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Regeneration of high pressure turbine blades. Development of a hybrid brazing and aluminizing process by means of thermal spraying

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Abstract

Besides welding, high temperature vacuum repair-brazing is already established for nickel-based alloy turbine blades in the aerospace and power plant industries. After the worn turbine blade has been decoated to its substrate material, the filler metal is deposited as a paste, (melt-spin) foil or tape which also consists of a nickel-based alloy. Following this, the hot-gas corrosion protective coating (e.g. NiCoCrAlY) is applied using thermal spraying. The brazed turbine blade is ground or milled to size and subsequently aluminized to further increase its corrosion resistance. Using the current state of technology, a turbine blade can undergo approximately 3 to 4 repair cycles. In the present study, the development of a two-stage hybrid technology for repairing turbine blades is considered which incorporates, on the one hand, a process technology and manufacturing aspects and, on the other hand, considers material-technological mechanisms. During the first stage of this hybrid technology, the filler metal together with the hot-gas corrosion protective coating is applied using thermal spraying. The subsequent second stage combines the brazing and aluminizing processes. The technology developed here brings technical and economic advantages whilst enabling the current state-of-the-art's corresponding process chain for repairing turbine blades to be shortened.

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Keywords: thermal spraying, repair-brazing, aluminizing

1. Introduction

The repair of nickel-based alloy turbine blades, such as those employed in the high-pressure turbines of aircraft, are essentially carried out in two processes which depend on the size and type of defect [1, 2]: laser cladding and high-temperature brazing. Repair brazing, which is the focal point of the current study, generally consists of the following processing steps [3]: Firstly, the defective turbine blade is decoated to its substrate material and subsequently cleaned using Fluoride Ion Cleaning (FIC). After the subsequent inspection and assessment of the defects, the filler metal which also consists of a nickel-based alloy, is manually applied as a paste using a spatula or dispensing needle. Tapes and (melt-spin) foils as well as moulded parts of braze material are employed as well. Owing to the materials used, the brazing process is carried out at high-vacuum ($p < 10^{-5}$ mbar). The filler metal wets the component and, due to capillary action, the existing defects, such as cracks, are filled and a material integrated bond is produced. Following this, time-consuming and expensive post-grinding is carried out to restore the brazed turbine blade to its near-net-shape. The cooling holes are redrilled using (laser) drills. In order to protect the turbine blade against hot-gas corrosion, an MCrAlY coating (M = Nickel and/or Cobalt) is applied using either vacuum-plasma-spraying (VPS) or electron-beam physical vapour deposition (EB-PVD). In addition to this, high-velocity oxy-fuel (HVOF) and atmospheric plasma spraying (APS) are increasingly employed since the technical equipment is being continuously developed with regard to low oxide coatings. To increase the oxidation resistance of thermally sprayed coatings (particularly APS), additional

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aluminizing of the MCrAlY coating is carried out. Independent of the spraying process, a diffusion heat treatment of the MCrAlY coating takes place in all cases. In addition to this, pure aluminizing- or PtAl-coating (without MCrAlY) are carried out. Aluminizing is usually produced using chemical vapour deposition (CVD), the PtAl coating is generated by means of the following process steps; Pt metallizing, diffusion heat-treatment and aluminizing. The repair process depicted here reflects the current state-of-the-art. In this contribution, the development of a two-stage hybrid technology is introduced for repairing turbine blades.

The material structure of a turbine blade is nickel-based from the substrate material and filler metal to the hot-gas corrosion protective coating. The alloys are metallurgically compatible and can, to a large extent, be easily matched to each other. This is particularly the case for the filler metal alloy's system (Ni-(Co)-Cr-(B)-Si) and the hot-gas corrosion protection system (Ni-Co-Cr-Al-Y). In addition to this, both systems are powder metallurgically processed which, in turn, implies simultaneous processing by means of thermal spraying. Besides applying the hot-gas corrosion protective coating, the application of the filler metal using thermal spraying was also verified by Bach et al. [4, 5] as a standard technology. Thus the simultaneous application of the filler metal and the hot-gas corrosion protective coating using an integrated technology appears consistent and therefore constitutes the first stage of the hybrid technology. In the second stage, the brazing and aluminizing processes are integrated. In earlier studies [6, 7], it could be shown that by using this technology it is, in principle, possible to shorten the process chain, corresponding to the current state-of-the-art, for repairing turbine blades (figure 1).

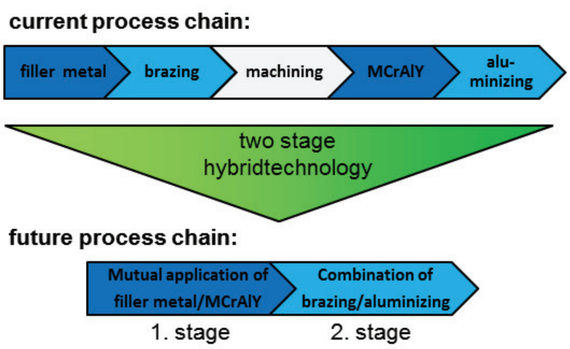

Fig. 1. Process chain (present and future) for repair brazing turbine blades

Figure 2 depicts the principle of the hybrid technology introduced in this study.

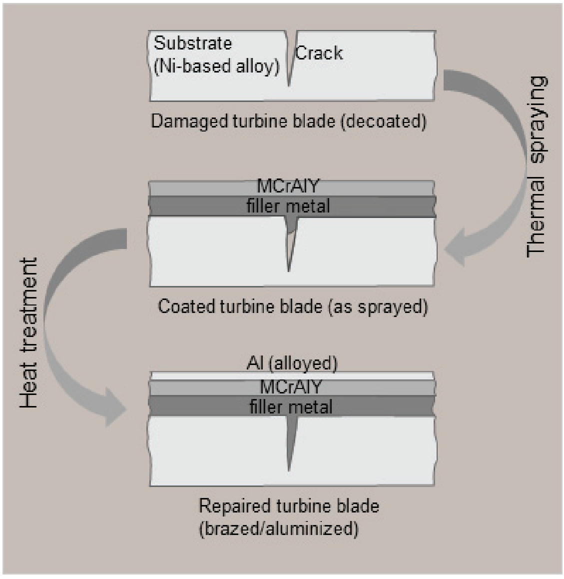

Fig. 2. Principle of the two-stage hybrid process

With the development of this two-stage hybridtechnology it is possible to reduce the current process chain for repairing turbine blades which has technological and economic advantages. This technology fits well in the concept of Through-life engineering Services (TES) providing product support.

2. Experimental method

The details of experimental work are described in [7]. Flat specimens of Inconel 718 were employed. The specimens were blasted with fused alumina EKF 54 and the residual blasting particles were removed in an ultrasonic bath. The coating (filler metal Ni650 + MCrAlY) was applied by means of atmospheric plasma spraying (APS, F4 torch, Oerlikon Metco) or by high-velocity oxy-fuel (HVOF, K2 torch, GTV Verschleißschutz). The chemical composition of the materials employed is shown in Table 1.

Table 1. Composition (in wt. %) of the material used for repair brazing

Material	Ni	Co	Cr	Si	Al	Y
Ni650	71		19	10		
NiCoCrAlY	47.5	23	17		12	0.5

The brazing was carried out in a high vacuum furnace at 10^{-5} mbar and at a temperature of 1,190 °C. The spraying parameters for the filler metal and the MCrAlY alloy are identical and are listed in table 2.

Table 2. Spraying parameters

	APS	HVOF
Ar /L·min^{-1}	55	-
H_2 /L·min^{-1}	9.5	-