Method of accelerated industrial testing of hydroabrasive wear of polymer coatings of steel pipes

R B Kuskildin¹, A M Vatlina¹

¹ Saint-Petersburg Mining University, 2, 21st Line, St. Petersburg 199106, Russia

E-mail: kuskildin_rb@pers.spmi.ru

Abstract. The article is devoted to the discussion of the problem of choosing a protective coating for the inner walls of the slurry pipeline of mining enterprises. For the correct choice among the many polymer coatings, it is necessary to test various coatings for water-jet wear. Standardized test methods are not entirely suitable for assessing the durability of coatings in a specific production environment, they do not take into account the nature of the slurry flow, temperature, etc. Solid inclusions of a different particle size and chemical composition are often used in ready-made and published studies, which makes them irrelevant for mining specialists. Often, for a comparative assessment of the wear resistance of various coatings, enterprises conduct their own industrial tests for hydroabrasive wear, in which they recreate the same granulometric composition of the pulp and its concentration. However, they come with a significant investment of time and energy. The article proposes to use a method of accelerated wear testing based on a comparison of the wear of a straight section of a pipeline and a shaped one in the form of a rotary insert at an angle of 90°.

1. Introduction
For many mining operations using hydraulic transport, the question of the need to use pipes with a protective inner coating is often raised. Recently, pipes with various polymer coatings, which have significant wear resistance as compared to conventional steel pipes, have become widespread [1, 2]. At the same time, many engineering services face a difficult choice of the type of polymer coating for the inner surface of the pipe, since slurry pipelines of mining enterprises have been made of steel pipes for a long time [3, 4].

Referring to various sources, you can find different ways of assessing waterjet wear. Many papers report many different steel pipe lining materials and wear test results. But it is practically impossible to make an unambiguous decision on the use of one or another material as a protective coating on the inner surface of the pipeline under specific conditions [5].

2. Materials and methods
2.1 Standard Test Method for Waterjet Wear
Various studies indicate the results of water jet wear measured using the Darmstadt method, which is as follows.

A sample of a polymer-coated pipe is installed on a two-way traverse mounted on a fixed base. The traverse has the ability to tilt relative to the horizontal axis of rotation by an angle of ± 22.5° and...
produces rolling at a constant speed (about 10 rolling per minute) under the action of the drive [6]. The standard DIN EN295-3: 2012-03 stipulates the rolling speed of 20 rolls per minute.

![Diagram of a test facility according to the "Darmstadt" method.](image)

Figure 1. Diagram of a test facility according to the "Darmstadt" method.
1 - end plate fixing device; 2 - sample; 3 - drive; 4 - control device; 5 - installation base; 6 - water level; 7 - abrasive material; 8 - end plate; s is the width of the water mirror; \(\alpha\) - angles of deflection of the traverse with the pipe sample.

After testing, which in serial tests reaches 100 thousand cycles, the pipe wall thickness is measured using a high-precision instrument. The Russian standard GOST R 55877-2013 provides for measurement at control points along a longitudinal line located in the lower part of the inner surface of the sample.

Some researchers make up to 70 measurements of wall thickness to determine a reliable sample of the wear result [5].

For all the academic and scientific nature of this method, it should be recognized that the results of such tests will often be contradictory for researchers of hydroabrasive wear of polymer coatings. Abrasion rates during such tests will be lower. Many factors that will affect the pipe lining during industrial use will be eliminated (flow regime, temperature, pressure in the standpipe, etc.).

### 2.2 Industrial Comparative Waterjet Test Method

For many mining professionals who compare the polymer linings of steel pipes, standard academic research is of little interest, they need to know how the polymer coating will behave in their industrial environment.

In addition, often the same brand of polymer from different manufacturers may differ in performance properties. As a result, the company's specialists may find it difficult to choose a supplier and grade of steel pipe lining material.

Therefore, mining companies often conduct additional studies in closed loops with installed test pieces of pipe to evaluate various lining materials [9].

