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On The Development of the Manufacturing Technology of Fiberglass Cylindrical Shells of Gas Exhaust Trunks by Buildup Winding

V.M. Astashkin, M.V. Mishnev*

South Ural State University, 76, Lenin Avenue, Chelyabinsk, 454080, The Russian Federation

Abstract

The new mobile technology for manufacturing of large-sized shells made of polymeric composite materials (PCM) based on a wet winding with rearing is set forward. The basic principles of the technology are developed, the equipment is manufactured, its approbation is held, and the development prototypes of shells made of fiberglass are produced. The proposed method allows producing the shells of the theoretically unlimited length directly at the construction site. The most promising implementation direction is the vertical-based production of large-sized gas exhaust liners made of PCM for chimneys. The technology is oriented at large-sized structures, the diameter of the gas exhaust duct of which is more than 3 m.

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Keywords: flue pipes; gas pipes; gas exhaust trunks; polymeric composite materials; fiberglass; winding.

1. Introduction

Gas exhaust trunks of large-scale industrial enterprises are designed for the gas elimination and dispersion in the atmosphere generating in the result of fuel combustion (flue gases) or in the result of technological processes such as, for example, chemical etching (technological processes). Vertical liners and gas-flue ducts adjacent to them are in the combination of gas exhaust trunks. More often the liners and flue ducts are produced in the form of closed-loop cylindrical shells.

* Corresponding author. Tel.: +7-906-864-1725.
E-mail address: mmv2004@list.ru

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Some aggressive components are present in the combination of allocated gas. Thus in flue gases these are mainly dip-ping acid and sulfur oxides, in technological gases of chemical productions more wide range of aggressive substances, caused by certain technological process can be present.

Besides the chemical composition of allocated gases, the degree of their aggression also depends on temperature which for flue gasses can exceed 300^{o}C at the output of gas pipe. However, today this situation is becoming less common, and it is connected: with a change in the structure of the fuel balance (utilization capacity of natural gas as fuel increases), current trends in energy saving (heat recovery of allocated gas), as well as the requirements of environmental safety [8].

At the present time over 90% of allocated gases, including flue ones, have the temperature lower than 200^{o}C [5, 8, 11], particularly because of the implementation of energy effective technologies of heat recovery and the systems of wet-gas purification. The transfer to the technology of deeper heat recovery of stack gases (cooling the low pressure dewpoint), when the heat transfer agent is additionally given, the heat of condensation is perspective.

The relatively low temperature and high flue gas moisture content leads inevitably to the formation of a large amount of chemically aggressive condensate dropping out within the flues pipes and gas exhaust ducts which toughens the conditions for their exploitation and makes their manufacturing of traditional materials (brick, 'black' steel, concrete) ineffective due to the difficulty in obtaining reliable and long lasting corrosion protection.

The implementation of constructions of gas exhaust trunks of stainless steel does not entirely justify itself, because often they are not sufficiently stable to aggressive influence at certain combination of the chemical composition and temperature of allocated gas [1, 2]. Besides, a significant increase in the cost of stainless steel has been observed in recent years [3, 5].

A radical way to enhance the durability and reliability of gas exhaust trunk structures is their production of polymeric composite materials (PCM), mainly fiberglass.

2. Experience in fiberglass application in the gas exhaust trunks

The number of gas exhaust trunks structures made of fiberglass has increased considerably both in Russia and abroad for the last 10…12 years.

Over 120 fiberglass flue pipes with the height of 150 m and with the diameter of up to 5 m, as well as approaching gas pipes in the enterprises of metallurgy and heat energetics of Moscow, Ural, Siberia, Udmurtia, Far East, and Ukraine have been planned, produced, incorporated and successfully exploited in Russia from the period of 2005 - 2015. Particular examples are given in Figure 1.

Fig. 1. Fiberglass gas exhaust ducts: (a) with the diameter of 5,0 m at the plant named after A.K. Serov, the city of Serov; (b) with the diameter of 3,25 m at the regional heating station Birulevo, Moscow.

