Brazing technology with silver brazing paste

by **Toshiki Nagano and Toshiyasu Takei (Japan)**

Introduction

Recently the demand for dot matrix printers has increased as automated office equipment - such as word processors, personal computers and office computers - has become more popular. As computers are being increasingly designed for multiple uses, the demand for printers has also been increasing. Consequently, manufacturers have been required to achieve higher productivity and have succeeded as a result of automation. Among the operations making up the fabrication of printers, the assembly of the printhead is one of the most important, and especially the brazing of the armature. There are many ways to automate the armature assembly (Table 1), but the conventional systems cannot be adapted to many kinds of armature. The reason is that these systems are designed for certain types of printer, and is an obstacle to automation in general production.

The automated brazing process is briefly shown in Fig. 1. Since the flexible brazing system must be able to handle every type of armature, the following points should be taken into consideration:

1. Is it possible to vary the quantity of brazing flux?
2. Is it possible to vary the quantity of silver brazing filler metal?
3. Is it possible to vary the brazing temperature?
4. Is it possible to vary the brazing area?

It was found that questions 1 and 2 could be answered positively if silver brazing paste containing brazing flux was used. As the result of using brazing paste, there was no need to use brazing flux. The same applies to questions 3 and 4, if induction brazing was used. In addition, induction brazing equipment lends itself to automation.

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Messrs. Nagano and Takei are at the Production Engineering Center, OKI Electric Industry Co., Ltd. (Japan).

Table 1. Brazing filler metal and brazing method

1. Brazing filler metal	2. Brazing method
wire	flame brazing
board	furnace brazing
band	arc brazing
powder	resistance brazing
paste	dip brazing
preform	
(ring, washer, ball, tip)	induction brazing
	laser brazing
	electron beam brazing

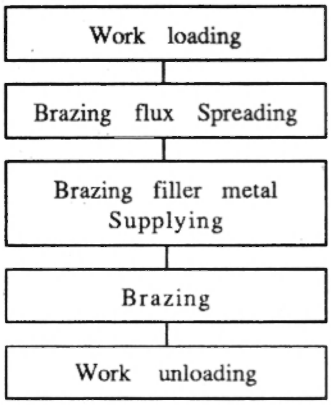

Fig. 1 *Automated brazing process*

In spite of these advantages, new problems arise as follows :

1. Is it possible to apply very small and precise quantities of silver brazing paste?
2. Is the wettability of silver brazing paste good when high-frequency induction brazing is used?

To reply to these questions, it was necessary to perform some experiments.

Measurement of the characteristics of silver brazing paste

Silver brazing paste consists of silver brazing filler metal (AWS-ASTM. B Ag-1), a binder, a solvent and a brazing flux. A dispenser was used for applying very small quantities of paste, the paste being viscous

