Many branches of industry are currently facing the problem of finding suitable filtering materials capable of resisting corrosive media. The possible forms of rigid filtering partitions include porous tubes made from a corrosion resistant metal, such as titanium.

In view of the future high demand for porous tubes, our aim was to produce these from nonspherical powder. The starting powder consisted of fine fractions of titanium sponge (Fig. 1). Short tube lengths were produced by compacting in a closed-bottom die. Paraffin wax was used as plasticizer. These experiments revealed that tubes not more than 120 mm long can be made by compacting in a closed-bottom die. The resultant tubes had nonuniform porosity distribution (the ends being of low porosity), and filtered only with their central portion. During vacuum sintering at 950°C, the paraffin wax volatilized, and was deposited in the piping of the vacuum system.

Subsequent work aimed at developing a technique for the production of tubes by extruding powder paste through a die, followed by sintering. Basically, the production technology of porous tubes comprised the following principal operations:

1. Preparation of powder of the required particle size.
2. Preparation of paste for extrusion.
3. Tube extrusion.
4. Drying and sintering.

PARTICLE SIZE OF STARTING POWDER

In the first experiments, a coarse starting powder with particle sizes beginning at 2 mm was used; the amount of the −53 μm fractions was about 5%. Tubes made from this powder had a rough surface with large pores. The tube surface, as characterized by the external tube diameter, was of major importance, since the tubes were intended for a circulating filter operating without the formation of a deposit layer [1].

The principle of this method of filtration is that a stream of a suspension prevents the settling of a deposit onto the filter surface. The filtering element in this case is a porous tube inserted into an ordinary one. The suspension is fed under pressure along the annular space between the two tubes.

Filtering tests using rough tubes with coarse pores in a suspension stream showed a rapid drop of throughput. During operation, solid-phase particles in the suspension became trapped in the large pores and blocked them. As a result of these tests, it was decided to employ a powder of approximately the following particle size composition: 35% 0.5 + 0.25 mm, 15% 0.25 + 0.055 mm, 30% 0.055 + 0.30 mm, and 20% 0.030 + 0.005 mm.

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PREPARATION OF PASTE FOR EXTRUSION

As shown in the literature [2, 3], the plasticity of an extrusion paste is determined by the amount of plasticizer, the method of its introduction, and the moisture content of the paste. Tests were made with two plasticizers: crude rubber dissolved in gasoline and a weak alkaline solution of starch. The former was soon abandoned because of its poor miscibility with the powder and the gasoline vapors which contaminated the surrounding atmosphere. The latter plasticizer, consisting of one part by weight of edible starch in six parts of a 0.5% NaOH solution, was used. The amount of starch was about 5% of the weight of the dry powder.

Considerable difficulties were encountered in blending the powder and the plasticizer until the full plasticity of the paste was attained. Originally, this operation was performed in rolls, but it was almost continuously necessary to return the material from under the rolls into the charging hopper. Subsequently, this operation was successfully carried out in an ordinary muller with a pan diameter of 450 mm. In a muller, 5-6 kg of paste can be brought to the required plastic condition in 1.5-2h.

For imparting homogeneity to the resultant paste, the latter was rubbed through a wire sieve with apertures 2 x 2 in size. With the proportions indicated above, the moisture content of the paste is 25%. Before extrusion, the paste must be dried to a moisture content of 19-20%, as otherwise the extruded tubes are not strong enough, and can easily be deformed during drying. At moisture contents down to 15%, tubes can be extruded, but tend to break; at moisture contents below 15%, the paste cannot be extruded.

TUBE EXTRUSION

Extrusion was performed through a die assembly. The length of the extruded tube is determined by the paste charge volume. The die assembly was calculated for the production of tubes 37 x 7.5 and 50 x 7.5 mm in diameter and 1000 mm long. The press design permitted the extrusion of tubes not longer than 800 mm. In view of their low strength, the moist tubes should be supported on pins and in channels. The very first experiments demonstrated how greatly extrusion results depend on the plasticity of the extrusion paste, which is determined by the particle size of the starting powder, amount of plasticizer, thoroughness of mixing, moisture content, etc.

It was established that, for a given method of paste preparation, the extrusion pressure depends on the moisture content of the paste. This relationship is shown in Fig. 2. The optimum extrusion pressure is 11-15 x 9.8 kN (absolute pressure). At a lower pressure, the structure of the extruded tubes is not firm, while at a higher pressure, the tubes crack or break under their own weight.

DRYING OF MOIST TUBES

As was indicated above, the extruded tubes have very little strength, and remain soft until they have dried up. They harden after drying for 8-10 h at room temperature. After 20-24 h, they can be moved on a pin without a metal channel.

In order to protect the tubes against crack formation during sintering, they should be thoroughly dried. At room temperature, drying requires not less than 70-120 h. With the aim of speeding up drying, experiments were made with infrared heating. With this method of drying, the process is not localized on the surface, but takes place within the material [4], which prevents crack formation. In our dryer, the irradiation of moist tubes was effected from one side only, which, at a temperature of 90°C on the green tube surface, gave rise to cracking. No cracks were formed when the temperature on the specimen surface did not exceed 50-60°C. Under such conditions, drying time is 8 h, but the tubes must be regularly (every 30-50 min) turned round.

SINTERING

The theoretical principles of the sintering of parts compacted from metal powders are set out in [2]. The properties of titanium make it necessary to perform sintering in an inert gas or vacuum atmosphere. On the basis of the