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USING the WAVELET TRANSFORM for MECHANICAL ACTIVATION and THERMAL EXPLOSION of Ti – Ni MIXTURE

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Abstract

The experimental study of Ti and Ni powder mixture subjected to mechanical activation (MA), followed by the self-propagating high -temperature synthesis (SHS) in the mode of thermal explosion with the formation of a synthesized product.

This system is investigated as a self-consistent system. The formation of agglomerates during MA, the temperature characteristics of thermal explosion, and the composition of the synthesized product are studied. The MA times for obtaining the main events in the system, the optimal MA times for obtaining the compositions of a certain phase, and the corrected limiting values for the operation of the system are found. The inheritance of the behavior of each subsystem is revealed in the further steps to obtain a synthesized product.

Introduction

A holistic, system approach is used for processing experimental data, constructing histograms with the concept of self-consistency of all processes and the factors that form a single nonlinear system. **The system "Ti - Ni mechanically activated powders - explosion wave - synthesized product" is considered to be a single self-consistent system. Three subsystems are connected by one goal: the initiation of an explosion wave accompanied by the formation of Ti - Ni alloys, compounds, solid solutions.**

The main goal of any synthesis is to obtain a desired product with the necessary properties. For this, it is necessary to study the behavior of the system at the stages preceding the synthesis. A study with a holistic, synergistic approach can give a new insight and be useful. Synergetics associated with the search for common mechanisms of self-organization, including physical and chemical systems, is one of the leading areas of studies.

All processes existing in this system obey to two main opposite processes, namely, relaxation and tension processes. They always act together, helping the system achieve its goal.

EXPERIMENTAL

The Ti and Ni powder mixture with a stoichiometric composition of TiNi was subjected to MA under the following conditions:

initial Ti powder (PTM1 grade), Ni (PNE1 grade),

a planetary mill M-3 of 45 g acceleration,

MA medium – argon, and the use of a lining.

The MA time was limited by the formation of mechanosynthesized phases and controlled by X-ray phase analysis.

The ball-to-powder mass ratio in all experiments was 5:1.

The weight of powders was 80 g.

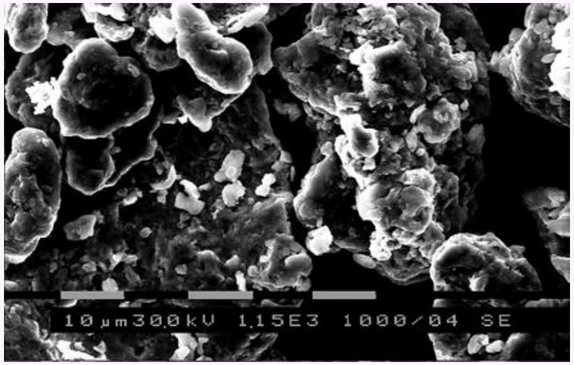
The diameter of the balls was 5 mm.

After MA, the SHS was performed in the thermal explosion mode in a constant-volume calorimeter (5 L) in the argon medium. Temperatures were measured in the center of the sample with a chromel-alumel thermocouple to determine the characteristic thermal explosion temperatures (the critical and maximum explosion).

The structure and composition of the powder mixtures were studied by scanning electron microscopy (Philips SEM515), optical metallography (Axiovert200M), and X-ray diffraction (Dron-Um).

RESULTS

During MA the initial particles are ground and agglomerated particles are simultaneously formed. The shape and amount of such particles continuously change during MA.



The powder mixture after 2 min MA. Particles adhered and grouped to each other. Such groups of deformed particles formed agglomerates.

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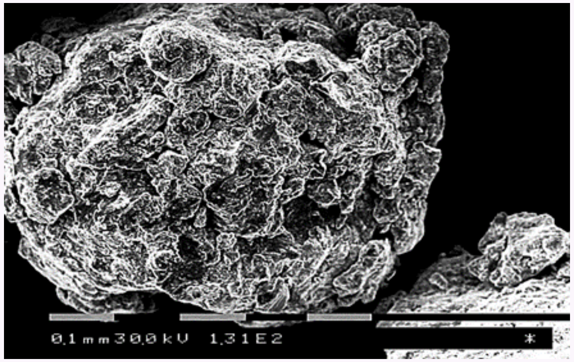
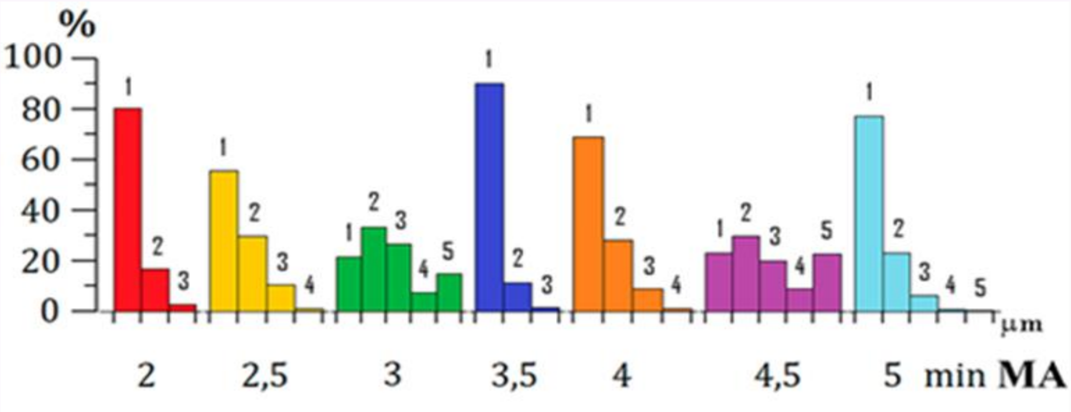