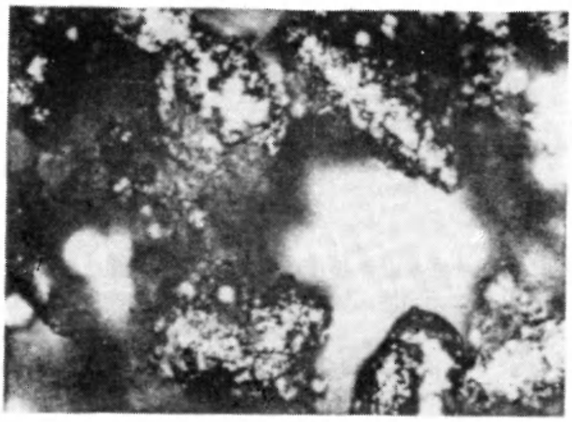

Fig. 2. *Micrograph of silver brazing paste, #60 (X200)*

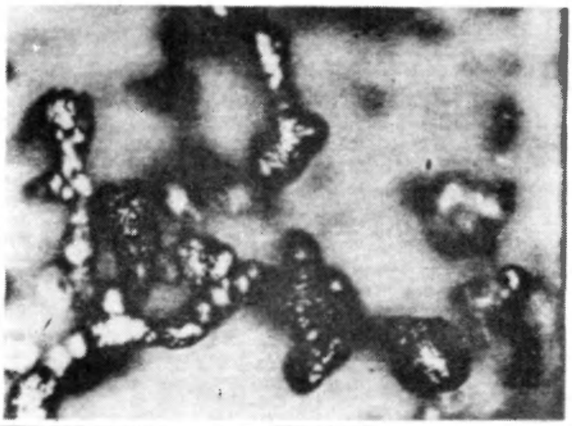

Fig. 3. *Micrograph of silver brazing paste, #250 (X200)*

Table 2.. Viscosity of silver brazing paste

Particle size	Viscosity
60 mesh	98,000 cps
250 mesh	145,000 cps
(25°C, Brookfield HBTD, SC4-14/6R, 10 rpm)	

fluid. The characteristics of the paste, such as viscosity, particle shape and the distribution of particle size influence dispensability. Then, two types of paste were prepared, one was 60 mesh (250μm) particle size, the other was 250 mesh (63μm) particle size.

First, the viscosity was measured by the Brookfield digital viscometer (HBTD type, with small sample adapter SC4-14/6R), and the results are shown in Table 2. The viscosity of solder paste for dispensing is generally fixed in the range of 100,000 to 200,000 cps, so this range was adopted for these pastes.

Second, the particle shape was observed with a microscope. It showed that the particle shapes of

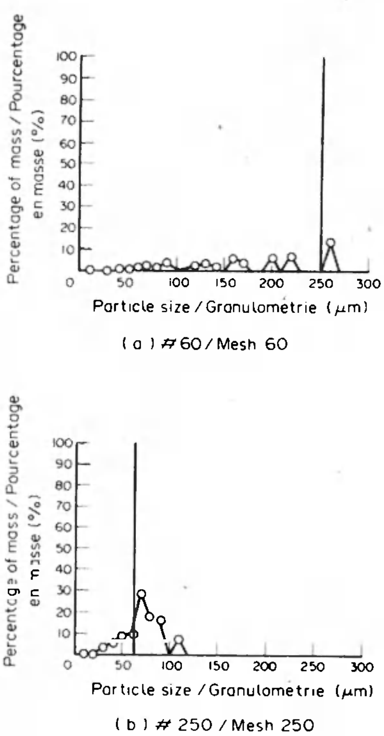

Fig. 4. *Particle size distribution*

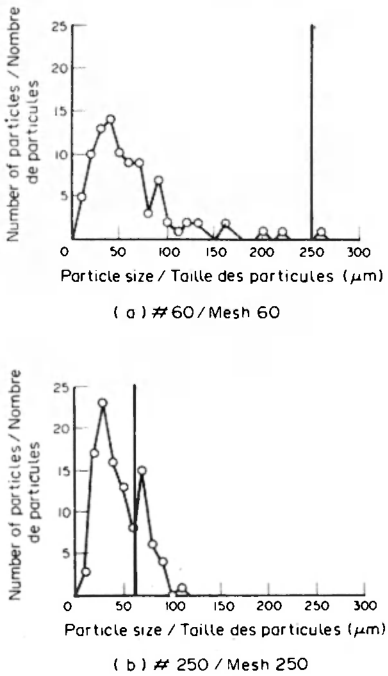

Fig. 5. *Histogram of particle size*

both pastes were irregular (Figs 2 and 3). It is usually said that the dispensability of irregularly shaped particle is worse than that of spherical particles.

Finally, the particle size distribution was measured in an original way. The image obtained with the microscope was entered in the image processing system by the TV camera, then the diameters of the particles were calculated after image processing. The results are shown in Figs 4 and 5. The curve of 250 mesh size is on the 63 μm line, but that of 60 mesh size is separate from the 250 μm line. The range of the curve of 250 mesh size is narrow, but that of 60 mesh size is wide. In the light of these facts, it can be said that the 250 mesh size paste would have better dispensability than 60 mesh size paste.

Dispensing experiment

When the same size of syringe and the same dispenser are used, the factors which play a part are dispensing pressure and time and the diameter of needle. Before the experiment, the quantity of dispensed paste with varying dispensing times and pressures was measured (Fig. 6). Then the dispensing target was decided on at 5 mg, because the average weight of the brazing tips was about 4 mg, and the mass of brazing filler metal in the brazing paste was about 80%. The dispenser was set for the corresponding pressure and time and the paste was dispensed precisely. The dispersion of quantity of dispensed paste was evaluated by the non-dimensioned value, standard deviation divided by average.

