

Welding of Platinum Jewellery Alloys

COMPARISON OF FUSION, LASER AND SPOT WELDING

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The relatively recent application of laser welding and spot welding to platinum has supplemented the traditional joining techniques of conventional welding and brazing with a gas torch. Several recent publications (1–3) have promoted the use of laser welding, because of the superior strength of the joins compared with that of joins by conventional welding and brazing. In this paper we compare welds in three different platinum alloys, produced with three different welding techniques: conventional welding, laser welding and spot welding. The welds joining cold-rolled bars were performed by jewellers operating in their own workshops. The extents of the heat affected zones and consequent decrease in hardness were assessed in our laboratory. Laser and spot welding produced very narrow heat affected zones, with correspondingly narrow regions of diminished hardness, while the conventional welding resulted in samples being annealed and softened for their full lengths. Complete joining was difficult to achieve by laser and particularly spot welding, which could be problematic in joining thicker sections. With this knowledge, jewellers can design appropriately to take advantage of the novel joining techniques.

Welding Techniques

Various joining techniques are theoretically available to the platinum jeweller, including traditional brazing with 'solder alloys', fusion welding, friction welding, arc welding and electron beam welding (1). Until recently, only brazing and fusion welding were accessible to the small- or medium-sized jeweller. In the past decade, laser welding units have become small enough and inexpensive enough for application in the jewellery workshop (1–3). Even more recently, miniature electric resistance spot welding machines have been developed specifically for the jewellery studio (4).

Traditional welding of platinum is carried out by inserting a thin over-sized sheet of identical metal between the pieces to be joined. Heat is applied to the projecting sheet, fusing and sealing the joint (5). This contrasts with traditional brazing, using an alloy of lower melting point, as is commonly the practice in gold- or silver-smithing (1). Laser welding uses high-intensity, focused laser light beams to apply energy to very small areas, resulting in very rapid and efficient local melting (2). The position of the weld spot is located using a stereomicroscope with cross-hairs. Very little heat is generated,

and laser welds can be made on complicated parts, between dissimilar metals, and close to set stones without damaging them (3). The new spot welding units use an electrode to create a high-intensity electric spark, either to melt the parent metal or a thin wire, to effect the weld (4). Both laser and spot welding take advantage of the fact that platinum has a low thermal diffusivity when compared with silver or gold jewellery alloys (3). This means that the focused application of a small spot of intense energy can cause localised melting, without significant heating of the surrounding metal. This results in a comparatively small heat affected zone around the weld, and the mechanical properties of the bulk of the workpiece remain unchanged.

Fusion welding, laser welding and spot welding are now the three most commonly used joining techniques in platinum jewellery manufacture (1–3). We set out to compare these three techniques on three different platinum alloys, using equipment actually in use in jewellery workshops.

Alloys and Sample Preparation

Three different platinum alloys were tested: the commonly-used platinum-5 wt.% ruthenium (Pt-

5% Ru) and platinum-5 wt.% copper (Pt-5% Cu), and a novel heat-treatable platinum-3 wt.% vanadium (Pt-3% V) alloy (currently the subject of a patent application). Rectangular strips 1.2 mm thick were prepared by cold rolling. The Pt-5% Ru and Pt-5% Cu were hardened by cold work, and the Pt-3% V specimens by heat treatment. The resulting initial microhardness values were 256 HV for Pt-5% Ru, 270 HV for Pt-5% Cu, and 457 HV for Pt-3% V.

Joining was performed in all cases by abutting flat surfaces which had been prepared by sawing through the bars transversely. Most of the samples were prepared without bevels or notches at the surfaces to be joined. This was to test the penetration of the laser and spot welding.

The fusion welding on all three sample materials was carried out by the conventional method of inserting a thin sheet of the identical alloy between the two parts to be joined, and heating the sheet locally with an oxygen/propane flame until it fused. Laser welding was performed using a Rofin 'StarWeld' YAG model SWL-Y 65 laser welding machine, in air. Owing to limited availability of the Pt-3% V material, spot welding was carried out only on the Pt-5% Ru and Pt-5% Cu samples, using a Lampert PUK2 microwelder, with an argon stream to exclude oxygen.

