WEAR RESISTANT SCREEN

Inventor: Iain Stuart Hall, Midlothian, VA (US)

Correspondence Address:
Alexander D Raring
John H Thomas
536 Granite Avenue
Richmond, VA 23226 (US)

Assignee: METAL SPRAY INTERNATIONAL L.C., Richmond, VA (US)

Appl. No.: 10/547,611

PCT Filed: Mar. 5, 2004

PCT No.: PCT/IB04/00605

 Provisional application No. 60/452,494, filed on Mar. 7, 2003.

Publication Classification

Int. Cl.  
C23C 4/00 (2006.01)

U.S. Cl. 427/446

ABSTRACT

A method of manufacturing a screen used to block the passage of particulate material in a gas flow path is disclosed. A screen substrate, typically comprising a steel mesh, grate or perforated plate, is coated by thermal spraying to apply a coating comprising a relatively soft metallic base material and a hard phase in the base material. Various feedstock materials for the thermal spraying process are disclosed. Preferably, the coating is applied by providing a number of spray heads, each of which is inclined relative to the plane of the screen at an angle between 15 and 45 degrees, so that a greater than 180 degree coating of each portion of the screen is achieved. The resulting screens have application in exhaust systems of fossil fuel fired plants, upstream of a selective catalytic reduction (SCR) system.
Fig. 4

![Graph showing thickness loss (microns) for different materials: steel, Armacor M, coating X, coating Y, and 1-021.]

Fig. 5

![Images of coated surfaces labeled A and B.]
WEAR RESISTANT SCREEN

BACKGROUND OF THE INVENTION

[0001] This invention relates to a method of manufacturing a screen used to block the passage of particulate material, and to a screen manufactured by the method.

[0002] Combustion exhaust or flue gas generated in fossil fuel fired power and heat generating plants contains nitrous oxides (NOx) which generally cannot be freely exhausted into the atmosphere. A method of controlling nitrous oxide emissions is to pass the flue gas through a Selective Catalytic Reduction (SCR) system which is normally situated downstream of heat extraction systems and upstream of air pre-heaters and ash separation and control equipment in a typical plant. The SCR system comprises two principal components. The first is an ammonia injection system, and the second, situated downstream of the ammonia injection system, is a bank of catalytic material that encourages a reaction between ammonia and nitrous oxide, forming harmless nitrogen gas and water.

[0003] A practical problem experienced in operating such a system is the presence of fine particulate material or fly-ash which can agglomerate to form larger clumps of material entrained in the flue gas, which can block the honeycomb catalyst structure, decreasing the efficiency of nitrous oxide control.

[0004] To deal with this problem, screens can be installed upstream of the SCR assemblies, in order to catch particulates above a certain size that could block the catalyst structures. However, the fly-ash passing through and impacting upon the screens is erosive, eventually causing failure of the screens. The potentially corrosive nature of the flue gas can increase the rate of the wastage mechanism generated in conjunction with this erosivity. This can cause damage to the SCR components, or at least necessitate maintenance and possibly shut down of the plant.

[0005] It is an object of the invention to provide a screen suitable for use in the above application and which is resistant to wear.

SUMMARY OF THE INVENTION

[0006] According to the invention there is provided a method of manufacturing a screen used to block the passage of particulate material in a gas flow path, the method comprising:

[0007] providing a substrate of suitable material defining a screen structure; and

[0008] applying a wear resistant coating to the substrate by thermal spraying, the coating comprising a relatively soft metallic base material and a hard phase in the base material.

[0009] The material of the substrate may be metallic. For example, the substrate may comprise a steel mesh of woven wire, a perforated plate or alternatively a grid or grate. The geometry of the holes may be rectangular, round or any other polygonal shape.

[0010] The screen structure of the substrate preferably defines apertures having a size selected to be within a predetermined range after application of the wear resistant coating in the substrate.

[0011] The apertures may be rectangular, round or polygonal in shape.

[0012] The screen will typically be a screen used upstream of a Selective Catalytic Reduction (SCR) system in an exhaust conduit of a fossil fuel fired plant, such as a power or heat generating plant, with the range of size of the apertures being selected accordingly.

[0013] The wear resistant coating may be applied by one of several thermal spraying techniques.