The result is shown in Fig. 7. The curve of 60 mesh size paste is flat, and the paste clogged when the 0.4 mm needle was used. In the case of 250 mesh size paste, the dispersion diminished with the size of the needle. Incidentally, dispersion of 250 mesh paste with the 0.4 mm and 0.5 mm needles was smaller than with the brazing tips made by stamping.

Brazing experiment

The specimens and their specifications are shown in Fig. 8 and Table 3. The experiment was designed for the two way layout method, and the specimens were brazed using high-frequency induction equipment 2 kW at 2 MHz. The factors considered were the particle size of the paste and the brazing temperature. The levels of brazing temperature were set at 680°C, 710°C and 740°C. The temperature of the brazing area of the armature was measured by an infrared radiation thermometer during the heating with induction brazing (Fig. 9), and the peak value of the temperature curve was taken as the brazing temperature.

Evaluation

The results of the brazing experiment were evaluated by visual inspection, tension shear test, cross-section analysis of the X-ray image of the Electron Probe Micro Analyzer (EPMA), and repeated tension fatigue testing.

Table 3. Works and materials

Work	Material
armature	Fe
wire	WC-Co
silver paste	45Ag-15Cu-16Zn-24Cd binder, solvent, brazing flux

1. Visual inspection

The results after flux cleaning are shown in Table 5. There are many traces of flux at low brazing temperatures, but as the temperature rises, the

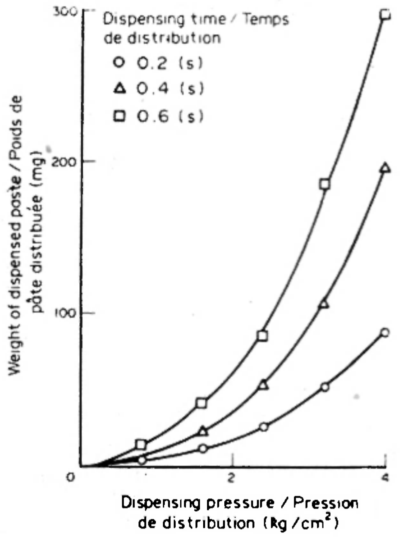

Fig. 6. *Quantity of dispensed paste with varying dispensing pressure for different dis pensing time*

