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(54) Titre : ARBRE GRAVE ET PROCEDE DE FABRICATION CORRESPONDANT
(54) Title: ENGRAVED SHAFT AND METHOD FOR MANUFACTURING THEREOF

(57) Abrégé/Abstract:
The invention relates to an engraved shaft which is entirely or principally made of an aluminum alloy. A raster surface is created on the cylindrical surface of said shaft. Said raster surface comprises recessed cells having a predetermined volume. A layer of oxide-ceramics is formed on the raster surface by process of electrolytic oxidation, whereby such a layer, which has a depth between 15 and 50 micrometers and a micro-hardness between 700 and 1500 Hv, adequately reproduces the outline of the external surface of the raster. The high hardness and strength of the oxide-ceramic layer enable the raster cells to maintain a correct shape and dimensions for a long time during the use of the shaft. Said oxide-ceramic layer may be additionally impregnated with metal or organic materials so as to further strengthen the raster surface, increase the corrosion resistance thereof and provide it with special properties (oleophilic, absorbent, hydrophobic, etc.) as required in various systems involving the dosed transfer of liquids and suspensions.

ENGRAVED SHAFT AND METHOD FOR MANUFACTURING THEROF

ABSTRACT

The proposed invention is an engraved roll, fully or largely made from an aluminium alloy, to the cylindrical surface of which a screen surface consisting of cell-recesses of calculated volume is applied. An oxide-ceramic layer 15-50 μm thick and with microhardness 700-1500 Hv, which adequately reproduces the external surface of the screen, is formed on the screen surface by the plasma electrolytic oxidation process. The great hardness and strength of the oxide-ceramic layer make it possible for the cells of the screen to retain their correct dimensions and shape for a long period of exploitation of the roll.

The additional impregnation of the porous oxide-ceramic layer with metal or organic materials still further hardens the screen surface, increases its corrosion resistance and imparts to it the required special properties (lipophily, hydrophily, hydrophoby et al.) for different systems for the dosed transfer of liquids and suspensions.

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ENGRAVED SHAFT AND METHOD FOR MANUFACTURING THEROF

Technology field

This invention relates to the field of producing high-precision rolls with engraved relief surface, which are used in printing equipment, in the production of textiles, for making wallpaper, and for applying lacquers, glues or suspensions to sheet materials, fabrics etc. In particular, the invention relates to screen (anilox) rolls for flexographic and offset lithographic printing, which have the finest engraved relief surface.

Prior Art

In the course of printing, a layer of ink is applied to the screen surface of the roll, consisting of regularly disposed recess-cells. The excess is removed by a doctor. Thus, the cells receive a dosed volume of ink, which is then transferred to the surface of the printing form or inking roller. To obtain high quality printing, high precision is required in the positioning of the cells on the cylindrical surface of the screen, and also in the shape and depth of the cells themselves. The depth of the cells is from 10 to 50 μm. Constant contact with the hardened steel doctor causes wear of the screen surface. The mechanical wear process is augmented by the corrosion effect of the inks, which include solutions of salts, organic solvents etc., reducing the serviceable life of the engraved roll.

In practice, the most widely used screen rolls are those made of construction steel. The cells are rolled onto the cylindrical surface by a knurling roller made of tool steel. The high cost of the knurling roller (which has to be made to a higher order of precision than the screen roll cells) and its low strength make it necessary to use slow, undemanding rolling regimes, and cause the productivity of the process to be low.

To increase resistance to wear and corrosion, the steel rolls are chromium-plated. An example of such a roll may be found in US Patent No. 3,613,578. The thickness of the chrome plating should not be more than a few microns (maximum 15 μm), since increasing the thickness of the plating alters the geometry and volume of the cells in the screen surface. Power contact with the doctor in the course of operation leads to rapid wear of the thin chromium layer and greatly reduces the serviceable life of the roll.

A more modern method of imparting wear and corrosion resistance to the screen surface of the steel roll is the ion nitriding process described in US Patents Nos. 5,514,064 and 5,662,573. The chemical conversion of the steel surface to iron nitride forms a hard well-bonded protective layer (Hv 700-1000). However, there is a serious problem with this method, namely the high temperature of the nitriding process, leading to distortion of the roll due to thermal deformations, which means that a correcting operation has to be carried out on the roll. Furthermore, the use of high-chrome steel for this process makes it more difficult to knurl the screen and reduces the life of the knurling tool.

Attempts to increase the wear resistance of the screen roll by applying a ceramic coating to the screen surface by the plasma spraying process (US Patents Nos. 4,009,658, 4,601,242 and 4,912,824) proved unsuccessful; too fine a ceramic coating did not protect the roll against premature wear, whereas the application of a thicker coating filled the screen cells to a considerable degree, reducing their size considerably.

The heavy weight of steel rolls is a drawback in using them. A roll about one metre long weighs about 70 kg. This causes difficulties in fitting and replacing rolls, requiring special experience and tools. There is a high probability of chance damage to the screen surface.

Furthermore, during use at relatively high revs., the slightest imbalance in steel rolls causes dynamic vibrations, making the rolls “judder”, which aversely affects the quality of the printing.