Results

The welded specimens were sawn longitudinally with a jeweller's saw, cold mounted in resin, and ground and polished for microscopic examination in reflected light. The fusion welds exhibited the best penetration, whereas all the laser and spot welds had median gaps, of various sizes up to half the specimen width, which were evident in the sawn sections (Figure 1).

Microhardness was measured with a Zwick microhardness tester and Vickers indenter. Figures 2 and 3 show the effects of welding on the microhardness of Pt-5% Ru and Pt-5% Cu, respectively. These alloys showed similar patterns, with significant but narrow drops in microhardness in the weld zones for both laser and spot welding, and extensive softening due to recrystallisation along the length of the samples for fusion welding. All

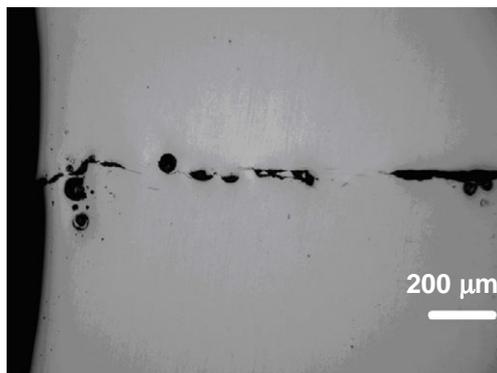


Fig. 1 Polished section through the spot weld in Pt-5% Ru, showing incomplete joining

three samples started out with very similar microhardnesses, so the overall softening due to fusion welding was very obvious (Figures 2 and 3).

Etching showed that for Pt-5% Ru and Pt-5% Cu, both the laser and spot welds had local recrystallisation

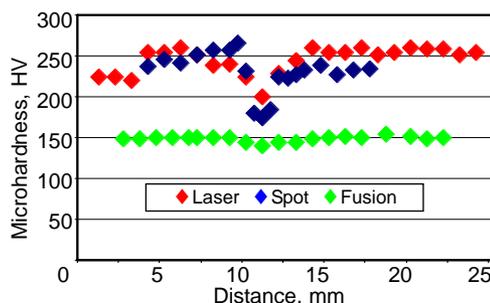


Fig. 2 Plot of microhardness (HV) against distance along the length of welded bars of Pt-5% Ru, showing loss of hardness restricted to the weld zone of laser and spot welding, but an overall drop in microhardness along the entire length of the fusion weld specimen

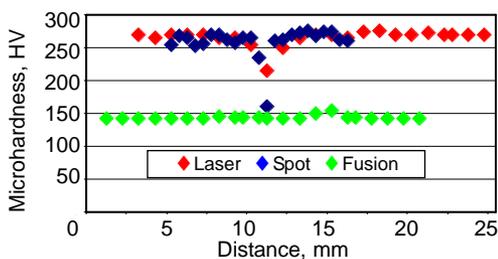


Fig. 3 Plot of microhardness (HV) against distance along the length of welded bars of Pt-5% Cu, showing localised loss of hardness in the weld zone in both laser and spot welding samples. The fusion weld sample had the same initial hardness as the other samples, and showed reduced post-weld microhardness along its entire length

tallisation only in the immediate vicinity of the welds. The cold worked microstructure, with flattened and elongated grains, was preserved without heat-affected alteration to within 2 to 3 mm of the weld line, whereas the heat affected zone of the fusion weld samples extended the full length of the specimens. They were completely recrystallised.

Figure 4 shows the effect of laser and fusion welding on the microhardness of Pt-3% V. The laser welded sample showed a steep but narrow drop in microhardness across the weld zone. After etching, it was clear that local recrystallisation had taken place only in the immediate vicinity of the weld. The fusion welded Pt-3% V sample, which started out with a microhardness of about 457 HV, showed a significantly decreased microhardness of about 200 HV across the specimen after welding, due to recrystallisation along the entire length of the sample, as evident from light microscopy (Figure 5).

Scanning electron microscopy with a KeveX energy-dispersive X-ray analysis system on a Leica S440 microscope was carried out principally to assess the effect of welding on alloy composition, which was determined at closely spaced points along the lengths of the polished sections of selected welded specimens. Detectable loss of the alloying element was observed only in the case of fusion welding of the Pt-3% V specimens. No loss of vanadium was detected in the weld zones of the laser welded specimens, nor was alloying element lost in the Pt-5% Ru and Pt-5% Cu specimens joined by all three techniques.

