Dispersion-Strengthened Rhodium-Platinum

A NEW MATERIAL FOR HIGH-TEMPERATURE STRUCTURAL APPLICATIONS

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This article describes the properties and characteristics of a new addition to the range of platinum-based alloys for high-temperature structural use, known commercially as ZGS 10 per cent rhodium-platinum. The processes developed at the Johnson Matthey Research Centre for the introduction of a highly dispersed non-metallic phase into pure platinum, outlined in a previous article in this journal, have now been further optimised to a stage where a similar strengthening dispersion can be produced within a rhodium-platinum alloy matrix. The resulting material is significantly stronger and more creep resistant than the conventional high-temperature rhodium-platinum alloys, while retaining the useful electrical and chemical properties that have made these alloys so attractive as materials of construction in many industrially important areas.

The traditional solution to the problem of utilising the unique chemical inertness of platinum in high-temperature engineering structures subject to high stress has been to strengthen the platinum matrix by alloying with rhodium. With the exception of certain critical industrial processes such as optical glass production, where even small additions of a second element can interfere with product quality, this approach is of wide application, and has been used to great advantage in such processes as glass-fibre manufacture.

More recently, alternative strengthening techniques have become available, based on the use of a very fine well-dispersed zirconium oxide phase (1) which when incorporated within a pure platinum matrix at very low total concentration (<0.5 volume per cent) provides for increments of creep resistance far greater than those which can be achieved by alloying, without detriment to corrosion resistance and chemical compatibility. Pure platinum strengthened in this way—known commercially as ZGS platinum—is now well-established as a constructional material in a wide range of industrial applications.

The basic oxide-strengthening process employed has now been further developed for application to rhodium-platinum alloys, and it is now possible to combine the benefits of solid solution additions of rhodium with a dispersed oxide phase in platinum to optimum effect. This paper describes the properties and characteristics of a new addition to the range of dispersion-strengthened materials, ZGS 10 per cent rhodium-platinum, and outlines its areas of application.

Properties of Rhodium-Platinum Alloys

While the primary use of rhodium in platinum alloys has been for strengthening purposes, the presence of the second platinum metal has strong effects upon several other

Table I

Room and Elevated Temperature Properties of Platinum and the Commercially Important Rhodium-Platinum Alloys

	Pure Pt	10% Rh–Pt	20% Rh–Pt	40% Rh–Pt
Specific gravity at 20°C, g/cm³	21.4	20.0	18.8	16.8
Specific resistance at 20°C, μΩcm	10.6	18.4	20.0	17.5
Temperature coefficient of resistance per °C, Mean 0–100°C	0.0039	0.0017	0.0014	0.0014
UTS, kg/mm² (annealed)	12.7	33.75	48.8	57.5
Elongation, per cent (annealed)	40	35	33	30
Hardness, Hv (annealed)	40	75	115	130
100h Rupture strength at 1400°C in air, kg/mm²	0.14	0.36	0.63	0.69

industrially significant properties, some of which can be used with advantage. Others are less acceptable, but have to be tolerated in the interests of high strength. The significance of the ZGS 10 per cent rhodium-platinum development within this context is most readily appreciated from a detailed consideration of these basic alloy properties. Table I compares some physical and mechanical properties of pure platinum and of a number of conventional rhodium-platinum alloys. The electrical properties are, as expected, significantly affected by the presence of rhodium, and the low-temperature coefficient of resistance can be exploited to advantage when platinum is employed in a resistance heater role as a furnace element. The high-temperature strength of rhodium-platinum alloys increases markedly with increasing rhodium content, the optimum properties being achieved in the 20 to 25 per cent alloy range, as shown in Figure 1. Above this level oxidation effects impose a limit to the properties which can be realised in practical situations in air.

Rhodium in solid solution has a pronounced effect upon both room- and high-temperature mechanical properties, and the fabrication of complex equipment becomes more difficult in the more highly alloyed compositions.

