Application of active powders at fluidised bed heat treatment technologies

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Abstract: The paper describes the principles and conditions of carrying out of a new type of fluidised bed thermo-chemical treatment in chemically active powders with different ways of fluidisation. These new fluidised bed thermo-chemical treatments in chemically active powders are primarily for the formation of surface diffusion layers on parts made of constructional and tool steel. This method can be used for sherardising, alitising, carbonitriding, nitrocarburising, carburising or boronising. Characteristics of chemically active powders are compared with the chemically inert powders, used in conventional fluidised bed treatments. In addition, the paper presents the feasible ways to use fluidisation by gas flow or by mechanical vibrations for different processes and their main stages, i.e., heating up to treatment temperature, soaking at treatment temperature and cooling down after the soaking. Advantages and disadvantages of these processes, in comparison with the conventional methods of fluidised bed thermo-chemical treatment, are given.

Keywords: fluidised bed heat treatment; termofluid; TermoActivFluid®; VibroTermoFluid®.

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Natalia Kucharieva received her PhD from Byelorussian Polytechnic Institute. She published over 120 publications on various aspects of heat treating and quenching. She is also an owner of seven patents of BELARUS in the field of heat treating and quenching. Now, she is the scientific director of three State scientific Programmes. Currently, she is an Assistant Professor at Belarussian National Technical University, Research Division.

1 Introduction

Studies on thermo-chemical treatments in fluidised bed were carried out for many years to increase the properties of tools and machine parts. These technologies have been used in two areas:

- volumetric heat treatment
- thermo-chemical surface treatment, whose aim is to change the properties of the surface layer of the part or tool.

Selection of fluidised bed technology for thermo-chemical treatment was based on unique properties of this technology, such as:

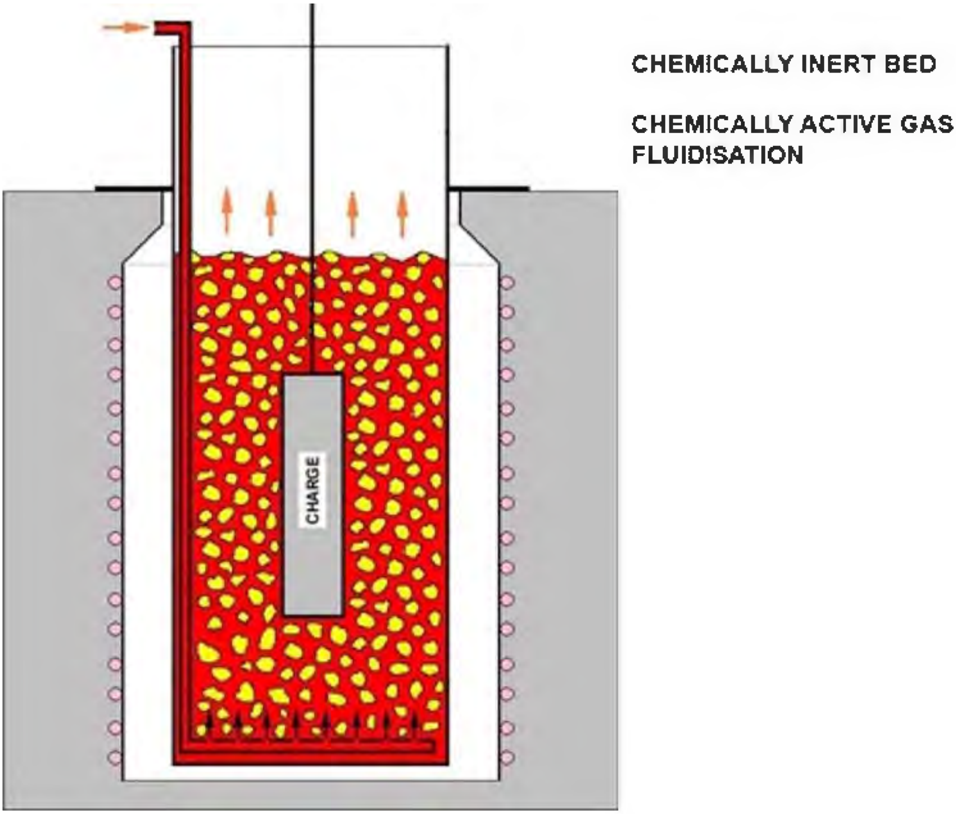
- easy access to the work area of the furnace
- rapid heating of the charge
- uniform temperature in the workspace
- uniform temperature on the surface and along the cross-section of workpiece regardless of its size and shape
- possibility of diffusion processes with open furnace
- easy adjustment of the furnace when changing the type of treatment
- can operate in a wide range of temperature
- possibility of treating workpiece with complex shapes
- possibility of using it for all types of steel and colour metal alloys
- ease of use, which does not require involvement of highly qualified personnel.