[0014] For example, agglomerated metal/carbide powders may be applied with an oxygen/fuel thermal spray system.

[0015] Alternatively, blended metal/carbide materials may be applied with an oxygen/fuel thermal spray system.

[0016] Further alternatively, wear resistant metal alloys with hard phase precipitates in the form of wires may be applied with Arc and Hybrid Arc spray systems or in the form of powders in oxygen/fuel thermal spray systems.

[0017] Still further alternatively, powder cored feedstock wires may be applied with either Arc/Hybrid Arc or oxygen/fuel thermal spray systems.

[0018] It will be appreciated that the above thermal spray techniques and materials are exemplary and non-limiting.

[0019] The wear resistant coating may be applied to at least one side of a generally planar substrate.

[0020] Preferably, the coating is applied to the substrate at a predefined angle relative to a plane defined by the substrate, to ensure uniform coating of the substrate with a desired extent of coating of individual elements of the substrate.

[0021] The coating may be applied by one or a plurality of spray heads.

[0022] An angle of inclination of the spray head or heads relative to the plane of the screen of between 15 and 45 degrees is generally preferred, with an angle of approximately 30 degrees being used in the preferred embodiment.

[0023] Preferably, the coating is applied by a plurality of spray heads arranged in a predetermined relationship, each being inclined relative to the screen and being aimed at a common point on the screen.

[0024] In the preferred embodiment, four spray heads were mounted in a spaced apart relationship so as to lie at intervals of 90 degrees on a circle adjacent and parallel to the plane of the screen, with each spray head being inclined at an angle relative to the plane of the screen so that the spray heads were aimed at a common point on the screen.

[0025] The wear resistant coating may be applied to the opposite side of the screen to allow for increased lateral coverage on the sides of individual elements of the screen.

[0026] Preferably, multiple passes of the spray head or heads are made over the screen to attain the coating thickness required.

[0027] The invention extends to a screen manufactured by the method of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] Fig. 1 is a schematic side view of a portion of an exhaust gas conduit of a fossil fuel fired power or heat generating plant, showing an SCR emission control system thereof;
FIG. 2 is a pictorial view of a screen according to the invention, for use in the SCR system of FIG. 1;

FIG. 3 is a set of comparative photographs showing the relative wear resistance characteristics of three different screen coating materials compared with untreated screen material;

FIG. 4 is a graph comparing the wear resistance of four different coating materials to that of steel screen material;

FIGS. 5A to C are photographs of sections of screen wire elements coated by the method of the invention;

FIG. 6 is a comparative photograph, showing a portion of a screen substrate comprising a woven wire mesh treated by the method of the invention (left) with a section of untreated screen material (right); and

FIG. 7 is a similar comparative photograph, showing a portion of a screen substrate comprising a perforated metal plate treated by the method of the invention (left) with a section of untreated screen material (right).

DESCRIPTION OF PREFERRED EMBODIMENTS

Nitrous oxides are emitted by the combustion of fossil fuels as a source of energy for electric power and heating. The same emissions are also produced in the petrochemical, pulp and paper industries. Nitrous oxide (NOx) emission is regulated under the Clean Air Act of 1990 in the USA, similar legislation in most parts of the Europe, and by other environmental agencies worldwide. As a consequence, emission control technologies are necessarily implemented by these industries. The present invention, although applicable across these industry sectors, inter alia, is described here in the context of fossil fuel fired power and heat generating plants.

Nitrous oxides may be controlled by passing the combustion exhaust (flue) gas through Selective Catalytic Reduction (SCR) systems. These are normally situated downstream of heat extraction systems of a boiler, and upstream of air pre-heaters, ash separation and control equipment, as shown schematically in FIG. 1. This equipment is comprised of two principle components. The first is an ammonia injection system, and the second, situated downstream of this, is a bank of catalytic material that encourages the reaction between ammonia and nitrous oxides to form harmless nitrogen gas and water.

