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# EFFECT OF THE BASE METAL SURFACE ROUGHNESS ON THE BAg-8 SPREADING BEHAVIOUR

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## ABSTRACT
This research was done to investigate influence of the base metal surface roughness on the BAg-8 spreading behavior and to get a proper surface roughness number for large area brazing. The filler metal was melted at 830$^{o}$C for 15 minutes on a S50C surface for with various roughness levels. After solidified, the spreading area was observed and characterized in macro and micro scale. The results show that physically the filler spreading consists of two kinds of spreading forms: true and apparent filler spreading with composition of the both being almost same; 77% Ag and 23% Cu. For some roughness numbers, irregularities in uniformity of the heating and cooling process on the filler and dissolving of contaminant into the molten filler caused the true spreading that tend to separate became several parts and tend to flow out from initial placement. Increasing of the surface roughness tends to increase the capillarity effect and to decrease imbalance in the surface tension. Optimum surface roughness was obtained at Rz = 0.92. At this number, the ratio, as well as fitness of the true spreading with initial condition, was at the maximum. During the application process, this condition is predicted as being able to prevent or avoid weaknesses in the joint, thereby increasing the joint strength and its appearance quality.

*Keywords:* EPMA; Filler spreading; S50C; Surface roughness

## 1. INTRODUCTION
The spreadability of liquid filler metal on solid base material surface is one of the important factors that needs to be considered in brazing, especially for large area application to obtain better joint quality. Spreading of the filler metal depends on the constituent element present, composition of the base material, surface condition of the base material and processing condition used (Jacobson & Humpston, 1993). Modelling for the description of the spreading phenomenon based on physical and chemical principles has been conducted by some researchers, but the mentioned modelling has not considered all factors affecting the spreading because many factors are ignored in making assumptions. So the modelling results obtained have not been enough to describe and explain the real spreading phenomena. Therefore researches about the spreading are still required to obtain a complete description or a comprehensive explanation, along with relationship among the involved internal parameters.

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The spreading phenomenon has been studied by many researchers from the standpoint of surface energy, interaction between the filler metal with base metal, viscosity and so on, for the following adjustable parameters: the brazing condition (temperature, time, pressure and kind of surrounding gas used), composition of the filler metal and base metal, alloy of the filler metal with other composition and so on (Palasantzas, et al., 2001; Hasouna, et al., 1988; Kawakatsu, et al., 1971). The majority of these studies are concerned with spreadability of the filler in pure or alloy composition on an ideal surface base material (smooth and perfectly clean). There are a few reports dealing with the effects of base material surface condition on spreadability of the filler, such as the research by Okamoto et al., who investigated the effect of base material surface roughness on the wetting and spreading behaviour (Jacobson & Humpston, 1993). The results showed that the roughness has a significant effect on both of the wetting and spreading behaviour. It is well known that for each base material there is an optimum surface roughness for maximizing the spreading of the filler metal. That conclusion is based only on measurement results of the spreading area without reviewing its microstructure aspects and specifically only for Al-I2Si filler metal. However microstructure analysis needs to be conducted in order to determine the spreading mechanism and the interaction between filler metal and the base metal during the complete process. Such research needs to be done for other filler metals because each filler metal has specific spreading behaviour and is different from each other.

Therefore this research was carried out to get more complete information or knowledge about the effect of surface roughness on spreading behaviour, especially for case of spreading of BAg-8 on a S50C surface based on the results of macro and microscopic observation. In addition, this research was also prepared to get a proper surface roughness number for large area brazing applications from spreadability viewpoint of the filler metal.

## 2. EXPERIMENTAL PROCEDURE

The spreading behaviour was investigated in terms of the ratio of the true spreading area with the initial area of the filler, fitness of the true spreading area on the initial filler placement, and the spreading phenomenon in micro scale. The base metal used was S50C plate with 3 mm thickness and mass composition: 0.47-0.53% C, 0.15-0.35% Si, 0.6-0.9% Mn, <0.030% P, <0.035% S and balance % Fe. Whereas the filler metal selected was a BAg-8 sheet with 50 µm thickness and mass composition: 28% Cu and balance % Ag. The surface roughness was made by polishing in same direction using silica paper manually for roughness numbers. Calculation of the roughness number was based on ASME Y14.36M - 1996 Surface Texture Symbols.

