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(54) Titre : PIECES DE FONDERIE AVEC UNE RESISTANCE ACCRUE A L'USURE
(54) Title: CAST PART WITH ENHANCED WEAR RESISTANCE

(57) Abrégé/Abstract:
The invention concerns a cast wear part with its structure reinforced by at least a type metal carbide, and/or metal nitride, and/or boride, and/or metal oxides, and/or intermetallic compounds, referred to below as constituents. The invention is characterized in that the raw materials used as reagents for said constituents have been introduced in a mould (1) before casting in the form of compacted powder inserts or preforms (3) or the form of slurries (4), and the reaction of said powders has been activated in situ by casting a metal, forming a porous conglomerate in situ, and said metal has infiltrated the porous conglomerate, thus forming a reinforced structure leading to inclusion of said constituents in the structure of the metal used for casting, thereby creating a reinforcing structure on the wear part (2).

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(54) Title: CAST PART WITH ENHANCED WEAR RESISTANCE

(54) Titre : PIECES DE FONDERIE AVEC UNE RESISTANCE ACCRUE A L'USURE

(57) Abstract: The invention concerns a cast wear part with its structure reinforced by at least a type metal carbide, and/or metal nitride, and/or boride, and/or metal oxides, and/or intermetallic compounds, referred to below as constituents. The invention is characterized in that the raw materials used as reagents for said constituents have been introduced in a mould (1) before casting in the form of compacted powder inserts or preforms (3) or the form of slurries (4), and the reaction of said powders has been activated in situ by casting a metal, forming a porous conglomerate in situ, and said metal has infiltrated the porous conglomerate, thus forming a reinforced structure leading to inclusion of said constituents in the structure of the metal used for casting, thereby creating a reinforcing structure on the wear part (2).

(57) Abrégé : La présente invention se rapporte à une pièce d'usure réalisée en fonderie à structure renforcée par au moins un type de carbure métallique, et/ou de nitrure métallique, et/ou de borure, et/ou d'oxydes métalliques, et/ou de composés intermétalliques, ci-après dénommés les composants, caractérisée en ce que les matières premières servant de réactifs pour lesdits composants ont été introduits dans un moule (1) avant la coulée sous forme d'inserts ou de préformes de poudres compactées (3) ou sous forme de barbotines (4), en ce que la réaction desdites poudres a été amorcée in situ par la coulée d'un métal, formant un conglomérat poreux in situ, et en ce que ledit métal a infiltré le conglomérat poreux, constituant ainsi une structure renforcée pour aboutir à une inclusion desdits composants dans la structure du métal utilisé pour la coulée, en créant ainsi une structure de renfort sur la pièce d'usure (2).

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CAST PARTS WITH ENHANCED WEAR RESISTANCE

Field of the invention

[0001] The present invention relates to the production of cast parts with enhanced wear resistance by an improvement in the resistance to abrasion whilst retaining acceptable resistance to impact in the reinforced areas.

Technological background at the basis of the invention

[0002] Installations for extracting and breaking up minerals, and in particular crushing and grinding material, are subjected to numerous constraints of performance and costs.

[0003] As an example, one might cite in the area of the treatment of aggregates, of cement and of minerals, wear parts such as ejectors and anvils of grinding machines with vertical shafts, hammers and breakers of grinding machines with horizontal shafts, cones for crushers, tables and rollers for vertical crushers, armoured plating and elevators for ball mills or rod mills. With regard to mining extraction installations, one might mention, among others, pumps for bituminous sands or drilling machines, pumps for mines and dredging teeth.

[0004] The suppliers of wear parts for these machines are faced with increased demands for wear parts which meet the constraints of resistance to impact and resistance to abrasion at the same time.

[0005] Traditional materials generally meet one or the other of these types of requirement but are very rarely resistant to both impact and abrasion. Indeed, ductile materials offer enhanced resistance to impact but have very little resistance to abrasion. On the other hand, hard abrasion-resistant materials have very little resistance to violent impact.

[0006] Historically, the first reflections on this problem led to an exclusively metallurgical approach which consisted in suggesting steels with manganese that are very resistant to impacts and nevertheless achieve intermediate hardness levels of the order of 650 to 700 Hv (Vickers hardness).

[0007] Other alternatives such as castings with chrome have also been suggested. These allow to achieve hardness levels of the order of 700 to 850 Hv after suitable thermal treatment. These values are achieved for alloys containing a percentage of carbide up to 35%.