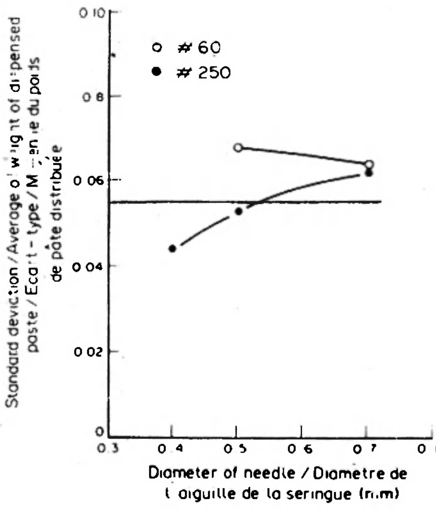

Fig. 7. *Dispensability of silver brazing paste*

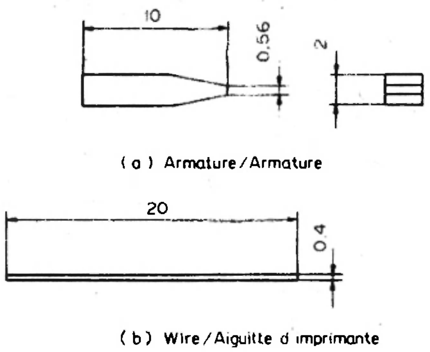

Fig. 8. *Configuration of works*

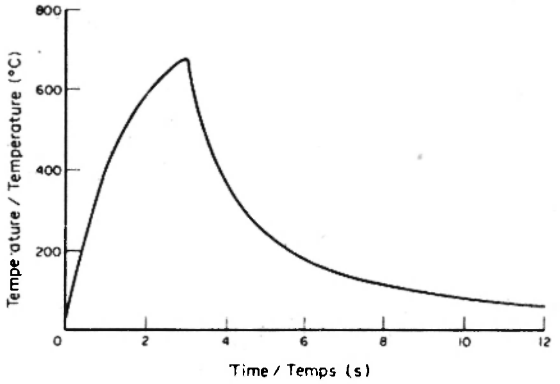

Fig. 9. *Temperature curve using high-frequency induction brazing*

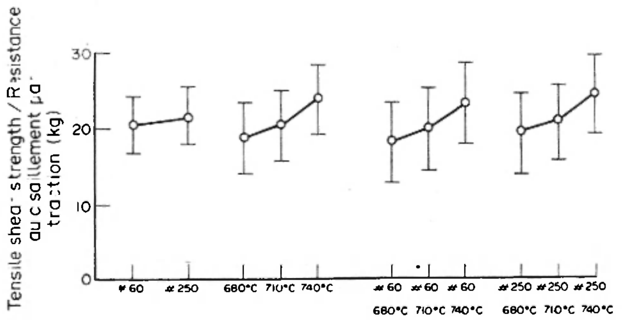

Fig. 10. *Result of measurement of tensile shear strength*

Table 4. Conditions of brazing experiment

Factor	Level 1	2	3
particle size	60 mesh	250 mesh	
brazing temperature	680°C	710°C	740°C

traces diminish. It seems that the brazing flux solidifies at low temperature without flowing well. On the other hand, burns diminish as the temperature falls. The black colour of the burns seems to be from the crystallized cobalt from the wire. The conclusion is that the best brazing conditions are 250 mesh and 710°C.

2. Tension shear test

Tension shear tests were performed on a compressive-tensile testing apparatus. Because the wire is brittle, the brazed wire was pushed in the shear direction. The average values of tensile shear strength and confidence limits were calculated by analysis of the variance, and the result is shown in Fig. 10. It is clear that the strength of pastes with a smaller particle size is greater than that of pastes with a larger one, and it increases as the brazing temperature rises. It seems that the silver brazing paste flows well when the brazing conditions combine the smaller particle size with the higher temperature.

3. Cross-section analysis of X-ray image of Electron Probe Micro Analyses (EPMA) and metallographical observation

The brazed specimens were cut, and a cross-section analysis of the X-ray image from the EPMA for Ag, Cd, Cu and Zn was performed. The results at 710°C are shown in Figs 11 to 20. The silver brazing filler metal flowed sufficiently into the joint clearance and did not affect the wire and the armature. But these photographs do not show clearly the difference between 60 mesh and 250 mesh, so a metallographical observation was carried out (Figs 21 and 22). It also

Table 5. Result of visual inspection

	680°C		710°C		740°C	
60 mesh	α – 0 x – 3	Δ – 2 O – 2	α – 0 x – 4	Δ – 4 O – 3	α – 0 x – 2	Δ – 2 O – 4
250 mesh	α – 0 x – 1	Δ – 4 O – 2	α – 2 x – 0	Δ – 1 O – 1	α – 1 x – 0	Δ – 0 O – 3

α – good, Δ – flux remained, x – wet failure, O – burned.