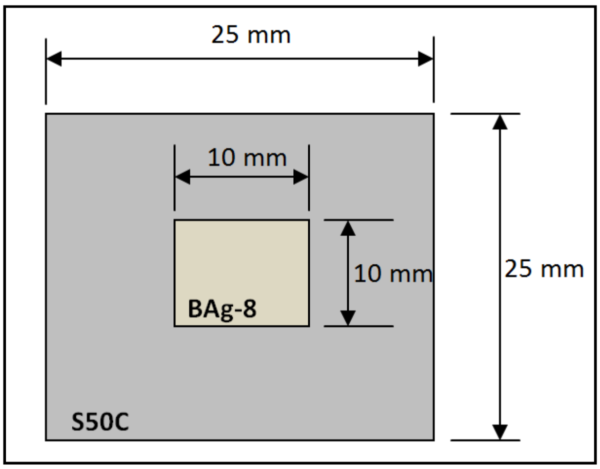


Figure 1 Illustration of the specimen

The spreading was created by heating BAg-8 square above a S50C plate in the vacuum furnace (SHIMADZU VHP gr 18/15) at a temperature of 830°C for 15 minutes with heating rate being around 25°C/min. Cleaning of the specimens from any contaminants and mocks were performed before and after heating. Afterwards, respectively, the spreading dimension measurement and the spreading microstructure observation were carried out by using optical microscope and Electron Probe X-ray Micro Analyzer (EPMA).

## 3. RESULTS AND DISCUSSION

The spreading phenomena can be explained by the following classical model: the liquid will spread over a solid surface until the three surface tensions: between the liquid droplet and the solid substrate, the liquid droplet and the atmosphere, and the substrate and the atmosphere, are in balance as shown in the following Figure 2.

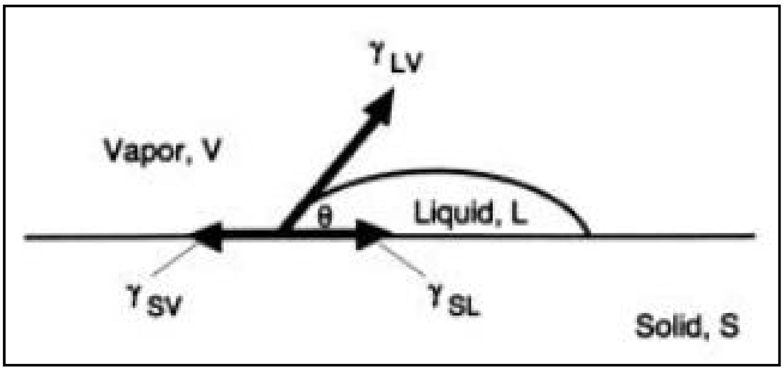


Figure 2 Surface tension force acting when a liquid droplet wets a solid surface

According to the forces balance:

$$\gamma_{SL} = \gamma_{SV} - \gamma_{LV} \cos\theta \qquad (1)$$

where $\gamma_{SL}$ is the surface tension between the solid and liquid, $\gamma_{SV}$ is the surface tension between the solid and vapor, $\gamma_{LV}$ is the surface tension between the liquid and vapor, and $\theta$ is the contact angle of the liquid droplet on the solid surface.

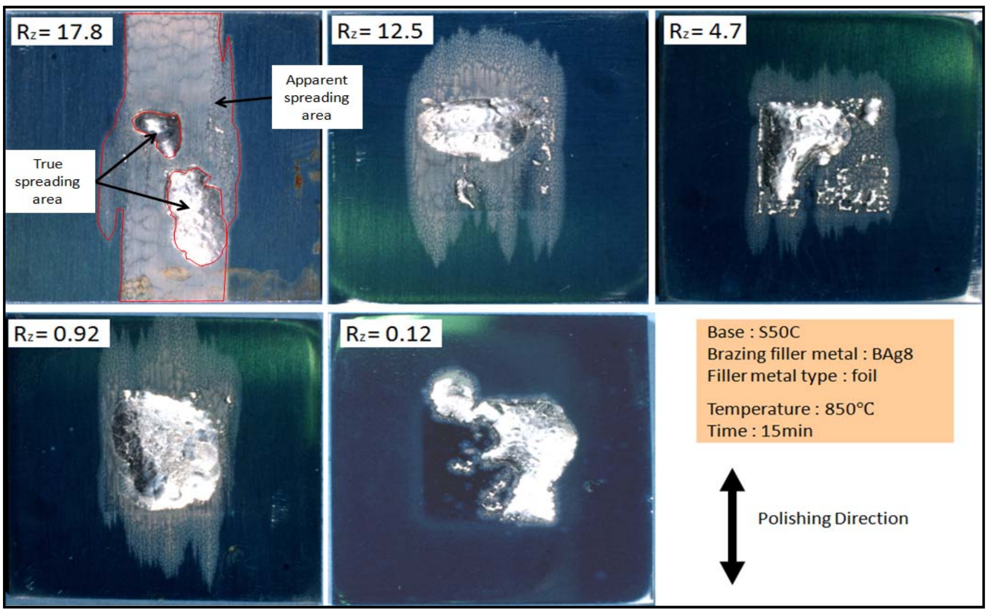


Figure 3 The filler spreading condition after solidified for roughness variations