The process takes place in a temperature window between 600°F. and 780°F. At temperatures above this, the catalytic process continues, but ammonia (NH₃) adversely oxidizes to form nitrous oxide (NOx) and water (H₂O). Below this, the presence of sulphur dioxide and sulphur trioxide (SOₓ) with ammonia in the flue gas result in the formation of ammonia bisulphate or ammonia hydrogen sulphate. These salts form undesirable deposits in downstream systems. In order for the nitrous oxide reduction mechanism to take place, flue gas needs to come into contact with the catalyst. To facilitate this, a number of restricted, or small diameter gas paths are created with catalytic walls. These typically take the form of a honeycomb structure, engineered to provide the highest possible gas to surface contact. It is contained in an expanded section of the ducting, also referred to as the reactor, where reduced gas velocities and increased surface area lead to longer contact time for the reaction to occur.

The flue gas also contains a significant percentage of solid, mostly fine (10-30µm) post combustion particulate, known as “fly-ash”. This ash can agglomerate to form larger clumps of material entrained in the gas path. These can block the catalyst material either at the surface or deep within the structure. This reduces the total area available for reaction to occur and blocks the gas path. Decreased efficiencies result, and sulphate salts can form from excess ammonia “slipping” through the bed and reacting with sulphates at lower temperatures downstream.

To deal with the blockage problem, screens or gratings are installed upstream of the SCR assemblies to catch particulate above a certain size that could block the catalyst in the system. Any material passing through the screens would be small enough to pass through the catalyst material. These screens are mounted such that the gas and particulate flow through them, either normally or at some inclination. The fly ash that passes through the screens is erosive and erodes the screen material at elevated temperature and velocity. When screen failure occurs, damage and blockage to SCR components result, requiring extensive maintenance and possible shut down of plant operations should emission levels exceed preset limits.

According to the present invention, the screen material is provided with a protective coating, extending the time to failure or serviceable life expectancy of the screen. The protection is afforded by the application of a hard, erosion resistant thermal spray coating to the screen material. Thermal spray may be defined as encompassing the activities and related technologies required to identify, develop and implement a process by which finely divided material in a molten (or semi-molten) condition is sprayed onto a substrate to form a coating. Feedstocks used in such a process typically take the form of a powder, wire or rod.

Impinging particulate tends to erode the SCR upstream screens preferentially. This erosion mechanism removes material predominantly from the front and the sides of the screen cross-section. A thermal spray coating is therefore applied to these areas to prevent wastage of the screen material. As the coating material contains both hard (e.g. carbides, borides) and soft metallic phases (e.g. Nickel, Chrome), the relative erosion resistance of this coating is an order of magnitude greater than that of the screen material.

The metal matrix that binds coating hard phases together imparts toughness to the coating that prevents cracking, an inherent failure mechanism of hard, brittle materials. The matrix material also serves to prevent the permeation of corrosive gas species through the coating that would attack the substrate material and cause the coating to disbond and fail. By tailoring the percentage of the metal binder as well as the alloy used, the thermal expansion coefficient of the coating can be closely matched to the screen to prevent thermal stresses from exceeding bond strengths.

The coating material may be applied with the use of singular or multiple coating systems. The use of multiple systems allows simultaneous coating of the screen around the leading edge. This forms a coating with a mechanically
contiguous structure and greatly increases adherence (see FIG. 3). The coating process may be conducted on the screens already installed in the SCR unit (in-situ), or in a workshop prior to screen installation.

In order to verify the efficacy of the invention, high temperature accelerated erosion tests were conducted on candidate coating materials. The erosion resistance of a coating with an incident erosive angle of 90 degrees can differ substantially at, say, 45 degrees. Some materials offer better characteristics at a glancing angle than at a normal angle and vice versa. The thickness loss of uncoated material was compared to that with coated specimens. Where coating failure occurred, the mode of failure was determined and modifications to the coating composition were made to abate the responsible mechanism.

Screen geometries and materials differ from one SCR installation to another. Operational conditions vary, such as flue gas composition and temperature, fly ash composition, and NOx and SOx levels. Plant regulatory emission limits and shut down cycles also change from one area to the next. As such, the material and application process used need to be considered on an individual basis. The coatings used in the method of the invention all contain hard phase particles worked into the original coating feedstock material. These may be structured as agglomerates, blended with softer tougher materials or precipitated into the coating material either prior to, or during spraying. In principle, although not exclusively, four different groups of materials are typically recommended:

- agglomerated metal/carbide powders applied with an oxygen/fuel thermal spray system;
- blended metal/carbide materials applied with an oxygen/fuel system;
- wear resistant metal alloys with hard phase precipitates, as wires applied with Arc and Hybrid Arc spray systems or as powders in oxygen/fuel systems; and
- powder cored wires applied with either Arc/ Hybrid Arc or oxygen/fuel systems.