The powder mixtures after 4 min MA. The general trends in the development of agglomerates can be traced. Consolidation and compaction of agglomerates occurs with an increase in the MA time.

RESULTS

The frequency histogram of the fraction sizes after grinding in a planetary mill.



There are the experimental data from 2 to 5 min MA.

Periodic peaks of the fragile fraction and changes in the values of the remaining fractions are seen. 5 min MA is not a limit value. In our case, the maximum value is 7 min. This limit value was found earlier using data cloud analysis and graphical construction of phase portraits [1,2].

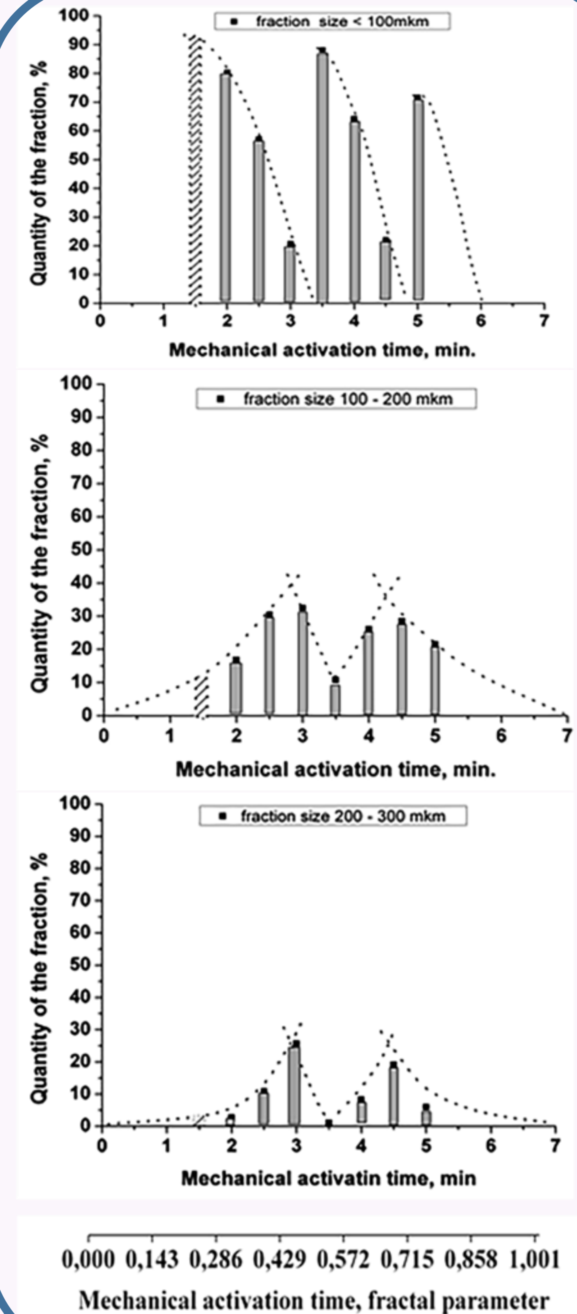
This histogram is divided into self-similar zones. Each zone is similar to the previous one; differences in size and scale. It was found that the role of resonance effects (peaks) was played by the amount of the most fragile fraction in this self-similar histogram. Here a whole fractal spectrum is observed, i.e. a picture in a picture.

The size of the most fragile fraction varies periodically and has a sharp increase in the range from 20 to 80% of the total amount. A sharp increase to 80% at certain MA times and a smooth decrease to 20% are observed. The dashes show the continuous distribution curves that are part of the Boltzmann distribution curve. The singular points are the points at 3.5 $\pm$ 0.25 min MA, 5 $\pm$ 0.25 min MA, 7 $\pm$ 0.25 min MA, 1.5 $\pm$ 0.25 min MA. The areas of these points contain the minimum or maximum values.

