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DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E. V.	Thermal spraying with cored wire	Technical Bulletin DVS 0941-5

Inhalt:

1. Scope

This technical bulletin contains information about the use of cored wires in thermal spraying applications. Notes and recommendations on the proper selection of spray materials and process optimisation are given, especially in relation to the themes of arc spraying and wire flame spraying of cored wires. Using an iron-based material as an example, different strategies to produce high-quality coatings are illustrated.

2. Introduction

Within the context of DIN EN 657, thermal spray processes are coating processes in which a spray material is melted, near-melted or plastified inside or outside the spray device and propelled onto a workpiece surface. The component surface is generally not molten during this operation.

Thermal spraying of filler materials in wire form is characterised by high reproducibility and process-specific advantages that are achieved by using wires instead of fillers in powder form. Wires can be manufactured, stored, transported (without segregation) and conveyed relatively easily. Owing to the possibilities inherent to cored wire production, materials are provided that are not available as solid wires due to their low ductility. The use of cored wires therefore opens up a wide range of possible applications.

Arc wire spraying, wire flame spraying, high-velocity wire flame spraying (also known as HVOF wire spraying) are particularly suited to the processing of cored wires, while plasma technologies, such as PTWA (plasma transferred wire arc) are suitable for a few specific applications.

Component pre-treatment to DIN EN 13507 is recommended when using wires to produce high-quality coatings.

Wire-sprayed coatings are frequently used as a prepared surface or a buffer layer. Various surface preparation methods are illustrated in Technical Bulletin DVS 2310. The main principles concerning the production of metallic and other non-organic coatings are outlined in DIN EN ISO 2063 and Technical Bulletin DVS 2301. The issue of wires, rods and cords for thermal spraying is discussed in DIN EN ISO 14919. Technical Bulletin DVS 2304 contains important notes and a checklist for assuring the quality of thermally sprayed coatings.

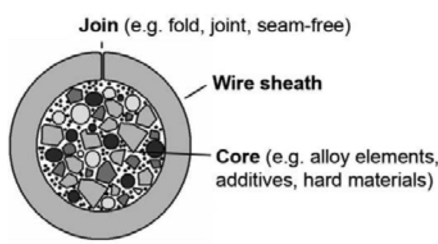
Some instructions on handling cored wires, especially regarding work preparation and wire feeding, are derived from the field of welding technology and can also be applied to thermal spraying applications. Notes on proper wire feeding can be found in DIN EN 60974-5 and Technical Bulletin DVS 0926-2.

This technical bulletin is intended to facilitate the processing of cored wires using wire flame spraying, high-velocity wire flame spraying and arc spraying methods. The process optimisation strategies presented here are universally applicable and are illustrated using selected examples. When using cored wires, the specifications and guidelines of the respective cored wire and system manufacturers must be observed, even in the event of discrepancies with the instructions listed below.

3. Selection of material

Choosing the correct filler material is fundamental to achieving a high-quality coating. Wire manufacturers offer special sold wires and cored wires for thermal spraying processes. These may differ from welding consumables in their chemical composition, as a process-dependent burn-off of certain constituents has to be taken into account when spraying. Elements with an affinity for oxygen, such as free chromium for protection against corrosion on steel, are normally present in a higher concentration in the wire than in the coating. Some cored wires also contain additives that help to stabilise the arc. Wires containing slag-forming elements should not be used for spray coating as the slag separates out in the coating and forms a defect.

The design of cored wires differs greatly owing to specific production conditions. The user must always be aware of this when selecting a material. Even when the chemical composition is the same, the processing characteristics and coating results can vary significantly. Figure 1 shows the schematic structure of a cored wire for thermal spraying. This is mainly characterised by its manufacture (e.g. seamless cored wire or tube cored wire, enclosed cored wire with fold, enclosed cored wire with joint), the overall diameter, the thickness of the sheath, the chemical composition of the sheath, the chemical composition of the core, the particle sizes of the core and the density of the core (see Table 1). Two-component systems filled with a wire core (e.g. NiAl) represent a special type of cored wire.



