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The Influence of Deformation Process at Titan Aluminides Retrieving by SHS-compaction Technologies

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The researches of deformation process at titan aluminides receiving by SHS-compacting are carry out. The dependences of compacting pressure on ingot's geometrical sizes and density are established for various types of titan aluminides. The kinetics force parameters at pressing process are modeled and experimentally confirmed. Also the researches on determination of different ingots zones compacting at pressing are executed. It is established that central zone of ingots are compacted with more degree in comparison with border zone. The radial pressure changing on pressure equipment at SHS-compacting is analyzed. The non-isostatic deformation coefficient at pressing of titan aluminides batched ingots was founded.

It is determined that SHS-compacting depends not only on energy-force parameters but also on temperature, phase structure, synthesized product aggregative state. So the model of force SHS-compacting depends on many factors and its researching can directly solve the question of heat-resistant materials retrieving on Ti-Al base.

Keywords: SHS, COMPACTING, INTERMETALLIC COMPOUNDS

Introduction

The effectiveness of critical parts in aerospace engines increases with operational temperature increasing. The higher temperature level reaches by the way of new heat-resistance materials creation. These materials must work at higher temperature then nickel and titan superalloys. It has less weight than tungsten metals and more heat-resistant then usual chrome alloys [1, 2].

The materials without previously marked lacks are intermetallic compounds on Ti-Al base. Up to date the self-propagation high-temperature synthesis (SHS) is one of the most progressive methods for intermetallic compounds retrieving. It is determined by technology equipment simplicity, process efficiency, acceptable process time [3, 4].

Experimental procedure

For experimental procedure the aluminum and titan powders were used. Its dispersion was varied in the range 100-180 mcm with the purpose of researching of influence on gained structure [5].

The basic facility diagram for titan aluminides SHS-compacting is shown on **Figure 1**. For compaction at SHS-compacting was used hydraulic press with maximum force 1.22 MN.

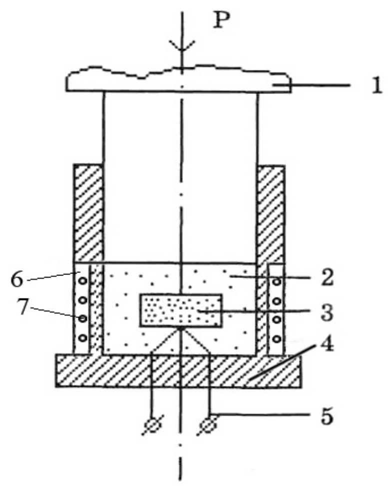

Figure 1. Basic facility diagram for titan aluminides SHS – compacting: 1 – punch; 2 – heat insulator; 3 – burden ingot; 4 – press-form; 5 – initial device; 6 - heat insulator; 7 – heating element

The experimental compacting process consists of several stages. The first one is initial, where pow der components are formed into porous charged ingot. It has known sizes such as height (h_{ch}), radius (R_{ch}), absolute (d_{ch}) and relative (ρ_{ch}) density.

The ingots size and rated values of initial and relative density of charge ingots and synthesized products are given in **Table 1**.

During the second stage the charged ingot is placed into reaction press-form with heat insulator. The charged ingot burning is initialized by electric current passing through heating coil. The non-isochoric heating by moving burning front is the reason of nonuniform cooling time of different parts. Accordingly up to pressing time in SHS products the nonuniform fields of temperatures T_c and rheological dependences are formed. The used schematization of thermal mode allows homogeneous distribution of properties in all volume. That is why we need to consider average time-temperature characteristics which relate to central part of ingots. The cooling time of this zone t accepts equal to cooling time of central zone of round plate with radius R_1=10 mm.

$$t = \frac{R_1}{U_b} + \mathrm{t_d}, \qquad \text{(Eq. 1)}$$

where, t_d is pressing delay time which equals to time of press actuation. For hydraulic presses this time is 0.5 sec. The burning speed was found experimentally [6].

Results and discussion

The calculated results of activation height h_1, relative density r_1 and experimental data of synthesized products average width from average compacting pressure p_k are shown on **Figure 2**. The average compacting pressure equals to compaction force divided on die area (die diameter amounts to 35 mm, initial height of deformed value h is 10 mm). The SHS products compaction occurs owing to axial deformation. Thus the ingots axes compression reaches up to 45 % and radial deformation doesn't exceed to 5 % (**Figure 2b**). It is need to mark that alumina content influence on material rheological properties. On the one hand, alumina content increasing causes the burning and compacting temperature decreasing with pressure resistance increasing. And on another hand, with alumina content increasing the liquid phase value increases too and effective viscosity of solid phase decreases. It leads to material viscosity decreasing and to increasing its density. As a result there is no depending on alumina at material compacting and full compaction happens at constant pressure (p_k = 750 MPa). There are four typical pieces on curve of sizes and density changing (**Figure 2**). On first piece the material size and density changing happens by linear low and depends on pressure value. Next, the size and density changing stops jumpy with horizontal part formation. After horizontal part there is piece of non-linear compacting which leads to nonporous aggregation.