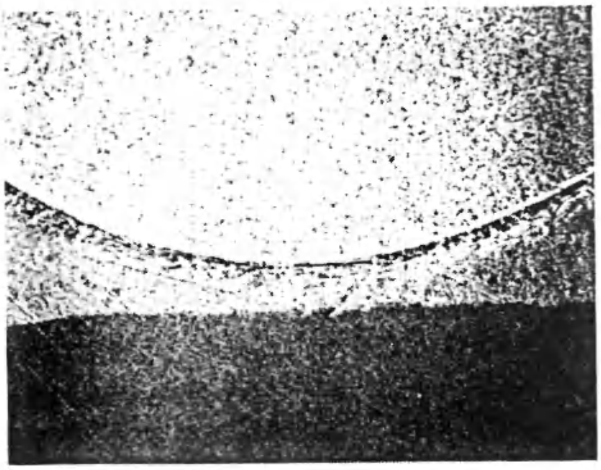

Fig. 11. *SEM micrograph of cross-section (#60. 710° C) (X500)*

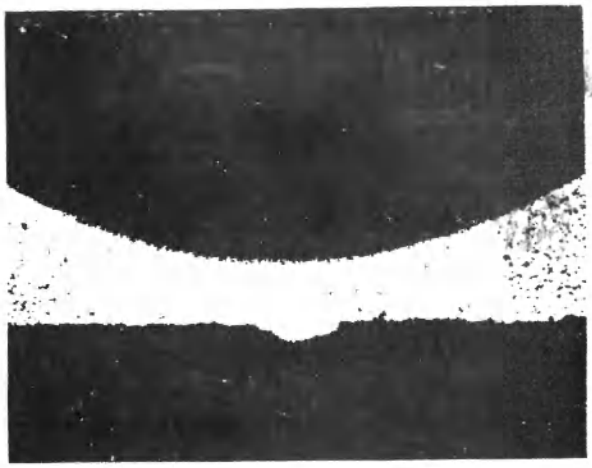

Fig. 14. *X-Ray image of EPMA - Ag, (#250, 710° C)*

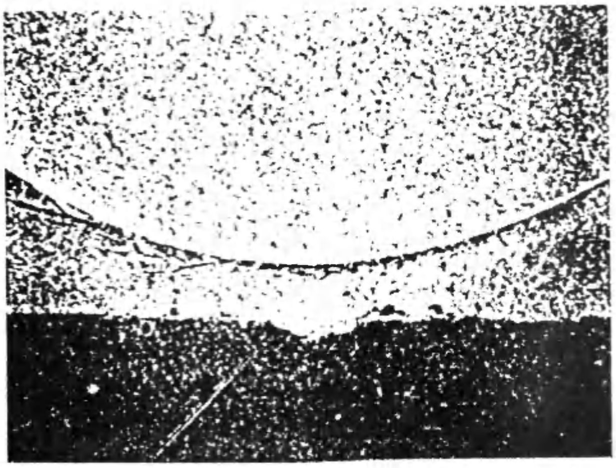

Fig. 12. *SEM micrograph of cross-section (# 250, 710° C), (X500)*

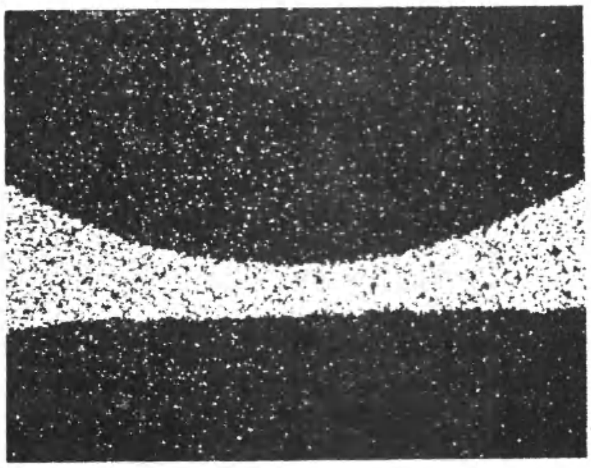

Fig. 15. *X-Ray image of EPMA - Cd, (#60, 710° C)*

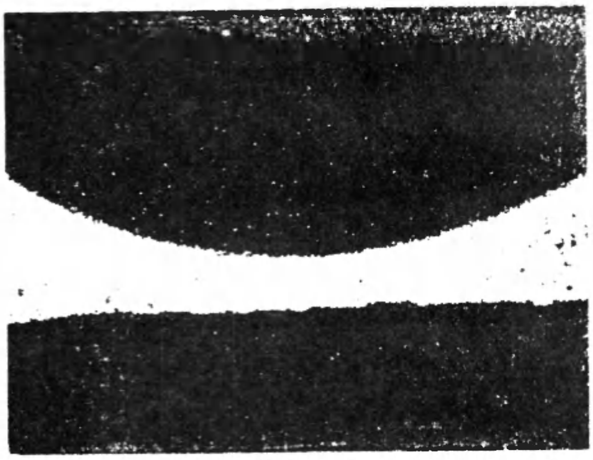

Fig. 13. *X-Ray image of EPMA - Ag, (#60, 710° C)*

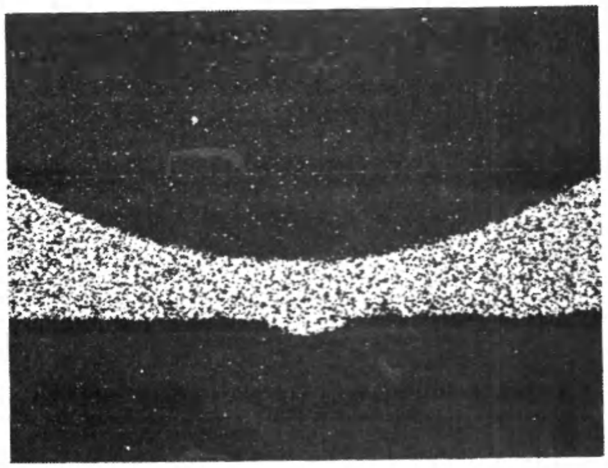

Fig. 16. *X-Ray image of EPMA - Cd, (#250, 710° C)*

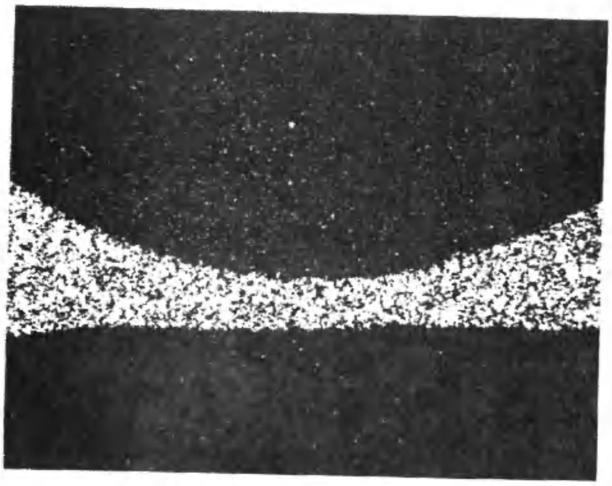

Fig. 17. *X-Ray image of EPMA - Cu, (#60, 710° C)*

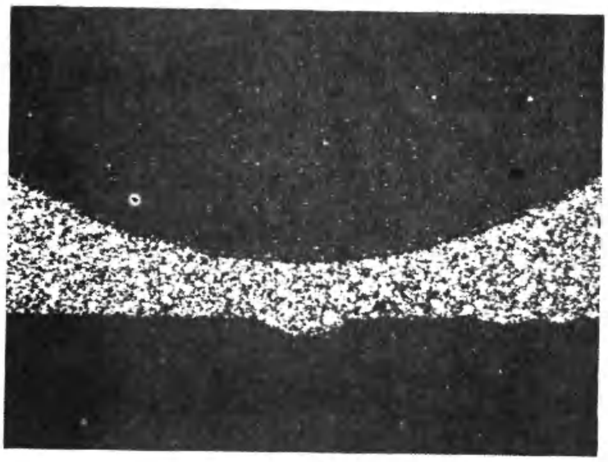

Fig. 18. *X-Ray image of EPMA - Cu, (#250, 710° C)*

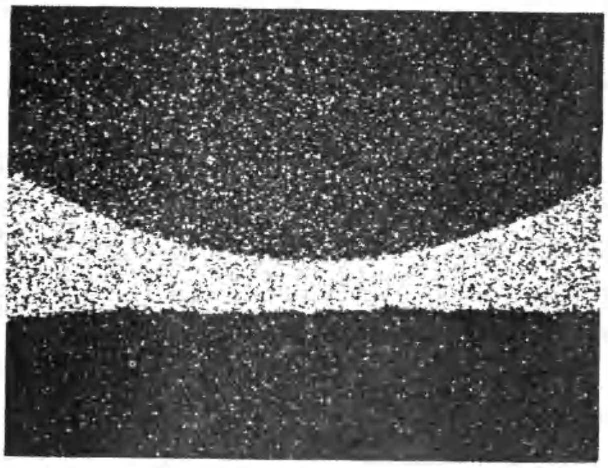