In glass-making practice the wetting behaviour of containment materials is of very

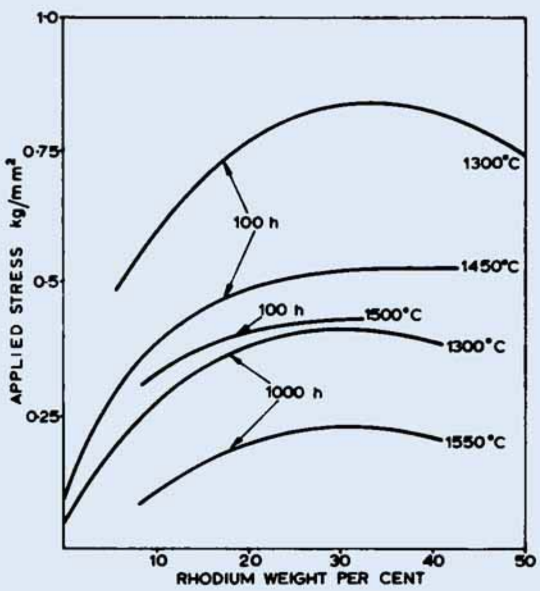

Fig. 1 Stress rupture data for rhodium-platinum alloys of varying rhodium content (2)

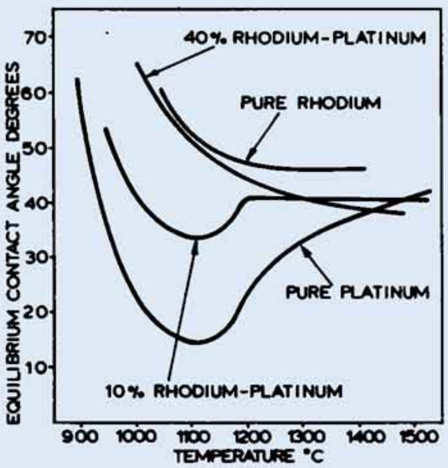

Fig. 2 The equilibrium contact angle of 'E' glass on pure platinum and rhodium-platinum alloys as a function of temperature

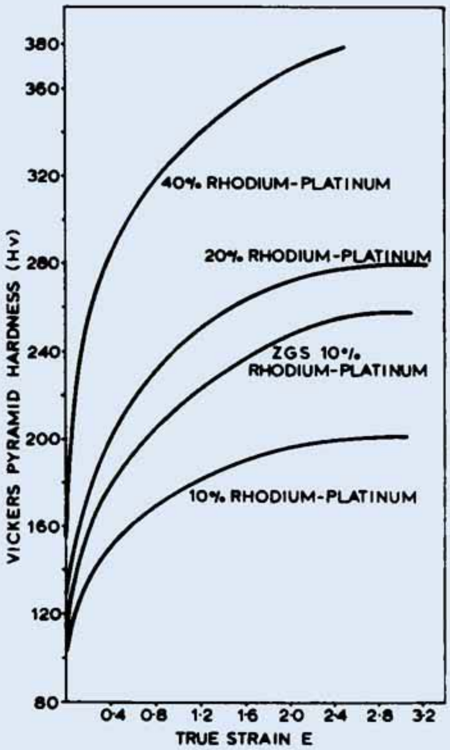

Fig. 3 Work-hardening characteristics of ZGS 10 per cent rhodium-platinum compared to those of the traditional melted alloys

considerable importance, and the effect of temperature and rhodium content upon the equilibrium contact of 'E' glass on platinum is illustrated in Figure 2. Although rhodium increases the contact angle considerably at lower temperatures, in the industrially interesting 1150 to 1400°C region little if any advance in wetting resistance is achieved by increasing the rhodium content above about 10 per cent by weight.

