Electrodes for contact electric welding of aluminium alloys

M.P. Bondar. Lavrentyev Institute of Hydrodynamics, Russian Academy of Sciences, Novosibirsk, Russia.

J.G. Moon. Korea Institute of Machinery and Materials, Taejon, Korea.

Aluminium and aluminium alloys have the high electrical and heat conductivity. It gives rise to difficulties for a choice of electrodes material for their contact electric welding.

This paper describes the investigations performed to solve the above problem. The purpose of this investigation was to obtain dispersion-hardening alloys by the internal oxidation method, to optimize their contents and treatment modes, to produce electrodes of these alloys and to test them.

The strengthing effect of alloys with oxide particles depends on their size stability at high temperatures. Despite of the fact, that oxides are the most stable of all the non-metallic phases their coagulation takes place.

Based on the early results, we chose two types of alloys, first No. 1 Cu - 0,4%Al and second No. 2 Cu - 0,2%Be for production of electrodes. These alloys had not additional alloying elements. These alloys were prepared as 1 mm plates and flake-formed 200 m thick, and also No. 1 as a powder of size 100 mkm (received from Korea).

The large samples for electrodes were produced by three methods : explosive welding method, dynamic one including the explosion compression of electrode blank and the quasi-dynamic method including the high-speed compression of dense briquest and the further hot extrusion of a rod.

1. Explosive welding

The electrode blank was obtained by the explosive welding method (USSR patent N 669570 of February 28, 1979)
- Fig. 1.

The explosive welding of internally oxidized plates was realized for the asymmetric scheme on Fig. 2. Plates having an area of size 200.60 mm were welded on copper basis. The explosive welding parameters (Vo is the throwing velocity, Vk is the contact point velocity, and ... is the collision angle) were chosen for a maximum strengh of welded plates, which should be equal to, or more than, 340-360 MPa. From the above reasoning the optimal parameter values were found such as: Vo = 450 -500m/s, Vk =1700 - 2000m/s, = 12- 14 .

Composite electrodes were made of the blank, copper being the basis of them and a working part was presented as the packet of tightly connected plates of internally oxidized alloys No. 1 or No. 2 - Fig. 3.

Electrodes can be produced both by bench working and by forging. The packet microstructure and microhardness variation for its section are presented on Fig. 4.

The characteristic periodicity of hardness changes (Fig. 4) determines the high resistance to a propagation of fatigue cracks, and their development is braked in "soft" parts of the packet.

In the present investigation for packets being the working electrode part, along with previously used plates of the Cu-AlO alloy, the plates of the Cu-BeO alloy were first used.

2. Dynamic method

The explosive compression was realized according to the axisymmetric loading scheme (Fig. 5, so see Fig.4, 7, 8 of Appendix of Part 2) (USSR patent N1098149 of February 15, 1984)

The rod quality, on compression by the given schemes, depends on a lot of factors : the non-homogeneous porosity on the rod section, at other times complicated by the presence of the Mach-channel in the center, and by a gas capture under compression. The last factor determines the "non-weldability" of the fraction even at the further extrusion. All the above defects can be elimineted by complicating the technology, in particular, the gas cleaning up can be performed under vacuum and pressure on heating.

Microstructure and mechanical properties of the obtained rods were investigated. The shape of the initial fraction and the rod production method specified their structure. On explosive compression the fraction particles deformation is observed, which is expressed as the localized shear bands (Fig. 6a). The structure fragmentation of a fraction in annealing at 800 C (Fig. 6b) is caused by shear bands.

The explosive compression of internally oxidized fraction of the Cu-0.2%Be alloy didn't provide a considerable strengthening, an average microhardness varied from 130 to 150 MPa. The tension strength equals 30 MPa. The tension strength after an agglomeration at 800 C increased to 150 MPa, for compact density measuring 99.95% of the theoretical one.

The presented results suggest that the explosive compaction method by the given scheme can be unusable to obtain a high-strength material. This method can be used to obtain a dense briquet for futher extrusion.

