Working the wonder metal

Orenda blazes a trail in titanium
Find many difficulties exaggerated

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The following article is based on a paper delivered by Mr. Gray at the annual meeting of the Canadian Aeronautical Institute at Montreal.

The recent developing of techniques in the use of various commercial grades of titanium has reasonably well assured that metal an important place in industry and particularly in the aviation field.

The last few years have seen a considerable improvement in the consistency of the material from the foundries and mills. In our experience, many of the predicted difficulties in the machining area were found to be exaggerated.

The phenomenal stability of the metal offsets the reduced cutting speeds required and many machine operators preferred to work titanium rather than the heat resisting stainless steels.

In most machining operations it was necessary to provide fixtures made heavier and more stable than is the usual practice for limited quantity development requirements. Not only is the cutting facilitated in this way but more than adequate tools are preferred in order that operator errors may be reduced.

▶ **Absorbs Gases.** It is commonly known that hot titanium has the unfortunate ability to absorb most common gases resulting in embrittlement and general deterioration of its mechanical properties. In welding, as in melting, it is obvious that such injurious gases must be excluded either by a vacuum system or in an inert gas.

The problems connected with structures and vessels in a vacuum system —and the consequent expense—guided our own research in the direction of gas chambers.

It is only proper to point out that this equipment presently in use, like "Topsy"—grew. Parts were added as the requirement arose and continuing improvement has resulted in a very versatile chamber and control gear.

This equipment is capable of doing automatic longitudinal and circumferential welds consistently, the majority of the manipulation required while welding being controlled from a panel outside the chamber. Welding not possible by automatic methods can be accomplished by hand through suitably placed glove holes.

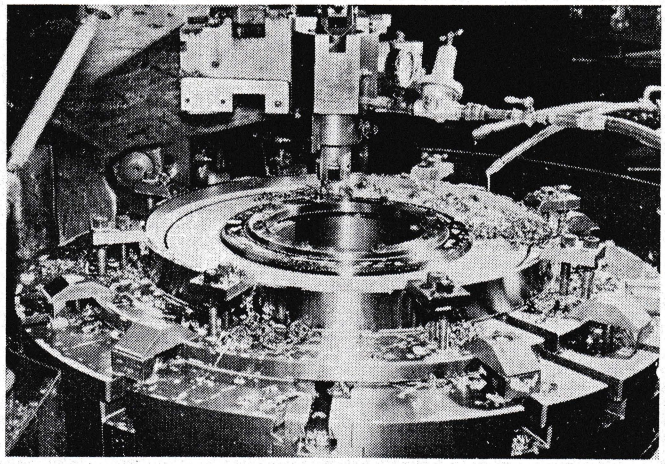
Two smaller chambers were constructed, one of which was used in most of the metallurgical examinations into welding but which permitted only automatic circumferential welds. From this chamber came the information which resulted in the more successful larger chamber.

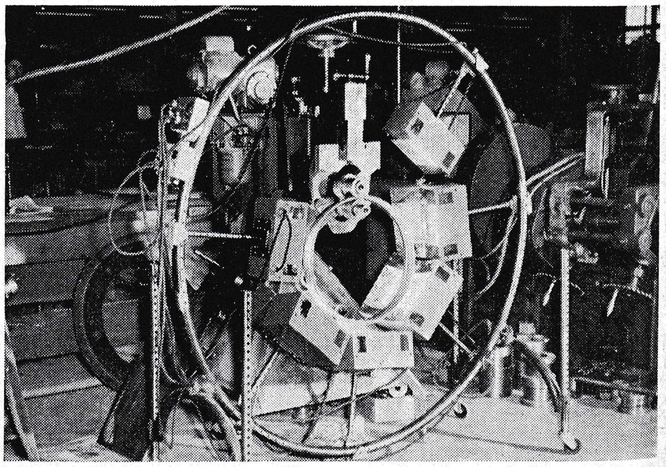
▶ **Color Clue:** The absorption of atmospheric gases causes a discoloration indicating that contamination has occurred. Light straw colors are tolerable depending on the depth of color which in the extreme instance becomes a purple blue.

While these colors are indicative, a considerable amount of laboratory investigation must precede the acceptance of welds on that basis. In view of the fact that the liquid metal seems to be a universal solvent and can be contaminated by nearly everything including all known refractories, extreme cleanliness is essential on all back up rings, fixtures and components.

In all instances it is necessary to stress relieve the titanium fabrications, to which end rigid stress relieving fixtures were supplied in order to facilitate the control of distortion after welding.

These fixtures, where possible,





WORKING TITANIUM. Above are shown two of the machines used by Orenda in working with titanium. Left a roughing operation on a compressor wheel or disc. Heavy radius at the hub of the disc requires rigid clamping. In this instance finger clamps were found adequate, but provision was made within the fixture to vertically support the thin web of the disc against the tool pressure. Right shows the method used in rolling a titanium sheet metal ring approximately 0.062 gauge size. Due to bad thermal conductivity of the metal, care must be used to prevent local overheating and pick-up of gasses which cause embrittlement.

stretch the welded joint to a slightly larger size after stress relieving, and, having yielded the material at the relieving temperature, reduced distortion is usually found after the weld has been run. The affinity of the metal for atmospheric gases at elevated temperatures limits the maximum stress relieving temperature to around 1,125 F. which is common to both low and high tensile alloys.