The use of lightweight rolls made from aluminium alloys, which are just as rigid as steel ones, has considerable advantages. Aluminium alloys are easy to machine at high cutting speeds and to high precision. Thanks to its high precision and light weight, an aluminium alloy roll has low dynamic inertia and low dynamic imbalance. This enables the roll to rotate more uniformly in operation, and reduces or eliminates vibration and "judder".

There are known processes for producing screen rolls of aluminium alloys with protective coatings (US Patents Nos. 5,411,462 and 5,548,897), in which the following sequence of operations is proposed:

- making a high-precision roll from an aluminium alloy;
- applying a protective corrosion- and wear-resistant ceramic layer to the external cylindrical surface;
- finishing the cylindrical surface of the roll by polishing;
- engraving the screen cells in the ceramic surface by using a laser beam.

The proposals include two types of protective coating. The first type consists of a layer of chromium oxide or aluminium oxide 200-250 μm thick, applied by plasma spraying. The second type is a layer of aluminium oxide 25-50 μm thick, formed on the cylindrical surface of the roll by anodising in sulfuric acid electrolyte. In this case, the depth of the screen cells cut by the laser beam should not exceed the thickness of the anode-oxide coating.

The main problem with the laser engraving (burning-out) process is that it requires the use of very expensive equipment for the automatic control of the laser. Furthermore, the recesses engraved by the laser beam are not always of the correct shape. Differences in the roughness of the walls and bottom of the cells lead to the retention of a certain volume of ink and its random release, which is detrimental to the quality of the printing.

But in spite of this, the use of "ceramic" rolls on steel and aluminium bodies is increasing all the time, due to the absence of any alternative which would provide high wear resistance and durability in the operation of the rolls. "Ceramic" rolls last 5-10 times as long as steel chromium-plated rolls, but cost 4-6 times as much.

Anode oxide coatings consist mainly of amorphous phases of aluminium oxides, so their strength and microhardness are not great. The coatings are hydrated to a considerable degree (their water content exceeds 10%), and also contain in their composition 10-20% of electrolyte anions forming part of the structure of the coating. When the roll heats up in use, the electrolyte components and water are removed from the structure of the coating, leading to fracturing and breakdown of the anode-oxide layer and degradation of its protective properties.

There is also a known process for making an aluminium screen roll for lithographic printing proposed in US Patent No. 4,862,799. The screen cells are first made in the precision cylindrical surface of the roll by engraving (pricking) with a diamond needle. This surface is then anodised to form a fine, relatively hard layer, 1-3 μm thick, and finally, a relatively soft layer of copper, 5-8 μm thick, is applied on top of the anode layer. This is done to impart to the screen surface the surface properties required for lithography as regards the attraction of oil (lipophily) and the repulsion of water (hydrophoby).

The problem with this process is the low thickness of the copper oxide layer on the screen surface of the roll. This layer cannot withstand the mechanical and chemical stresses occurring in a corrosive medium with the screen in friction contact with a steel doctor. Increasing the thickness of the anode-oxide layer to 15-20 microns leads to unacceptable changes in shape and dimensions of the screen surface cells. This is because in anodising, no less than 50% of the thickness of the oxide layer grows out from the surface being treated. Allowing for the thickness of the copper layer applied on top of the anode-oxide layer, it is virtually impossible to obtain screen cells of an acceptable volume. The considerable problems with the anode-oxide layers themselves have already been described.

Substance of the Invention

The main aim of this invention is to create a light and relatively cheap engraving roll with virtually no inertia and a long serviceable life for use in various systems for the dosed transfer of liquids and suspensions.

Another aim of this invention is to develop an efficient process for producing an engraved roll, including high-precision and high-productivity processes for applying the screen cells, and up-to-date technologies for hardening the screen surface by forming wear- and corrosion-resistant coatings on them without significantly altering the set volumes and shapes of the screen cells.

These and certain other aims of the invention will be explained in the course of the detailed description of the invention.

The engraved roll proposed in this invention is made in the form of a high-precision base cylinder of a deformable aluminium alloy. A screen surface with a set disposition, shape and volume of recess-cells is engraved on the working (external) cylindrical surface. A hard wear-resistant oxide-ceramic coating 15-50 μm thick with microhardness 700-1500 Hv is formed on the screen surface of the roll by the plasma electrolytic oxidation method. The oxide layer bonds strongly with the aluminium base and is applied uniformly in thickness, adequately repeating the configuration of the screen. To impart various functional properties to the screen surface, further to improve the strength and corrosion resistance of the coating, and also to produce a smoother surface from which ink will wash off easily, a fine (1-5 μm) layer of metallic or organic materials is applied to the porous oxide-ceramic surface. And finally, to create a smooth external screen surface consisting of the boundary ribs between the cells, which is as symmetrical as possible relative to the central axis of the roll, this surface is subjected to a finishing treatment in the form of fine circular polishing with an allowance of 2-10 μm per side.

Although the plasma electrolytic oxidation (PEO) process is known, it has never been used in the manufacture of engraved rolls. The PEO process makes it possible to produce uniform-thickness coatings on complex-shaped surfaces, since, unlike anodising, the greater part (80-90%) of a coating produced by PEO builds up inwardly from the surface.

The selection of optimal oxidation regimes for the screen surface of the rolls ensures the production of a hard, relatively thin coating which is sufficient for prolonged operation.