3. Quasi-dynamic method

The method involves the following operations: 1. A briquet is pressed from fraction or powder weighing as much as 500g, at room temprature, at a pressure of 500 Mpa the residual porosity is from 1 to 15%. 2. Dense briquets are heated in an electrovacuum furnace to 950 C and held for about 1 hour, then the hot briquts are tightened at 1500 MPa, and the residual porosity is no more than 1%.

3. Dense briquets, previosly heated to 1000 C in an inductor, are extruded as rods. The extrusion coefficient varies in the range from 11 to 16.

The operations performed in the air with and without heating will not cause the hydrogen embrittlement of finished rod. To avoid embrittlement of the fraction, a quantity of oxygen inserted into the alloy, on oxidising, is calculated in such a way, as to remain a non-oxidized part of the oxide-forming element before a briquet production. When compressed, oxygen reaching the briquet is absorbed by the non-oxided part of the oxide-forming element.

Flakes of the alloys Cu-0.4%Al, Cu-0.2%Al and Cu-0.2%Be are compressed by the quasi-dynamic method. The fibrous nature of the structure in the extrusion direction (Fig. 6b) is determined by the rod production method.

The mechanical properties of samples are determined by the tension test at room temperature and at 450 C. The results are given in Table 1.

Table 1. Mechanial Properties of Specimens produced by Quasi-Dynamic Method

alloy	T = 20 ℃			T = 450 ℃	T = 800 ℃
	σ_t (MPa)	Hv(MPa)	HRB	σ_t (MPa)	HRB
Cu - 0,2%Al	310	110		185	
Cu - 0,4%Al	340	130	70	180	70
Cu - 0,2%Be	400	155	75	190	70

The rod samples are annealed in the temperature range from 200 to 1000C. The sample microhardness values depending on the annealing (performed for 2 hours) temperature are presented on Fig. 7(Fig.7 gives the volumetric contents of an oxide phase in alloys corresponding to weight values of oxide-forming elements: 1.8 vol%BeO - 0.2%Be; 1.9vol%Al O - 0.4%Al and 1vol%Al O - 0.2%Al).

The results of Hv variations are presented versus the 叔?material conventionally used for electrodes of the contact electric welding. As indicated in Fig. 7, the drastic changes of microhardness values of internally oxidized samples occur on annealing at the higher temperature than 1000 C, but for 叔?this happens at 420 C.

The given results reveals the structure stability of internally oxidized alloys at the working temperature of electrodes and, hence, the prospects for their use. also turned from rods made by the quasi-dinamic method.

3.3. The preliminary results of testing electrodes.

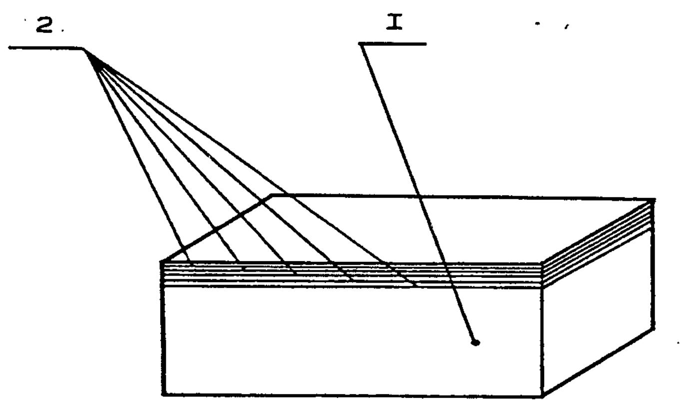
The electrodes were made of internally oxidized Cu-0.2%Be and Cu-0.4%Al alloys by the explosive welding and quasi-dynamic methods. A blank (Fig. ...) was produced by explosive welding, and electrodes were machined from the blank. Also, electrodes were machined from rods made by the quasi-dynamic method.

Prior tests were performed when welding aluminium alloy plates 1.2 mm in thickness and 1 mm thick mild steel plates. (?) The prior tests revealed that electrodes made of internally oxidized alloys surpasse, in wear-resistance than electrodes made of conventionally used copper. It was shown that the number of points welded between cleaning of electrodes are determined by darkening a print on welded plates, is 10 times more for electrodes made of the Cu-0.4%Al alloy, and 70 times more for electrodes made of the Cu-0.2%Be alloy as compared with electrodes made of BrX and the Cu-Kd alloy common-applied for welding aluminium alloys.

