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A METHOD AND A DEVICE FOR MACHINE REGENERATION OF ANTI-WEAR COATING FOR PIPELINES

Key words: anti-erosion protection, pneumatic conveying, industrial pipelines, dust transport.

Summary: One of the techniques to improve the durability of pneumatic conveying used in industry is covering the inner surface of the pipe with a layer of plastic ceramic material, which, as a result of the chemical binding reaction, creates an anti-erosion coating. The disadvantage of the method is that coating is labour-intensive, since it is usually done by manual shaping. This paper presents a method and a device for efficient machine moulding techniques of such layers in the curved sections of pipelines for the transport of coal dust and ash in the power industry. The moulding is done within the system with an active, round moulding core placed inside the fitting undergoing regeneration that has been removed from the pipeline. The technological trials indicate a possibility of obtaining good quality erosion-control layers that are developed by a moulding method that allows quick and precise shaping of the pipeline conduit with plastic ceramic mass.

Metoda i urządzenie do maszynowej regeneracji przeciwzużyciowych pokryć rurociągów

Słowa kluczowe: zabezpieczenia przeciwerozyjne, transport pneumatyczny, rurociągi przemysłowe, transport pyłów.

Streszczenie: Jedną z technik poprawy trwałości urządzeń transportu pneumatycznego stosowanych w przemyśle jest nakładanie na wewnętrzną powierzchnię rurociągu warstwy plastycznego materiału ceramicznego, który w wyniku reakcji chemicznego wiązania tworzy wykładzinę przeciwerozyjną. Wadą metody jest duża pracochłonność wykonania wykładziny, najczęściej poprzez ręczne formowanie. W pracy przedstawiono metodę i urządzenie do efektywnej, maszynowej techniki formowania takich warstw w krzywoliniowych odcinkach rurociągów do transportu pyłu węglowego i popiołów w energetyce. Formowanie jest realizowane w układzie z aktywnym, kulistym rdzeniem formującym prowadzonym wewnątrz pokrywanej w procesie regeneracji kształtki wymontowanej z rurociągu. Przeprowadzone próby technologiczne wskazują na możliwość uzyskiwania warstw przeciwerozyjnych dobrej jakości opracowaną metodą formowania pozwalającą na szybkie i precyzyjne kształtowanie kanału rurociągu w plastycznej masie ceramicznej.

Introduction

Pneumatic transport is most often used for the movement of mineral aggregate materials, (dust in particular), in the technological processes, e.g., with this method, coal dust and ash in the power stations and power plants are transported (Fig. 1), quartz sand and used mass from a foundry, cement in cement kilns, etc. As a result of the flow of large amounts of grainy materials, the elements of the pneumatic transport undergo erosive wear [1, 2, 3]. All the elements exposed to contact with the granular material are exposed to wear. Among the elements that undergo a particularly intensive wear process include those in which there is a change in flow velocity or direction, e.g., elbows, bends, diffusers, reducers, nozzles, etc. Those that wear more slowly include containers and straight segments of the conduit.

a) b)

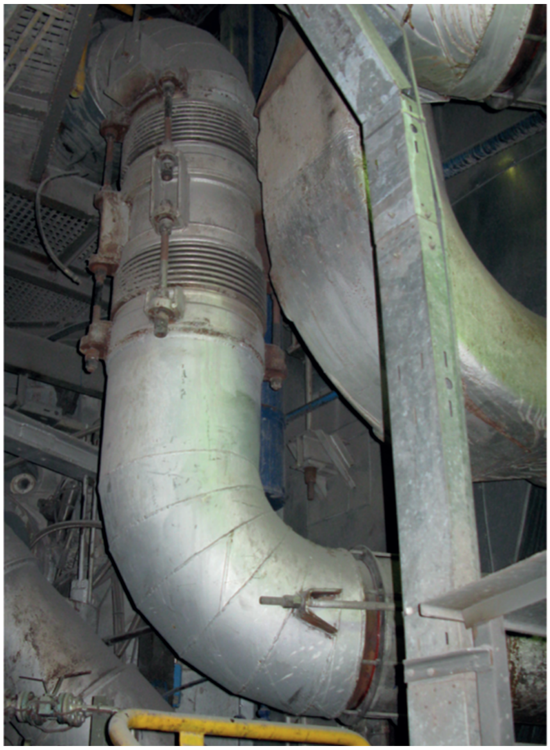

Fig. 1. A fragment of a large energy block installation: a) conduit elbow, b) a chute

Preventing the processes of intensive wear in the systems of pneumatic transport with the aid of research results on the abrasive wear processes [4, 5] consists in the proper shaping of the conduits (smooth transitions, axial connections) in applying erosion resistant materials in the areas exposed to greater wear [1]. The elements of the pneumatic transport that are exposed to accelerated wear are usually constructed as set of steel casing and liners made of highly wear-resistant materials. When the wear occurs at low angles between the dust currents and the walls of the pipeline and has a micro-chipping character, iron alloys with chromium mainly chromium cast-iron are used as a lining. Increasingly more frequently, the material of choice is ceramic, mainly basalt or Densit and also plastics [1].