The oxidation is carried out in ecologically safe, weakly alkaline aqueous electrolytes at a temperature of 15-55°C. Impulse voltage of 50-1000 V (amplitude values) is supplied to the components. The pulse repetition rate is 50-3000 Hz. The current density is from 2 to 100 A/dm^2.

An intercrystalline oxide layer of 700-1500 Hv microhardness, 15-50 μm thick, is created on the screen surface of aluminium alloy rolls under the effect of plasmo-chemical reactions.

The oxide-ceramic coating formed on the surface of the aluminium components consists mainly of a composition of different crystalline phases of the oxides of aluminium (alpha, beta, gamma etc.). Therefore, in spite of their great hardness, they possess a certain plasticity, and compared with ceramic coatings formed by plasma spraying, they are less liable to micro-chipping and flaking on the surface.

The porous structure of oxide coatings forms an ideal matrix for the creation of composition coatings by filling this matrix with compounds possessing specific functional properties.

For this purpose, this invention makes use of various metals and organic compounds (depending on the functional properties required).

Such materials, penetrating into the pores and capillaries and forming a film on top 1-5 μm thick, protect the oxide coatings, while hardly changing the volume of the screen cells or smoothing out their rough surface at all. Unimpregnated oxide-ceramic coatings absorb ink so intensively that difficulties arise when washing off the rolls for a change of ink in the system.

The strongly developed surface of the porous structure of the oxide layer gives excellent adhesion between itself and the impregnating compound, and consequently, excellent cohesion strength for the entire composition.

Oxide rolls impregnated with one of the metals of the series Ni, Cr, Mo or a compound of one of these metals with its oxides and carbides can be used successfully in systems for letterpress book printing, photogravure printing and flexography, i.e. in those cases in which liquids on aqueous, oil or synthetic bases are being transferred.

In offset lithographic printing systems, where inks on an oil base are used in the presence of water, the surface of the engraved rolls is required to attract oil (lipophily) and to repel water (hydrophoby). It is known that copper is such a material by its nature. Therefore, in lithography, it is efficient to use engraved rolls with oxide-ceramic coatings impregnated with copper.

The application of thin protective layers of metallic compounds may be done by chemical or electrochemical precipitation from aqueous or organic solutions, by chemical precipitation from the gas phase, or by physical precipitation methods.

Organic substances for the impregnation of the microporous structure of an oxide-ceramic coating must have good adhesion to ceramic surfaces, or should at least be gripped by the cavities in the ceramic coating. In the reaction process (heating, ultraviolet irradiation, etc.), they form a hard smooth corrosion-resistant layer.

Since organic substances must penetrate as deeply as possible into the porous structure of the ceramic coating, it is preferable to use low-viscosity diluted solutions or ultra-disperse suspensions.

To apply the organic materials, simple technologies of the immersion of a rotating roll in a liquid, spraying on a solution with an atomiser, and the method of precipitation from a gaseous phase can be used.

Apart from corrosion resistance, the organic layers may possess special properties (lipophilic, hydrophilic or hydrophobic) and may accordingly be used in different printing systems.

For the impregnating compositions, the most suitable are the widely known self-vulcanising elastomers: butadiene-styrene, butadiene-nitrile, acryl-nitrile, and also paired regulating epoxy and formaldehyde resins and modified elastomers.

Others can also be used: polymethyl methacrylate, chlorosulfonated polyethylene, ethylene-propylene elastomer and the like.

The external surface of the screen, consisting of the projecting intervals (ribs) between the cells, is subjected to fine circular polishing on a precision circular polishing machine. The polishing depth is 2-10 μm. The aim of the operation is to ensure the maximum symmetry of the external surface relative to the central axis of the roll and the smooth operation of the printing system. Furthermore, due to the fine polishing, the initial period of working in the oxide-ceramic external surface of the roll with a steel doctor, during which the doctor may vibrate severely and wear intensively, can be eliminated.

Example of the Implementation of the Invention

This invention can be used for making engraved deformable aluminium alloy rolls of different dimensions and designs, and is illustrated by the drawings, which show:

Fig. 1: Design of small engraved rolls of length up to 500 mm. The monolithic body (1) is machined entirely from rolled aluminium alloy rod.

Fig. 2: Sectional design of medium-sized engraved rolls of length up to 1000 mm with apertures (3) machined into the endfaces, into which are pressed journals (shanks) (2) of aluminium alloy or steel.

Fig. 3: Sectional design of large engraved rolls of length more than 1000 mm, consisting of a thick-walled aluminium bush (5) pressed onto a roll (core) (4) of hardened steel.

Fig. 4: Section of the screen surface of aluminium roll (1) with engraved standard cells (6) of set shape and volume.

Fig. 5: Section of the same roll as in Fig. 4, with an oxide-ceramic coating (7) formed on the screen surface.

Fig. 6: Section of the same roll as in Fig. 5, with a layer (8) of metal or organic compound applied on top of the oxide-ceramic layer (7).

Fig. 7: Section of the same roll as in Fig. 6, after the finishing circular polishing operation.

Fig. 8: Photograph with 1000-fold magnification of the screen surface of a flexographic roll after the plasma electrolytic oxidising operation.

The rough surface of the oxide-ceramic layer at the boundaries (ribs) of the cells can be seen clearly.

