

Mechanical Properties Data for Pt-5 wt.% Cu and Pt-5 wt.% Ru Alloys

WORK PRESENTED AS A BASIS FOR FUTURE COMPARISONS

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Scant data exist for the mechanical properties of commercial platinum jewellery alloys Pt-5 wt.% Cu and Pt-5 wt.% Ru. Here data from new evaluations are presented on 90% cold worked and fully recrystallised heat treated alloys at 800°C. Recommendations are made for procedures in reporting future evaluations including disclosure of full processing details.

Platinum-5 wt.% copper (Pt-5% Cu) and platinum-5 wt.% ruthenium (Pt-5% Ru) are widely used alloys for platinum jewellery manufacture. It is therefore surprising that their mechanical properties are not well documented, as the mechanical properties of jewellery alloys are of fundamental importance in determining: (a) the ease with which the alloy may be formed into a jewellery item; and (b) the strength and durability of the finished item in service. Knowledge of mechanical properties is therefore beneficial to both jewellers and materials' developers. Equally important is knowledge of the

processing and microstructural condition of the alloy for which data are quoted, but even when mechanical property data are available, this information is often missing.

Some mechanical properties of pure platinum, Pt-5% Cu and Pt-5% Ru obtained from a review of available literature are shown in Table I. It can be seen that hardness values are well documented for most conditions, probably because determination of hardness involves a simple, non-destructive test which is quickly and easily carried out. However, while hardness testing is useful, it does not yield

	Vickers hardness strength, MPa	Ultimate tensile at fracture	% Elongation	Reference
Pure Pt				
Annealed	40–50	117–159	30–40	1, 2, 5, 6
Cold worked	100	234–241	2.5–3.5	2
Pt-5 wt.% Cu				
As cast	127	398	20	4
Annealed	110–120	?	29	3, 5
50% cold worked	215	?	?	5
90% cold worked	?	?	?	
Pt-5 wt.% Ru				
As cast	127	456	25	4
Annealed	125–130	414–415	32–34	2, 3, 5
50% cold worked	200–211	793	?	2, 5
Worked "hard"*	210	795	2	3
90% cold worked	?	?	?	

* The amount of cold work is not specified in the reference; ? indicates no information is available

easily interpreted results. Hardness is related to strength, ductility and elastic modulus, but these properties are not simply extracted from the hardness value. Conversely a properly conducted tensile test is easily interpreted, and the yield strength, tensile strength, elastic modulus and ductility can be more simply distinguished. For precious metals such as platinum, considerations of cost (tensile test specimens being relatively large) probably account for the paucity of tensile test data.

Table I also shows that most of the available information is for the annealed and as cast conditions, which are expected to exhibit similar values. With the exception of Lanam and Pozarnik (4), very few sources give processing information such as annealing temperature, or microstructural information, such as grain size. Also lacking are experimental details that allow other researchers to evaluate the data.

In order to test platinum jewellery alloys, a microsample tensile testing machine has been built at the University of Cape Town that can test samples of total length 8 mm. This paper reports on measurements of both the hardness and tensile properties of Pt-5% Cu and Pt-5% Ru, in the annealed and 90% cold worked conditions. The aim is to provide mechanical property values, averaged from multiple tests, from specimens for which detailed processing and microstructural information is provided.

Experimental Procedure

Although there is a pressing need to measure the mechanical properties of platinum alloys, it is not a very practical undertaking when the expense of the material is considered. Even the smallest specimens in the ASTM tensile testing standards (7) are beyond the means of many researchers. The approach used here: microsample tensile testing, has been used previously for other materials with success (8). It uses a very small sample that is as close to the ratios of the ASTM standard as possible while minimising the amount of material used. It is useful in this situation because it reduces the cost of carrying out multiple tests to provide adequate data. A schematic of the specimen design can be seen in Figure 1.

