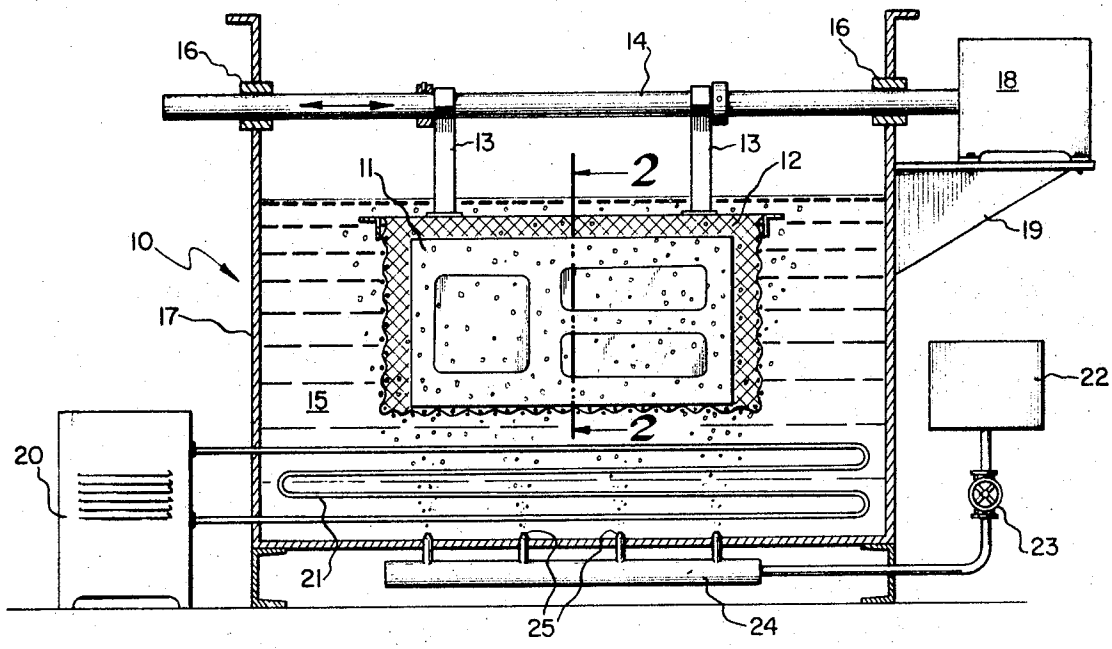
July 10, 1973 D. O. COWLES ET AL 3,745,079

CHEMICALLY MILLING TITANIUM ALLOY WORKPIECES

Filed April 21, 1971

Fig. 1



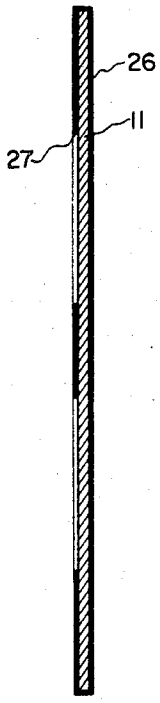


Fig. 2

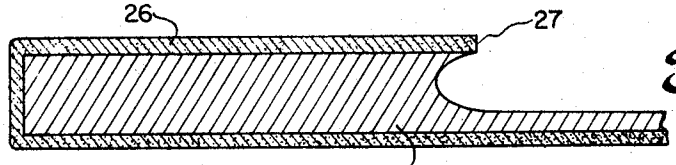


Fig. 3

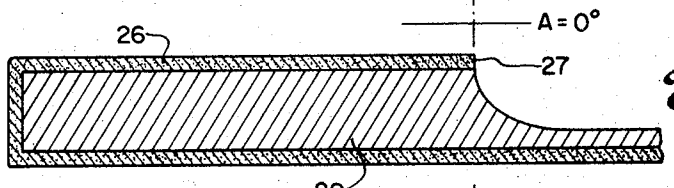


Fig. 4

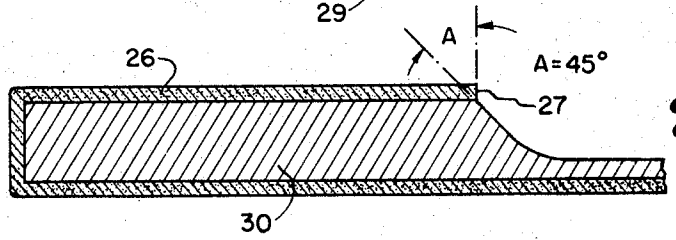


Fig. 5

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CHEMICALLY MILLING TITANIUM ALLOY WORKPIECES

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U.S. Cl. 156—18 2 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus and etchant compositions are disclosed for chemically milling titanium alloy workpieces to develop recessed areas having non-undercut edge characteristics.

SUMMARY OF THE INVENTION

Structural members such as aircraft skin components and the like with recessed surface areas are chemically milled from titanium alloy stock using essentially conventional apparatus and an etchant consisting of hydrofluoric acid solution, wetting agent, and ammonium nitrate etch control additive to obtain non-undercut recessed area edges and other improved workpiece characteristics. The configuration and slope of the recessed area edge may be varied within limits by varying the concentration of etch control additive in the etchant.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic elevational and sectional illustration of essentially conventional apparatus preferred for use in the practice of the present invention;

FIG. 2 is a workpiece sectional view taken at line 2—2 of FIG. 1;

FIG. 3 is a sectional view of a titanium alloy workpiece having a recessed surface area etched in a conventional manner; and

FIGS. 4 and 5 are sectional views of titanium alloy workpieces chemically milled in accordance with this invention.