[0008] Currently, bimetallic castings have also been used, but these nevertheless have the disadvantage of being limited to parts of simple shape, which drastically reduces their opportunities for industrial application.

[0009] Wear parts are generally considered as consumables, which means that apart from purely technical constraints, there is also a financial constraint which limits the opportunities for solutions that have an average cost of US$4/Kg. It is generally estimated that this price level, which is twice as high as that of traditional wear parts, is the threshold of financial acceptability for customers.

Description of the solutions according to state of the art

[0010] Achieving a wear part that is resistant to abrasion and impact has already been the subject of studies of various types.

[0011] In this context, one has naturally turned to composite parts based on ceramics and, in this area, the Applicant already discloses in document WO 99/47264 an alloy based on iron and ceramics which is very resistant to wear and impact.

[0012] In document WO 98/15373, the Applicant proposes to insert into a mould, before casting, a wafer of porous ceramic which is infiltrated by the metal during casting. The opportunities for application of this invention are nevertheless limited to parts of strong cross-section and to alloys with high fluidity in casting. Moreover, the positioning of these ceramic wafers is rather conditioned by the requirements of infiltration by the cast metal than by the actual requirements of the part's use.

[0013] Without aiming at the same objectives, Merzhanov discloses in document WO/9007013 a fireproof porous material obtained by cold compression of the raw material, of an exothermic mixture of powders under vacuum, followed by starting the combustion of the mixture. Here, we are dealing with a chain reaction. With this method, he obtains extremely hard materials but without any resistance to impact. This is essentially due to the high porosity of the products.

[0014] Moreover, in document WO/9011154, the same inventor proposes a similar method where, in this case, the mixture of powders, after having reacted, is subjected to pressures as high as 1000 bars. This invention results in the production of layers that are extremely resistant to abrasion but with insufficient resistance to impact. The aim here is above all to produce surfaces for abrasive tools that are greatly solicited in this sense.

[0015] In general, the use of very pure powders such as titanium, boron, tungsten, aluminium, nickel, molybdenum, silicon, carbon, etc. powders results in extremely porous pieces after the reaction with porosity rates close to 50%. These therefore require compression after the reaction involving compaction and thus an increase in density, which is indispensable for industrial use.

[0016] The implementation complexity of such a method, the control of the reactions and the cost of the raw materials nevertheless considerably limit the introduction of these technologies into industry.

[0017] German patent application 1949777 - Lehmann discloses a production method for cast parts that are highly wear resistant. In this method, carbide powders are combined with combustible binding agents and/or metallic powders with a low melting point. During casting, the binding agent gives up its place to the casting metal which then surrounds the carbide particles. In this method, there is no chemical chain reaction and all the particles highly wear resistant are present in the mould from the start.

[0018] Numerous documents disclose such a method for surrounding hard particles, and in particular US-P-5,052,464 and US-P-6,033,791 - Smith, which are based on the presence of hard particles before casting which is to infiltrate the pores between the ceramic particles.

[0019] The invention avoids the pitfalls of the state of the art by producing wear parts of original structure and produced by an original and simple method, which is thus inexpensive.

Aims of the invention

[0020] The present invention aims to provide wear parts resistant both to abrasion and to impact at a financially acceptable price as well as a method for their production. It aims in particular to solve the problems associated with the solutions according to the state of the art.

Summary of the invention

[0021] The present invention relates to a cast wear part, with a structure reinforced by at least one type of metallic carbide, and/or metallic nitrides, and/or metallic oxides, and/or metallic borides, as well as intermetallic compounds, hereafter called the components, characterised in that the raw materials acting as reagents for said components have been put into a mould, before casting, in the form of inserts or pre-shaped compacted powders or in the form of barbitones, in that the reaction of said powders is triggered in situ by the casting of a metal forming a porous conglomerate in situ, and in that said metal infiltrates the porous conglomerate, thus forming a reinforced structure, so as to achieve the inclusion of said conglomerate in the structure of the metal used for the casting of the part, and thereby to create a reinforcing structure in the wear part.

[0022] One of the key aspects of the present invention shows that the porous conglomerate, created in situ and later infiltrated by the molten metal has a Vickers hardness of over 1000 Hv_{20}, the wear part thus obtained providing an impact resistance higher than that of the considered pure ceramics and at least equal to $10 MPa\sqrt{m}$.

[0023] According to one of the features of the invention, the reaction in situ between the raw materials, i.e. the reagents for said components, is a chain reaction and it is triggered by the heat of the molten metal by forming a very porous conglomerate capable of being simultaneously infiltrated by the molten metal without significant alteration of the reinforcing structure.