For all roughness variations in this experiment, the filler spreading consists of true filler spreading and apparent filler spreading as shown in Figure 3. From the picture can also be shown that the filler spreading tends to follow the polishing direction. It means that grooves produced by polishing created capillarity effect on the molten filler that help the $\gamma_{SV}$ to drive the filler spreading. Theoretically, the contribution of the roughness can be explained by the following equation:

$$\cos\theta^* = R\cos\theta \qquad (2)$$

whereby the effective contact angle is $\cos\theta^*$, and $R$ is the average roughness measured as the average deviation from the center line of surface profile. From Equation (2) an optimum surface roughness for maximizing the spreading of a filler metal will lie somewhere in between the extreme surface conditions (very smooth and/or very rough surface) because the surface roughness reduces the $\cos\theta^*$. This experiment results proved the above theory as is indicated in the following graph.

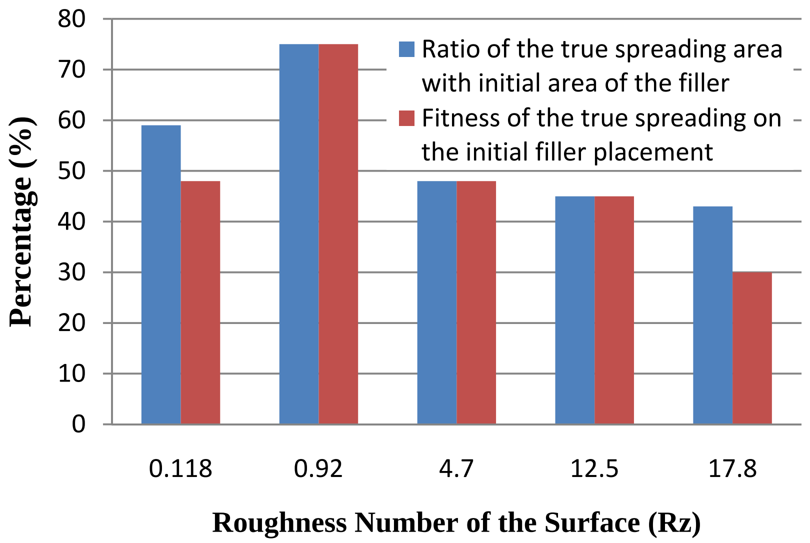


Figure 4 Ratio and fitness of the true spreading area with initial condition

From Figure 3, it was also found that in very small amounts, the molten filler was easier to flow on a rougher surface because of an increase in the groove hydraulic diameter and a decrease of the molten filler kinematic viscosity caused by contaminant and surface components dissolving into the molten filler. In the case of a rougher surface, other phenomenon that also be met is the true spreading tendency to separate and to become several parts. Especially in the cases of the two roughness extremes, there is a tendency to flow outwards from the initial place of the filler. The phenomena were probably caused by irregularity in the uniformity of the heating and cooling process on the filler and this was strengthened by dissolving the contaminant into the molten filler. The dissolved contaminant tends to reduce cohesive force in the molten filler.

EPMA results as are shown in Figure 5 indicate that composition of the true as well as apparent spreading were dominated by silver and copper with coexisting ratios that were around 77% Ag and 23% Cu respectively. Dissolution of base metal components into the liquid filler took place in very small amounts, therefore, it can be understood in this way because the melting and spreading occurred in a short time period.