These different processes can be qualified in terms of life expectancy requirements, cost, suitability to environmental conditions and application rate requirements (e.g. emergency plant shut down conditions). Quality control of these processes extends to:

- pre-testing under simulated erosion conditions,
- microstructural evaluation,
- thickness measurement and mapping across areas coated,
- surface preparation qualification (roughness and cleanliness), and
- post coating handling procedures

The following example describes the intended application of the prototype screens made by the method of the invention.

A number of similarly constructed pulverized coal fed power stations in the USA have experienced catalyst clogging with agglomerated fly ash referred to as “popcorn ash” or LPA (Large Particle Ash). The solution proposed for these units has been the introduction of woven wire mesh screens upstream of the SCR unit to catch the oversize material. The screen material consists of 2 mm diameter wire in woven mesh format with 6 mm by 6 mm square holes. The known operating conditions were given at an upper limit of 90 ft/s and a temperature of 850° F. The screens are installed in at an angle of up to 45 degrees to the flow. Prior experience has shown they have only lasted for 4 to 6 months prior to erosion of the wire material with the subsequent development of holes and localized functional failure.

An attempt to solve the problem by changing the material composition of the wire itself to a stainless steel did not result in any significant life extension.

FIG. 2 shows a planar rectangular screen 10 of the kind in question, comprising steel wire mesh 12 and a supporting peripheral frame 14. The screen 10 is used as a substrate to be sprayed.

The solution of coating the screens with an erosion resistant coating was investigated and a proprietary metal/carbide cermet material, UTEx 1-021, was specified. Several other coating processes were considered, by testing the behavior of the coatings on wire segments similar to those used to fabricate the screens. The wire elements comprising the screen mesh 12 were 2 mm diameter cold drawn, low carbon steel.

A number of parameters specific to the plant and the construction of the screen material were considered in the selection of the preferred coating material. Coating toughness, micro-hardness, permeability, corrosion resistance, bond strength and most importantly erosion resistance were examined. As the erosion characteristics of a material are not easily linearly defined with any specific set of parameters, it was important to conduct accurately scaled tests.

The accelerated erosion testing in this instance was performed with a 200 ft/s stream of air entraining 12 oz of boiler ash erodent at 570° F. The coating test materials to be placed in the path of the erodent were applied to a representative section of screen material. As a cylinder placed transversely to the erodent path presents a full range of incident angle from 0 to 90 degrees all erosion conditions could be evaluated. Photographs of the erosion of three different coatings are shown in FIG. 3. The erosion test results for four coatings are given in FIG. 4. A photograph of the samples after testing is also shown in FIG. 5. An agglomerated metal carbide/cermet powder material applied by an oxygen-fuel system, the UTEx 1-021 coating performed the best under these conditions and was selected as the preferred material for this application. This material also provided desirable corrosion resistance properties.

On arrival at the coating site the screens were subject to initial quality control acceptance criteria to ensure that the surface to be coated was free of defects that could generate poor conditions to good coating deposition. An aluminum oxide grit (grade 24) was employed in an oil and water free grit blasting process to remove any surface oxidation and to provide a suitable profile. The screens were placed in automated coating assemblies in batches and concurrently sprayed with four HVOF (High Velocity Oxy-
Gen-Fuel) Excalibur 4000 processes at four different optimized spray angles to provide acceptable coating distribution around the wire. This was required to provide protection from the plant process flow conditions within the previously stated 30 degree installation window. The distribution had to generate protection irrespective of orientation of the screen after installation as the screens were rectangular units and correct orientation could not be guaranteed.

[0064] The four spray heads were mounted in a spaced apart relationship in an assembly so as to lie at intervals of 90 degrees on a circle adjacent and parallel to the plane of the screen, with each spray head being inclined at an angle relative to the plane of the screen so that the spray heads were aimed at a common point on the screen. This ensured that the screen wires were coated over roughly 270 degrees, rather than the approximate 180 degrees coating distribution that would be achieved by a spray head or heads oriented normally to the screen.