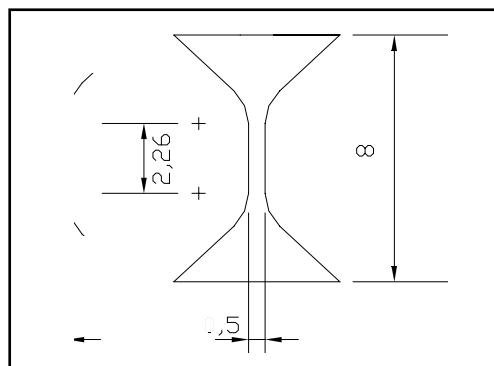
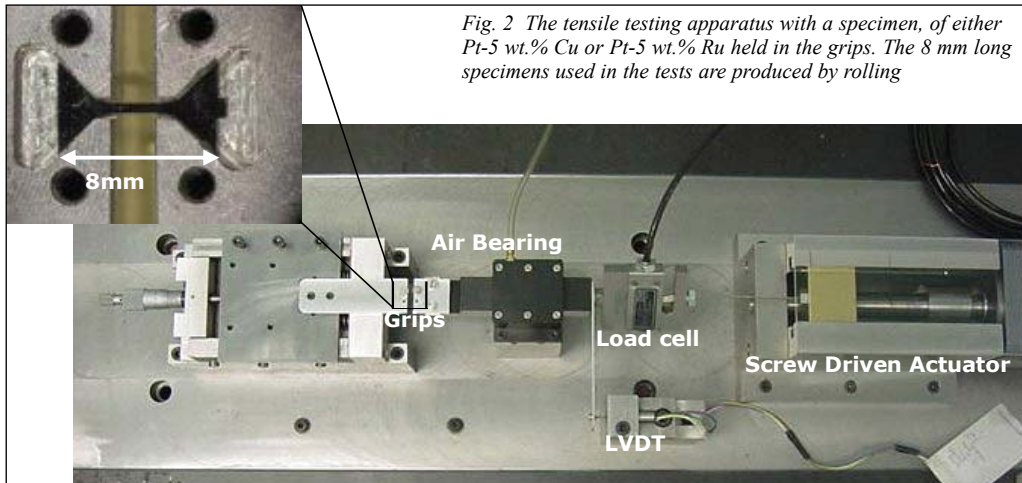


Fig. 1 Schematic of the small tensile specimen ready for testing; all the dimensions are in mm

The specimen has a total length of 8 mm, with a nominal gauge width of 0.5 mm and a nominal gauge length of 2.26 mm. The thickness can be varied by the amount that the starting plate is rolled and is kept of the same order as the width. Typically the gauge width contains 5 to 10 grains but this is obviously determined by grain size.

The custom built apparatus is shown in Figure 2. A tensile specimen is positioned in the grips. The operation of the tensile testing apparatus is based on a screw driven actuator that applies a load to the specimen in the grips. Friction is reduced to a negligible amount with an air bearing. Load is measured with a 500 N load cell and displacement is measured with a miniature linear variable displacement transducer (LVDT) sensor. A computer records both displacement and load. Because displacement is not measured directly on the specimen, we do not regard the elastic strain data as reliable; furthermore analysis of the elastic response is complicated by elongation of the specimen ends in the grips. However, the recorded plastic elongation is reliable and compares well with direct measurements made on the specimens after testing. Examination of specimens after testing confirms that the plastic behaviour is concentrated in the gauge section.

To make the tensile specimens a plate is first rolled to the required thickness. If required, the plate is then annealed. This can take place before or after cutting. The cold worked specimens were cut with the tensile axis parallel to the rolling direction. The samples were cut using both a computer



numerical control (CNC) mill and wire electro discharge machining. The choice of cutting method was found to have little effect on the materials. The Pt-5% Cu and Pt-5% Ru samples were measured at two extremes of mechanical behaviour: the recrystallised and 90% cold rolled states.

Specific information about their processing is as follows: the as received material was homogenised first at 1000°C for 12 hours. It was then cold rolled to 90% reduction in thickness. Half of the material from each alloy was retained to perform testing of 90% cold rolled material. The remainder was heat treated at 800°C for six hours under vacuum. Light micrographs of the grain structure were taken. Hardness and tensile specimens were polished to a mirror finish for consistency. Small sample tensile tests and Vickers hardness tests with a 100 g load were performed with each set of specimens.