ZGS 10 per cent Rhodium-Platinum

Consideration of this kind highlighted the advantages to be gained if it proved to be possible to apply the oxide-strengthening principle to rhodium-platinum alloys, it being clear that if the requisite hot strength could be achieved independently of the rhodium concentration, the rhodium content could be adjusted to obtain optimum benefits in terms of electrical properties, chemical compatibility and room-temperature workability.

Development work was put in hand with this aim in mind. Ten per cent rhodium-platinum was chosen as the alloy base, and it was found that with some modification, the internal oxidation processes developed earlier for ZGS platinum production (1) could be applied successfully to the rhodium bearing alloy to produce a stable, dispersed, oxide distribution and to have a considerable strengthening effect.

Room-temperature Properties

The room-temperature properties of ZGS 10 per cent rhodium-platinum and the conventional melted alloy are compared in Table II. The presence of the dispersion has little effect of practical significance upon the important physical properties of the alloy. The hardness and ultimate tensile strength show an increase, as expected, but as the work-hardening curves presented in Figure 3 demonstrate, the dispersion-strengthened alloy is more readily fabricated than the 20 and 40 per cent rhodium-melted compositions.

Microstructure

Annealed ZGS 10 per cent rhodium-platinum displays the highly aligned re-

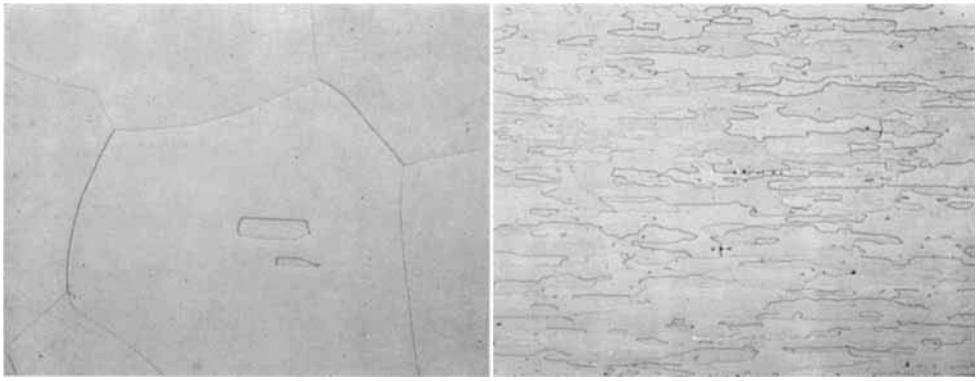

Fig. 4 The microstructures of 10 per cent rhodium-platinum (left) and ZGS 10 per cent rhodium-platinum (right) after heating for 500 hours at 1400°C in air. The high stability of the oxide-stabilised alloy is well illustrated by these photomicrographs ×50

crystallised microstructure characteristic of a low dispersoid concentration, and the grain structure is extremely stable as the thermally exposed microstructures in Figure 4 demonstrate.

High-temperature Properties

Creep data for the dispersion-strengthened alloy in sheet form at 1400°C are presented in Figures 5 and 6, which highlight the substantial improvements in both endurance to ultimate failure and steady state creep rate which have been achieved by means of the dispersoid addition. The material thus displays both a high rigidity and a long life under stress at high temperatures, highly desirable requirements in a high-temperature structural material.

Applications

The ZGS 10 per cent rhodium-platinum alloy is being examined under service conditions in a variety of roles in the glass industry, where the characteristics of the basic alloy have been exploited successfully for many years, and the high strength and rigidity imparted by the presence of the dispersion provides an added bonus, particularly for components subject to very high stresses whose service life has previously been very short indeed. The solid-state joining techniques developed for the assembly of ZGS platinum apparatus (1) have been found to be equally applicable to the dispersion-strengthened alloy, although more use can be made of correctly sited fusion welds, since the melted

Table II

Room Temperature Properties of 10 per cent Rhodium-Platinum and ZGS 10 per cent Rhodium-Platinum