The initial mechanism of compaction and size changing are only determined by rheological properties of shell-mold material. After compaction to packed density and formation of simple stable structure the second stage of compacting comes. At this stage there is the consecutive impact of solid phase particles. On compaction curve the second stage begins from shock-free flow area with active phase w increasing by law:

$$\omega = \rho^2 \frac{\rho - \rho_0}{1 - \rho_0}, \qquad \text{(Eq. 2)}$$

where ρ_0 is packed density of powder material. For quantitative rating investigation of solid-liquid macrostructure the effective density of solid phase (ρ_s) was used. Depending on rs the SHS-products at compacting can be at several states:

a) aero-dispersed equilibrium;

b) spatial solid porous structure;

c) non-porous structure.

The information about compaction laws of shell and force parameters results on **Figures 3** and **4**. They have a great importance for process engineering and optimization.

The compacting curves of shell material at central part and ring peripheral part at alloy compaction are represented on **Figure 3**. During compaction stages the material laying in peripheral part is consolidated more than in central part. That's why the more part of press power and tonnage goes to peripheral part consolidation. The calculation results of bulk material kinetic parameters at compacting confirm this regularity. These parameters calculated by following relation:

$$\mathrm{Q} = \int_{S_2} |\sigma_{Z2}| dS + \int_{S_3} |\sigma_{Z3}| dS + \int_{S_2} f_{fr} |\sigma_r| dS = Q_2 + Q_3 + Q_{fr} \qquad \text{(Eq. 3)}$$

Table 1. The density and size of charge ingots and synthesized products

Al content, % w.	h_{ch}, mm	R_{ch} , mm	d_{ch}, gr per cm^3	ρ_{ch}	d_{SHS}, gr per cm^3
15,8	10	10	3,24	0,8	4,216
36,03	11	10	2,75	0,8	3,63
62,81	12	10	2,66	0,8	3,37