Results

Light micrographs from each set of material are shown in the figures. Figures 3 and 4 show the microstructure of the materials in the 90% cold rolled and 800°C heat treated conditions, respectively. As expected the 90% cold rolled material shows grains that are elongated in the direction of rolling. The heat treated Pt-5% Cu exhibits complete recrystallisation, with equiaxed grains of size $\sim 100 \mu\text{m}$. By comparison, the heat treated Pt-5% Ru alloy, Figure 4(b), shows finer grains, of size $\sim 50 \mu\text{m}$.

Figure 5 shows some typical tensile test results. As expected, the 90% cold rolled alloys exhibit a higher yield stress and significantly lower ductility than the recrystallised alloys.

The calculated average results of tensile tests are seen in Table II along with the hardness results.

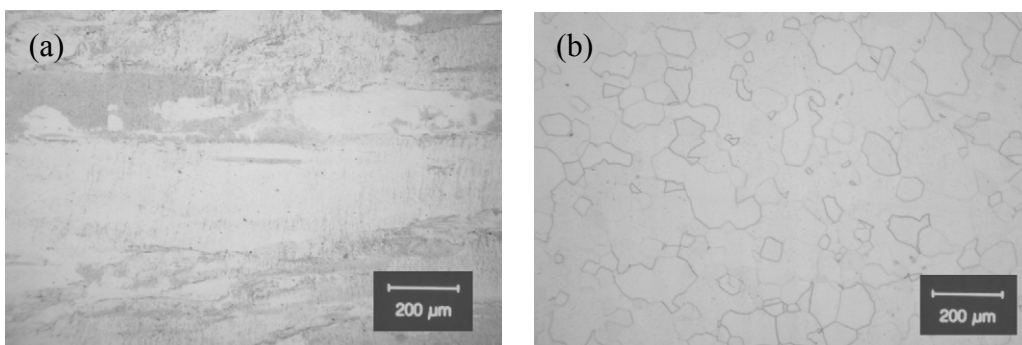


Fig. 3 (a) Pt-5 wt.% Cu in the 90% cold rolled state and (b) Pt-5 wt.% Cu in the 800°C heat treated condition

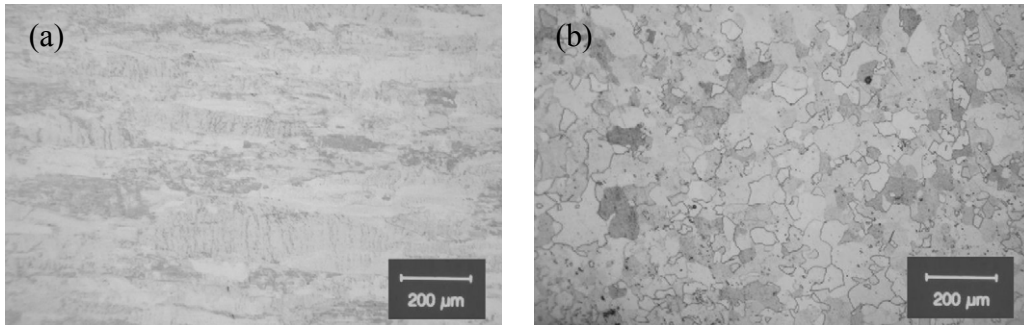


Fig. 4 (a) Pt-5 wt.% Ru in the 90% cold rolled state and (b) Pt-5 wt.% Ru in the 800°C heat treated condition

It can be seen that the two alloys are not significantly different in strength, however, the Pt 5% Cu alloy is more ductile than the Pt 5% Ru alloy.

Discussion

If the new data in Table II is compared with the literature values quoted in Table I, it can be seen that the hardness and strength values obtained in the present work are consistently higher. This is expected for the cold rolled specimens, since the values obtained from the literature were for 50% cold worked alloys, and the results in the present work are for 90% cold work. The increased dislocation density in the 90% cold rolled specimens results in higher values for both hardness and strength, and very low ductility.