It has been found that the wear-resistance of electrodes made of the above alloys in welding a mild steel shows better resistance of BCr electrodes by 3 - 4 times.

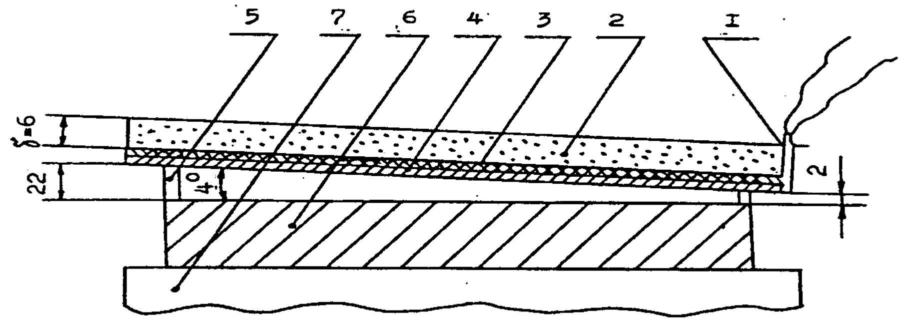
Electrodes made of Cu-2vol%BeO have the most resistance of all the investigated internally oxidized alloys. The analysis results of the structure and physicomechanical properties have showed, that the advantages of these alloys are determined by the high dispersity grade of the strengthing phase particles, providing its high strength characteristics compared with other alloys for an equivalent volumetric contents of the oxide phase. Besides, BeO has high values of heat and electric conductivity as compared with other oxides (heat and electric conductivity of berillium oxides is one order larger than these values for alumina ( )). This provides the resistance decrease at the electrode-welded metal boundary. As shown above, berillium does not interact chemically with aluminium. With decreases a carring away (?)of a welded material to the electrode made of the Cu-0.2%Be alloy as compared with that of the Cu-0.4%Al alloy.

On the basis of the above knowledge, the internally oxidized alloy Cu-0.2%Be can be recommended for welding aluminium alloys.



1. - **Base;**
2. - **Internally oxidized plates, sequently welded with explosion;**

Fig .1. The blank for electrode production



1. **Electrodetonator;**
2. **BB chrage;**
3. **Inertial padding;**
4. **Throwed plate;**
5. **Support;**
6. **Base;**
7. **Stage of explosion chamera.**