Rolls of aluminium alloys are easy to machine. Therefore, using high-precision metal-cutting equipment, it is possible to make high-precision rolls with an external surface close to the cylindrical and co-axial with the central axis of the roll. Such lightweight, low-inertia, dynamically balanced rolls do not require further balancing after they have been made.

However, the rolls must be strong enough and rigid enough to prevent deformations due to the forces arising from hydrodynamic pressure in the ink wedge between the roll and the printing form during operation.

The appropriate designs of rolls and grades of aluminium alloys from which the rolls are to be made are selected depending on the required dimensions (diameter and length) of the roll and the pre-calculated strength.

Small rolls of length up to 500 mm (Fig. 1) are machined completely (monolithically) from rolled rods of deformable aluminium alloys of grades of the SAE 5000 series (5082, 5086, 5056, 5356), 6000 series (6061, 6063, 6067, 6082), 2000 series (2021, 2024, 2018, 2618) and 7000 series (7075, 7175, 7475). Rolls of medium length up to 1000 mm (Fig. 2) are made sectionally from an aluminium cylinder with deep apertures (3) machined co-axially into the endfaces, into which journals (shanks) (2) of steel or aluminium alloy are pressed. Large rolls of length more than 1000 mm are also made sectionally (Fig. 3). They consist of a high-precision thick-walled bush (5) of aluminium alloy pressed onto a high-precision roll (core) (4) of hardened steel.

In making rolls of the medium and large sizes, only high-strength heat-treated aluminium alloys of the 2000 or 7000 series are used.

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A significant advantage of this invention is the fact that the cells of the screen surface can easily be knurled at low specific pressure with high productivity and precision. This ensures the long life of the knurling roller. But the best results for precision of the screen and the productivity of the process are achieved by high-speed electronically-controlled engraving with a diamond needle (at about 3000 cells per minute).

Another advantage of this invention is the possibility of a calculated increase in the volume of the cells when they are engraved to 10-25% more than the necessary final volume of the cells in the finished cylinder. This is necessary to compensate for a certain reduction in the volume of the cells in the course of the oxidation, impregnation and finishing treatment of the screen surface.

Corrosion tests in a hydrochloric mist chamber of PEO-oxidised specimens of the aluminium alloys from which engraved rolls might be made, without additional impregnation, showed that the guaranteed time before the appearance of traces of corrosion were: for specimens of alloys SAE 5082 and 6082 – more than 2000 hours; for those of alloy 7075 – about 700 hours; and for those of alloy 2024 - about 200 hours.

The example given below illustrates the practical implementation of this invention. A high-precision roll 165 mm long and 38.6 mm in diameter was made from heat-treated SAE 6082 alloy. A screen surface with cell volume exceeding the required volume by 20% was applied to the cylindrical working surface by the diamond engraving method. The lineature (density) of the screen was 100 lines per centimetre. The roll was then subjected to plasma electrolytic oxidation. The roll was placed in a bath of an aqueous solution of an alkaline electrolyte (pH 11.5) at a temperature of 30°C. Electrolysis regimes: pulse repetition rate 1000 Hz, current density 40 A/dm^2, amplitude value of voltage at the end of the process – anode 900 V, cathode 250 V. Oxidation time 15 min. Thickness of oxide-ceramic coating on the screen and shanks was 25 ± 2 μm. An enlarged photograph of a fragment of the oxidised screen is shown in Fig. 8. The roll thus produced was subsequently subjected to chemical nickel-plating with the application to the oxidised surface of a uniform nickel layer 2-3 μm thick. The shaft was then polished on a circular polishing machine, taking off an allowance of 2 μm per side.

The roll was fitted to a flexographic printing press for printing packing materials. The roll demonstrated excellent printing qualities. The prints produced after making 3,000,000 copies and 6,000,000 copies were virtually identical.

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CLAIM

1. Engraved roll, including:

- a base cylinder made completely or largely of a deformable aluminium alloy, with numerous cell-recesses applied to the external cylindrical surface to form the screen surface;

- a hard wear-resistant oxide-ceramic coating, formed on the screen surface, uniform in thickness;

- an external layer of metallic compounds or organic materials, applied directly onto the said oxide-ceramic coating.

2. An engraved roll in accordance with Claim 1, *characterised* in that the thickness of the oxide-ceramic coating is 15-50 μm, microhardness 700-1500 Hv.

3. An engraved roll in accordance with claim 1, *characterised* in that the thickness of the external layer is 1-5 μm.

4. An engraved roll in accordance with Claim 1, *characterised* in that the external layer applied to the oxide-ceramic coating possesses hydrophilic and lipophilic properties and is made of at least one metallic compound selected from the following metals: Ni, Cr, Mo, or a mixture of one of these metals with its carbides or oxides.

5. An engraved roll in accordance with Claim 1, *characterised* in that the external layer applied to the oxide-ceramic coating possesses hydrophobic and lipophilic properties and is made of copper.

6. An engraved roll in accordance with Claim 3, *characterised* in that the external layer applied to the porous oxide-ceramic coating consists of at least one organic compound selected from a group of compounds including: butadiene-styrene, butadiene-nitrile, acryl-nitrile, epoxy and phenolformaldehyde elastomers,

polymethyl methacrylate, chlorosulfonated polyethylene and ethyl propylene elastomer.