[0024] According to one particularly advantageous embodiment of the invention, the reaction between the raw materials takes place at atmospheric pressure and without any particular protective gaseous atmosphere and without the need for compression after the reaction.

[0025] The raw materials intended to produce the component belong to the group of ferrous alloys, preferably of FerroTi, FerroCr, FerroNb, FerroW, FerroMo, FerroB, FerroSi, FerroZr or FerroV, or belong to the group of oxides, preferably TiO_2, FeO, Fe_2O_3, SiO_2, ZrO_2, CrO_3, Cr_2O_3, B_2O_3, MoO_3, V_2O_5, CuO, MgO and NiO or even to the group of metals or their alloys, preferably iron, nickel, titanium or aluminium and also carbon, boron or nitride compounds.

Brief description of the figures

[0026] Figure 1 shows a barbitone 1 spread over the areas where the cast part 2 in the mould 1 is to be reinforced.

[0027] Figure 2 shows the invention in the form of reinforcing inserts 3 in the part to be cast 2 in the mould 1.

[0028] Figures 3, 4 and 5 show hardness impressions for a casting with chrome (Fig. 3), a pure ceramic (Fig. 4) and an alloy (Fig. 5) reinforced with ceramic as in the present invention.

[0029] Figure 6 shows particles of TiC in an iron alloy, resulting from a reaction in situ of FeTi with carbon to produce TiC in an iron-based matrix. The size of the TiC particles is of the order of a few microns.

Detailed description of the invention

[0030] The present invention proposes cast parts whose wear surfaces are reinforced by putting in the mould, before casting, materials comprising powders that are able to react in situ and under the sole action of the heat of the casting.

[0031] To this end, reagents in compacted powders are used and placed in the mould in the form of wafers or inserts 3 in the required shape, or alternatively in the form of a coating 4 covering the mould 1 where the part 2 is to be reinforced.

[0032] The materials that can react in situ produce hard compounds of carbides, borides, oxides, nitrides or intermetallic compounds. These, once formed, combine with any possible carbides already present in the casting alloy so as to further increase the proportion of hard particles with a hardness of Hv>1300 that contribute to the wear resistance. The latter are "infiltrated" at about 1500°C by the molten metal and form an addition of particles resistant to abrasion incorporated into the structure of the metal used for the casting (Fig. 6).

[0033] Moreover, in contrast to the methods of the state of the art, it is not necessary to use pure metallic powders to obtain this reaction in situ. The method proposed advantageously allows to use inexpensive ferrous alloys or oxides in order to obtain extremely hard particles embedded in the matrix formed by the casting metal where reinforcement of the wear resistance is required.

[0034] Not only does the invention require no subsequent compaction, that is compression, of the areas with reinforced structure, but it benefits from the porosity thus created in said areas to allow the infiltration of the molten metal into the gaps at high temperature (Fig. 6).

[0035] This requires no particular protective atmosphere and takes place at atmospheric pressure with the heat provided by casting, which clearly has a particularly positive consequence on the cost of the method. A structure with very favourable features in terms of the simultaneous resistance to impact and abrasion is thus obtained.

[0036] The hardness values achieved by the particles thus embedded into the reinforced surfaces are in the range of 1300 to 3000 Hv. Following the infiltration by the casting metal, the compound obtained has a hardness higher than 1000 Hv_{20} whilst retaining an impact resistance higher than $10MPa\sqrt{m}$. The impact resistance is measured by indentation, which means that a dent is made by means of a diamond piercing tool of pyramidal shape at a calibrated load.

As a result of the load, the material is bent and may develop cracks at the corners of the dent. The length measurement of the cracks allows the impact resistance to be calculated (Figures 3, 4 and 5).

[0037] The raw materials intended to produce the component belong to the group of ferrous alloys, preferably of FerroTi, FerroCr, FerroNb, FerroW, FerroMo, FerroB, FerroSi, FerroZr or FerroV, or they belong to the group of oxides, preferably TiO_2, FeO, Fe_2O_3, SiO_2, ZrO_2, CrO_3 Cr_2O_3, B_2O_3, MoO_3, V_2O_5, CuO, MgO and NiO or to the group of metals or their alloys, preferably iron, nickel, titanium or aluminium and also carbon, boron or nitride compounds.