One of the best known and often used in ceramic coating is Densit [6, 7]. The basis of this technology is a highly durable matrix that binds the abrasion-resistant particles: bauxite, corundum, carborundum, and aluminium oxide. Mechanically, the binder is stronger than the abrasion-resistant granulate, which means that every fracture in the ceramics occurs across the grain of the aggregate not the binding. There are different ways in which the abrasion-resistant layer is made by Densit coating in the form of mortar prepared with an addition of water, i.e. manual placing through the anchoring system, a flat or curved casting, or spraying the material through the anchoring system.

Typical elements that are made using this method are curved elements of the pipeline (elbows) (Fig. 2a) that have an enlarged diameter in comparison with straight segments of the pipeline connected with them by welding the stub pipe. The enlarged diameter for curved segment serves for the placing of the protective ceramic layer inside the elbow.

The ceramic coating is not just done during the manufacturing of new technological pipe installations. Long-term use results in gradual wear of the coating (Fig. 2b) and requires refurbishing work consisting in removing the remaining coating and replacing it with new.

Ceramic coatings are a very good, inexpensive, and effective solution, mainly due to the ease in forming the coating. Their disadvantage is being labour intensive. It particularly applies to the manual coat application, which additionally does not ensure the best shape if the inner working surface of a given element. On the other hand, the casting of the ceramic material in the core requires lengthy waiting for the initial bonding and a manual finish after the removal of the core.

The Institute For Sustainable Technologies – PIB has carried out a project for the purposes of manufacturing and verifying in practice a machine system for moulding ceramic layers in curved segments of the pipelines.

a) b)

Fig. 2. The elbows for dust transport: a) prefabricated elbows, b) used internal ceramic coating (with visible wear and cracks in the layer)

1. The method for layer moulding

The machine method of anti-wear layer moulding forming was applied, which is presented in Figure 3 [8].

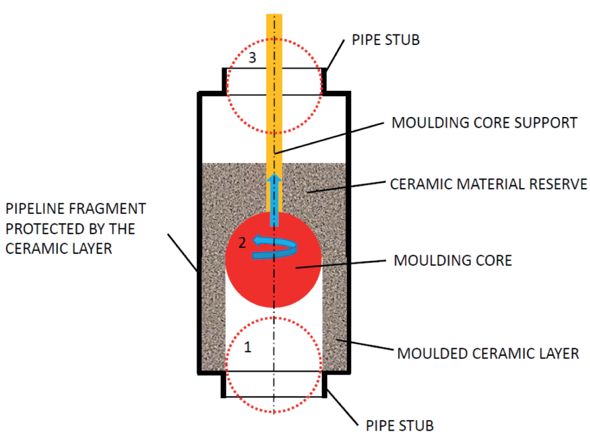

Fig. 3. A diagram illustrating the machine method of anti-erosion, ceramic coat forming in an element of a pipeline

This method provides machine moulding of the surface of the inner layer of the coating made of plastic ceramic mass. It consists in forming in the curved segment of the pipeline (elbow) a layer of a plastic ceramic material with an accurately guided revolving core (Fig. 3). The core, which rotary mounted on the core support, is positioned initially at the location marked with the number 1 on the stub element below of the pipeline, thus closing the opening of the stub. In this position, through the stub pipe located above, a portion of plastic ceramic mass (mortar) is poured into the inner part of the element. The core begins to rotate and move along the geometrical axis of the pipe element, e.g., an elbow. The rotational motion causes the mass to spread on the internal walls of the steel casing, and the forward motion forms the internal conduit in the mass. Moulding is complete when the core reaches the final position marked with the number 3 and when the excess of the ceramic mass is removed. If, right after the moulding, the mass has the proper strength to hold its shape, this element (the elbow) can be left for the completion of the intrinsic chemical binding of the ceramics. During the binding, various careful tasks may be performed to provide the proper conditions of the process, e.g., wetting, maintaining the right temperature or applying impregnating preparations that improve the structure [6, 7].