By correct design the amount of stretching realized can be controlled by the differential expansion between the steel fixture and the titanium part. The plate from which the fixtures are usually constructed has a co-efficient of expansion roughly twice that of titanium; the prestressing feature of the relieving and stretching fixture, unless controllable, can result in excessive yielding of the work due to inconsistent amounts of stress applied in the cold condition.

We are quite well aware that a remarkable amount of stretching can take place.

Forming Sheet. The forming of sheet also presents peculiarities.

The metal seems to possess some of the attributes of spring steel and in certain cases will shatter in the same manner while being cold formed. At elevated temperatures between 800 F. to 1,000 F. its behavior is more tractable.

Although many people have claimed to successfully cold form sheet, our own experience on limited quantities, has been confined to the hot process. Rings hot-rolled to a rough form have been hot-coined to improve size and shape where neither single method has proved satisfactory.

In a similar manner, welded structures have been stretched longitudinally across the weld where weld shrinkage in that direction has been excessive; the parts pressed at around 800 F. show no signs of failure at the weld or any tendency to crack.

The forging industry is adequately meeting the demands for supplying closed die contour forgings to tolerances as good and better than usually found with the steel or aluminum equivalents.

Compressor blades with finished forged aerofoil shapes are available from Canadian sources and are quite comparable to those from larger American companies. It is usual to find heavier guttering and increased flash thickness on titanium forgings.

Heating Important. Die heating is also more important than with steel components. Titanium has its own forging characteristics and more noticeable is its poor die flow.

Compressor wheels of SAE 4340 steel take far fewer forging blows at 2,250 F. than do the titanium wheels at 1,750 F.

Heated titanium, when provided with a plentiful supply of compressed air, burns with a brilliant white flame, even as large pieces. Less air is required to sustain a fire of titanium cuttings.

Swarf fires are handled in the same manner as for magnesium, a dry sand-like substance is available as a commercial supply for that purpose. We have conducted burning tests on heavy sections of titanium and steel with rather surprising results. The titanium is no worse than steel in that respect under similar laboratory conditions.

Limited Treatment. It is impossible in this brief look at Titanium, to cover much ground and a great many important considerations have been neglected, not the least of which is the regrettable ease with which the metal galls and also the fatigue aspect consequent on fretting and galling, for which no entirely satisfactory solution has been found.

Even plate glass rubbed together with the metal will show titanium discoloration on the glass due to galling.

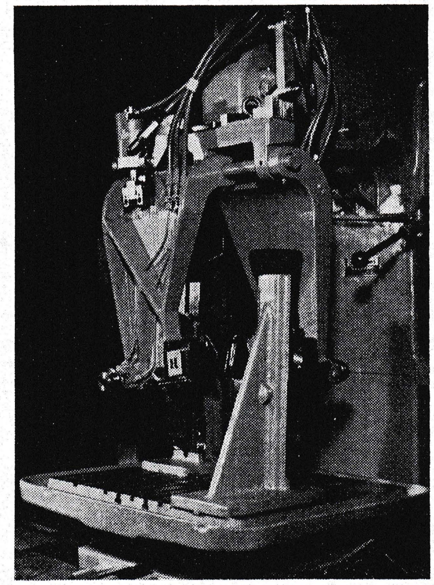
As with the early use of aluminum, the consuming industry is alternately reflecting exaggerated optimism and pessimism which state of flux, we hope, will improve along with the price.

The product potential of titanium has hardly been scratched. Surgeons have acclaimed its use prosthetically in orthopaedic work, and are asking for bone bolts in the high tensile grades to facilitate removal; the bone apparently grows while in contact with this metal.

The phenomenal corrosion resistance offers remarkable advantages against body acids and acids in general. The metal has made considerable headway into industrial fields with those problems, although it may be quite some time before we see ships' propellers made from the stuff.

There has been little mention of cutting angles, rakes, speeds and feeds, or cutting tool materials in view of the considerable range of titanium alloys affecting to some degree each or all of those considerations.

It can be said that people possessing the equipment and know-how, while being familiar with high temperature stainless alloys, should have little or no trouble in handling titanium machined parts. It is reasonably obvious that welding poses a different problem and some sort of special equipment is desirable.



BLADE FORMING. Initial object in Orenda's titanium program was forming the compressor blade aerofoil from a rough forging. Past performance indicated a single tool had the least injurious effect from the distortion viewpoint. A slotting machine was converted for this purpose.

It should be mentioned that we have had no experience with grinding titanium. Our efforts were rather to dispense with the necessity to grind, in which we count ourselves fortunate to have succeeded.

The foregoing remarks have been based mainly on experience obtained from the development end of jet engine building at Orenda Engines Limited. Our production facilities, following in our footsteps, are producing parts in titanium in semiproduction quantities with equal success.

Machining Difficulties? You will have noticed that the difficulties of machining titanium have not been discussed in this paper. Despite the technical papers that have been written, the books that have been published by large manufacturing organizations and the research carried out by certain U. S. A. universities on the difficulties of machining titaniums, we at Orenda have not experienced these difficulties.

Difficulties are, of course, relative, compared with machining aluminum or mild steel. Yes, it's more difficult, but, compared with the machining of the high temperature alloy steels, which are commonplace in the jet engine industry, titanium is by no means as difficult. Some evidence of this can be gauged by the fact that we are constantly machining parts in titanium in approximately 75% of the time necessary to machine a similar part in 4140 steel.