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Influence of welding parameters on microstructure and wear behaviour of a typical NiCrBSi hardfacing alloy reinforced with tungsten carbide

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ABSTRACT

Wear parts which are exposed to severe abrasive conditions must withstand high wear demands. Abrasive loading superposed with impact due to abrasive particles are a dominating wear mechanism restricting lifetime in many different industries, for example mining and farming. In practical application, different welding technologies such as plasma transfer arc (PTA), metal active gas (MAG) and laser are used to form wear resistant materials. The aim of this study is to evaluate the influence of welding parameters on the microstructure and wear behaviour of these wear resistant materials using MAG welding technology. To simulate real field conditions on a lab-scale, tests were performed with a standard ASTM G65 dry-sand rubber-wheel tester (3-body abrasion). In order to investigate impact abrasion, a special impeller-tumbler apparatus was designed and used for wear tests (combined impact and abrasion wear). Wear tests were performed on Ni-based alloys containing large amounts of hard phase.

Within this work it was shown that welding parameters such as current intensity and number of layers strongly influence dilution with the base material and furthermore the formation of transition zones between welding layers and overlap zones. Concerning wear behaviour it was found that high content of uniformly distributed tungsten carbides in a metallic matrix show the best behaviour under a condition of pure abrasion, whereas under cyclic impact loading (high energy level) massive breaking of the tungsten carbides results in a high wear regime, compared to martensitic materials which perform best.

1. Introduction

Basic operations to used process raw materials, such as crushing, classifying or delivering, are typical for mining, steel and many other industries. These components are subjected to abrasive wear and the combined action of abrasion and impact. Core components, such as delivery screws, require efficient surface protective measures against the above mentioned tribological demands to avoid costly downtime and to reduce costs for expensive spare parts. To achieve high wear resistance, metal matrix systems are reinforced with hard particles. However, its effectiveness is strongly dependent on the relationship between the wear mechanisms and the microstructure of the multiphase material. The importance of the microstructure of multi-phase materials has been reported in [1,2] where the amount and size of hard phases, as well as the toughness and type of phases determine wear resistance of Fe–Cr–C alloys. Similar observations have been done by Chatterjee et al. [3] where the microstructure proved to be more important than hardness in determining abrasion resistance. It was shown in [4,5] that the wear resistance of tool steels increases with the size of hard particles within the microstructure.

Synthetic composite alloys consisting of a Ni-based matrix reinforced with fused eutectic tungsten carbide (W_2C/WC) are widely used to increase the lifetime of machinery equipment which is exposed to abrasion, erosion and impact [6,7]. As compared with other carbides, tungsten carbide combines favourable properties such as high hardness, a certain amount of plasticity and good wettability by molten metals. Therefore the above mentioned alloys, mainly containing 40 to 60mass.% tungsten carbides in a metal matrix, become dominant wherever the performance of chromium carbides is not sufficient [8–10].

The ever increasing demand for economical solutions in applying welded overlays, i.e. higher deposition rates, pushed the use of MAG (Metal Active Gas) and PTA (Plasma Transfer Arc Process) techniques instead of formerly more popular oxy-acethylene processes. In comparison to this technology, the MAG process, especially, exposes the welding consumables to much higher temperatures [11]. The influence of different processes on the microstructure of NiCrBSi alloys is presented in detail in [12]. During welding process, the tungsten carbides are partially molten in the electrical arc, dissolved in the Ni-based matrix and partially precipitated again. On the other hand, PTA welded deposit shows tungsten carbides which are present in the Ni-based matrix mostly in their original shape, which is mainly a consequence of low dilution with the base material and the fact that

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Table 1
Chemical composition of the Ni-based hardfacing alloy investigated

Chemical composition [wt.-%]							
C	Si	Mn	Cr	Ni	Fe	B	WC/W_2C
0.5	1.0	1.0	3.0	44	3.0	2.5	55.0

Table 2
Welding parameters of the Ni-based hardfacing alloy investigated

Deposition	Current [A]	Voltage [V]	Layers	Wire speed [m/min]
A	70	12.8	1	1.1
B	70	12.8	2	1.1
C	170	16.2	1	3.3
D	170	16.2	2	3.3

the carbides are not exposed directly to the arc. Additionally, the wear resistant hardfacing alloy can be deposited in 1 or 2 or even multilayer systems where the heat input depending on the welding current can be varied in a broad range. Variation in deposit composition can be explained in [3,13] due to the dilution with the base material governed by the heat input depending on the welding current, powder feed rate and translation speed, where the first layer of hardfacing is especially strongly affected by the base material. The final properties of the coatings deposited are thus heavily influenced by the process itself which always has to be considered in evaluation of the wear properties.

The presented research work has the main goal to evaluate the influence of welding parameters on microstructure and wear behaviour of a special Ni-based flux cored wire containing 55mass.% of W_2C/WC. It has to be shown how the interaction between welding parameters, welding consumable and dilution with the low alloyed base material affects the final overlay performance both under pure abrasion and under combined impact and abrasion wear.

