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Part 3
ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.2. Ash removal

3.2.2.12. The wear-resistant pipelines with aluminothermic corundum coating

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ABSTRACT

Abrasive wear of pipelines contributes significant share to operating cost of industrial hydro- and pneumatic systems and facilities for transport of abrasive materials (sand, cement, ash, slags and etc.) that, in particular relates to dust preparation and ash and slag removal system of coal-fired TPP. The usage of abrasion-resistant materials in the manufacture of those pipelines is one of the ways to increase their resistance. The comparison of three materials for the manufacturing of abrasion-resistant pipelines - wear-resistant steels, stone casting and corundum aluminothermic coating shows the significant advantage of the latter. Except the best wear resistance, the pipes with aluminothermic coating can be connected by electric welding, that allows making shaped pipelines.

WEAR RESISTANCE OF PIPELINES

At the thermal power plants, especially coal-fired, the problem of the abrasion wear of equipment, including pipeline, is one of the most actual. Wear of the pipeline mainly exist in hydro- and pneumatic transport systems:

- pulverized fuel pipe in dust-preparation systems and
- ash and slag removal (ASR) systems.

At coal-fired TPP of Russia the most part of ash and slag is transported to wet ash and slag landfills in the form of low concentration hydrous slurry. Reliability and efficiency of hydraulic ASR systems largely depend on the abrasive wear of the main equipment: pumps, shut-off-and-regulating equipments and pipelines. Due to a number of significant shortcomings of hydraulic ASR (large water consumption, environmental and ecological aspects of the land-use, reducing the possibility of reuse of ash and slag, etc.) the possibility of wider application of pneumatic ASR systems is currently being studied. But among the advantages of pneumatic ASR systems there is a disadvantage – the more significant abrasion of shaped and straight sections of air tube conveyor.

Among the measures to improve the life of hydraulic and pneumatic conveying pipelines proposed by researchers, one of the most effective is the use of special abrasion resistant piping elements: stone casting inserts, and pipes with aluminothermic cover [1].

It is established that the overhaul period of dust transportation pipelines protected by stone casting increases in 4…6 times. However, the usage of pipes with stone casting inserts has some difficulties: cracking of inserts in the shaped pipes due to high temperature changes during operation, knock-out of individual fragments of the inserts to dust flue; the significant mass of the inserts; the complexity of installation; insufficient standard sizes of internal diameter of the knees.

According to [1] dust flues with aluminothermic coating have more significant abrasion resistance compared with dust flues made of the other materials. Based on studies, numerical values of the relative wear resistance coefficients of dust flues made of pipes with aluminothermic coating are in the range of 300…400. The relative wear resistance of dust flues made of various materials is given in Tab. 1.

Table 1. **Relative wear resistance of pipes made from various materials**

Material of pipeline	Vikkers Hardness, HV	Relative wear resistance coefficient of pipelines made of various material, $c_{w.r.}$
Copper	125	1,00
Steel 5	130	1,01
Steel 25Л	130	1,01
Steel 3	135	1,02
Steel 10	137	1,02
Steel 4сп	140	1,03
Steel 5сп	150	1,06
Steel 20	156	1,08
Steel 35Л	160	1,10
Steel 35	187	1,28
Steel 25Г2	200	1,40
Steel 40, 40Х (after annealing)	217	1,59
Gray cast iron	223	1,66
Steel 30ХГС, Steel 30ХГСА (after annealing)	229	1,74
Steel 55Л	240	1,90
Steel 45	241	1,92

Continuation of the table

Steel 30X13	270	2,41
Steel 40X13	300	3,04
Steel 55Л	340	4,05
Pipes with aluminothermic coating	2500	364,00

It is established that the usage of pipes with aluminothermic coating reduces abrasion to 100 times or more, with stone casting – no more than 10 times, and steel pipes with a hardness more than 300 HV to 4-5 times as compared with steel pipelines made of steel 20 [2].

According to [1] aluminothermic coatings are recommended for the manufacture of curved sections of pneumatic conveying ASR and dust-preparation systems of coal-fired TPP.

