

A Method Of Manufacturing a Component by Consolidating
Powder Material

This invention relates to a method of manufacturing an
5 aerofoil component using a consolidated powder material
union piece and articles so manufactured.

US 5,788,142 describes a method of joining components
using an intermediate part of compacted and formed
particles. The compacted intermediate part is formed of
10 constituent elemental particles which in admixture provide
a composition similar to the composition of the components.
The intermediate part is formed as a sheet.

Aerofoils used in turbine engines may be grouped into
a unitary assembly of similar aerofoils, commonly, and
15 generally known in the industry as a blisk. Blisks are high
value components and are at risk from sustaining damage
from handling and machining operations as well as
sustaining in service damage from ingestion of foreign
objects into the engine or by erosion or wear to the
20 aerofoils. Because of their high value it is desirable to
repair damaged portions of blades and disks to return the
blisk into service.

One method that has been proposed is to deposit metal
onto the damaged area by localised molten metal deposition.
25 This technique may have been acceptable for conventional
blades but newer blades use materials which can resist
higher temperatures but are more brittle and are damaged by
the melting. Because aerofoils in turbine engines rotate at
many thousands of RPM any damage to their internal
30 structure can have catastrophic effects.

It is an object of the present invention to seek to
provide an improved method of manufacture of an article, or
particularly repair of an article using consolidated powder
material.

According to a first aspect of the invention there is provided a method of manufacturing an aerofoil component comprising a first workpiece joined to a second workpiece, the method comprising, providing a first workpiece and a
5 second workpiece, providing a union piece formed of partially sintered powder, the union piece having an alignment feature for aligning the first workpiece with the second workpiece, assembling the first workpiece to the second workpiece via the alignment feature, and applying
10 heat and pressure to consolidate the first workpiece, the union piece and second workpiece.

Preferably the alignment feature comprises a recess into which at least a portion of the second workpiece is inserted.

15 The second workpiece may comprise a second union piece formed of partially sintered powder and having an alignment feature complementary to the alignment feature and wherein the second workpiece is connected to the union piece via the alignment feature and the complimentary alignment
20 feature.

Preferably the alignment feature is a pyramidical recess and the complementary alignment feature a pyramidical projection.

Preferably a portion of the union piece is removed
25 following consolidation by machining.

Preferably the first workpiece has an aerodynamic surface and the second workpiece has an aerodynamic surface and the portion of the union piece removed blends the aerodynamic surface of the first workpiece to the
30 aerodynamic surface of the second workpiece.

The aerodynamic surface of the first workpiece may be a pressure flank or suction flank on the aerofoil component.

The first workpiece may have a faying surface which abuts the union piece prior to consolidation and the second workpiece a faying surface which abuts the union piece prior to consolidation, wherein the thickness of the union
5 piece between the faying surface of the first workpiece and the faying surface of the second workpiece is less than 500 μ m.

The first workpiece may comprise part of a unitary assembly of aerofoils. The second workpiece may be a repair patch
10 for the aerofoil component.

The method may comprise the step of allocating the first workpiece with a plurality of standard zones and removing a portion of the first workpiece corresponding to at least one of the standard zones to provide a faying
15 location, wherein the alignment feature of the union piece complements the faying location.

Preferably the standard zones are arranged along the leading edge and /or trailing edges of the aerofoil.

According to a second aspect of the invention there is
20 provided a method of repairing an aerofoil component having damage or a defect comprising the step of allocating the aerofoil with a plurality of standard zones, determining the zone in which the damage or defect resides, removing a portion of the aerofoil in accordance with the zone in
25 which the damage or defect resides to provide a faying location, providing a union piece formed of partially sintered powder and having an alignment feature complementing the faying location, assembling a repair patch to the aerofoil via the union piece, and applying
30 heat and pressure to consolidate the aerofoil, union piece and repair patch.

Embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 depicts a blade with a damaged portion;

5 Fig. 2 is a depiction of the preferred manufacturing route for the union piece;

Fig. 3 is a perspective view of a manufactured union piece, aerofoil portion and repair patch;

Fig. 4 depicts an embodiment where the repair patch is
10 bonded to a second union piece prior to joining to the first union piece.

Fig. 5 depicts an aerofoil subdivided into a series of preselected zones.

Fig. 6 depicts a zone in which damage has been
15 identified.

Figure 1 depicts an aerofoil blade 2 having a damaged portion 4 possibly damaged by foreign object impact (FOD) or some other wear or impact damage.

The aerofoil 2 is formed of a material suitable for
20 use in the gas turbine. Particularly preferred materials are intermetallic alloys such as gamma titanium aluminide though it will be appreciated that the invention is appropriate to metals and their constituent alloys.

The damaged portion has a rough surface and before any
25 repair is made the surface is machined to provide a more uniform surface finish of the order $1\mu\text{m Ra}$. The surface may be cleaned, preferably using a swab etch of HF and HNO_3 followed by an acetone swab for a titanium alloy. This provides a clean recess for attachment of a repair patch.

30 A mould or other 3-dimensional scan is taken of the aerofoil blade to determine the shape of the union piece required. The union piece itself is formed of a powder with a particle diameter typically below $100\mu\text{m}$ and preferably below $50\mu\text{m}$ in the range 20 to $40\mu\text{m}$. The powder preferably

with the same nominal chemical composition of the aerofoil blade and the repair patch. Where the two components have different chemical compositions the composition of the powder is preferably an intermediate the two compositions.

5 Other powder compositions may be used provided the function of the repaired component is not impaired.

The manufacturing process of the union piece is depicted in Figure 2. The mould is transposed to a shaped die 10 into which the powder 12 is inserted, compacted and
10 partially sintered to form the preformed union piece 14. The compacting pressure is of the order 200MPa with the sintering being performed at a temperature of around 600-900°C for about 15-60 minutes.

The union piece 14 is bespoke to the components being
15 joined and preferably has a thickness X which between the faying surface of the aerofoil and the faying surface of the repair patch of between 200µm and 2000µm. For the majority of aerofoil repairs, where damage occurs to the leading or trailing edges of the blade it is desirable that
20 the thickness is between 200µm and 500µm. Blade at this location have a width Y typically between 2 and 8mm.

The union piece 14 is machined to form an alignment feature or features 16, 16' which will assist the alignment of the repair patch with the aerofoil. The alignment
25 feature is at its simplest a recess or groove into which a complementary portion of the repair patch is inserted.

Figure 3 depicts a perspective view of one embodiment of a sintered union piece 14, aerofoil 2 and repair patch 20. The aerofoil is inserted into the groove in the union
30 piece till the machined faying face of the aerofoil 24 abuts a corresponding flat face 22 on the union piece. The union piece extends widthwise beyond the aerofoil to aid both alignment and the joining step which consolidates the union piece with the aerofoil and repair patch.

The union piece is clamped to the aerofoil and the repair patch 20 connected to the assembly using the alignment feature of the union piece. The repair patch is provided with a recess which mates with the alignment features in the union piece.

The alignment features enable the repair patch and aerofoil to be presented to each other with correct positioning. Beneficially, it is possible to create alignment features which allow the parts to be assembled in just one orientation thereby reducing the chance of mistakes. As an additional benefit, the alignment features may be sized to provide an interference fit with the repair patch or aerofoil to aid assembly and reduce the number of clamps required.

As mentioned above it is desirable that the thickness of the union piece 14 between the faying surface 24 of the aerofoil and the faying surface 25 of the repair patch is kept below 500µm. It has been found that the thicker the union piece, which does not have the same material structure as the virgin cast aerofoil 2 and repair patch 20, the greater the risk of pores or other deleterious artefacts damaging the integrity of the repaired aerofoil.

In an alternative method of construction the union piece is attached to the aerofoil and the alignment feature formed therein whilst the union piece is in situ.