[0065] Where necessary, the coating procedure can be repeated on the opposite side of the screen. The main purpose of this would be to increase the lateral coating coverage of the sides of the screen holes.

[0066] An angle of inclination of the spray heads relative to the plane of the screen from 15 to 45 degrees is generally preferred, with an angle of approximately 30 degrees being used in the present example.

[0067] Multiple passes of the spray head assembly were made over the screen to attain the coating thickness required. The mesh, as supplied, was constructed so as to make allowance for the encroachment that coating would make on the pass-through hole size. As such, the final mesh size was defined as the final QC on coating thickness. Two additional coating procedures were included on smaller batches as trial screens. These would provide additional full-scale test data at later stage.

[0068] FIGS. 6 and 7 shows sections of coated (left) and uncoated (right) screen material. The screen material in FIG. 6 is a woven wire mesh, while that in FIG. 7 comprises a perforated metal plate. An in-line production sample of the screen shown in FIG. 6 was taken for analysis. A wire section from the screen was analyzed micrographically. Analysis of these production samples highlighted the need for critical control of the coating angle to minimize the deleterious effect of increased porosity and inter-particle bonding of the coating.

[0069] It will be appreciated that the screen material need not be a woven mesh or perforated plate, as described by way of example above, but could instead be a grid, grate or other screen element.

1. A method of manufacturing a screen used to block the passage of particulate material in a gas flow path, the method comprising:
   providing a substrate of suitable material defining a screen structure; and
   applying a wear resistant coating to the substrate by thermal spraying, the coating comprising a relatively soft metallic base material and a hard phase in the base material.
2. A method according to claim 1 wherein the material of the substrate is metallic.
3. A method according to claim 2 wherein the material comprises steel.
4. A method according to claim 2 wherein the substrate comprises a mesh of woven wire, a perforated plate, a grid or a grate.
5. A method according to claim 1 wherein the screen structure of the substrate defines apertures having a size selected to be within a predetermined range after application of the wear resistant coating in the substrate.
6. A method according to claim 5 wherein the apertures are rectangular, round or polygonal in shape.
7. A method according to claim 5 wherein the range of size of the apertures is selected to be suitable for use upstream of a Selective Catalytic Reduction (SCR) system in an exhaust conduit of a fossil fuel fired plant.
8. A method according to claim 1 wherein the wear resistant coating comprises agglomerated metal/carbide powders applied with an oxygen/fuel thermal spray system.
9. A method according to claim 1 wherein the wear resistant coating comprises blended metal/carbide materials applied with an oxygen/fuel thermal spray system.
10. A method according to claim 1 wherein the wear resistant coating comprises wear resistant metal alloys with hard phase precipitates in the form of wires or in the form of powders, applied with Arc and Hybrid Arc spray systems in oxygen/fuel thermal spray systems.
11. A method according to claim 1 wherein the wear resistant coating comprises powder cored feedstock wires applied with either Arc/Hybrid Arc or oxygen/fuel thermal spray systems.
12. A method according to claim 1 wherein the wear resistant coating is applied to at least one side of a generally planar substrate.
13. A method according to claim 12 wherein the coating is applied to the substrate at a predefined angle relative to a plane defined by the substrate, to ensure uniform coating of the substrate with a desired extent of coating of individual elements of the substrate.
14. A method according to claim 12 wherein the coating is applied by a plurality of spray heads.
15. A method according to claim 14 wherein the spray heads are inclined relative to the plane of the screen at an angle of between 15 and 45 degrees.
16. A method according to claim 15 wherein the spray heads are inclined at an angle of approximately 30 degrees.
17. A method according to claim 14 wherein said plurality of spray heads are arranged in a predetermined relationship, each being inclined relative to the screen and being aimed at a common point on the screen.
18. A method according to claim 17 wherein four spray heads are mounted in a spaced apart relationship so as to lie at intervals of 90 degrees on a circle adjacent and parallel to the plane of the screen, with each spray head being inclined at an angle relative to the plane of the screen and aimed at a common point on the screen.
19. A method according to claim 17 wherein the wear resistant coating is applied to the opposite side of the screen to allow for increased lateral coverage on the sides of individual elements of the screen.
20. A method according to claim 14 wherein multiple passes of the spray heads are made over the screen to attain the coating thickness required.