ADVANTAGES OF ALUMINOTHERMIC COATING

The first works related to the formation of ceramic and metal-ceramic coatings on the inner surface of metal pipes were carried out at the Institute of Structural Macrokinetics and Material Science AS USSR (ISMAN), Chernogolovka, in the development of Self-propagating high-temperature synthesis (SHS) [3]. The method was completed by Japanese researchers [4]. Now steel pipes with aluminothermic coating are produced in China by centrifugal thermite process (centrifugal SHS-casting).

In the Soviet Union and then in Russian Federation the industrial experiments related to aluminothermic coatings were repeatedly undertaken. Energohimkomlect ltd. has been conducting such experiments since 2008.

Now the development of thermal- and wear-resistant aluminothermic coatings technology is one of the areas of activity of Energohimkomlect.

The ceramic coating by thickness of 2…4 mm is a fused ceramic on the base of corundum (Al2O3).

Comparative properties of the resulting aluminothermic coating, stone casting and gray cast iron are given in Tab. 2. The tests of the samples of materials were carried out at the Physical Chemistry Department of the South Ural State University.

Table 2. **Comparative properties of pipelines materials**

Characteristic	Aluminothermic ceramic coating	Wear-resistant stone casting (cast basalt)	Gray cast iron СЧ 12-28
Thickness of coating, mm	3 – 4	20	-
Density of coating, g/cm^3	2,9	3,0	7,2
Water uptake, %	0,09	0,13	не опр.
Compression strength, MPa	300…340	250…500	500
Flexural strength, MPa	70…110	30…50	280
Impact strength, kJ/m^2	1,50	1,25	3,00
Elastic modulus, MPa	102000	100630	120000
Wear resistance[1)], g/cm^2	0,02	0,30	0,79
Mohs hardness	8…9	7…8	not determ.
Microhardness, GPa	15…18	5…9	not determ.
Heat resistance, the number of thermo cycles from 800 °C to 20 °C in air	not less 10	1	not determ.
Heat resistance, the number of thermo cycles, quenching from 800 °C to 20 °C into water	not less 2	cracking	not determ.
Acide resistance, 20% HCl, %	98	89	not determ.
Acide resistance, H_2SO_4 (96%), %	99	97	not determ.

[1)] Wear resistance was determined by grinding abrasive wheel of normal electrocorundum 14A during 1 minute under load of 2 kg.

The comparison of aluminothermic ceramic coating characteristics with the other materials (wear resistance stone casting, gray cast iron) demonstrates that the ceramic coating has the better features that determine the wear resistance (wear resistance in 15 times higher compared with cast basalt, higher hardness). The heat endurance tests showed the stability of ceramic coating at the temperature of 1200 °C, and satisfactory heat resistance (sustains thermal shock at least for 2 times by immersion of the coated pipe at the temperature of 800 °C to water with temperature 20 °C).

The ceramic coating in the end zone of the pipe is resistant to electric welding (no chipping and damages) that allows to connect the coated pipes not only by the flanges, but also by electric welding.

The ceramic coating has also better acid resistance (in hydrochloric and sulfuric acids) compared with stone casting.

High mechanical and thermal endurance of ceramic coating, except the own properties of the corundum ceramics, is determined by the fact that during the centrifugal SHS-casting two-layer coating is formed (Fig. 1): between the steel pipe and ceramic layer is formed the intermediate metal layer (the iron based) which is welded to the pipe wall and diffusion bonded to the ceramic, which damps the loads to ceramic from external mechanical and thermal influences.

The microstructure of the ceramic layer (Fig. 2) is presented by uniformly distributed grains of the corundum (dark colour) with inclusions of alumosilicate phases (light areas).

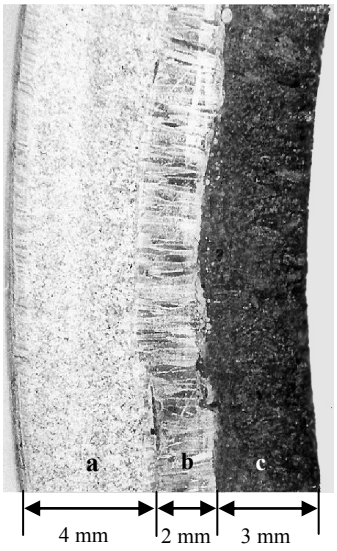

Fig. 1. The cross-section of steel pipe with aluminothermic coating: a – the pipe wall, b – an intermediate metal layer, c – ceramic layer.