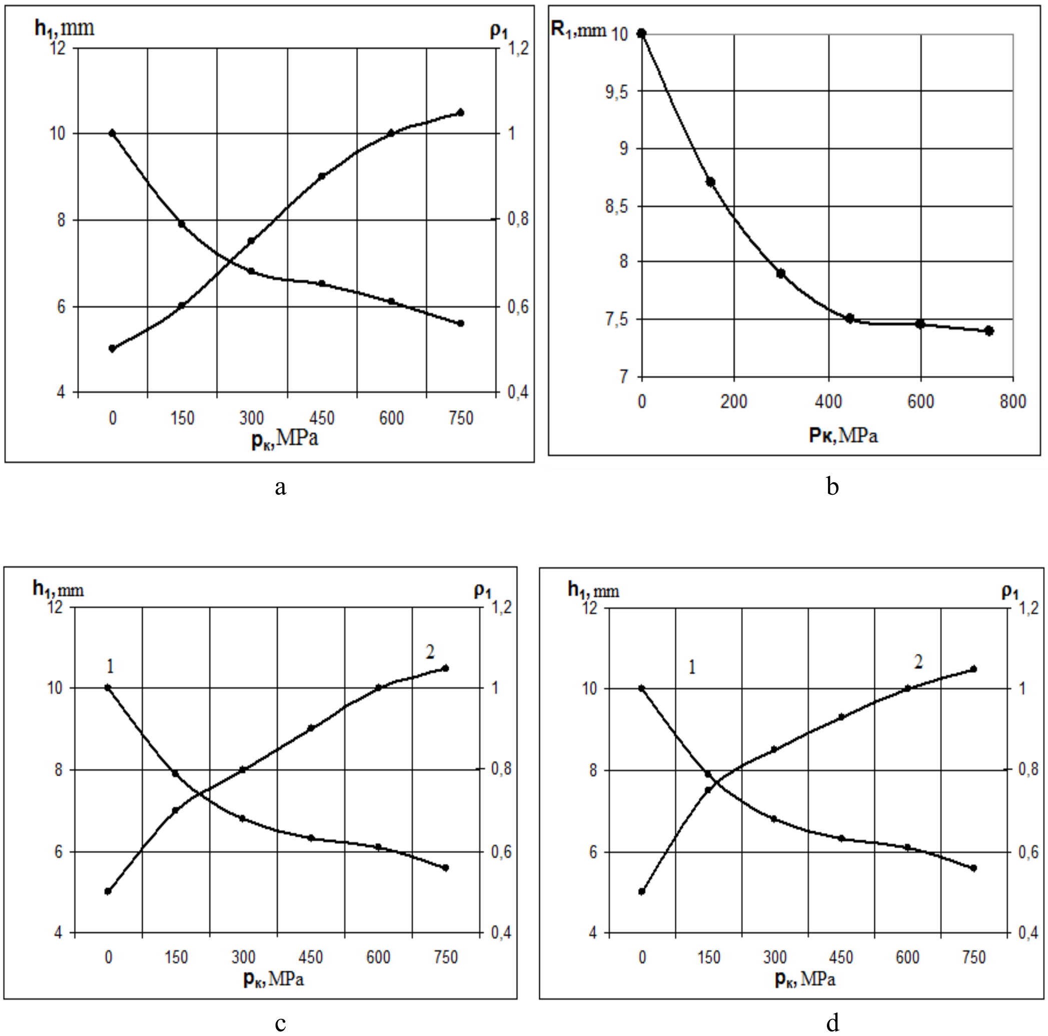

Figure 2. The dependences of size and density from compaction force for Ti-Al intermetallides: *a*, *b* – Ti_3Al; *c* – TiAl: *d* – $TiAl_3$

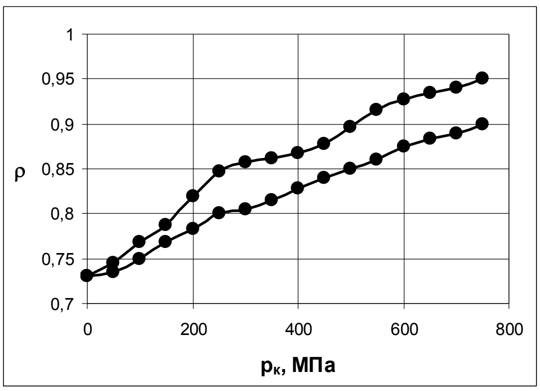

Figure 3. Shell parts consolidation: 1 – ring peripheral part; 2 – central part

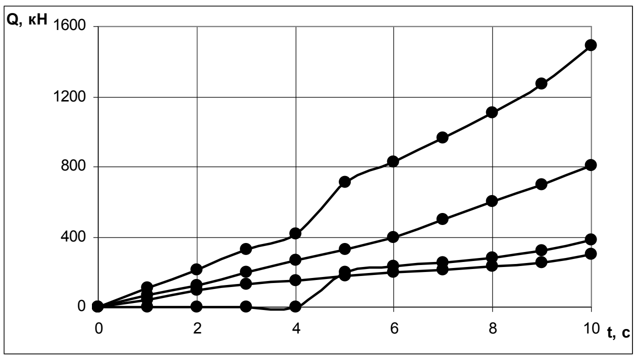

Figure 4. The force parameters kinetic of compaction process: 1 – Q; 2 – Q_2; 3 – Q_3; 4 – Q_{fr}

While SHS-products belong to aero-dispersed state the axial pressure from press-form on punch is absent. It appears at SHS-products consolidation up to packed density. From this moment the effort Q_2 increases at first with higher and later with slower speed. The effort Q_3 increasing monotone from the compaction beginning with higher value then Q_2 during all compaction zone. The force of external friction Q_{fr} also influences on total forces balance. Corresponding to calculation Q_{fr} amounts to 18-20% from total forces balance.

Conclusion

In given work the researches about deformation and compaction of synthesized products in Ti-Al system at SHS-compacting were done. Experimentally the dependences of geometrical size factors which yielded to compression from Ti_3Al, TiAl, $TiAl_3$ alloys from compacting force were adjusted. So, getting analyzed given dependences it is possible to come to conclusion that proposed technology gives possibilities to receive ingots from heat-resistance alloys with set operational characteristics with necessary geometrical parameters.

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Влияние процесса деформации на восстановление алюминидов титана при помощи технологии SHS-прессования

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Проведены исследования процессов деформации в алюминидах титана, полученных в результате уплотнений от самораспространяющегося высокотемпературного синтеза. Проведено моделирование зависимостей сжимающих напряжений от геометрических размеров слитка и его плотности для различных алюминидов титана. Промоделированы и экспериментально подтверждены кинематические параметры процесса прессования. Также проведены исследования по определению различных зон уплотнения слитка при прессовании. Установлено, что центральная зона слитка уплотняется в большей степени по сравнению с наружными зонами. Проанализировано изменение радиального давления на прессовое оборудование от уплотнений от самораспространяющегося высокотемпературного синтеза. Был найден неизостатический коэффициент деформации при прессовании партии слитков алюминидов титана.

Установлено, что уплотнение от самораспространяющегося высокотемпературного синтеза зависит не только от энергосиловых параметров, но и от температуры, фазовой структуры, агрегатного состояния синтезированного продукта. Таким образом, модель силы уплотнения при самораспространяющемся высокотемпературном синтезе зависит от многих факторов и ее исследование может напрямую решить вопрос создания термостойких материалов на основе титан-алюминия.