Fig .2.The explosive welding scheme

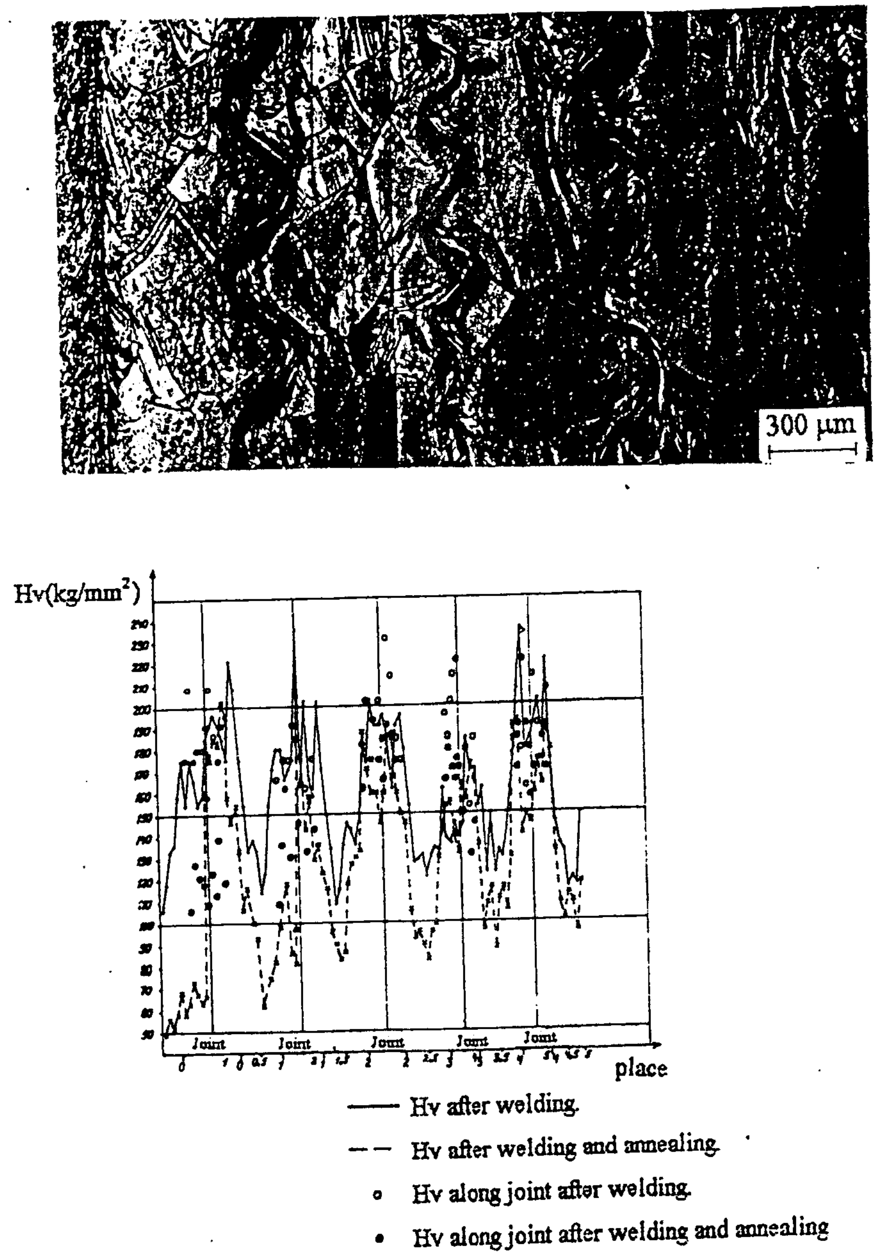


Fig .4. The variation of packet microstructure and microhardness

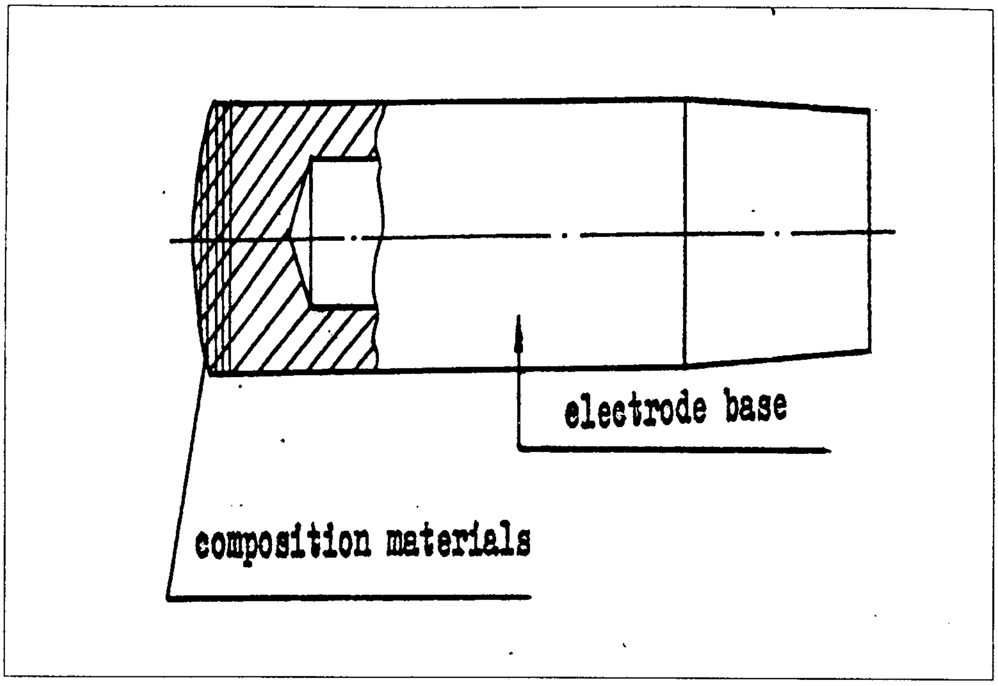


Fig .3. Electrode construction produced by explosive welding.