A schematic of such a test setup is shown in Figure 2.
Figure 2. Schematic of an industrial test setup
1 - reservoir with pulp; 2 - pipeline; 3 - manovacuum meter; 4 - ground pump; 5 - manometer; 6 - ultrasonic flow meter sensor; 7 - inserts of tubes with various polymer coatings

Before the experiment, samples with different polymer coatings 7 are weighed and recorded in the test log. The pulp in tank 1 is diluted with the required concentration and selected particle size distribution. The flow rate is measured using an ultrasonic sensor 5. After the tests, the samples 7 are weighed, and by the difference in mass before and after testing, the wear of the samples is determined. The results of such tests will be more reliable. This method is relevant for a mining enterprise that uses the hydrotransportation of tailings. When loading the slurry, you can use exactly the abrasive material that the processing plant has at the outlet, you can select the exact concentration of solid particles in the pulp that is used during transportation at the enterprise [10].

However, to determine the comparative wear of polymer coatings, it is necessary to carry out a very long test period. For example, when testing various polymer coatings in the hydrotransport laboratory of the St. Petersburg Mining University, the pulp was pumped with a concentration of 30% on solid at a speed of 2.2 m/s for 800 hours. At the same time, significant wear was not achieved for samples with a polymer coating. The weight of pipe inserts with different polymer coatings either changed slightly or remained the same. To obtain unambiguous conclusions, it is required to multiply the test time.

2.3 Accelerated test method for hydroabrasive wear
Based on a large number of experimental studies, a reasonable conclusion was made that in order to reduce the time and energy consumption during experiments, it is necessary to change the methodology and scheme of the test setup.

The known methods of testing for hydroabrasive wear in most cases differ in their wear mechanism, therefore they are often not reliable. For example, installations for testing for hydroabrasive wear of a jet type wear out polymer samples rather quickly, but the mechanism of such wear has an impact character, therefore, it cannot be used to determine the wear resistance of polymer coatings of slurry pipelines [2, 3].

The second disadvantage of alternative methods of testing for hydroabrasive wear is the complexity of assessing the resource of the polymer coating. To obtain comparative wear resistance, many methods are quite applicable, but they are unsuitable for determining the coating resource in industrial conditions.

It is widely known that pipe fittings experience increased wear on the pipe walls. In this case, increased wear occurs due to increased pressure on the inner surface of the pipe due to a change in the direction of the pipe flow, which does not change the nature of wear, which is characteristic of the linear part of the pipeline.
It is proposed for a comparative test of various grades of polymer coatings to make rotary pipe sections with a rotation angle of 90° and a control steel sample (uncoated) and draw up the following hydraulic circuit (Fig. 3)

![Figure 3. Scheme for accelerated testing for waterjet wear of pipe sections: 1 - reservoir with pulp; 2 - pipeline; 3 - manovacuum meter; 4 - ground pump; 5 - manometer; 6 - ultrasonic flow meter sensor; 7, 8, 9, 10 - rotary inserts with various internal polymer coatings; 11 - pipe insert without inner coating; 12 - swivel insert without inner coating](image)

The insert of the pipe sample 11 and the rotary insert 12 by 90° without coating serve as control samples by which the resource of the polymer coating is determined. And they must be made in such a way that the length of the insertion of the straight section is equal to the length of the arc of the turning part of the pipeline. And the rotary inserts with polymer coatings 7, 8, 9, 10 must be made with a flow path that is geometrically identical to the rotary insert of the uncoated pipe 11. Steel samples and coated rotary inserts are preliminarily weighed and fixed in the system.

After pumping the pulp of a given concentration for a certain time test, the samples are removed and weighed.