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During thermal spraying, an alloy (mixture of core and sheath material) only forms at the melting wire tip, and is normally incomplete. To support a homogeneous coating structure, it is therefore advisable to use cored wires with a sheath material that already matches as closely as possible the desired matrix composition of the coating. With some material systems, thermal loading of the filler material or the creation of an alloy is not desired. A typical example are wires with filler particles of tungsten carbide that should, where practical, only be melted at the surface, so that they can be firmly bonded to the layer with as little transformation as possible.

Typical cored wires for thermal spraying are listed in Table 2. The main application areas are anti-wear protection (e.g. hard alloys with and without particle reinforcement) as well as the separation of high-alloy materials and pseudo alloys. Furthermore, cored wire production offers extraordinary material development possibilities, since the coating properties can be influenced in other respects by varying the filler compositions. Wires with a diameter of 1.6 mm to 3.2 mm are used in most applications.

4. Work preparation

The processing of wires by thermal spraying requires a certain amount of advance preparation. To avoid violating the critical bending radius of the wire and thus changing its geometry, the wires must never be kinked after uncoiling from the wire coil. Such changes in the wire geometry can cause problems when feeding the wire and injecting it into the welding gun.

When cutting the wires to length (e.g. using diagonal pliers), care should be taken to avoid excessive pinching. Otherwise there is a risk combustible gases or flames can flash back through the welding gun (wire injector) due to major differences in shape compared with the internal contour of the wire injector. This danger is particularly high when wire flame spray guns are ignited.

When feeding the wires into the feed hoses of the packages, ensure that there are no sharp edges on the ends of the wires, as these may damage the inside of the hose and reduce its service life and functional capability. When feeding in heavily pinched wires, there is also the risk that particles will fall out of the wire core and into the hose, which then cause increased feed forces and increased wear when the gun is in use.

Before the gun is ignited, the length of the wire ends protruding out of the gun must be shortened as far as possible. This can prevent large pieces of wire - which could be deflected towards the system operator or gas lines - from being thrown out of the gun at the start of the spraying process.

In all cases it is considered best practice to test the correct wire-feed and gun manipulation, e.g. using a robot, with the system in a no-load state and without igniting the arc or flame.

Table 1. Classification of thermal spraying materials by manufacturing process and resulting wire design to DIN EN ISO 14919.

Designation	Manufacturing process	Structure
Solid wire/filler rod	Pyrometallurgical production and working	Homogeneous composition
Solid wire/filler rod	Powder metallurgical production and working	Homogeneous composition
Cored wire (tube cored wire)	Filling of a metallic tube with powder and subsequent working	Seamless metal shell with powder filling
Cored wire (flux-filled folded-strip wire)	Working of a metal strip with powder filler and binder	Metal shell with powder filling
Cord	Simultaneous extrusion of powder, binder and organic cord	Plastic shell with powder filling
Ceramic rod	Extrusion and sintering of ceramic materials	Porous rod, comprising bonded ceramic particles

Table 2. Typical examples of cored wires for thermal spraying.

Material system	Composition	Coating properties Sample application
Iron-based cored wires	FeCrNiMoSiC	Austenitic alloys for protection against corrosion
	FeCrAlSi	Protection against corrosion at hight emperatures, good machining properties
	Fe-based + WSC/WC	Protection against extreme abrasion wear
Nickel-based cored wires	NiCr/NiAl	Bonding agent, buffer layer
	NiCrB/NiCrBSi	Protection against abrasion, corrosion, e.g. in the chemical industry
	Ni-based + WSC/WC	Protection against extreme abrasion wear
Cobalt-based cored wires	CoCrWFeCSiMn	Abrasion resistance, friction wear resistance and corrosion resistance for wear rings and components in the chemical industry
	CoCrMoFeNiSiMnC	Impact resistance, friction wear resistance and corrosion resistance and high toughness for valve seats, hot-stamping tools
Special materials	$Al + Al_2O_3$	Anti-slip coatings
	Cu + hBN	Hexagonal boron nitride acts as a solid lubricant, abradable coatings