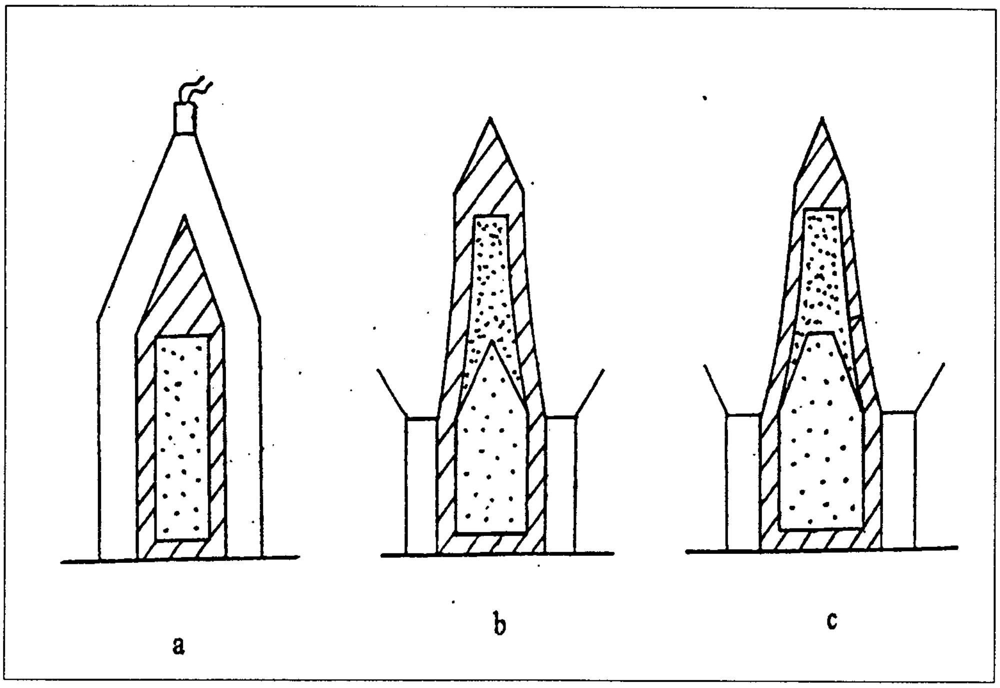
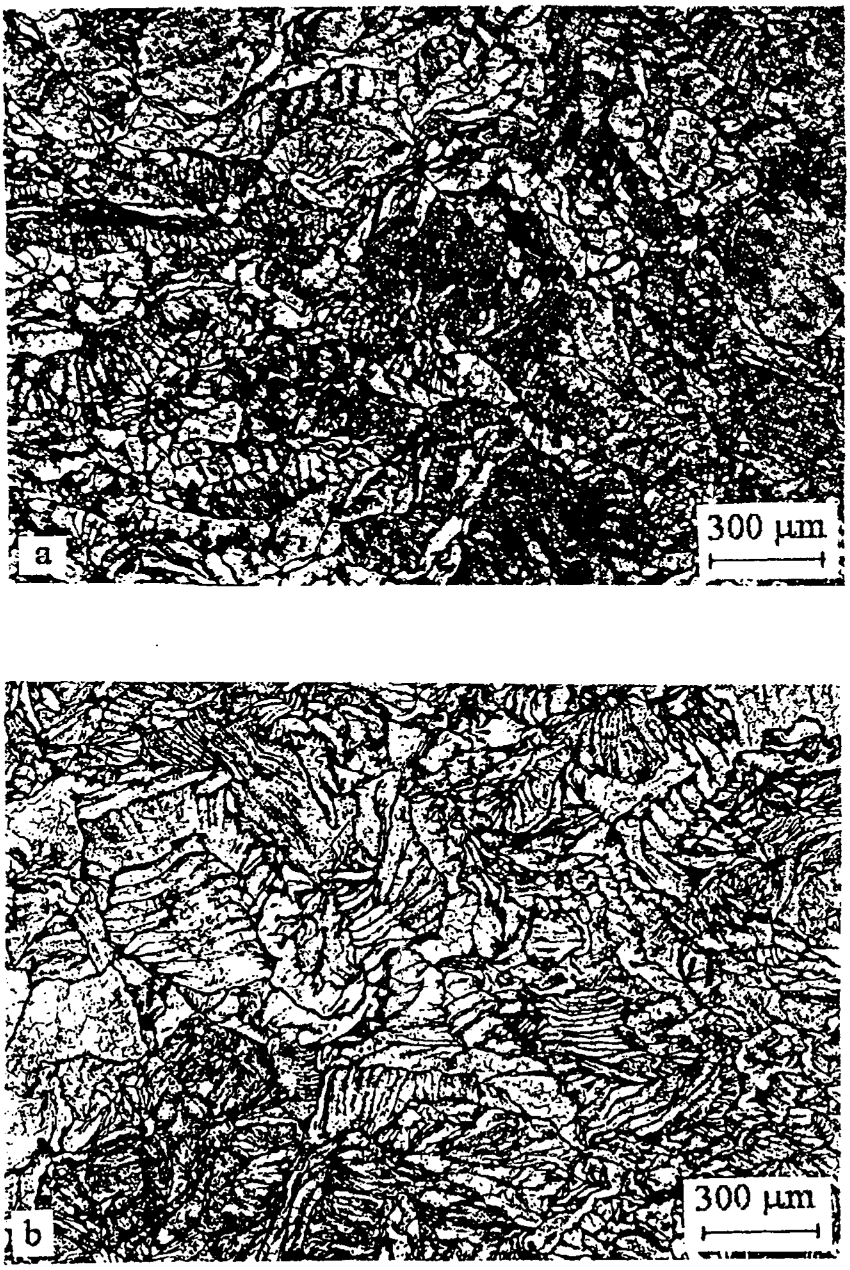