7. A process for producing an engraved roll, *characterised* in that it includes the following stages:

- the manufacture of the base cylinder completely or mainly from deformable aluminium alloy;
- engraving cell-recesses in the external surface of the cylinder;
- forming an oxide-ceramic coating on the engraved surface of the cylinder by the plasma electrolytic oxidation method;
- applying an external layer of metallic compounds or organic materials to the said oxide-ceramic coating;
- mechanical finishing treatment of the external surface of the cylinder.

8. A process in accordance with Claim 7, *characterised* in that during the engraving in the surface of the cylinder, cells are formed with a volume exceeding the required final volume by 10-25%.

9. A process in accordance with Claim 7, *characterised* in that the plasma electrolytic oxidation is conducted in weakly alkaline electrolytes at a temperature of 15-55°C, current density 2-100 A/dm^2, pulse repetition rate 50-3000 Hz and amplitude values of impulse voltage 50-100 V.

10. A process in accordance with Claim 7, *characterised* in that the finishing treatment of the cylinder surface is done by circular polishing, the depth of polishing being 2-10 μm per side.

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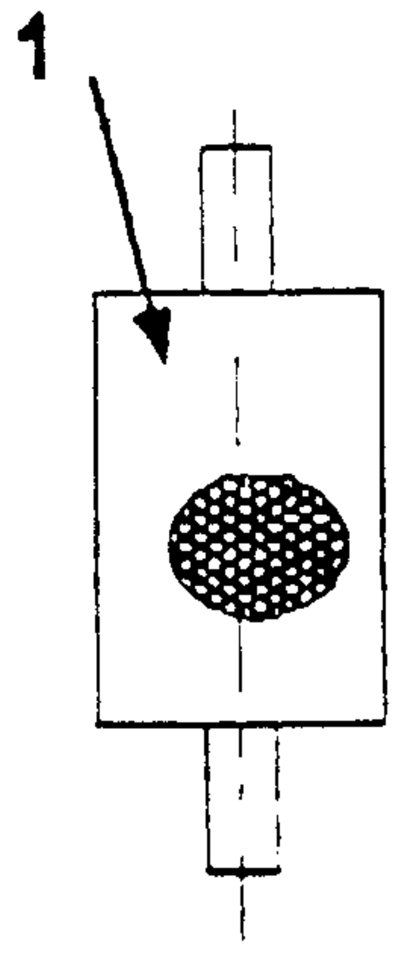

