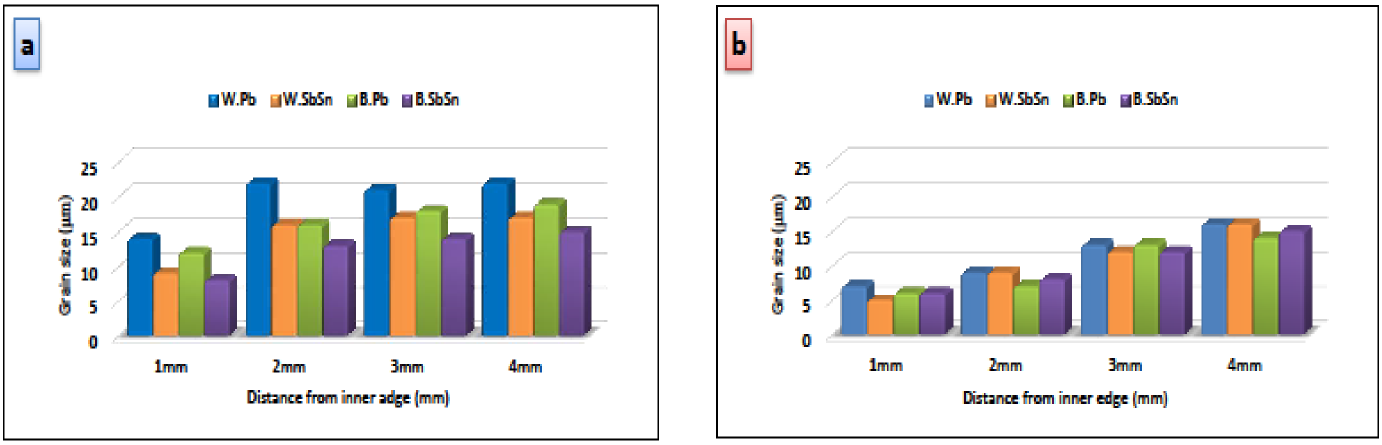

Fig.(10); Grain size of product with punch of nose (0) a: BE GDC , and b: BE RC

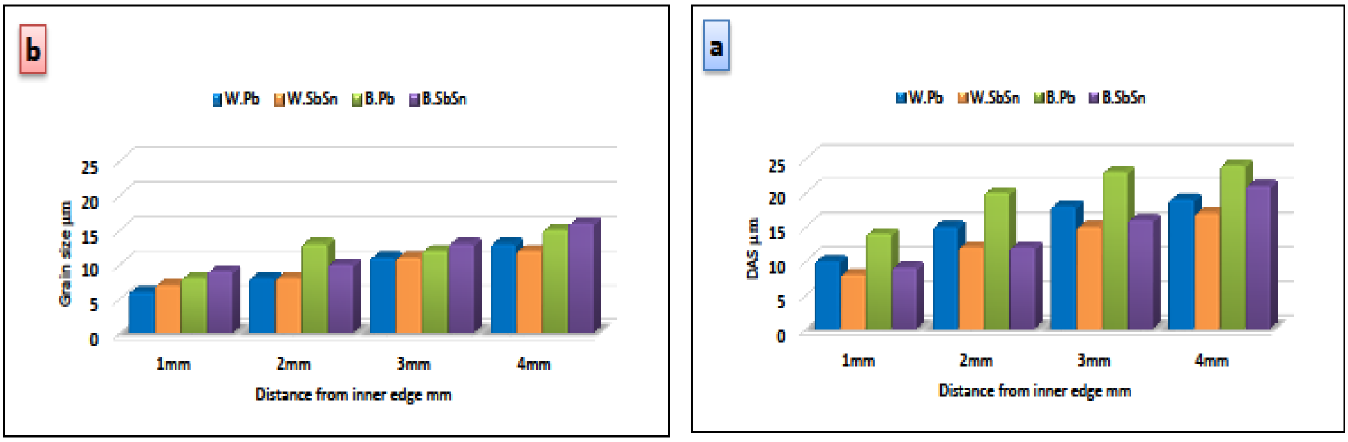

Fig.(11); Grain size of product with punch of nose (8mm) a: BE GDC , and b: BE RC