[0038] By way of an example, the reactions used in the present invention are generally of the type:

$FeTi + C \rightarrow TiC + Fe$

$TiO_2 + Al + C \rightarrow TiC + Al_2O_3$

$Fe_2O_3 + Al \rightarrow Al_2O_3 + Fe$

$Ti + C \rightarrow TiC$

$Al + C + B_2O_3 \rightarrow B_4C + Al_2O_3$

$MoO_3 + Al + Si \rightarrow MoSi_2 + Al_2O_3$

These reactions may also be combined.

[0039] The reaction speed may also be controlled by the addition of different metals, alloys or particles which do not take part in the reaction. These additions may moreover advantageously be used in order to modifythe impact resistance or other properties of the composite created in situ according to requirements. This is shown by the following illustrative reactions:

$Fe_2O_3 + 2Al + xAl_2O_3 \rightarrow (1+x) Al_2O_3 + 2Fe$

$Ti + C + Ni \rightarrow TiC + Ni$

Description of a preferred embodiment of the invention

[0040] The first preferred embodiment of the invention consists in compacting the chosen reactive powders by simple cold pressure. This takes place in a compression mould bearing the desired shape of the insert or the preformed shape 3, possibly in the presence of a binding agent, for the reinforcement of the cast part 2. This insert or preformed shape will then be placed into the casting mould 1 in the desired place.

[0041] For the powders, a particle size distribution is chosen with a D50 between 1 and 1000 microns, preferably lower than 100μ. Practical experience has shown that this particle size was the ideal compromise between the handling of the raw materials, the ability of the porous product to be infiltrated and the control of the reaction.

[0042] During casting, the hot metal triggers the reaction of the preformed shape or of the insert which transforms into a conglomerate with a porous structure of hard particles. This conglomerate, still at high temperature, is itself infiltrated and embedded in the casting metal making up the part. This step is carried out between 1400 and 1700°C depending on the casting temperature of the alloy chosen to make the part.

[0043] A second preferred embodiment is the use of a barbitone (paste) 4 containing the various reagents so as to coat certain areas of the mould 1 or of the cores. The application of one or more layers is possible depending on the thickness desired. These different layers are then allowed to dry before the metal is poured into the mould 1. This molten metal also serves to trigger the reaction in order to create a porous layer which is infiltrated immediately after its reaction to form a structure that is particularly resistant both to impact and wear.

CLAIMS

1. Cast wear part comprising a reinforced structure, said reinforced structure comprising at least one component selected from the group of metallic carbides, of metallic nitrides, of borides, of metallic oxides and of intermetallic compounds, characterised in that

- said components are formed by a reaction in situ from raw materials acting as reagents for said components, said reagents being first put into a mould (1) before casting, in the form of inserts or preformed shapes of compacted powders (3) or in the form of barbitones (4),
- the reaction in situ of said powders is triggered by the casting of a metal,
- said reaction in situ forms a porous conglomerate,
- said casting metal infiltrates said porous conglomerate, resulting in an inclusion of said conglomerate in the structure of the metal used for the casting, thus creating a reinforced structure on the wear part (2).

2. Wear parts as in Claim 1, characterised in that said porous conglomerate is created in situ and is infiltrated by the cast metal, in that said conglomerate has a Vickers hardness between 1300 and 3000 Hv, and in that said reinforced structure on the wear part has an impact resistance of over $10 MPa\sqrt{m}$.

3. Method for the production of wear parts with a structure reinforced by at least one component selected from the group of metallic carbides, of metallic nitrides, of borides, of metallic oxides, and of intermetallic compounds, characterised in that:

- said components are formed by a reaction in situ from raw materials acting as reagents for said components, said reagents being first put into a mould (1), before casting, in the form of inserts or preformed shapes of compacted powders (3) or in the form of barbitones (4),

- the reaction in situ of said powders is triggered by the casting of a metal,
- said reaction in situ forms a porous conglomerate,
- said casting metal infiltrates said porous conglomerate resulting in an inclusion of said conglomerate in the structure of the metal used for the casting, thus creating a reinforced structure on the wear part (2),
- said reaction in situ between the raw materials intended to form said components after said reaction is triggered and sustained by the heat of the molten metal.

4. Method for the production of the wear parts as in Claim 3, characterised in that the reaction between the raw materials forms a very porous conglomerate capable of being simultaneously infiltrated by the cast metal without any particular alteration of the reinforced structure.

5. Method for the production of wear parts as in Claim 3 or 4, characterised in that the reaction between the raw materials takes place at atmospheric pressure without the method requiring any compression after reaction of the powders.