Fig. 19. *X-Ray image of EPMA - Zn, (#60, 710° C)*

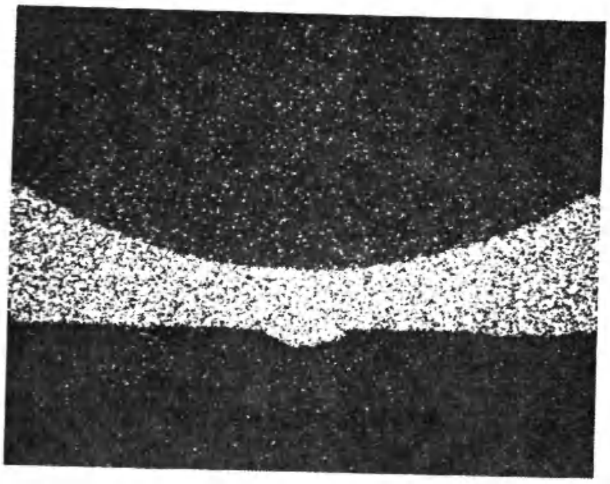

Fig. 20. *X-Ray image of EPMA - Zn, (#250, 710° C)*

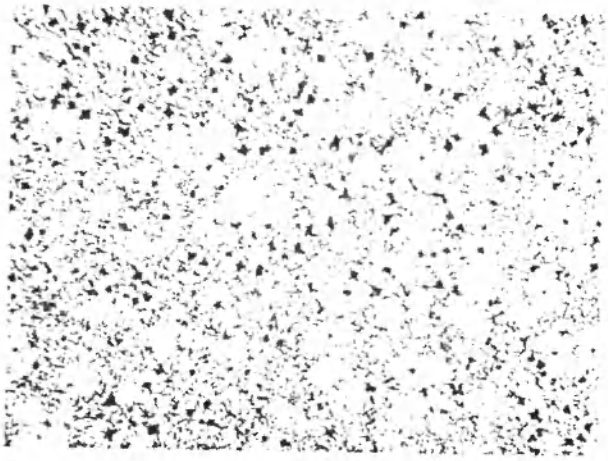

Fig. 21. *Micrograph of metallic crystal, (#60, 710°C) (X600)*

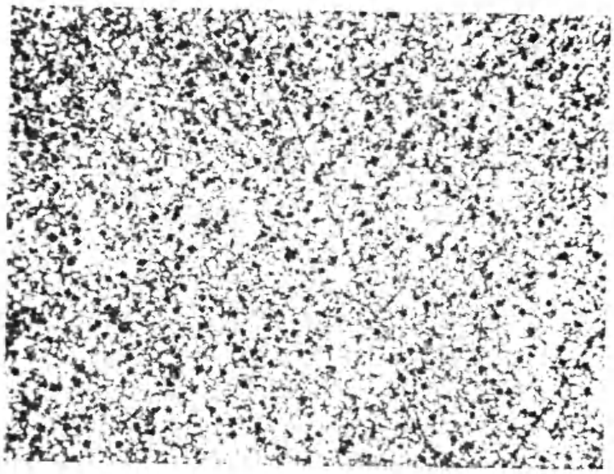

Fig. 22. *Micrograph of metallic crystal, (#250, 710° C) (X600)*

can be said that, at the same brazing temperature, there is no difference. It is considered that the tensile shear strength depends on the flow of the silver brazing filler metal, because the contact area between the silver brazing filler metal and the specimens will change when the particle diameter and the brazing temperature are varied. As a reference, Fig. 23 shows metallic crystals of the silver brazing filler metal when a brazing tip and preplaced brazing were used. The grain is larger than that of the silver brazing paste, because the heating methods and cooling processes are different. However, it is clear that both metallic crystals are similar.

4. *Repeated tension fatigue testing*

For the purpose of assessing the reliability of the armature assembly, repeated tension fatigue testing was performed using the following method (Fig. 24). A brazed armature assembly was fixed and wire was vibrated by a circular disc cam rotating at 2,000 rpm. The amplitude was 0.8 mm, and repeated tension applied to the brazed metal was varied by the distance between the armature and the axis of the cam. The result is shown in Fig. 25. The fatigue limit of the armature using the silver brazing paste was 94% of that obtained when using a brazing tip.