Fluidised bed technologies, owing to their advantages, replaced the salt treatment technologies by eliminating harmful effects to the environment wastes and fumes. The risk of the explosion of hot salt in contact with the moist surface of the workpiece and the need for drying and heating of parts in the process have been completely eliminated.

2 Classic termofluid technology

For this moment, the source of the diffusion elements of the surface layer of steel workpieces was supplied with gas fed to the bottom part of the retort while the bed mainly played the role of the heat accumulator and the distributor of the gas flow in the entire volume of the furnace. Figure 1 represents diagram with chemically active gases (red colour), which act on a fluidised bed of inert material (yellow colour) and charge for treatment.

Figure 1 Functional diagram of a typical fluidised bed furnace (red – chemically active gas, yellow – chemically inert bed) (see online version for colours)

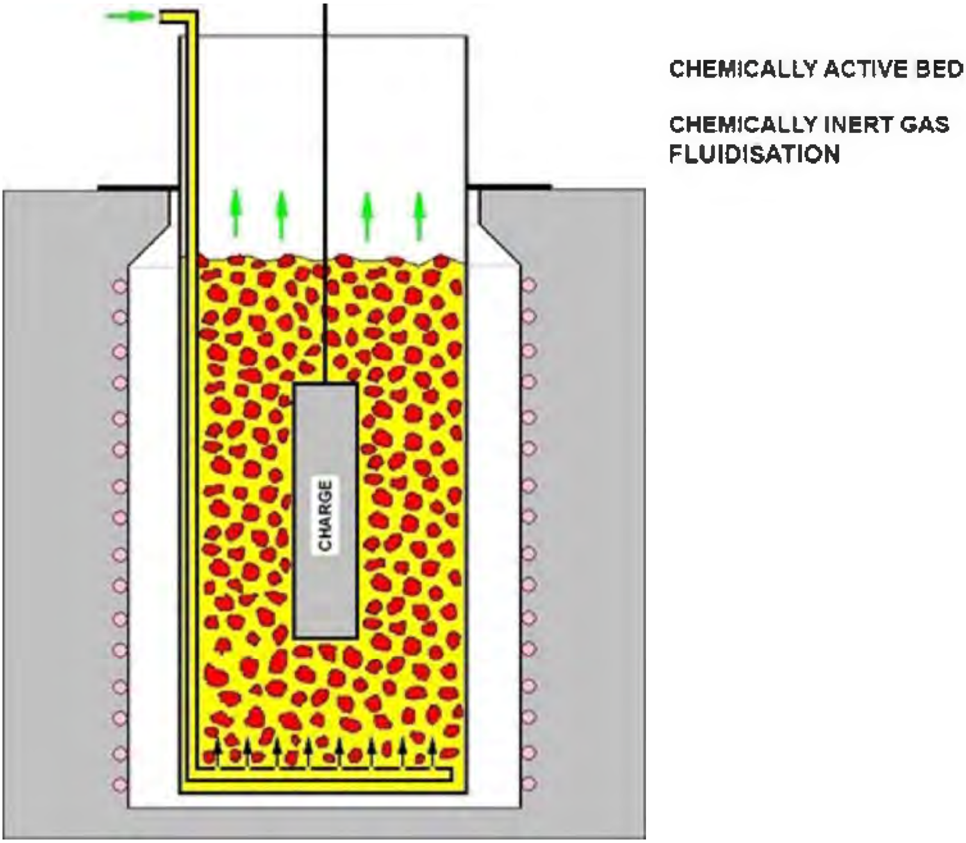


3 Termoactivfluid® technology

The proposed TermoActivFluid® technology uses an innovative method of thermo-chemical treatment of steel, in which the fluidised bed (special composition of powder mixture) fulfils not only the current job but is also a source of diffusible element to the workpiece. The advantage of this solution in relation to the previously used conventional thermo-chemical treatments in the retort, continuous, vacuum and the other furnaces is that the workpiece can be removed and placed in at any time. This means that one furnace can lead independent parallel processing of multiple parts that require times of the process by inserting and removing them according to the technological requirements without waiting for the completion of the processes carried out on other parts.

The adopted solution acts as a gas surface activator and is also responsible for: a variable exposure area of the powder in relation to the treated surface, the movement of powder to all surfaces of the workpiece and protection of the surface from oxidation. Figure 2 shows the diagram of the fluidised bed furnace, which uses chemically active fluidised bed with chemically inert gas.