2. Experimental details

2.1. Materials and welding parameters

A typical hardfacing alloy based on NiCrBSi reinforced by tungsten carbides was applied by welding as cored wire onto 1.0038 mild steel plates at a dimension of 195 × 125 × 6 mm which were used as substrate material for the hardfacing alloy. The chemical composition of the NiCrBSi hardfacing alloy can be seen in Table 1. Deposition of the Ni-based cored wire containing 55mass.% of W_2C/WC was carried out by a standard MAG process. The cored wire is manufactured by filling W_2C/WC (grain size, 65–250 µm) into a U-shaped strip made of Nickel which is closed afterwards and drawn to a final diameter of 1.6 mm. Typical sharp-edged fused and crushed W_2C/WC are shown in Fig. 1. Concerning the composition of the matrix of the alloy, Boron and Silicon are of major importance as they decrease the melting temperature thus reducing dissolution of tungsten carbides.

Table 2 shows the welding parameters, which were used by welding with a microprocessor controlled digital MAG welding equipment which already had a predefined program for this type of tungsten containing welding wire. The same welding parameters are used in industrial applications, e.g. on crusher systems. The welding was carried out in a flat position in 1 or 2 layers using different welding energies (low current, 70A; high current, 170A) to evaluate the influence of welding parameters on dilution with the 1.0038 substrate material (carbon steel, 0.2% C) and the effect on dissolution of tungsten carbides during welding process. Voltage which is in direct dependency to current was varied between 12.8 and 16.2V. Assumption based on previous experience is that high energy during welding (170A, 16.2V) results in higher dissolution of original carbides whereas with lower energy carbides remain in the original state. Material deposition rate is given mainly by wire speed during welding, and was varied between 1.1 and 3.3 m/min, For all deposits, welding gas was kept constant at Ar + 2.5% CO_2. The final samples were cut out of the original plates by water jet cutting to avoid any heat effect on the final overlay.

The reference material used in this study was a 50CrMo4 standard martensitic steel (AISI 4150) at a macro-hardness of approximately 410HV after quenching and tempering condition. Because of the typical application of this material in the mining industry and the comparison of the fine martensitic microstructure to the coarse multiphase microstructure of the Ni-based alloy on wear properties, this material was chosen for reference.

2.2. Wear testing apparatus

To simulate field condition in lab-scale as realistically as possible, wear tests were performed with a special impeller-tumbler apparatus (combined impact and abrasion wear) and a standard ASTM G65 dry-sand rubber-wheel tester (3-body abrasion). The impeller-tumbler testing device consists of a slowly rotating outer tumbler and a fast rotating inner impeller at a rotation speed of 60 and 650rpm, respectively, where the testing specimens are mounted on [14–17]. The tumbler is filled with a defined amount of abrasive, and is responsible for a controlled flow of abrasive particles hitting the fast moving testing specimens (see Fig. 2). Due to the kinematical situation the particles get in contact with the specimen (surface exposed to abrasive particles, 2.5 × 1.0 cm) at an impact velocity of approximately 10 m/s. For the experiments two different kinds of abrasives were used. At first, 5kg of fine grained silica sand

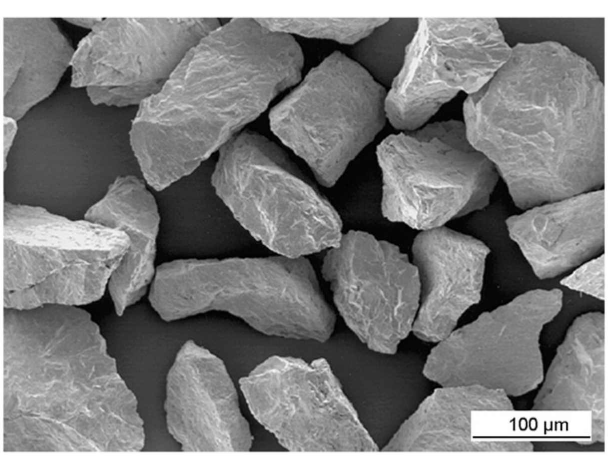

Fig. 1. Typical SEM image of fused and crushed WC/W_2C.

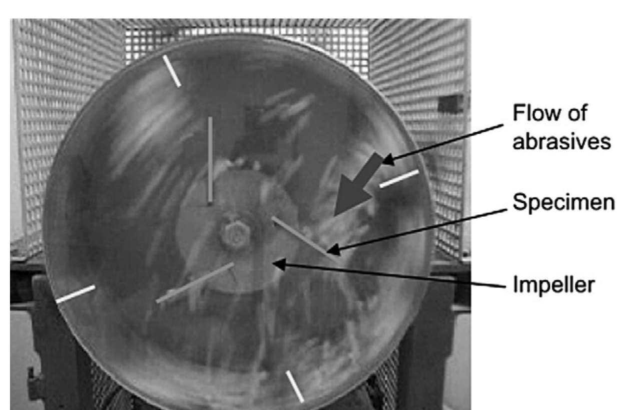

Fig. 2. View of the impeller-tumbler testing chamber (visualization of particle flow).