Applying the described techniques for moulding shortens the task duration and provides high precision in the shape and good quality of the internal surface of the pipeline element.

2. A model device for moulding forming ceramic layers

The design and the operation the model device for moulding ceramic layers is shown in Figure 4.

On the load-bearing structure (Fig. 4) made of steel profiles, there are two main working units with mountings. The elbow unit consisting of a spatial support for the elbow in which the ceramic coating is made and a contour master that guides the roll of the moulding forming core unit. The unit can be turned on the axis with a lever, or it can be immobilised at any point with a screw-clamp. The moulding core unit is mounted on the same axis, which consists of a self-aligning frame made of support for the moulding core connector and the arm for the guiding roll. The moulding core, mounted on the bracket is put into rotation by a drive unit with a gearbox powered with a frequency inverter, and a flexible shaft. The guiding roller mounted at the end of the arm is guided in the slot of the contour master connected to the elbow unit.

The bracket of the core unit is shaped in such a way that the geometrical axis of the guiding roll corresponds to the geometrical axis of the round surface of the moulding core. As a result, during a relative rotational motion of both units, the guiding of the roll in the contour masters causes such self-aligning motions of the bracket for the moulding unit that the core moves inside the elbow along the trajectory parallel to the trajectory of the roll.

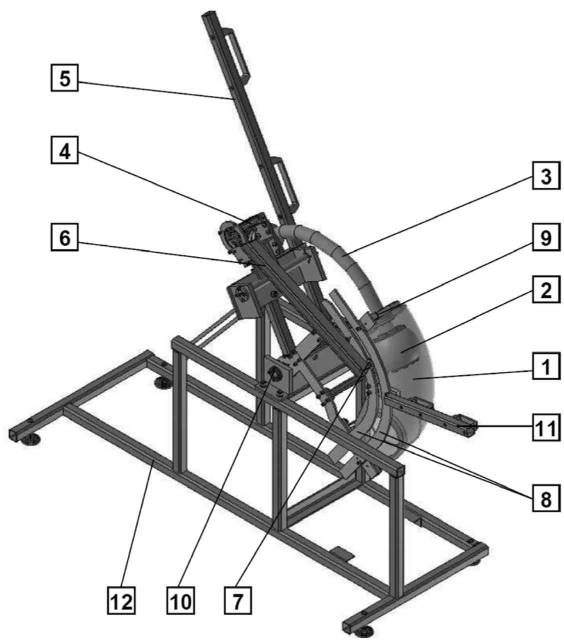

Fig. 4. A 3D model of the moulding unit: 1 – pipeline element (elbow), 2 – moulding core, 3 –moulding core support, 4 –moulding core drive shaft, 5 – manual lever for operating the motion of the core, 6 – guiding roll arm, 7 – guiding roll, 8 – contour master, 9 – pipe element bracket, 10 – turning axis of the elbow unit and moulding core unit, 11 – manual lever for operational motion of the elbow unit, 12 – load-bearing structure

This system of carrying out the working motion provides the possibility for free shaping of the interior wall of the elbow's passage by using a contour master with an appropriate shape [8]. This shaping method is suitable for producing ceramic layers in plane-symmetrical elements. The plane of symmetry of, e.g., an elbow, should be placed perpendicularly to the common revolving axis of the set moulding units.

The system allows the verification of two moulding methods:

– By turning the moulding core unit and "pulling out" of the core form a motionless elbow; and,
– By turning the elbow unit and "pulling off" the elbow from the motionless core.

There is also the possibility to verify a mixed method where the two motions are combined. It is very important from the point of view of the stability of the ceramic layer during the coating process and during the initial period after coating, before the process of chemical binding begins. Upon the plastic ceramic material the force of gravity and vibration are exerted during this time, and it must hold the desired shape with adherence to the steel casing and its own firmness.

The model system for ceramic coat forming was made at the Experimental Department at the Institute for Sustainable Technologies – PIB. It is presented in the following photographs (Fig. 5).

The photograph (Fig. 5a) shows the configuration of the moulding core and the guiding roll. It remains constant thanks to the coupling of these elements with a stiff mounted bracket on the slide bearings.