The introduction of corrosion-resistant composite structures of gas exhaust trunks is also developing abroad. For example, in the USA there is the growth of their use in the sulfur compound pollution abatement system in coal-fired power plants, due to the introduction of state programs on the limitation of harmful emissions into the atmosphere, as well as a significant increase of prices for stainless steel and nickel alloys.

So in 2006 the price for nickel increased from $ 6 to $ 15 per pound, and in 2007 it increased to $ 22 [3, 5]. And if for the period of 2004 ... 2005 only eight composite gas exhaust ducts for the allocation of flue gases were built in the USA, in 2006 ... 2008, there were already one hundred and eighteen of them. [5]

Composite gas exhaust ducts with large diameters, as a rule, are not bearing and hang up inside the framed steel towers, concrete or masonry chimneys, taking the main part of mechanic loads.

The gas exhaust duct of chimney at the metallurgical plant named after A.K. Serov in the city of Serov (Russia), with a diameter of 5 m and a height of 55 m, the gas exhaust duct of chimney, produced by the Plasticon Composites Company, with a diameter of 7 m and a height of 250 m [7], the gas exhaust duct of chimney produced by Ershigs, with a diameter of 8.5 m [6] and others can be given as examples.

3. Existing production technologies of shells of gas exhaust trunks made of pcm

The majority of existing technological schemes of production of large-sized shells made of PCM are based on the principles of wet and dry winding [1, 8, 11], with the help of which it is possible to obtain monolete, and as a consequence, high-reliable shells. At the same time the transportation of a large number of large-sized shell structures with a diameter of more than 3 m is difficult, that is why the production of large-sized shells is arranged in the vicinity of the installation sites both in Russia and abroad [1, 8].

There are cyclic and continuous ways of winding the shells made of PCM. In the cyclic process the length of cyclic shell can not exceed the length of mandrel on which it is wound, and in a continuous process the shell length is not limited by the mandrel length, and can theoretically be infinite. However, the existing equipment for the continuous winding is oriented at the production of pipes of relatively small diameter (up to 3 meters), they are technically complex and can not be deployed directly at the construction site.

That is why at the present time large-sized fiberglass shells of gas exhaust ducts, produced in proximity to the installation site, are produced according to the technology of cylindrical winding. Herewith the horizontal and vertical winding is used [9, 11].

Since the shell length can not exceed the length of the mandrel when the cyclic winding is used, the extended gas exhaust duct or gas pipe are collected from a large amount of prefabricated shells (cylinder shell), as a result, there is a large number of the mounting joints. For example, the chimney shaft with diameters of 7 m and 250 m, manufactured by Plasticon Composites Company, consists of 40 building blocks with the corresponding number of joints.

There are different variants of the structures of erection joints between cylinder shells, such as flare (in different versions), bandage (adhesive) or bolted (hairpin) joints [8].

With a large number of joints the reliability of the structure is reduced for 5 ... 10% because of the complexity of their sealing, the materials consumption and time and cost of construction increase, so the problem of reducing the number of mounting joints is important.

4. Development of the production technology of fiberglass cylindrical shells by the buildup method

In South Ural State University in the framework of Federal Target Program ‘Scientific and Academic Staff of Innovative Russia for 2009-2013’, new principles are developed, test equipment is produced and approbation of mobile technology is given, allowing to produce shells of non-limited length directly on the construction site of gas exhaust truck.

The main idea is in the production of shells by wet winding on the short console mandrel with cyclic buildup of the shell till taking on the necessary length.

The key moment is the mandrel construction [12], which must provide fast removal and movement of hardened shell, therefore a pneumatic mandrel with an outer layer of armor teflon fabric with a low adhesion to fiberglass has been developed and manufactured.

As the main field, where the most effective use of developed technology is possible, is the production of gas exhaust ducts of flue pipes, so we put the emphasis on the vertical winding (though the buildup method can be applied in the horizontal winding as well). The winding can be implemented both with glass threads (roving) and fiberglass. The patient on the useful model of the Russian Federation was taken out on the installation of vertical winding with fiberglass [13].

