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Short communication

Friction and wear behaviour of electron beam surface treated aluminium alloys AlSi10Mg(Cu) and AlSi35

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ABSTRACT

Because of their low density, Al based materials are increasingly used for state-of-the-art lightweight construction solutions. With regard to systems subjected to wear, Al alloys cannot be used for highly stressed components, unless they have been made resistant against wear by additional measures such as surface treatment.

Electron beam (EB) surface treatment offers a possibility for producing hard wear-resistant layers on components made of Al alloys. Concerning Al materials, distinct improvements of layer properties can be achieved exclusively by the use of liquid phase surface processes (remelting, alloying, dispersing and cladding).

The paper deals with current results of investigations in the field of EB surface remelting and alloying technologies of cast alloy AlSi10Mg(Cu) and spray-formed alloy AlSi35. The EB surface treatment of these alloys causes significant changes of properties in surface layers with depths of 0.5–4.0 mm basing on a local modification of microstructure. The hardness and scratch energy density of surface layers are 2–7 times higher than those of the base materials. Moreover, studies on friction and wear behavior under oil lubricated conditions at 80 °C impressively demonstrate the upgraded surface layer properties. Depending on the type of EB-alloying additives (Co, Cu, Ni powder) the specific wear rate decreases by a factor of 10–50 by effectuating a lower coefficient of friction simultaneously.

The technologies discussed give a picture of the potential of EB technologies and offer new possibilities for improving service life and reliability of engine components, among others.

1. Introduction

The worldwide demands for environmental protection and energy-saving solutions as well as the competitive situation have induced great efforts to develop recyclable lightweight construction solutions and hybrid material designs with high strength and adequate wear and corrosion properties. Thus, light materials are essential in all industrial fields [1]. The application of lightweight materials, such as Al alloys, in systems stressed due to wear and/or thermal effects, e.g. engine components, calls for an additional modification of stress functional surfaces. Different procedures concerning stress-related surface engineering are available and successfully used (e.g. thermal spraying, galvanic separation, laser surface treatment, PVD and CVD among others), however exemplarily or specially designed solutions in most cases [2–6]. Electron beam (EB) liquid phase surface treatment is one possible solution for special tribological requirements. Local properties (friction coefficient, wear and corrosion behavior, thermal properties) can be influenced positively and adjusted for specific applications [7–11] especially in combination with additional elements (e.g. Co, Cu, Fe, Ni) and hard material particles (e.g. TiC, WC) which are implemented into the surface layer in a controlled way. Known studies [8–10,12–16] demonstrated that surface alloying (EBA) with Fe and Ni (400 HV), Co (450 HV) as well as Cu (600 HV) can lead to significantly higher hardness in the surface layer of Al alloys. That mostly contributes to the improvement of wear behavior. The increase in hardness depends on the fraction of additional alloying elements, i.e. the degree of mixture between base material and additives and/or the kind of its metallurgical form of appearance (precipitation of intermetallic compounds). Increasing hardness results in connection with decreasing layer thicknesses (up to 1200 HV, however with cracks in the layer) because of higher amounts of additives. Beside cracks other effects like porosity, inhomogenities and strong surface deformations have to be resolved

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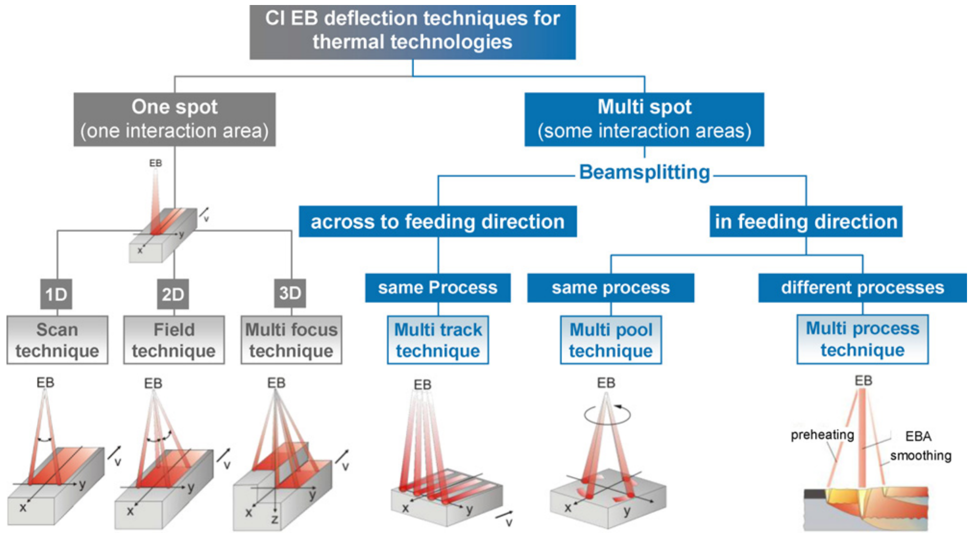