The wear on the mass of the straight section of the pipe will be $\Delta m_{\text{line}}$, and the wear on the mass of the turning part will be $\Delta m_{\text{surf}}$. Then, taking into account that wear by weight depends linearly on the time of action of the moving pulp, it follows that the equivalent test time for rotary parts will be equal to:

$$t_{eq} = \frac{\Delta m_{\text{surf}}}{\Delta m_{\text{line}}} \cdot t_{test}. \quad (1)$$

For example, when testing in laboratory conditions, the mass wear of a linear sample was $\Delta m_{\text{line}} = 16.39$ g after $t_{test} = 600$ hours of operation, and the weight of the turning part of the pipe changed by the value $\Delta m_{\text{surf}} = 68.26$ gr. Based on this, we can say that the equivalent test time for rotary pipeline
inserts is $t_{eq} = 2498$ hours. Subsequently rotary weighted inserts with polymeric coatings with the change in their mass will correspond to an equivalent test time of 2498 hours.

After carrying out such tests, it is possible to unambiguously identify the expediency of using one or another polymer coating as a lining of the inner surface of slurry pipelines.

To determine the resource of such a coating, an experiment should be carried out with a rotary insert with a coating of a given thickness, until the polymer coating is completely worn out and a contact of the pulp with a steel pipe occurs, and using formula (1), determine the resource of such a coating in hours.

Having the data on the resource of the protective coating of the inner walls of the pipeline and their cost, the company will be able to unambiguously determine the feasibility of using certain pipes with a polymer coating.

3. Conclusion
The presented form of the experiment to determine the value of hydroabrasive wear makes it possible to obtain reliable information about the amount of waterjet wear and the resource of various coatings in a shorter time and at significantly lower energy consumption.

It should be borne in mind that the data of such tests will be relative in each case, but will be important for the enterprise in terms of making a decision on the use of certain materials for pipe lining in their specific conditions.

4. Acknowledgments
Research is supported by Russian Science Foundation grant 19-79-10151.

References
[1] Antoev K P, Popov S N, 2017 Study of Resistance to Hydroabrasive Wear of GRP Pipes with a Polyurethane Coating. Education and Science, 1, 87-90
[2] Shtyrev O O 2015 On inadmissibility of use of Taber Abraser and similar devices for control of resistance of materials of polymeric coating of pipes of oil schedule to hydroabrasive wear in case of exposure to flow with solid particles. Territorija “NEFTEGAS” [Oil and Gas Territory] (9) 86-90.
[3] Chizhov E A, Chizhov A E, Novikov S G, Tolkachev Y A 2009 The Implementation Prospects for the Polimer Matherials in Hydraulic Mining. Gornyi-informatsionnyi analititscheskiy zhurnal; S1. 367-383.
[4] GOST R 55877-2013. 2014 Glass-reinforced thermostetting plastics (GRP) pipes and fittings. Test methods for determination of resistance to wear by abrasive wheels. Moscow.
[5] Bransburg A, Kovriga V, Puze V 2015 Slurry lines: from the Darmstadt method to the Darmstadt resource. Plastic Pipes. Industry Information and Analytical Digest. 1(47) 52-53
[6] Vasilyeva, M A, Volchikhina, A A 2018 Analysis of influence of pipeline roughness dispersion on energy consumption during fluid transportation (Conference Paper). Journal of Physics: Conference Series 1118, 1, Saint-Petersburg; Russian Federation
[7] Alexandrov, V I, Vasilyeva, M A, Vasilyeva, P A 2018 Efficiency of Using Polyurethane-lined Pipes in Hydrotransport Systems of Slurry Tailings. 1118, 1, Saint-Petersburg; Russian Federation
[8] Aleksandrov V I., Kibirev V I. 2018 The Kachkanarsky MCC iron ore processing tailings slurry hydraulic transport parameters determination Obogashchenie Rud 1, 56-63
[9] Kibirev, V I 2019 Analysis of the industrial practice of thickened tailings storage. Obogashchenie Rud, 2, 27-32
[10] Paipuri M., Fernández-Méndez S., Tiago C. 2018 Comparison of high-order continuous and hybridizable discontinuous Galerkin methods for incompressible fluid flow problems. *Mathematics and Computers in Simulation* 153, pp. 35-58