Figure 2 Diagram of the fluidised bed new generation furnace (red – chemically active bed, yellow – chemically inert gas) (see online version for colours)



Naturally, this option can be modified by the use of active bed including activated gaseous atmosphere. With the use of this technology can be carried out thermo-chemical treatment such as carburising, nitrocarburising, carbonitriding, aluminising and boriding. Application of active beds has become possible through the development of powders with the desired properties, particularly suitable composition, grain size, flowability and especially resistance to sintering at high temperatures (temperatures corresponding to thermo-chemical treatment for particular powder). Sample images of powders for processing in the chemically active fluidised bed are shown in Figures 3–5.

Figure 3 View of the powder mixture for the boronising in the chemically active bed

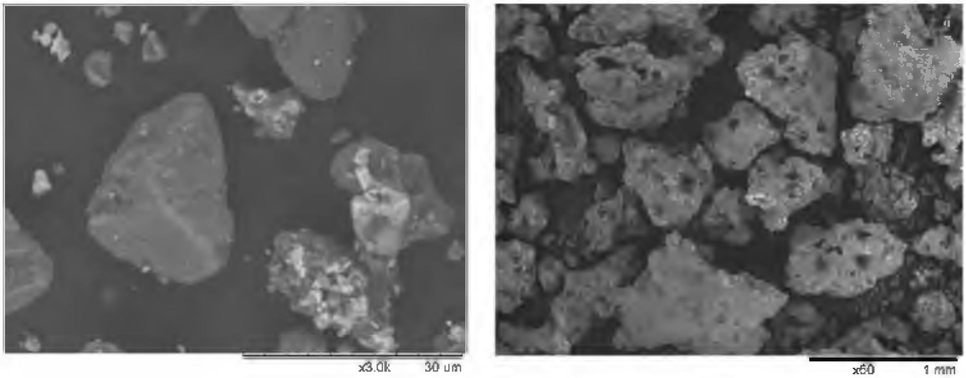


Figure 4 View of the powder mixture for the carbonitriding and nitrocarburising in the chemically active bed

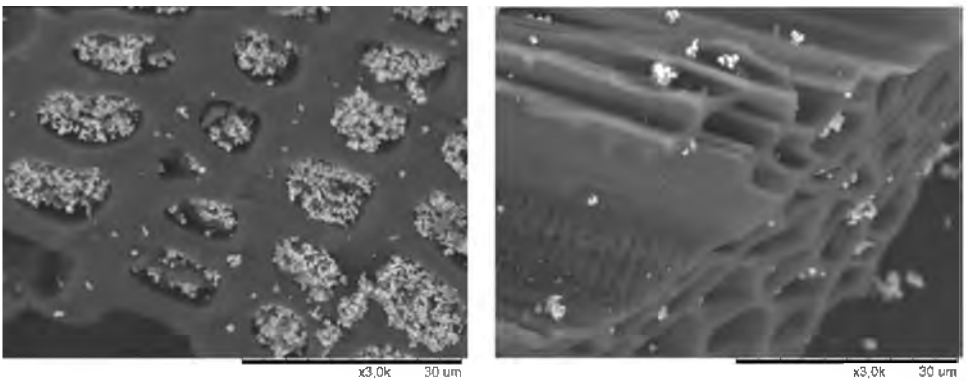
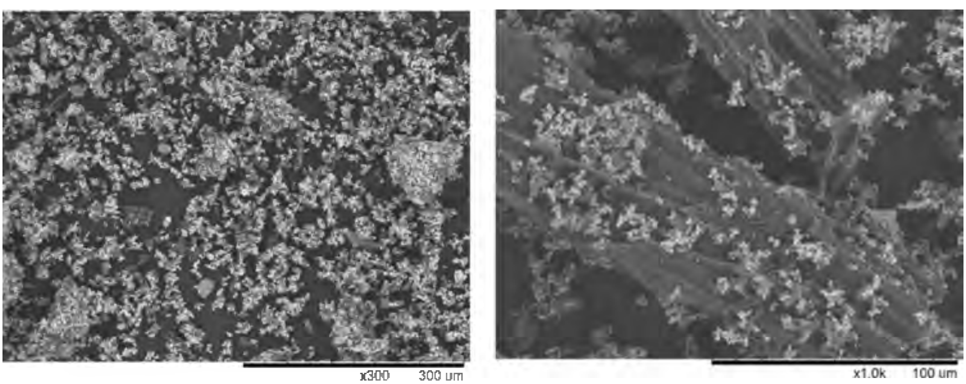


Figure 5 View of the powder mixture for the carburising in the chemically active bed