Fig. 1. EB deflection techniques for continuous interaction (CI) with relative motion between EB and component.

Table 1
Chemical composition of base materials.

Base material	wt.%								
	Al	Si	Fe	Cu	Mn	Mg	Ti	Ni	Zn
AlSi10Mg	Bal.	10.3	0.46	0.24	0.27	0.40	0.1	0.01	0.16
AlSi35	Bal.	34.9	0.25	–	–	–	–	–	–

and a satisfying metallurgical connection between base material and surface layer should be reached [8–16].

The modification of microstructure and properties in the surface layers are caused by rapid solidification and cooling because of the precipitous thermal gradient between surface and substrate material. This results in oversaturation of α-Al solid solution, very fine segregation structures and some non-equilibrium phases [7–10,13–16].

Since the development in the field of EB surface technologies is not completed yet, it permanently offers innovative and novel options to accomplish challenges in materials processing.

A modern generation of beam deflection techniques (Fig. 1) allows the development of EB technologies which cannot be carried out with conventional methods. High frequency 3D beam deflection serves as a basis for EB multi field, multi pool and, finally, multi process technologies for surface treatment which results in a significantly higher productivity and new combinations of properties [17–19]. Based on these technologies EB remelting of cast iron camshafts is successfully used as yet. EB multi track surface alloying of highly stressed Al components now runs trough industrial testing stages. For Al cylinder heads EB multi pool remelting is in report as technological solution. Overall, efforts were a success concerning EB multi pool welding of gearbox units in large-scale production [7,20–23].

Table 2
Chemical composition of thermal spraying alloy powders.

Type	wt.%								
	Co	Cu	Ni	B	Cr	Mo	Fe	Si	C
Co	Bal.	–	3	–	26	5.2	–	1	–
Cu	–	Bal.	38	–	–	–	–	–	–
Ni	–	–	Bal.	2.5	13	–	3.5	4	0.8

For the most part tribological investigations on EB surface treated Al alloys are related to very special objects. There are hardly any available results concerning methodical researches about the correlations between materials (surface) properties and stress-related friction/wear behavior. Moreover, these results are not generally comparable because of different testing conditions [8,14–16,24,25].

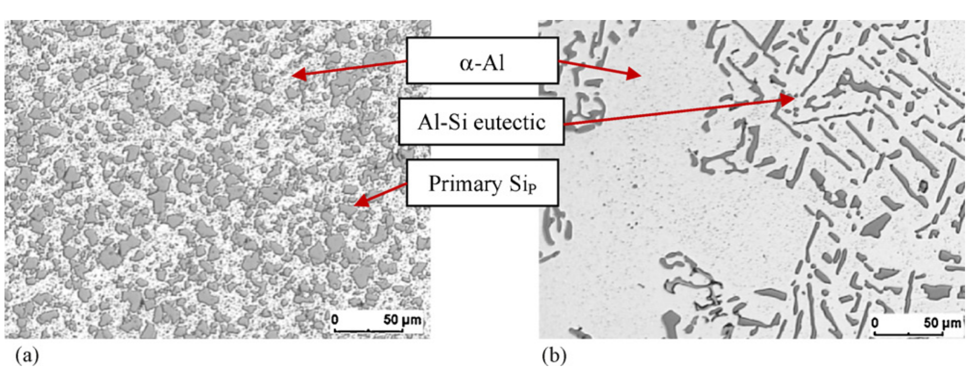

Fig. 2. Microstructure of the base materials: (a) AlSi35 and (b) AlSi10Mg(Cu).