The difference in values for annealed speci-

mens quoted in the literature and in the present work should also be evaluated on the basis of microstructure, but unfortunately heat treatment and microstructure data are not available for the values in the literature. The light micrographs in Figures 3 and 4 show that Pt-5% Ru has a finer grain structure than the Pt-5% Cu after heat treatment at 800°C. This suggests that the recrystallisation temperature of Pt-5% Cu is lower than that of Pt-5% Ru, consistent with the slightly lower melting temperature of Pt-5% Cu. The recrystallisation temperature for both materials is clearly 800°C or less after 90% cold work, and is certainly less than the 1000°C after an unspecified amount of prior cold work suggested in (3). The hardness and strength values in Table II show that the values for Pt-5% Ru are higher than for Pt-5%

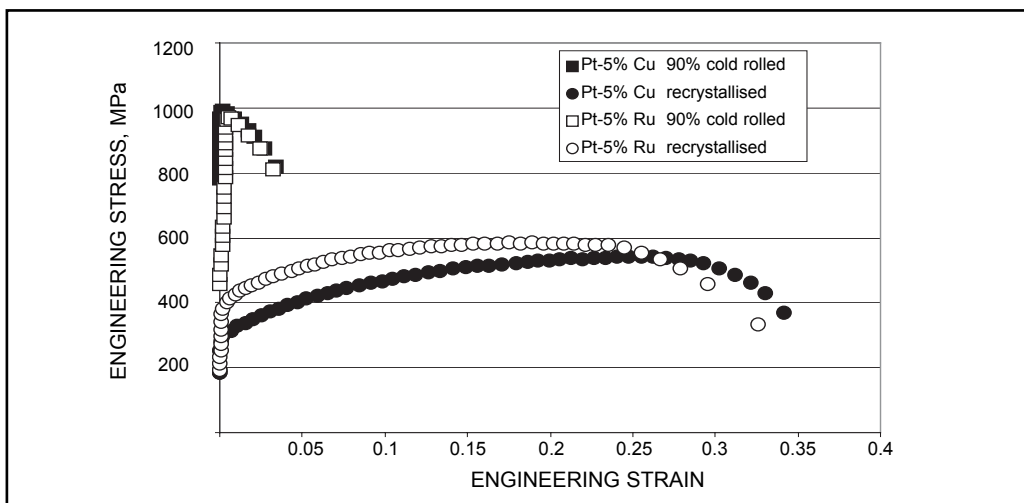


Fig. 5 Tensile stress-strain curves from Pt-5 wt.% Cu and Pt-5 wt.% Ru alloys

Table II Average Results from Tensile Tests, with Standard Deviation for Pt-5 wt.% Cu and Pt-5 wt.% Ru					
Material	HV	Yield stress, MPa	Ultimate stress, MPa	Fracture stress, MPa	% Elongation
Pt-5% Cu heat treated 800°C [22] [*]	150	280 ± 30	530 ± 40	360 ± 50	36 ± 9
Pt-5% Cu 90% cold worked [19] [*]	240	970 ± 100	990 ± 90	820 ± 100	2 ± 1
Pt-5% Ru heat treated 800°C [8] [*]	160	390 ± 40	540 ± 20	370 ± 70	29 ± 6
Pt-5% Ru 90% cold worked [8] [*]	280	930 ± 40	960 ± 50	780 ± 70	3 ± 1

* The figures in parentheses indicate the number of tests conducted to obtain each set of values

Cu after the same heat treatment, which can be explained by the finer grain size of the Pt-5% Ru. Similarly, the difference in elongation may have more to do with the difference in grain size rather than real differences in the alloys. This illustrates the importance of both processing and microstructural information in evaluating mechanical property data.

The standard deviations of the strength data shown in Table II, illustrating the variation in values obtained in repeated tests of the same specimen type, are relatively large at around 10%. This underscores the necessity of carrying out multiple tests on each specimen type in order to obtain reliable average values for mechanical properties.

Conclusion

The results presented provide data to serve as a basis for comparison in further research on platinum alloys. It has been shown that the two most widely used platinum alloys are not significantly different in mechanical properties, and in addition, microstructure information and hardness values for each tested sample have been included. This is the most comprehensive information available on mechanical properties of these alloys and can serve as a baseline for alloy development. It is recommended that published mechanical data should include full processing information, microstructural characterisation if possible, number of specimens measured, and standard deviation or

range of values obtained. This will greatly assist in evaluation of data and comparison with other measurements.

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