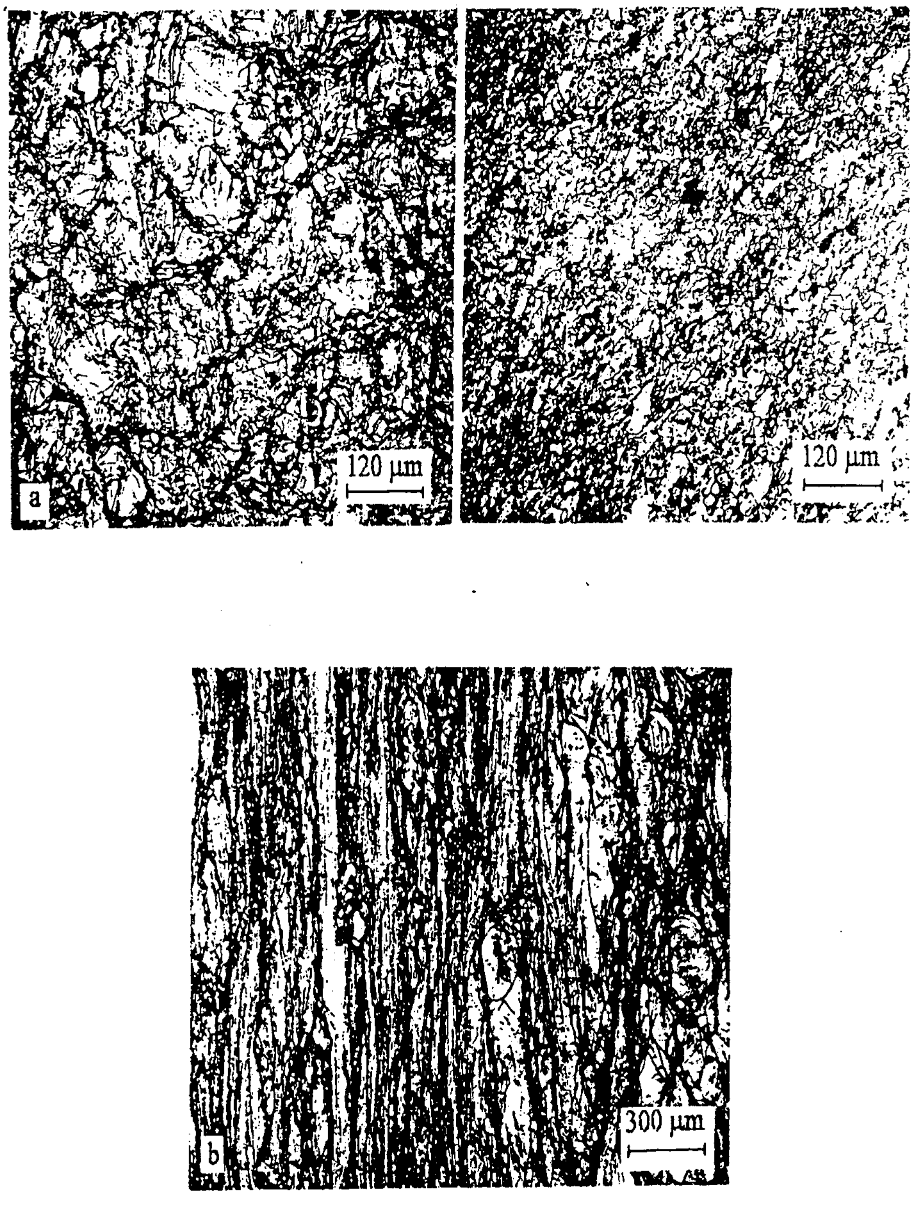
Fig .5. The axisymmetric compation scheme.