Fig. 1

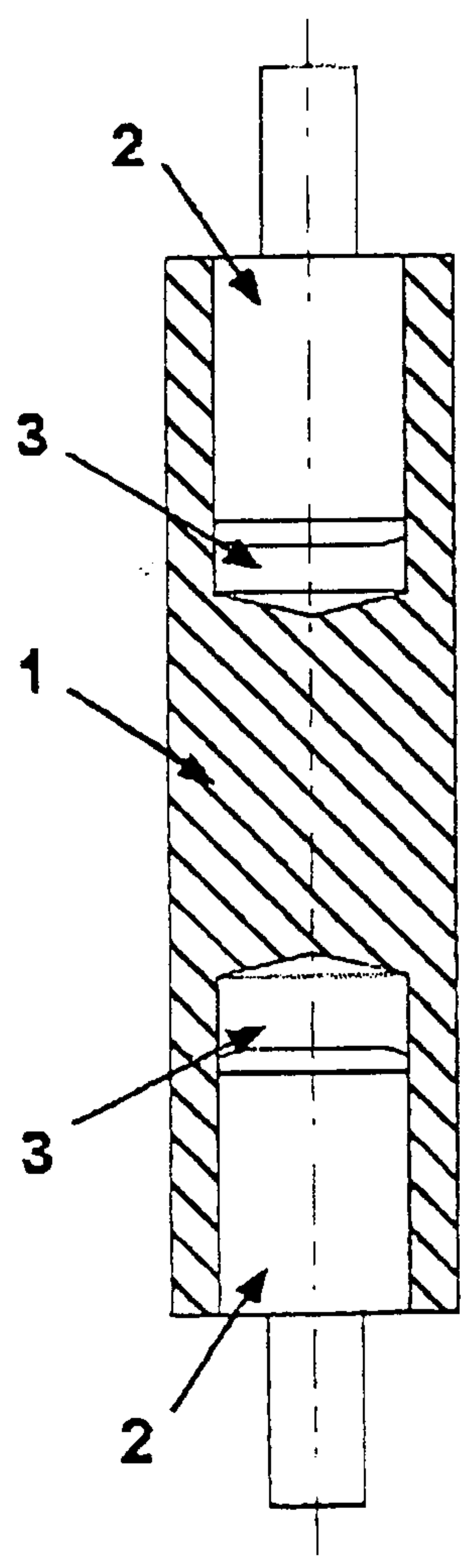

Fig. 2

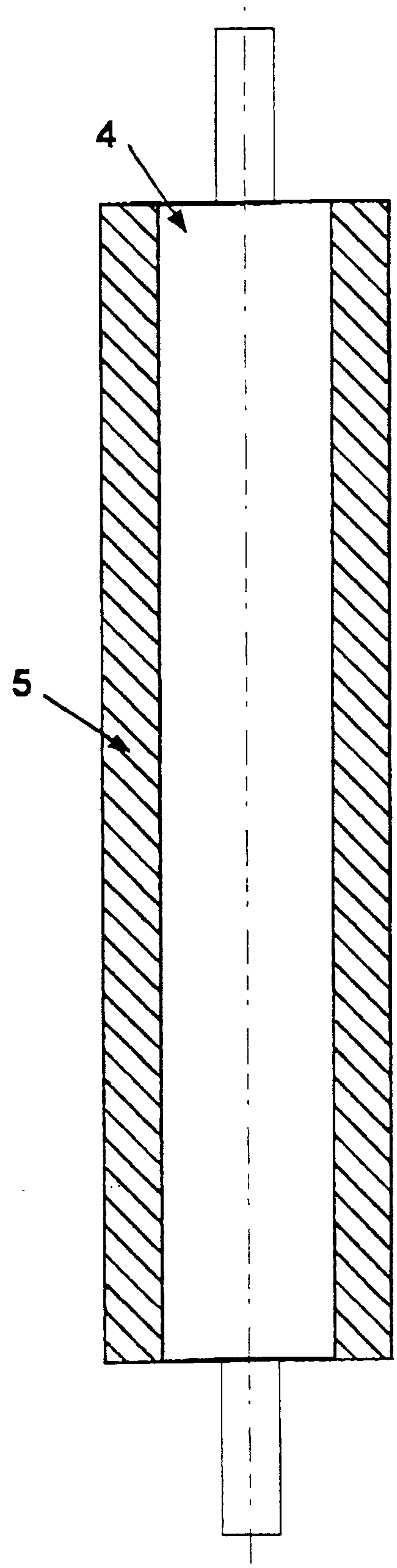

Fig. 3