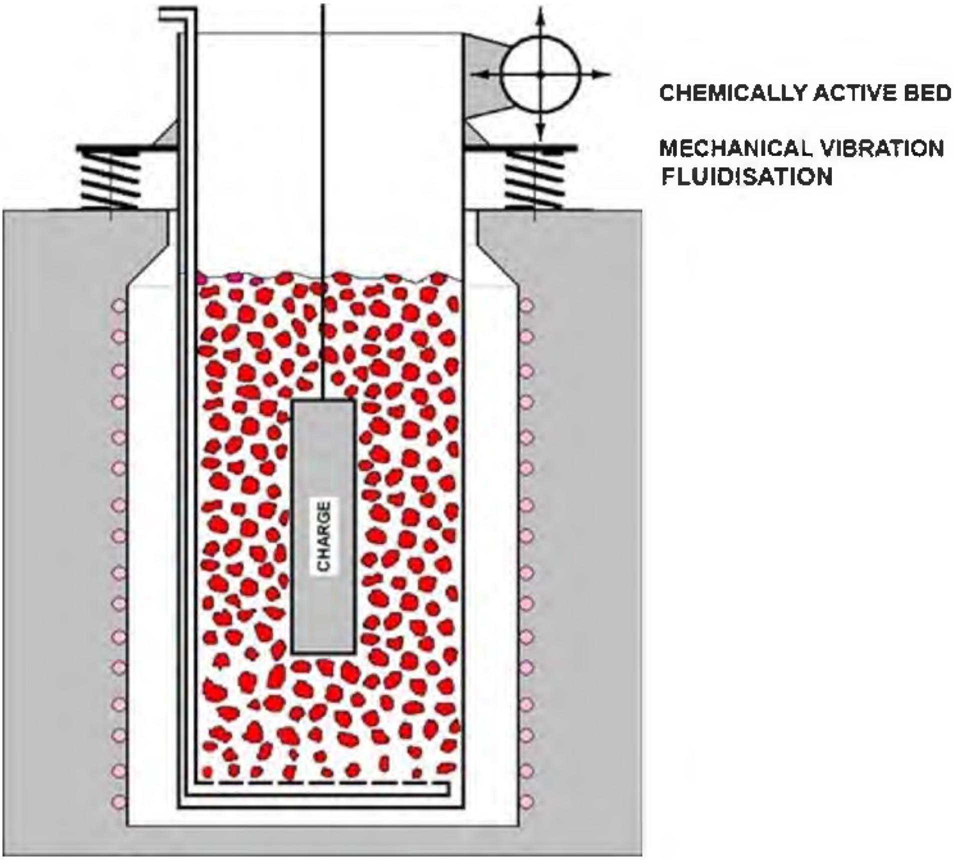
4 Vibrotermofluid® and Termoactivfluid® technology

In the second of the proposed solutions, bed is fluidised by forced vibration resulted from mechanical vibrations, which are subjected to retort and charge (Figure 6). Fluidised by vibrations bed has similar characteristics to bed fluidised by gas. Similar to gas, vibrations make that bed:

- moves in a retort and is heated uniformly
- has direct contact with the entire surface of the workpiece irrespective of its shape.

At the same time, vibrating powder mixture grains change their contact surface relative to the treated surface to provide surface exposure with high content of diffusion and activator element.

Figure 6 Schematic of the new generation fluid bed furnace with mechanical vibrations (red – chemically active bed) (see online version for colours)



Another solution combines the concept shown in Figures 2 and 6. In the proposed and applied solution, an active bed, active gas and vibrations are used to achieve fluidisation (Figure 7). The use of gas and vibrations for the bed movement in the retort can be performed independently based on the needs of the technological process and at every stage.

Because of the innovative nature of the work, the results were published in a limited way because of the need to preserve confidentiality.

Figure 7 Schematic of the new generation fluidised by mechanical vibrations bed furnace (red – chemically active bed, yellow – chemically inert gas) (see online version for colours)

5 Industrial research

Research conducted to study the use of powder mixtures for diffusion treatments has been performed on adopted fluidised bed furnace FP700 equipped with retorts (gas suppliers and distributors) for each powder mixture. Powder mixtures were fluidised by gas or mechanical vibrations in the various kinds of temperature diffusion treatments in the range from 580°C to 960°C and the process time from 1 h to 4 h.

A number of researches on tools and machine parts using combined TermoActivFluid® and VibroTermoFluid® technologies have been carried out. Some of the results of the tools and machine parts subjected to boronising and nitrocarburising are given.

Boronising at a temperature of 960°C for 8 h was conducted on inserts for closed cells and gaps for pressure forms (Figure 8). As a result of boronising of inserts, a diffusion layer formed during the process apart from the increased hardness and surface wear resistance is characterised by a high corrosion and oxidation resistance.