DETAILED DESCRIPTION

The apparatus illustrated schematically in FIG. 1 is preferred for use in connection with the practice of the present invention. As shown in that figure, a titanium alloy aircraft skin workpiece **11** is typically supported vertically in open basket **12** for purposes of removing metal from selected surface areas by chemical milling. Basket **12** is suspended by straps **13** from reciprocally moved support member **14**. Both workpiece **11** and basket **12** are immersed in etchant solution **15** and mechanical agitation of member **14** within bearing supports **16** and etchant-resistant tank **17** is accomplished by conventional vibrator unit **18** supported on platform **19**.

Apparatus **10** also preferably includes a refrigeration unit **20** that functions to control the temperature of etchant **15** by controlled circulation of a coolant through immersed cooling coil **21**. An air supply **22** cooperating with valve **23** and manifold **24** is provided to supply pressurized air to etchant **15** through inlets **25** and thereby obtain an additional degree of etchant agitation and circulation relative to the exterior surfaces of workpiece **11**.

In one embodiment of apparatus **10**, refrigeration unit **22** was typically operated to control the temperature of etchant **15** to a temperature in the nominal range of 90° F. to 130° F. with a temperature of approximately 115° F. normally being preferred. Vibrator unit **18** developed reciprocal transverse movement of support member **14** at a velocity of 12 inches per second on the average, such rate typically being in the normally preferred velocity range of from 6 inches per second to 12 inches per second. Variation of etchant temperature, and to a lesser degree agitation rate, noticeably affects the rate of metal removal from workpiece **11**.

The etchant preferred in the practice of the present invention for removing metal from alloys such as 6Al–4V titanium alloy is comprised of hydrofluoric acid water solution, an etch control additive such as ammonium nitrate, and a wetting agent. By way of example, one specific preferred composition of etchant **15** is: 92.5 gallons water; 7.5 gallons concentrated hydrofluoric acid (commercial grade); 0.94 pound ammonium nitrate (commercial grade); and 100 milliliters dodecylbenzene sulphonic acid wetting agent. As will hereinafter be detailed, the preferred amount of ammonium nitrate etch control additive may be varied over the range of from approximately 0.50 pound per 100 gallons of etch solution to 1.30 pounds per 100 gallons of etch solution to obtain different edge cross-section configurations and slopes at the perimeter of chemically milled recessed surface areas in titanium alloy workpieces.

FIG. 2 illustrates workpiece **11** in cross-section and shows a removable conventional etch-resistant film **26** adhered to the workpiece surface. Film **26** is typically comprised of a conventional polyvinyl chloride and is applied to workpiece **26** by spraying or dipping. After the coating is cured on the workpiece, surface areas from which metal is to be removed are defined by edges **27** scribed in the etch-resistant film. Inset film areas are typically stripped manually from the workpiece surface to expose the surface metal of workpiece **11** throughout areas from which metal is to be removed.

Conventional chemical milling etchants having esentially only water, hydrofluoric acid, and wetting agent function to remove surface metal from titanium alloy workpieces in a manner that produces an undercut or "fingernail" cross-sectional configuration at recess edges of workpiece **28** and film edge **27** as shown in FIG. 3. We have discovered that incorporating ammonium nitrate etch control additive in etchant **15**, generally in the range from approximately 0.50 pound per 100 gallons of etchant to 1.30 pounds per 100 gallons of etchant (based on an etchant equivalent of 7.5% volumetric concentration of hydrofluoric acid in water), is effective to eliminate such "fingernail" effect and to produce edge configurations of the type shown in FIGS. 4 and 5. Such latter type is generally acceptable in connection with producing aircraft quality chemically milled titanium alloy workpieces. The smooth recess fillet in workpiece **29** at film edge **27** (having a departure from normal of essentially 0° at the workpiece upper surface) is produced by practice of the instant invention if the amount of etch control additive included in etchant **15** is approximately 0.50 pound per 100 gallons of etchant with 7.5% hydrofluoric acid volumetric concentration in water. By increasing the amount of ammonium nitrate etch control additive to approximately 1.00 pound per 100 gallons of etchant with 7.5% hydrofluoric acid volumetric concentration in water, the slope condition shown in workpiece **30** of FIG. 5 may be obtained at film edge **27**. Such recess edge slope is approximately 45° and is normally obtained over the range of approximately 35° to 45° by the addition of from approximately 0.75 pound to 1.00 pound of ammonium nitrate etch control additive to the specified concentration of hydrofluoric acid etchant. When the quantity of etch control additive is increased to approximately 1.30 pounds per 100 gallons of specified etchant solution, the slope shown in FIG. 5 may be changed to a condition where angle A equals approximately 60°. For most aircraft quality work a recess edge slope of 35° to 45° is preferred.

Etchant solution **15** provides a smoother chemically milled edge in the titanium alloy workpiece when initially containing a small proportion of dissolved alloy mate-

rial. For this reason we recommend initially including approximately 2.0 pounds of dissolved titanium alloy in the etchant **15** (per 100 gallons) prior to initiating chemical milling of any titanium alloy workpiece. When the concentration of dissolved metal in the etchant reaches a level of approximately 10 to 12 ounces of dissolved metal per gallon of solution, it normally becomes necessary to replace the etchant or provide for adequate reconstitution.

We claim:

1. In a method of chemically etching a partially-masked titanium alloy workpiece containing aluminum and vanadium, the step of removing metal by chemical reaction between said titanium alloy workpiece and a solution consisting of approximately 4% by weight hydrogen fluoride, ammonium nitrate in the range of 0.06% to 0.5% by weight, and the balance water and wetting agent to eliminate undercutting at the workpiece metal edges adjacent workpiece unmasked areas.

2. The invention defined by claim **1** wherein said ammonium nitrate is provided in said solution in the range of approximately 0.09% to 0.12% by weight.

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JACOB H. STEINBERG, Primary Examiner

U.S. Cl. X.R.

156—345; 252—79.3