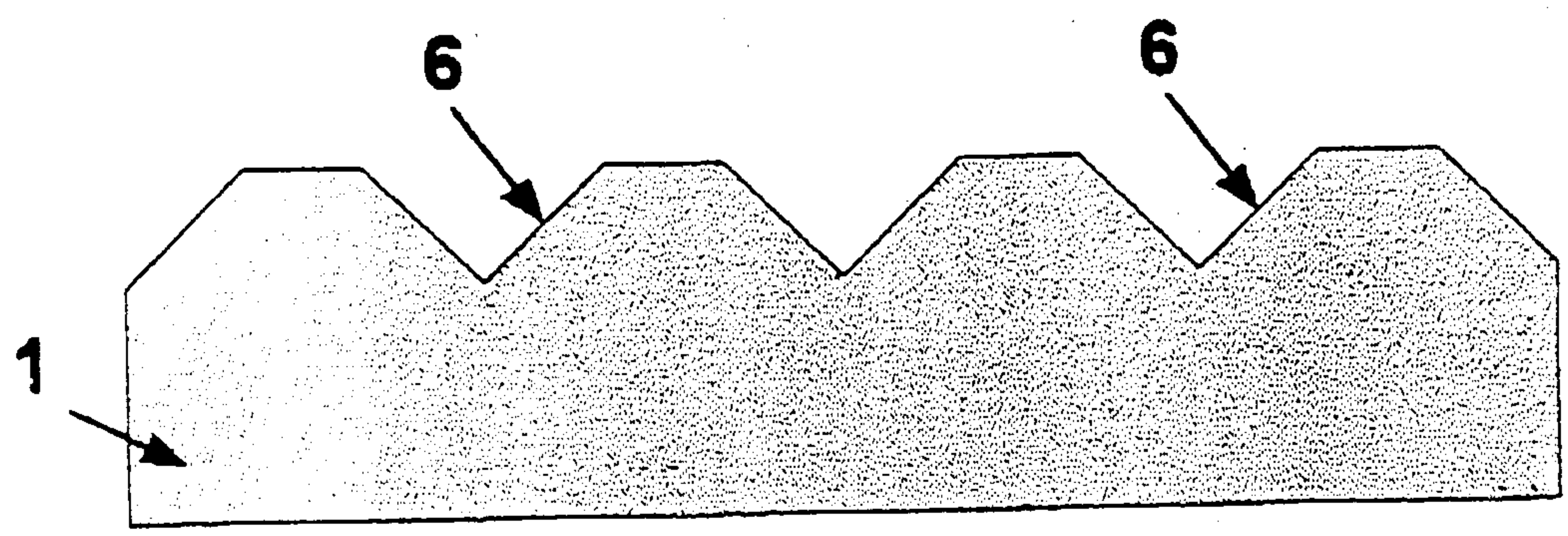

Fig. 4

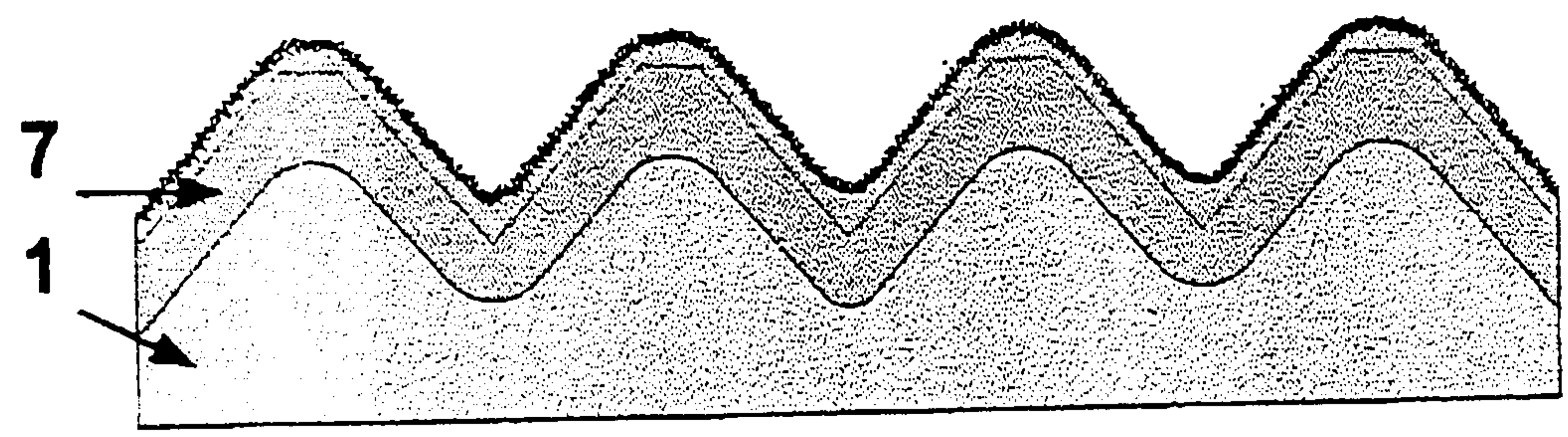

Fig. 5

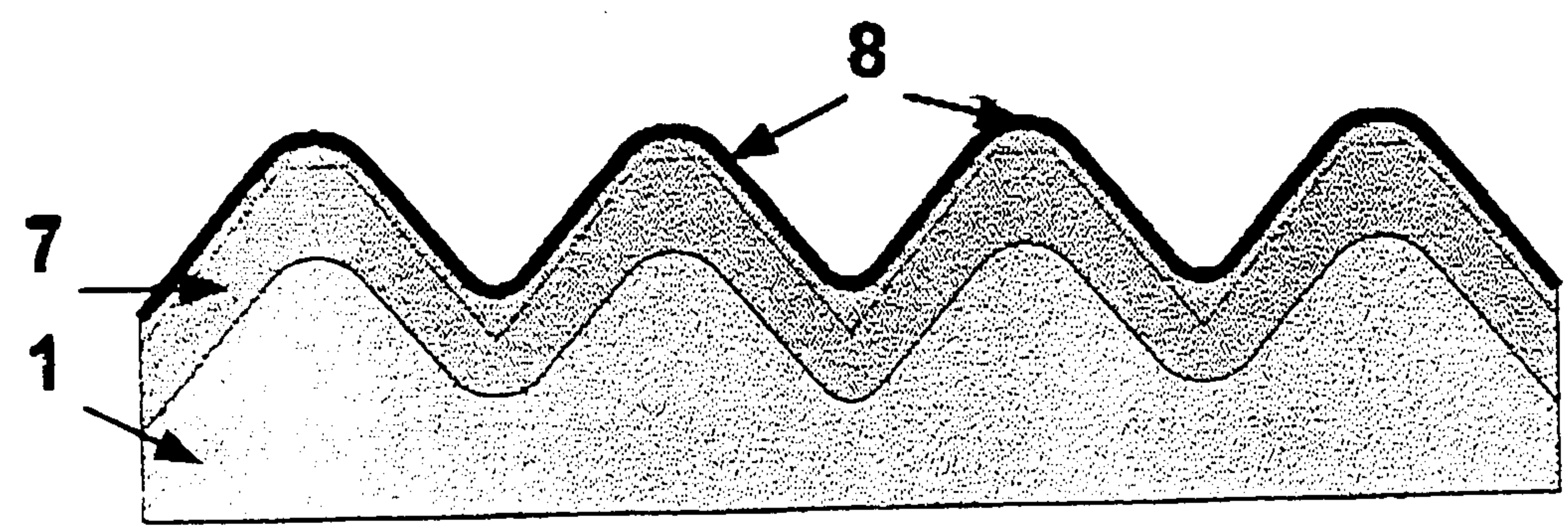