The photographs (Figs. 5b and c) show the typical position of the moulding core in relation to the pipeline element corresponding to each stage of moulding. In the initial position, marked as b), the core is at the lower pipe stub of the pipeline element closing its opening. In this position, the ceramic mass is poured through the upper pipe stub in sufficient quantity to mould the coating. It corresponds to the position 1 in Fig. 3. The final position, marked as c), corresponds to position 3 in Fig. 3 and corresponds to the end of moulding.

a) b) c)

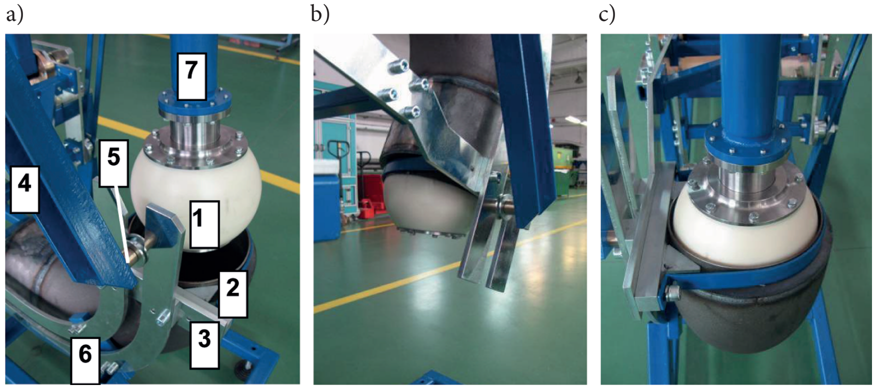

Fig. 5. Model forming system: a) core guiding system, 1 – moulding core 2 – pipeline elements (elbow), 3 – connector, 4 – guiding roll arm, 5 – guiding roll, 6 – contour master, 7 – moulding core support, b) moulding core in its initial position, c) moulding core in its final position

3. Technological trials of moulding ceramic layer in a pipe elbow

The studies of the moulding system were conducted according to the prototype testing methodology designed at ITeE – PIB [9, 10].

During technological trials, an anti-erosion ceramic material was used for forming the inner ceramic layer – Densit WearFlex 500 [9]. It consists of two ingredients:

- Binding material Densit WearFlex 500 Binder, and
- Grainy material (500) with grain size up to 5mm.
- According to the instructions provided by the manufacturer, the two ingredients are mixed at a 1:1 ratio, and after adding water, the mass for anti-erosion coating is ready.

The following were also used in the trial:

- Grainy ceramic material (100) with grain size of 1mm, and
- Polypropylene fibre for micro-reinforcing.

The fibres added to the fresh cement mix reduce plastic shrinkage and shrinkage cracks. They stop the formation of natural cracks in the initial period of the "life-span" of the cement [12].

The study used different mixes that are listed in Table 1. The amount of water added to the mix as selected experimentally to achieve the consistency of the mass that would allow the forming of the ceramic coating that holds its shape a sufficiently long duration until the beginning of matrix binding.

Table 1. The content of ceramic mixes used in the trails for machine forming of anti-erosive coating

Mixture symbol	Sand 500 [kg]	Sand 100 [kg]	Binding material [kg]	Micro-reinforcement [kg]
A	9.0	–	9.0	–
B	–	9.0	9.0	–
C	9.0	–	9.0	0.006
D	–	9.0	9.0	0.006

The aim of testing using different mixtures was to determine the possibilities of depositing layers from different mixes using the developed device. A correctly made ceramic layer should be characterized by continuousness, smoothness, and an even thickness over the entire surface and a durable embedding in the interior of the elbow fitting. The quality of the layer was assessed by visual inspection and by measurements carried out after cutting a cross-section of the fitting.

The following paragraphs describe the research for technological trials carried out for depositing ceramic layers using machine techniques for moulding internal shapes.

The examination of the impact of the consistency of ceramic material on the ability to form a layer:

The greatest influence on the consistency of the ceramic mass was the amount of the water used for the mix. Determination of the amount of water needed to achieve the right consistency is difficult, because the fractional composition of ceramic material and its moisture also have an impact on the consistency. The amount of water was selected experimentally based on organoleptic evaluation of the achieved consistency. The proper consistency was characterised by a porous structure that required thickening in order to achieve a uniform layer without pores or bubbles. A more plastic consistency, with a higher water content, caused difficulties in obtaining a smooth surface and an inherent deformation of the formed shape under the force of gravity (Figure 6a). The mass with too little water content makes it difficult to create a coating on the entire internal surface of the fitting (Figure 6b). The coating that is made correctly is shown in the photograph in Figure 6c.