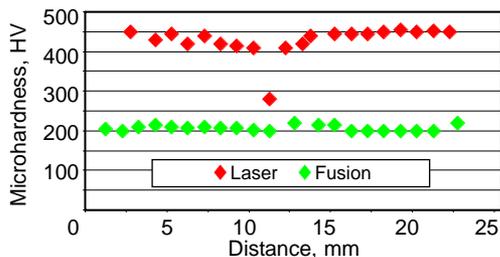


Fig. 4 Plot of microhardness (HV) against distance along the length of welded bars of Pt-3% V, showing localised softening associated with the weld zone in laser welding. The fusion weld sample had the same initial hardness as the laser weld sample, and showed reduced post-weld microhardness along its entire length

Discussion

It is clear from the results that traditional fusion welding is capable of producing a good join in platinum jewellery alloys, but that the degree of heating required causes extensive recrystallisation, which in turn reduces the overall hardness. Any fusion welding towards the end of the manufacturing process will compromise the aim of the platinum smith to increase the final hardness of jewellery through work hardening or controlled heat treatment.

In our tests neither laser welding nor spot welding produced good joins. All the welds were incomplete, with internal voids of varying extent, and with welding only effective on the outer margins. This is consistent with the results for butt welding obtained by Volpe and Lanam in an experimental study comparing fusion welding with conventional brazing using solder (1). Their study had more success with laser welding bevelled joints, and undoubtedly our welds would have been better if all the pieces to be joined had been bevelled. The jeweller conducting the spot weld tests reported great difficulty in fusing and joining the flat ends of the platinum workpieces. The recommended practice for microwelding is to melt a thin wire of the same metal into the groove created by a bevelled joint (5).

We did not carry out any strength tests on our experimental joints. Laser welding has been reported to produce consistently stronger joints in bend tests than does brazing, especially when using a wide 60° bevel joint in the laser welds (1). This is

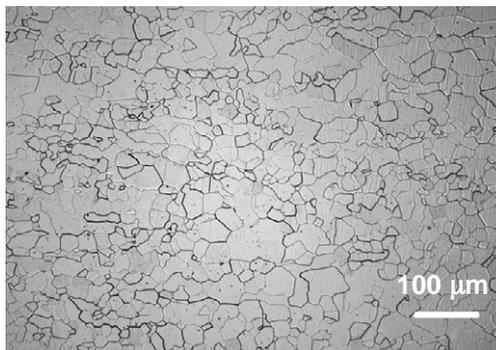


Fig. 5 Micrograph of polished and etched Pt-3% V through the weld zone (vertical) after fusion welding, showing recrystallised grains

easily done when joining simple components such as bars or two sides of a ring shank, but requires some ingenuity in making the bevel when joining thicker sections to surfaces, for instance attaching a ring shank to a bezel setting.

The results of the microhardness tests showed that both laser welding and spot welding caused minimal recrystallisation, and that was restricted to a narrow zone in the immediate vicinity of the weld. This left the overall hardness of the workpiece unchanged. The implications for manufacture include retaining prior hardness achieved through cold work or controlled heat treatment when welding in late-stage assembly or in repairing jewellery.

Fusion welding in air of the novel heat-treatable Pt-3% V alloy resulted in an appreciable loss of vanadium. Laser or spot welding would be the only effective ways of joining such an alloy.

Conclusions

This study has shown that laser and spot welding can be used to weld a variety of platinum alloys, producing a very narrow heat affected zone, and thus significantly limiting the extent of annealing and softening associated with the weld. This is in strong contrast to conventional fusion welding, where the heat generated tends to anneal large volumes of metal, if not the entire workpiece.

It is important to prepare the sections to be joined by laser or spot welding appropriately. If possible there should be a 60° notch or bevel between them, in order to get good penetration of

energy and to fill the gap with molten metal. This may require some ingenuity in design.

The primary advantage of using laser or spot welding is the retention of desirable hardening caused by prior cold work or low temperature heat treatment.

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