The sequence of operations in the buildup method is as follows: the first shell section is wound, after curing the mandrel is compressed and moves along the console mandrel. Further, without cutting the fiberglass or fiber glass fabric the winding of the next section continues, and at the same time a solid and scalable interface forms between buildup sections. The shell formation scheme on the mandrel is shown in Fig. 2.

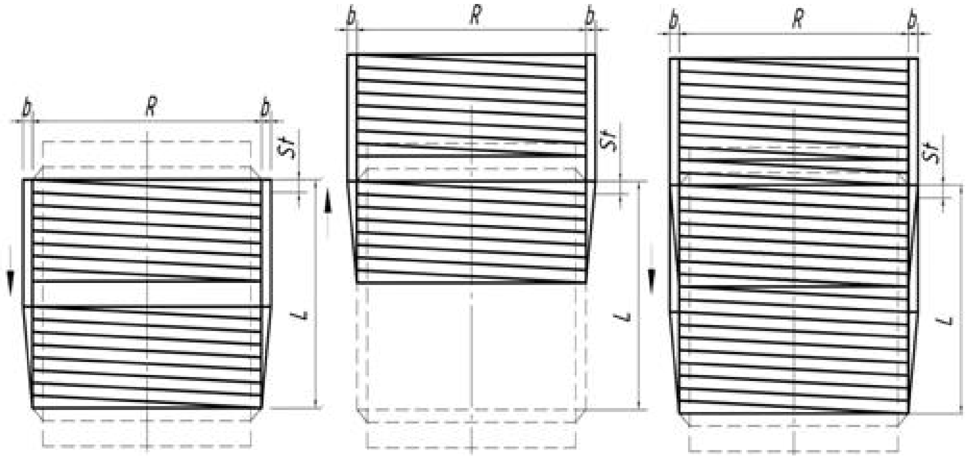

Fig. 2. The scheme of shell forming on the mandrel (down arrow – winding direction, up arrow – movement direction)

As a result of conducted work the installation of vertical winding with mandrel with a diameter of 1 m, impregnating apparatus for winding with fiber glass fabric with the roll width of 0,5 m are produced. The installation in the process of work is shown in Fig. 3. When producing additional mandrels, the shells with a diameter of 3 m can be produced on the manufactured installation.

The winding of prototypes of fiberglass shells was carried out using structural fiberglass T-23 at the epoxy binder of the hot curing (ED-20, IZOMTGFA, UP 606/2). The warming up of binder on the mandrel is realized with the help of two infrared radiators with the capacity of 6 kW, the curing temperature was 110 ... 120°C, the curing time - about 20 minutes.

Initially it was supposed that as the heated binder has a low viscosity, its intensive runoff from the mandrel under vertical winding and, consequently, its significant losses are possible. Therefore, the insert of the thixotropic additive Aerosil A380 in an amount of 5% of the binder mass into the composition of binder was tested.

The measured loss of the binder without the addition of Aerosil is about 5%, with Aerosil - 3%, which does not exceed analogical loss in the horizontal winding.

When processing the method of the vertical winding with the mandrel on the winding with a working length of 1 m, several samples of shells of 4 m long were produced (see. Fig. 3), which proved the functionality of offered method of manufacturing the shells made of the PCM (particularly fiberglass).

In total four of the experimental samples of shells were manufactured: 3 samples of the fabric T-23 and binding (ED-20, IZOMTGFA, UP 606/2); 1 sample made of the fabric T-23 and binding (ED-20, IZOMTGFA, UP 606/2 + Aerosil A380 in an amount of 5% of the binder mass).

5. Application field of the offered technology

The offered method allows producing the shells of theoretically non-limited length directly at the construction site by mobile technology. More perspective field of implementation is the production by vertical scheme of large-sized gas exhaust ducts made of PCM of flue pipes, and also the production of prolonged shells of gas pipes.