Once the patch, blade and union piece are aligned a shroud, jacket or bag is placed around the assembly and either evacuated or filled with an inert gas to minimise the risk of oxidation of the aerofoil or patch. Uniform pressure of between 25 and 100 Mpa is applied to form a butt joint and heat is applied locally to heat the union piece to a bonding temperature of between 850 and 1200°C to both fully sinter the union piece and to consolidate it with the joint surfaces.

Due to the application of heat and pressure a small amount of sintered powder is extruded from the join to leave a residue along the edges of the join. The residue is removed during the dressing stage along with the oversized
5 union piece to achieve final part geometry. Either chemical or mechanical machining may be used to remove the residue and / or the union piece.

The components are cooled at a rate of the order $5^{\circ}\text{C} / \text{min}$ to minimise residual stresses generated locally to the
10 join. A post join heat treatment may be used to further reduce residual stresses.

The repair patch may also be provided with a union piece as depicted in Figure 4. In this embodiment both the aerofoil 2 and the repair patch are provided with separate
15 union pieces formed from sintered powder as described above.

Beneficially, the union pieces are easier to machine than the aerofoil and repair patch particularly when these components are formed of an intermetallic material such as
20 titanium gamma aluminide. As the union pieces are easier to machine it is possible to provide better and more elaborate alignment features. For example, in Figure 4 the alignment feature in the first union piece 14 is a pyramidal projection 26. Such alignment features aid the butting of
25 the union pieces and consequently the joining of the aerofoil with the repair patch.

Various modifications may be made without departing from the inventive concept.

For example, the union piece may be formed primarily
30 as a generic cube which is machined to its final dimensions. As a further alternative the union piece may be formed by a process of direct metal deposition where powder or wire is fed onto a substrate, which may be the aerofoil blade, whilst the substrate is heated and partially melted

by a traversing laser beam. The traversing beam forms a melt pool into which the powder is directed and melted. As the melt pool cools the powder solidifies to provide a deposit with a height. Repeated passes of the laser over
5 the deposit enables layers of powder to be repeatedly provided, partially melted and solidified thereby increasing the height of the deposit. Beneficially manufacturing via this route, as the laser partially sinters the powder, it is possible to dispense of an
10 additional partial sinter step. In some circumstances it may be possible to sinter the material without heating it to a temperature at which it melts.

Similarly, whilst the above invention has been described with respect to aerofoils and repair patches
15 therefore it will be appreciated that the invention is equally appropriate to other components either inside the aerospace industry or outside the aerospace industry e.g. the energy industry.

It will be appreciated that the above described
20 invention provides a relatively simple and low-cost solution for repairing complex geometries. As the component parts are provided with alignment features the repair process can be automated.

The invention has been described with respect to
25 having union pieces specifically designed for the repair required. Because the union piece has to be manufactured using specialist equipment this can be time consuming, particularly where the piece needs to be ordered for manufacture. It is desirable to have the union piece, where
30 possible, as a stock item. Where the piece is a stock item the repair patch may also be a stock item and pre-arranged with the union piece.

As depicted in Figure 5, to make the union piece a stock item the most frequent repair reasons and locations

are identified. As mentioned above the most typical region experiencing damage in a aerofoil is its leading and trailing edges. Each edge is subdivided into a series of zones 30 to 38 extending part-way along the length of the blade. The zones can overlap

When damage or a defect is identified in the blade the zone in which it occurs is determined through routine inspection. Material is removed from the blade to match the profile of the standard zone in which it is found. Removal of material to the standard zone can result the much more of the aerofoil being machined away than strictly required to simply provide a surface suitable for attaching a new repair, as shown in Figure 6 where the damage occurs in zone 32 and the whole of zone 32 is removed.

A number of stock union pieces equivalent for each of the zones are manufactured and supplied to the repair facility in advance. The repair patch may be pre-assembled to the union piece allowing the piece to be tested prior to supply.