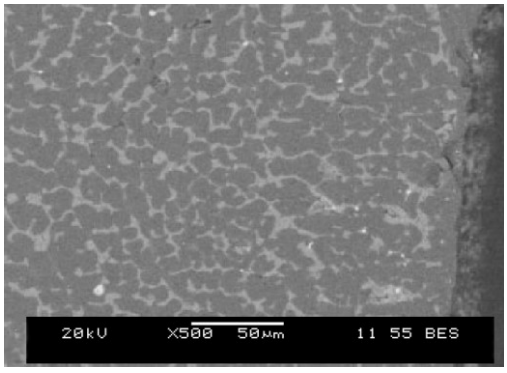

Fig. 2. The microstructure of the ceramic layer.

Having significant hardness, thermal- and chemical resistance such coating protects pipeline from abrasion, chemical and high-temperature corrosion. The possible applications of pipes with aluminothermic ceramic coating are specified below:

- the operation in conditions of intensive abrasion, for example, pneumatic- and hydrotransport of various abrasive materials (sand, cement, ash, slag, etc.);
- the operation under significant heat influence for the transportation in environment of various gases at temperatures up to 1000 °C (the temperature depends on stability of steel pipe);
- for transportation of some molten metals, salts and chemically aggressive substances.

INDUSTRIAL TESTING AND IMPLEMETATION

At present "Energohimkomplect" ltd. makes industrial testing and introducing of the pipes with wear-resistant aluminothermic coating of the own production. In 2011 the batch of pipes (diameter 159 mm, wall 8 mm) with thermo- wear resistant coating was made for JSC "Chelyabisk Zink Plant" ("CZP") which were mounted in bay of pneumatic transport of calcined Waelz oxide by electric welding. The pipeline had both straight sections, and elbows 90°. The test results showed the increase of the turnaround time of the pipeline more than three times (the replacement of coated sections was made in 10 months, whereas the uncoated pipes have been changed every 3 months of operation before). At present the wider nomenclature of coated pipes is being prepared for JSC "CZP".

In 2009-2010 12 cyclones having funnel shape (diameter 140…331 mm, length 556 mm, wall thickness of 12 mm) were made for Tobolskneftehim ltd. The material of cyclones is stainless steel 12X18H10T with inner aluminothermic coating. With the help of cyclones the powdered catalyst based on corundum with a velocity of 10 m/s and temperatures up to 650 °C is pneumatically injected into the reactor. Without coating such cyclones are changed annually owing to abrasive wear. The tested coated cyclones were also dismantled after one year of their work. The examination showed the presence of preserved coating on the undamaged inner metallic surface of all cyclones.

The primary positive results have been got after the replacement of the acceleration pipe of the jet mill of JCS "Malyshev Ore Department", where the grinding of mica is carried out. The usage of the acceleration aluminothermic coated pipe (diameter 67 mm, length 600 mm) instead of wear-resistant cast iron pipe allowed to increase the productivity of the jet mill up to 157 %. Testing of the jet mill wear-resistance elements is being continued.

CONCLUSION

One of the ways of increasing of the efficiency of operation, in particular, of the dust preparation and ash and slag removal system of coal-fired TPP is to increase the wear resistance of pipelines. This can be achieved by using of pipelines made of wear-resistance steel grades, stone casting inserts or pipes with aluminothermic coating in problem sectors. And the aluminothermic coatings show the highest wear-resistance among the other materials.

The sufficient mechanical strength and heat resistance of aluminothermic coatings allow to connect the pipe elements not only by means of flanges, but also by electric welding, that significantly simplified installation and allows to make curved segments (the knee) and various types of elbows.

The properties of aluminothermic coating allow to use the pipelines not only in abrasion conditions, but also in the conditions with the intensive heat influence, for example, for transportation of gases, molten metals, salts, as well as under the influence of a number of chemically aggressive mediums.

At the beginning of 2014 the putting into operation of the new centrifugal SHS-casting facility is planned, that will allow to improve the quality of coating,

productivity and possibility to coat the straight pipe up to 5 meters.

Coatings are applied to straight pipes up to 5 meters with standard diameters from 68 mm to 530 mm and a wall thickness of not less than 4 mm.

By means of electric welding or with the help of flanges from straight pipe elements elbows of any radius and length, as well as three- or four way pipes can be made.

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