	Melted 10% Rh–Pt	ZGS 10% Rh–Pt
Specific gravity at 20°C, g/cm^3	20.0	19.8
Specific resistance at 20°C, $\mu\Omega$cm	18.4	21.2
Temperature coefficient of resistance per °C, Mean 0–100°C	0.0017	0.0016
UTS, kg/mm^2 (annealed)	33.75	36.2
Elongation, per cent (annealed)	35	30
Hardness, Hv (annealed)	75	110

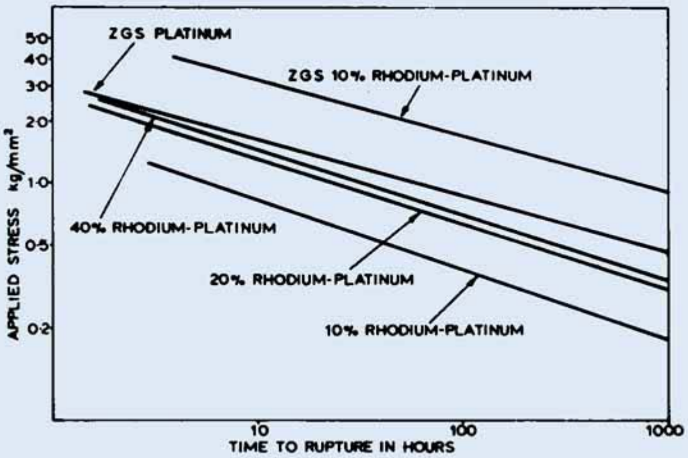

***Fig. 5** Stress rupture properties of ZGS platinum ZGS 10 per cent rhodium-platinum and the commercially important conventional alloy compositions. The curves refer to tests carried out at 1400°C in air on 1.5 mm thick sheet specimens*

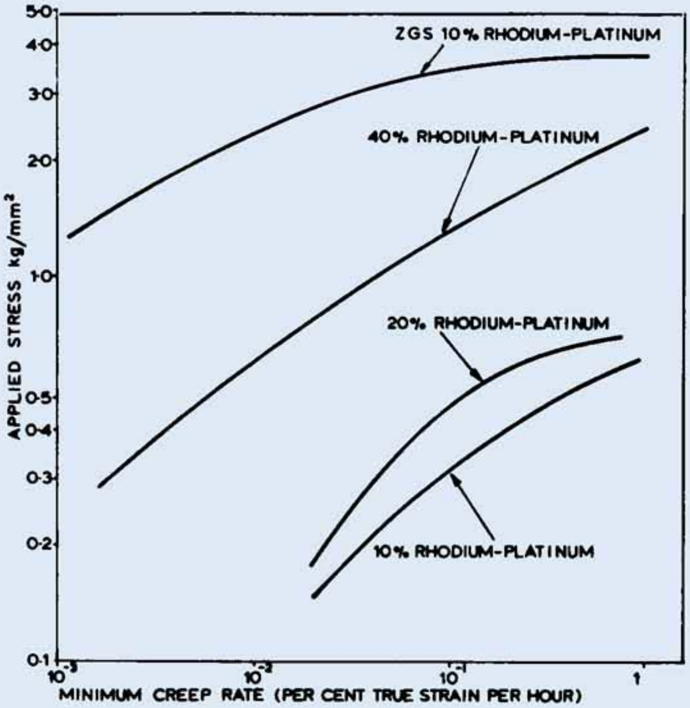

***Fig. 6** Minimum creep rate curves for ZGS 10 per cent rhodium-platinum and the commonly used rhodium-platinum alloys in sheet form, tested at 1400°C in air*

zone, while devoid of an effective oxide dispersion, still retains the strength increment provided by the rhodium addition.

It is to be expected that the material will find considerable application also in many resistance heating applications for furnace windings, heater tapes and ignition coils, particularly when the device concerned is required to be fully self-supporting.

References

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