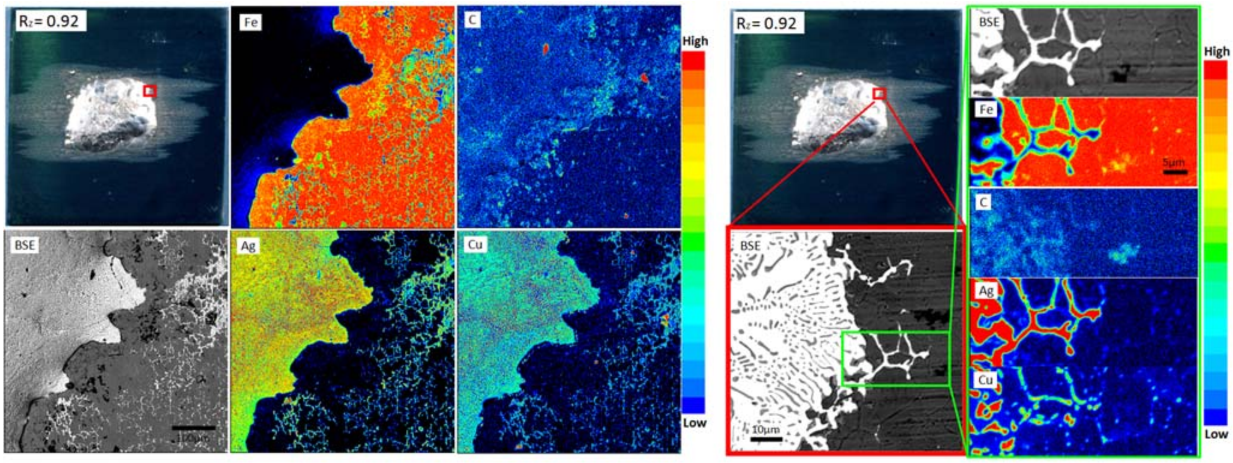


Figure 5 EPMA result on interface between the true and apparent spreading

The crystalline structure of the true spreading was dominated by Lamella, which means that at the solidification time, the majority of the constituent filler crystallized at the same time (simultaneously). The same phenomenon also occurred during the apparent spreading in a small part as is shown in Figure 6.

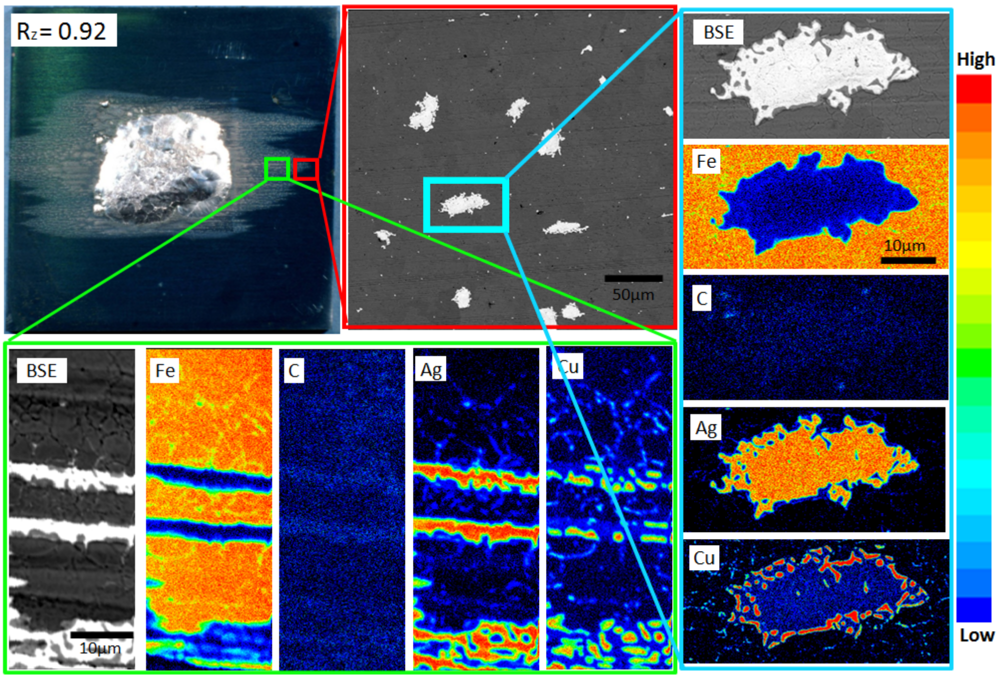


Figure 6 EPMA result on the apparent spreading area

## 4. CONCLUSION

From the results obtained in this investigation, the conclusions are as follows:

1. Composition of the filler spreading was dominated by silver and copper with a coexisting ratio of around 77% Ag and 23% Cu respectively. Other components from the dissolution results were also present in small amounts.
2. Increasing the surface roughness tends to increase the capillarity effect and to decrease the imbalance in surface tension of the molten filler.
3. The optimum surface roughness was obtained at Rz = 0.92. At this number, the ratio as well the fitness of the true spreading with initial condition of the filler was maximized.

## 5. ACKNOWLEDGEMENTS

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