a) b) c)

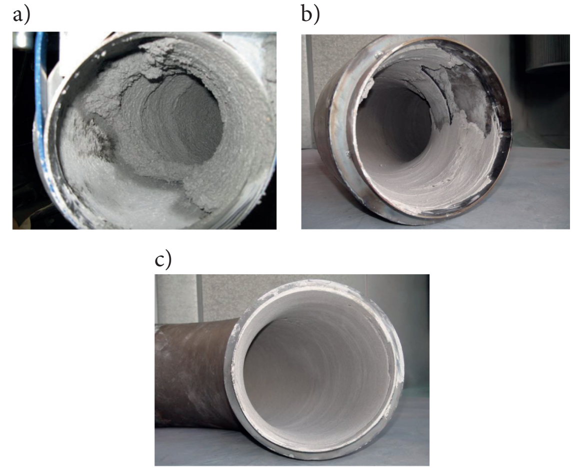

Fig. 6. The results of trials in forming ceramic layer in the pipe elbow: a) faults resulting from an excessive amount of water, b) deficiencies in the coating caused by an insufficient amount of water, c) a correctly made ceramic layer

The size of the grains of sand has an influence on the forming. Problems arise when the forming core moves along in the elbow of a nominal diameter pipeline in the pipe stubs of the elbow at the nominal diameter of the pipeline. In order to obtain an internal conduit of the elbow with the nominal diameter of the pipeline, the forming core has a minimal radial clearance in relation to the stub. When moving of the core through the stub, large ceramic grains get in between the core and the metal wall causing a significant resistance in movement, scratching of the core, and blocking the rotational motion. For the model forming system, there was an overload on the drive system and a destruction of the flexible shaft that transfers torque. When it is necessary to use large size grains, it is also necessary to apply a drive of much higher rotational strength and a core that is pliable under the pressure of grains. An alternative solution may be to stop the core from operation in the stub by starting forming right beyond the lower stub and ending right before the upper stub.

The examination of the impact of the micro-reinforcing additive to ceramic material on the ability to form a layer:

Polypropylene micro-reinforcing very significantly improves resistance of the wet ceramic mass to deformation under the influence of gravity. The layers obtained from such material have good smoothness and strength before chemical bonding of the matrix. However, the increase in the strength in the wet stage also results in certain difficulties during forming caused by increased resistance to deformation. The increased resistance makes the rotation motion of the forming core more difficult, and it makes it more difficult to move it along inside the elbow. Therefore, using a mass reinforced with polypropylene requires a rotary drive with an increased torque and a mechanical forward drive.

The examination of the impact of the position of a given element in the pipeline and the order of mutual movement of units on the ability to form a layer:

Among the possible mutual positions and movements of the forming core and the elbow, the best solution turned out to be moulding by turning the core unit. The position of the elbow is selected in such a way that both stubs (top and bottom) are directly aligned. In this position, the largest possible part of the elbow has a position that approximates vertical. This counteracts the gravity forces that pull the coating away from the metal walls, while the proper strength of the ceramic mass prevents the layer from running downwards.

The examination of the impact of forming core rotational velocity on the quality of ceramic layer:

The moulding core velocity was varied between 3 and 30 rpm. There was no apparent impact of the velocity on the quality of the resultant coating. Due to the desire to improve the technology, the research was mainly conducted at the highest velocity, which reduces the moulding time and the impact of generated vibrations on a freshly formed layer. During the research, it was found that one pass in forming the core does not always provide complete coverage of the internal surface of the elbow fitting. Thus, a double pass was applied, with a repeated administration of excess mass that had been removed during the first pass.

Conclusions

The results of this study confirmed the applicability of machine moulding of the internal curved surface in pipe segments protected by ceramic coating using a mechanical moulding system. Thus, a model moulding system with an active core was designed, manufactured, and constructed, on which trials in ceramic moulding in elbows were performed.

The results of the moulding tests indicate that this method gives the opportunity to obtain ceramic coatings of good quality in terms of the internal conduit shape and smoothness of the surface.

Technological trials were carried out for different configurations of the ceramic mix and different parameters of the moulding process. Technical parameters for which the obtained layers have good qualities were selected experimentally, with each experimental result further refining the parameters.

The developed model technology can be deployed in economic practice, provided the construction of the forming device follows the principle analogous to the developed model device, adjusted to the dimensions of the specific industrial installations. The conclusions on the conducted technological tests provide insights and recommendations that should be taken into account in the construction of such a device.

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