Comparative performance tests of inserts for closed cells and gaps for pressure forms made of C22 steel subjected to carburising and boronising, conducted during production of ceramic bricks, have shown approximately five times higher durability of boronised inserts than inserts subjected to carburising only. Comparative studies of holes sections have shown approximately four times higher durability of boronised parts.

Figure 9 shows the regulation shims for the combine-harvester made of C22 steel and subjected to boronising at a temperature of 950°C for 6 h. Comparative studies have shown approximately four times higher durability for boronised shims in comparison with shims subjected to carburising only.

Studies of the nitrocarburising process with the use of active fluidised bed were carried out on moulds parts for both plastic processing and die-casting of aluminium alloys. For those parts, nitrocarburising technology was conducted at temperature of 550°C for 8 h. Created diffusion layer significantly increased wear resistance and prevented from sticking of plastic or aluminium to mould surface, which greatly affected on the cost of burdensome cleaning and surface quality of products. Use of this technology results in increased wear resistance of forms for 2÷3 times in comparison with conventional thermo-chemical treatment.

Figure 8 Inserts for pressure forms subjected to boronising, made of C22 steel, designed for the production of ceramic bricks (see online version for colours)

Figure 9 Shims for combine-harvester made of C22 steel, subjected to boronising at a temperature of 950°C for 6 hours

Figure 10 shows a view of a set of moulds for plastic processing made of X37CrMoV51 steel subjected to hardening, tempering and nitrocarburising according to previously mentioned parameters. Tested set was applied in the factory of one of the producers of household appliances. Studies have shown two times higher durability of mould. At the same time, the phenomenon of hot plastic sticking to mould surface was eliminated.

Figure 10 View of a set of moulds for plastic processing made of X37CrMoV51 steel subjected to hardening, tempering and nitrocarburising (see online version for colours)

Figure 11 shows a view of the moulds bushings for pressure die casting of aluminium alloys, made of X37CrMoV51 steel, subjected to hardening, tempering and nitrocarburising according to previously mentioned parameters. Performance studies have shown increased durability of moulds for 2÷3 times compared with moulds subjected to hardening and tempering only.

Figure 11 View of the moulds bushings for pressure die casting of aluminium alloys made of X37CrMoV51 steel subjected to hardening, tempering and nitrocarburising (see online version for colours)

6 Conclusion

Research has shown that the use of VibroTermoFluid® technology results in significant gas saving compared with the both TermoFluid and TermoActivFluid® technology. Gas consumption can be reduced up to 80–90% depending on the process point at which gas will be delivered into the retort. At the same time, these technologies, especially VibroTermoFluid®, are eliminating the phenomena of dust elevation, typical for conventional fluidised bed processing. Performed metallographic and wear studies on obtained layers using VibroTermoFluid® and TermoActivFluid® technologies for different types of powders have shown significantly better results compared with conventional technologies of thermo-chemical treatment carried out in gases or powders (Babul et al., 2008; Kucharieva et al., 2011; Kuchariev et al., 1999; Babul and Obuchowicz, 2011).

The use of boronising and nitrocarburising technologies in fluidised bed on selected parts of machines and tools resulted in increased hardness and surface wear resistance and improved corrosion and oxidation resistance. Forming of boronised layers on treated parts increased their durability up to five times in comparison with elements subjected to carburising only. The use of nitrocarburising technology increased tools durability up to three times, in comparison with tools subjected to conventional heat treatment.

References

Babul, T. and Obuchowicz, Z. (2011) *Badania Dyfuzyjnych Procesów Cieplno-Chemicznych w Celu Opracowania Technologii Umożliwiających Podwyższenie Trwałości Eksploatacyjnej Narzędzi Skrawających i Kuźniczych*, Technical Report on the Realization of an International Project with the Belarusian National Technical University, IMP.

Babul, T., Obuchowicz, Z. and Grzelecki, W. (2008) 'The possibilities of applying fluidized bed heat treatment for small and middle-sized enterprises', *Surface Engineering*, Vol. 2, pp.32–37.

Kuchariev, B.S., Vaščev, S.E., Surkov, V.V. and Kucharieva, N.G. (1999) *Polučenie iissledovaniesvoistwodnofaznychdiffuzionnychpokrytij*, Beloruskaja Gosudarstvennaja Politechničeskaja Akademija, Minsk, s.8.

Kucharieva, N.G., Babul, T., Obuchowicz, Z. and Nakonieczny, A. (2011) Patent Application No. P-394532 from 12.04 2011.