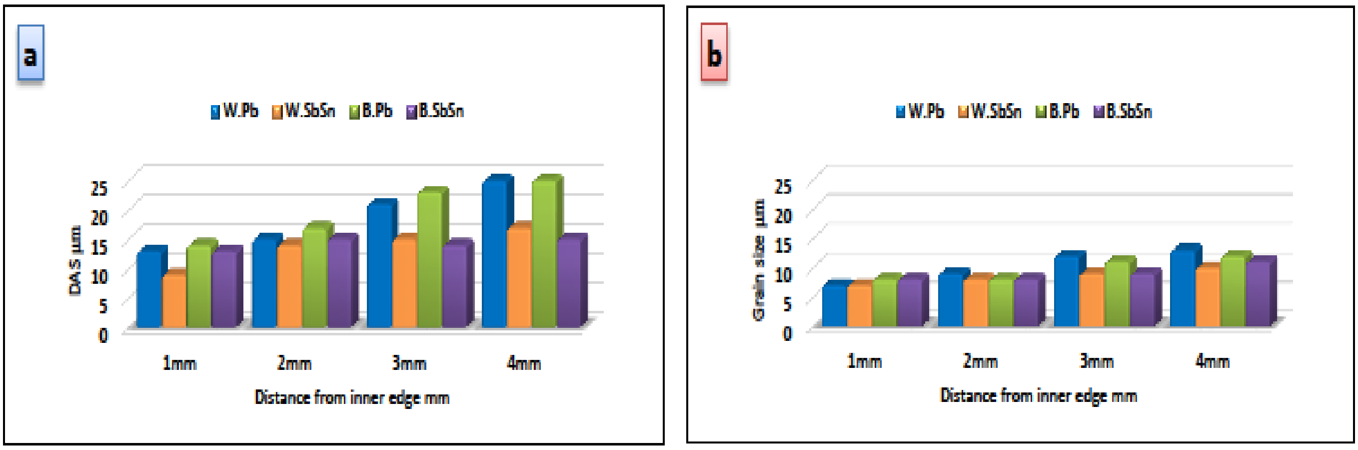

Fig.(12); Grain size of product with punch of nose (4mm) a: BE GDC , and b: BE RC

International Journal of Engineering Research & Technology (IJERT)
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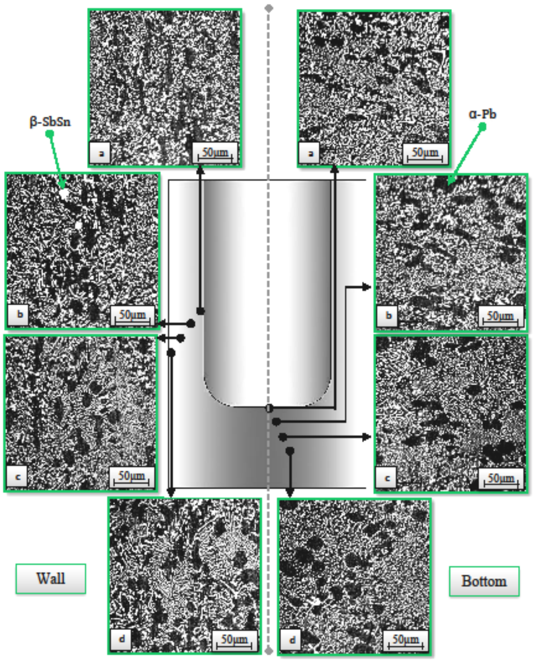
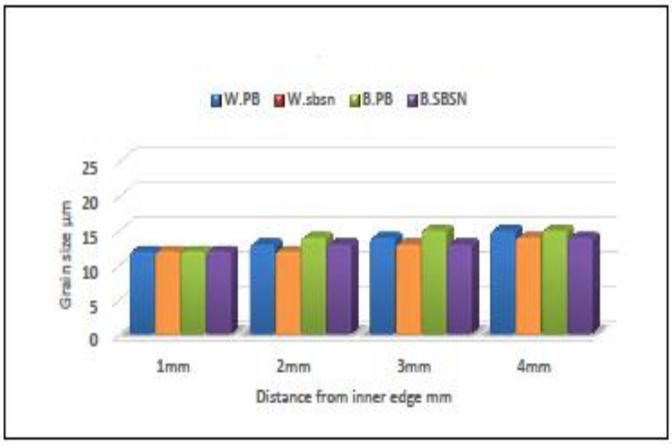


Fig.(13); The Microstructure of thixo backward extrusion at 230°C with punch nose (4).



Fig,(14); Grain size of product at 230° C with punch nose (4mm)

CONCLUSIONS

1- Tip test technique was useful in determin e friction behavior of Babbitt alloy
2- Casting method of Babbitt alloy is significantly influenced in friction condition through backward extrusion process.
3- RC method of Babbitt alloy leads to increase friction through forming this alloy at room temperature more than GDC method, while at high temperature the friction increases with GDC.
4- Punch geometry is greatly a ffected in friction behavior of backward extru sion of this alloy.
5- Thixo backward extrusion gives homogenous microstructure, in addition minimum extrusion load.

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