a. after compression

b. after annealing at 800 C

Fig .6. The microstructure of the rodes obtained by explosive compression.



a. crosssectional
b. longitudinal
Fig .7. The microstructure of the rodes obtained by quasi-dynamic method.

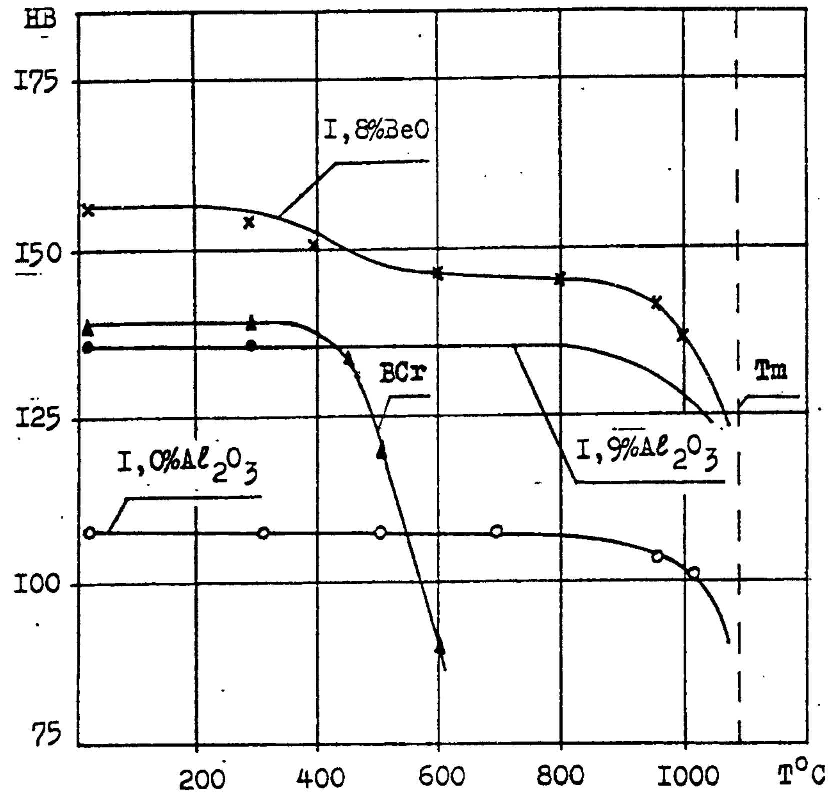


Fig .8. The change of the microhardness values depending on the annealing temperature.