Fig. 6

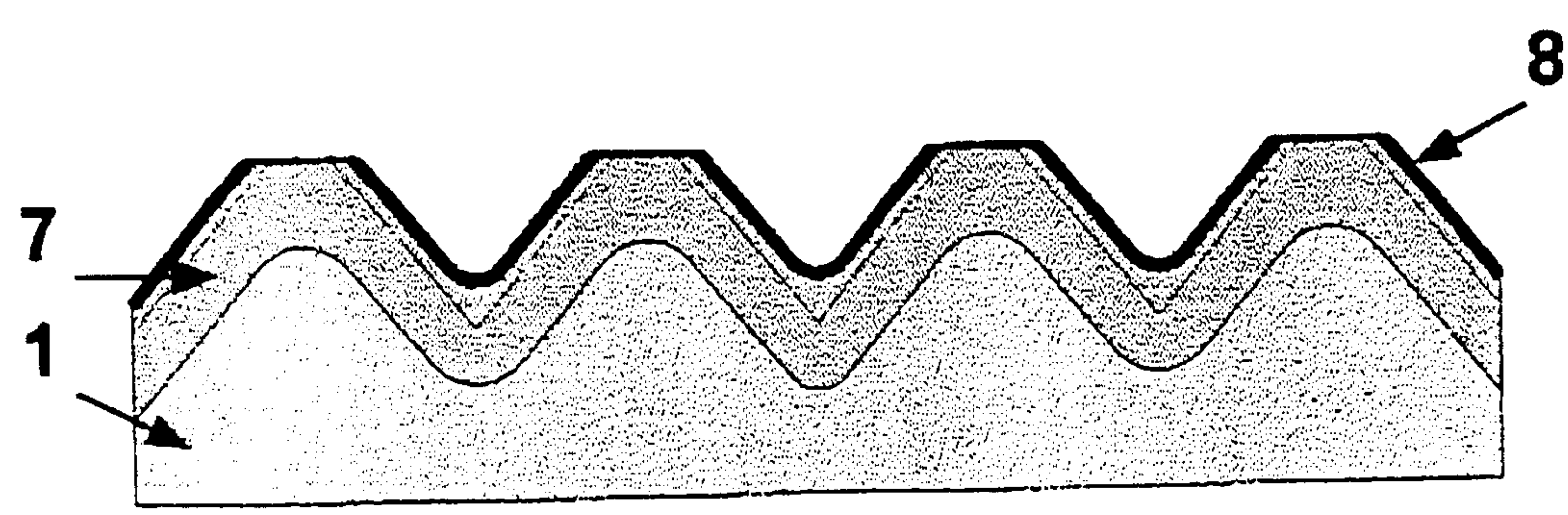

Fig. 7

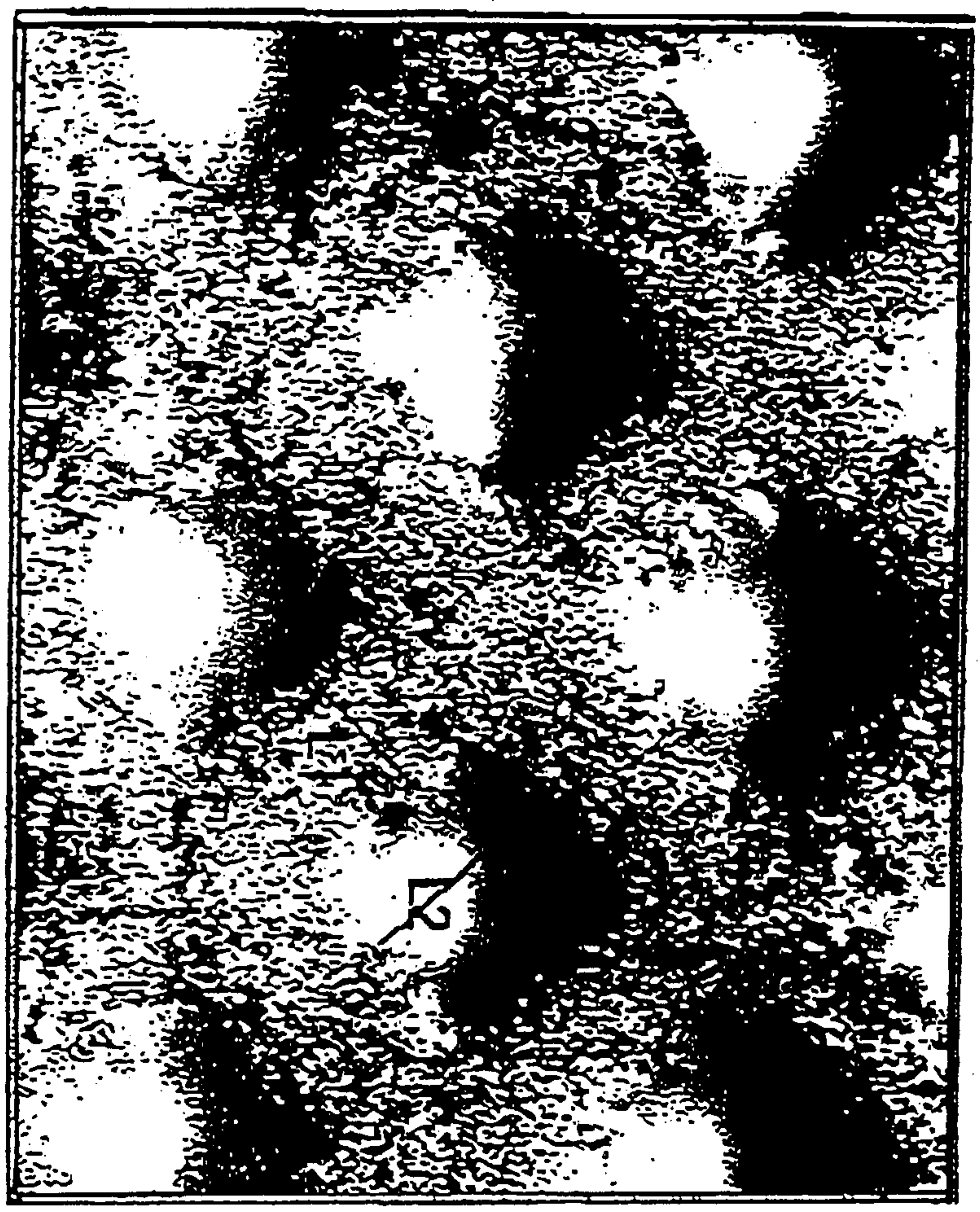

Fig. 8