The union piece is assembled to the aerofoil following the procedure detailed above.

It will be appreciated that by following the above method a repair may be made to most locations on the aerofoil using a relatively small number of stock items. Where damage occurs outside a designated zone it will be necessary to manufacture a specific union piece for that damage.

CLAIMS

1. A method of manufacturing an aerofoil component comprising a first workpiece (2) joined to a second
5 workpiece (20), the method comprising,
 providing a first workpiece (2) and a second workpiece (20),
 providing a union piece (14) formed of partially sintered powder, the union piece having an alignment
10 feature (16, 16', 26, 26') for aligning the first workpiece with the second workpiece,
 assembling the first workpiece to the second workpiece via the alignment feature, and
 applying heat and pressure to consolidate the first
15 workpiece, the union piece and second workpiece.
2. A method according to claim 1, wherein the alignment feature comprises a recess into which at least a portion of the second workpiece is inserted.
3. A method according to claim 1 or claim 2 wherein the
20 second workpiece (20) comprises a second union piece (14') formed of partially sintered powder and having an alignment feature (26') complementary to the alignment feature (26) and wherein the second workpiece is connected to the union piece via the alignment feature and the complimentary
25 alignment feature.
4. A method according to any preceding claim, wherein the alignment feature is a pyramidical recess.
5. A method according to claim 3, wherein the complementary alignment feature is a pyramidical
30 projection.
6. A method according to any preceding claim, wherein a portion of the union piece is removed following consolidation by machining.

7. A method according to claim 6, wherein the first workpiece has an aerodynamic surface and the second workpiece has an aerodynamic surface and the portion of the union piece removed blends the aerodynamic surface of the first workpiece to the aerodynamic surface of the second workpiece.

8. A method according to claim 7, wherein the aerodynamic surface of the first workpiece is a pressure flank on the aerofoil component.

9. A method according to claim 7, wherein the aerodynamic surface of the first workpiece is a suction flank on the aerofoil component.

10. A method according to any preceding claim, wherein the first workpiece (2) has a faying surface (24) which abuts the union piece prior to consolidation and the second workpiece has a faying surface (25) which abuts the union piece prior to consolidation, wherein the thickness of the union piece between the faying surface of the first workpiece and the faying surface of the second workpiece is less than 2000 μ m.

11. A method according to claim 10, wherein the thickness of the union piece between the faying surface of the first workpiece and the faying surface of the second workpiece is between 50 and 500 μ m.

12. A method according to any preceding claim, wherein the first workpiece comprises part of a unitary assembly of aerofoils.

13. A method according to any preceding claim, wherein the second workpiece is a repair patch for the aerofoil component.

14. A method according to any preceding claim, further comprising the step of allocating the first workpiece with a plurality of standard zones and removing a portion of the first workpiece corresponding to at least one of the

standard zones to provide a faying location, wherein the alignment feature of the union piece complements the faying location.

15. A method according to claim 14, wherein the standard zones are arranged along the leading edge of the aerofoil.

16. A method according to claim 14 or claim 15, wherein the standard zones are arranged along the trailing edge of the aerofoil.

17. A method of repairing an aerofoil component (2) having damage or a defect comprising the step of allocating the aerofoil with a plurality of standard zones (30-38), determining the zone in which the damage or defect resides, removing a portion of the aerofoil in accordance with the zone in which the damage or defect resides to provide a faying location,

providing a union piece (14) formed of partially sintered powder and having an alignment feature complementing the faying location,

assembling a repair patch (20) to the aerofoil via the union piece, and

applying heat and pressure to consolidate the aerofoil, union piece and repair patch.

18. A method according to claim 17, wherein the standard zones are arranged along the leading edge of the aerofoil.

19. A method according to any of claims 17 to 18, wherein the faying location is a surface bounding the zone in which the defect or damage was located.

20. A gas turbine engine incorporating an aerofoil component manufactured according to any of the preceding claims.