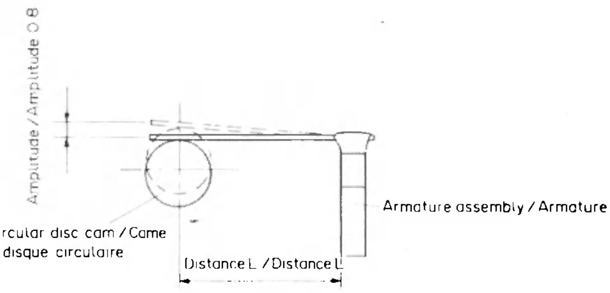

Fig.24. *Schematic diagram of repeated tension fatigue testing*

Fig.23. *Micrograph of metallic crystal (brazing tip used). (X600)*

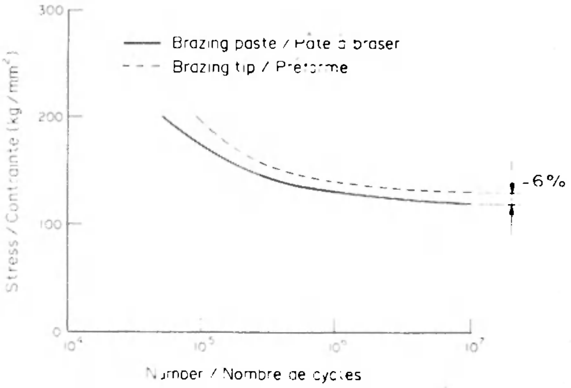

Fig.25. *S-N diagram*

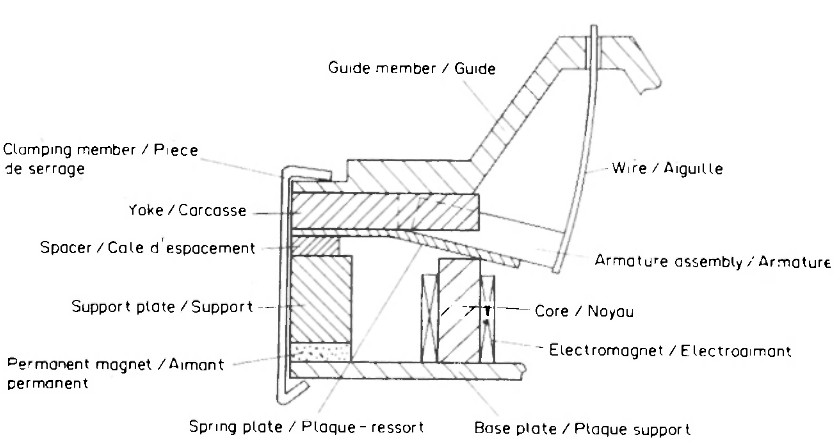

Fig. 26. *Cross-section diagram of printhead assembly*

Though its fatigue limit was lower by 6%, it was not clear whether there was any influence on the useful life of printer in service. Therefore, a printing test was performed after the assembly of the printhead (Fig. 26). It showed that neither the printhead fabricated with the silver brazing paste nor that fabricated with the brazing tip failed before 10^8 dots. Hence, it can be said that the difference in the limit did not influence on the length of the life of the printhead.

Application

After improving the brazing jig, fifty pieces of armature assembly were manufactured for a trial with 250 mesh paste at 740°C. The armature assemblies were evaluated by the same method, and about 10% of the pieces were found to be defective.

The silver brazing paste was also applied to a different type of armature (Fig.27). Because of its shape, a smaller quantity of the silver brazing paste was needed. However, its thermal capacity was different from the conventional one, so that the brazing conditions had to be adjusted to the same brazing temperature. The brazing time and the power of the induction system were varied and set to the equipment. The same evaluations were performed, and an improvement of 4% was obtained.

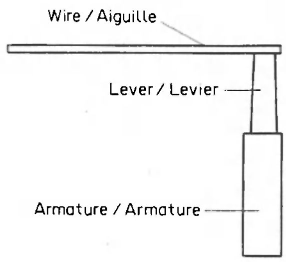

Fig. 27. *Configuration of different type*

Conclusion

In the development of a flexible brazing system, all the problems were solved by these experiments using a silver brazing paste and induction brazing. The armature assembly was brazed best with 250 mesh silver brazing paste at the brazing temperature 740°C by the method of high-frequency induction brazing.