For the shells of PCM of large diameter (over 2.5 m) defining the thickness of the section of their web are erection loads appearing during the transportation and installation, that is why a rational way of their manufacturing is a vertical winding with rearing, providing the distribution of the duct in the project provisions, omitting the stage of storage, transportation, piping, etc. This allows reducing the mounting load, and as a result the ability to manufacture shells with less web thickness, and respectively, material consumption is reduced and there is no need to provide a site for storing wound shells.

Fig. 3. The installation of vertical winding in the process of work (produced shells in the background)

When installing fiberglass trunk in the concrete pipe (see. Fig. 4) it is technically possible by this technology using the buildup method, to produce monolithic shells in a short time directly inside a concrete pipe (of an approximate length-up to 50...60 m). This significantly reduces the expenditure of material for the shell and supporting structures, reduces costs and facilitates their installation. Such works are more rationally implemented by construction organizations using mobile complexes.

The offered method combines the processes of production and installation of cylinder shells of gas exhaust ducts. In construction such-like methods have been successfully used for a long period of time. The most common example is structural construction made of monolithic concrete, when the formation of the construction is implemented in its project state directly at the construction site, that is to say the installation and creation of the construction in the framework of one process.

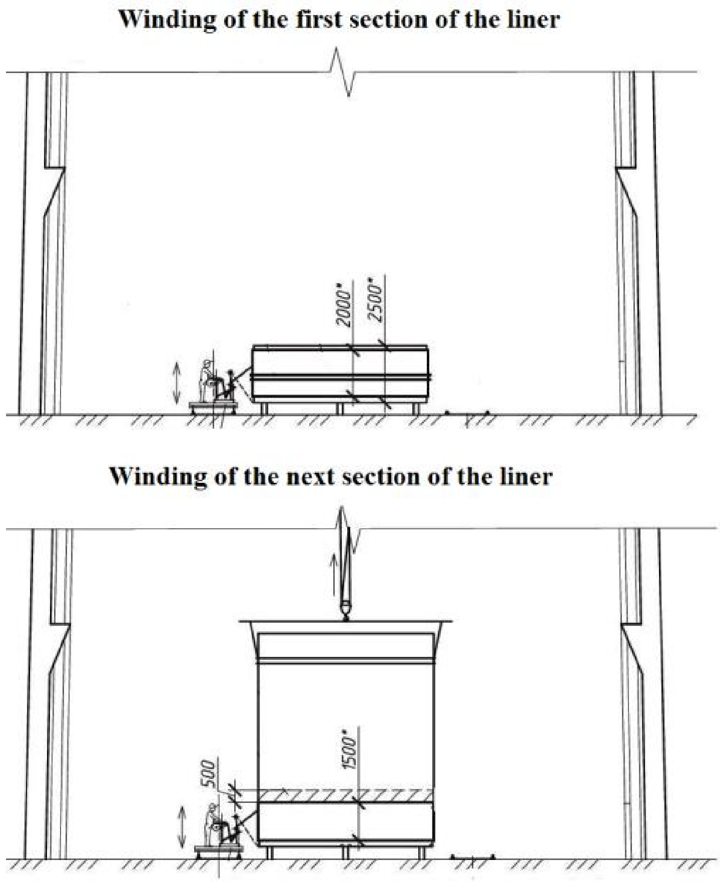

Fig. 4.The scheme of shell winding inside the pipe

6. Conclusion

Global experience shows perspectives of using PCM (mainly fiberglass) in the construction of gas exhaust ducts of industrial enterprises (flue pipes and gas pipes). However, existing methods of production and erection predetermine the need to perform a large number of installation elements and, as a consequence, the joints between them.

The main practical result of the work is to prove the possibilities of production of shells of long length of PCM (fiberglass particularly) in laboratory conditions by the method of vertical winding with buildup process, which excludes the necessity of implementation of large amount of joints.

This technological scheme is mobile and combines the production and installation of long shell constructions of PCM, exploited in vertical state, for example, of flue pipes' ducts.

The most perspective field of implementation is the production using the vertical scheme of large-sized gas exhaust ducts made of PCM for flue pipes; however the gas pipes production using the horizontal scheme is also possible. The technology is oriented at large-sized structures with a diameter exceeding 3 m.

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