RESULTS

The separation of data for other fractions of the powder mixture after different MA. The reverse course of the continuous curve affected the character of the graph. The curves go in the opposite direction. This is the fragile fraction. The smaller the amount of fragile fine fraction is, the higher the value of the large fraction, since the volume is single.

Therefore, the curves for the fractions of 100-200 and 200-300 microns have a slope in the other direction. The presence of a fragile fraction is manifested; it is still present, although in a smaller amount, therefore, a weak curve has a slope to the right, as in histograms with a fraction of less than 100 microns.



Histograms of the fraction distribution after different MA times.

Less than 100 μm , 100-200 μm and 200-300 μm

RESULTS

The fractal parameter was used to obtain the corrected MA times in minutes in which the main events take place, i.e. extreme values are observed. For example, at this point the amount of fragile phase will be either maximum or minimum.

Experimentally set values, MA time, minutes	*Corrected values of singular points of events on the MA time scale, minutes.*
1,5	1,675
2,0	2,09
2,5	2,51
3,0	2,92
3,5	3,35
4	4,19
4,5	4,61
5	5,03
7	6,7

Experimentally and corrected values of singular points of events

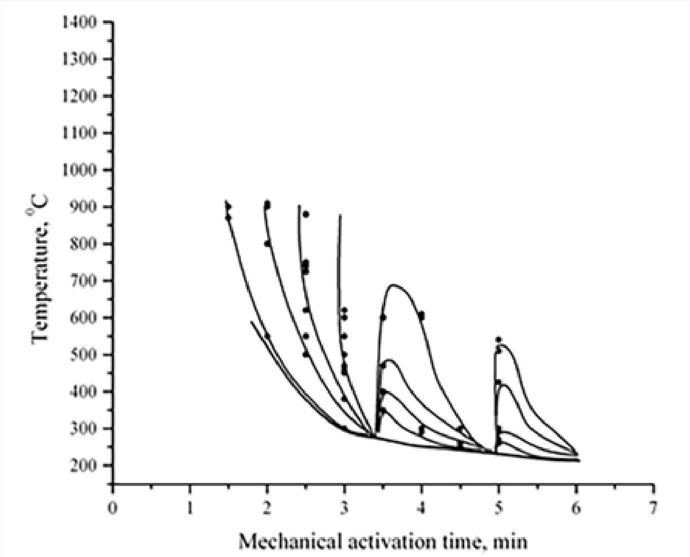


Figure shows the “wavelet histogram” consisting of three zones separated by sharp “peaks” in the “temperature - MA time” coordinates. These values for the critical temperature were obtained by varying other parameters, such as the size of the initial powder, various heating rates, etc. Each zone has 5 trajectories directed towards one attractor. The number of trajectories was determined by three heating rates and two sizes of the initial nickel powder.

RESULTS

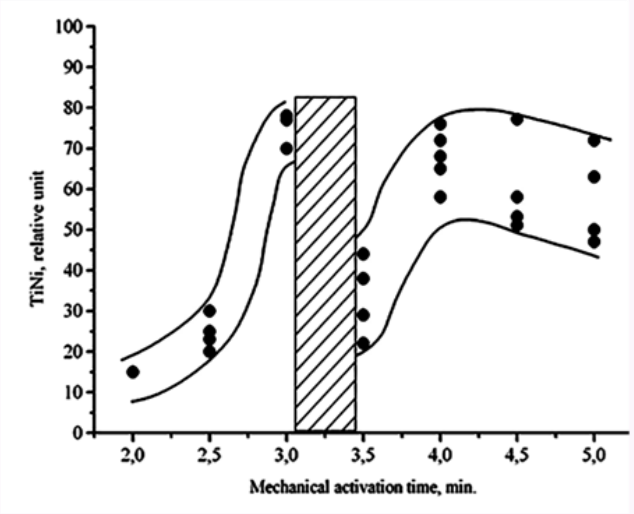


Figure shows the content of the TiNi phase in the product synthesized in the thermal explosion mode at different preliminary MA times.

In the interval from 3 to 3.5 min MA, there is a sharp inflection in the amount of the phase, which also indicates the existence of a singular point in this area.

CONCLUSION

The behavior of the nonlinear system "Mechanical activation - thermal explosion - product synthesis" obeys synergistic laws.

The inheritance of the behavior of each subsystem was revealed in the further steps to obtain a synthesized product.

The mechanical activation times required for obtaining the main events in the system were found, and the limiting values of system operation were corrected.

The mechanical activation times optimal for obtaining the compositions of a certain phase were revealed.

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