6. Method for the production of wear parts as in any one of Claims 3 to 5, characterised in that the reaction between the raw materials does not require any specific gaseous protective atmosphere.

7. Method for the production of wear parts as in any one of Claims 3 to 6, characterised in that said raw materials belong to the group of ferrous alloys, preferably FerroTi, FerroCr, FerroNb, FerroW, FerroMo, FerroB, FerroSi, FerroZr and FerroV.

8. Method for the production of wear parts as in any one of Claims 3 to 6, characterised in that said raw materials belong to the group of oxides, preferably TiO_2, FeO, Fe_2O_3, SiO_2, ZrO_2, CrO_3, Cr_2O_3, B_2O_3, MoO_3, V_2O_5, CuO, MgO and NiO.

9. Method for the production of wear parts as in any one of Claims 3 to 6, characterised in that said raw materials belong to the group of metals or their alloys, preferably iron, titanium, nickel or aluminium.

10. Method for the production of wear parts as in any one of Claims 3 to 6, characterised in that said raw materials include carbon, boron, or nitride compounds.

11. Use of the wear parts produced according to any one of the preceding claims for applications requiring resistance to both wear and impact.

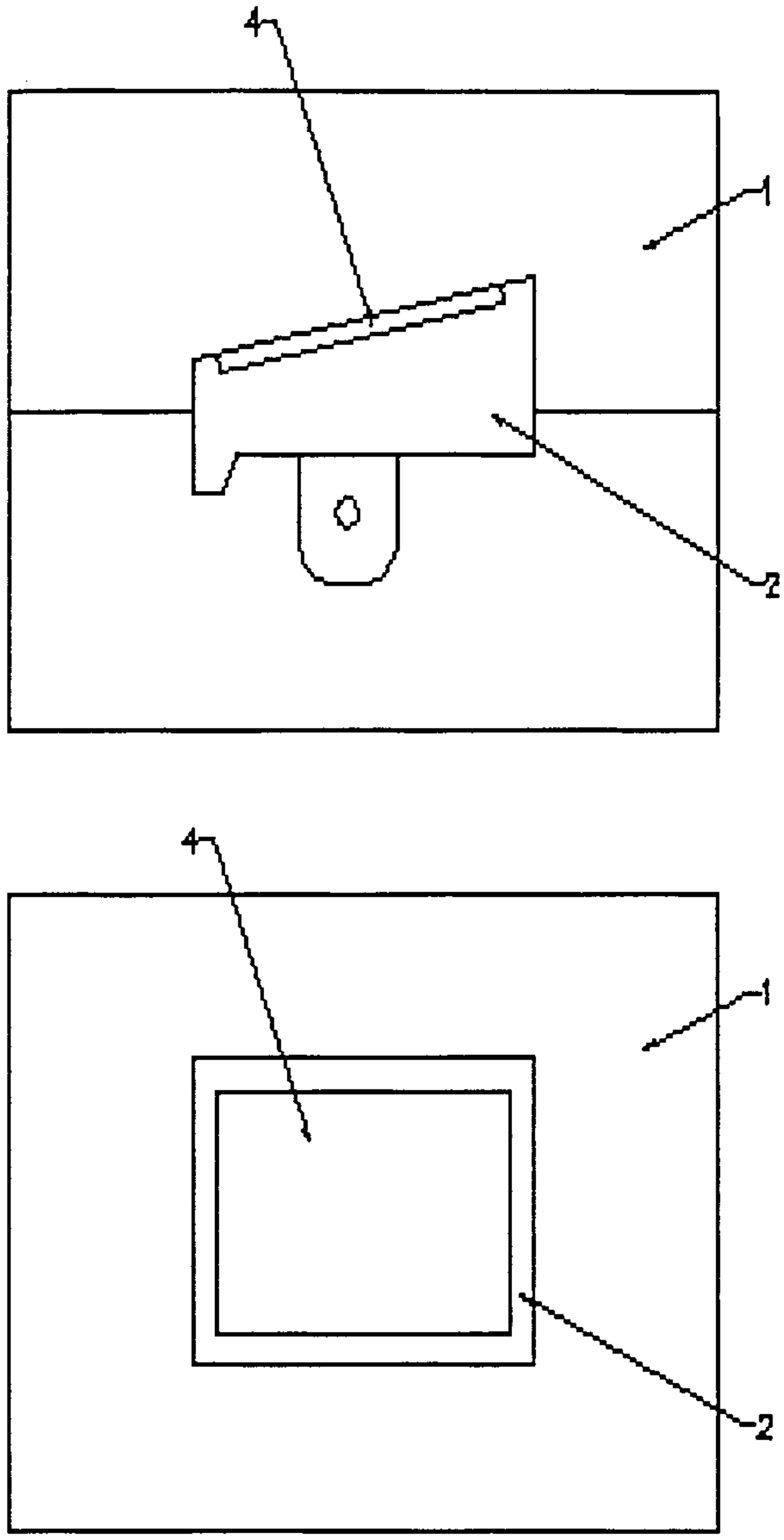

Fig.1

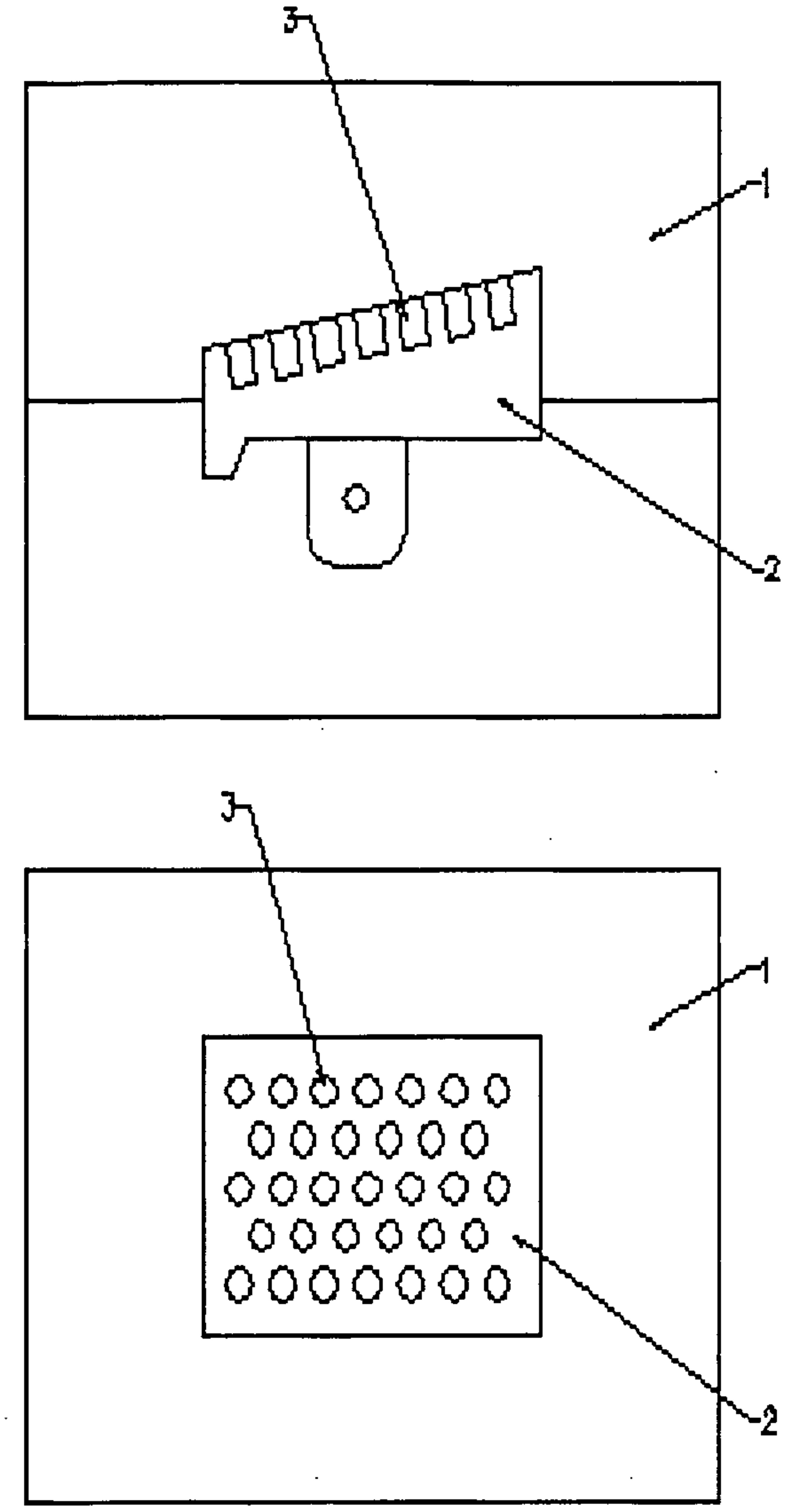

Fig.2

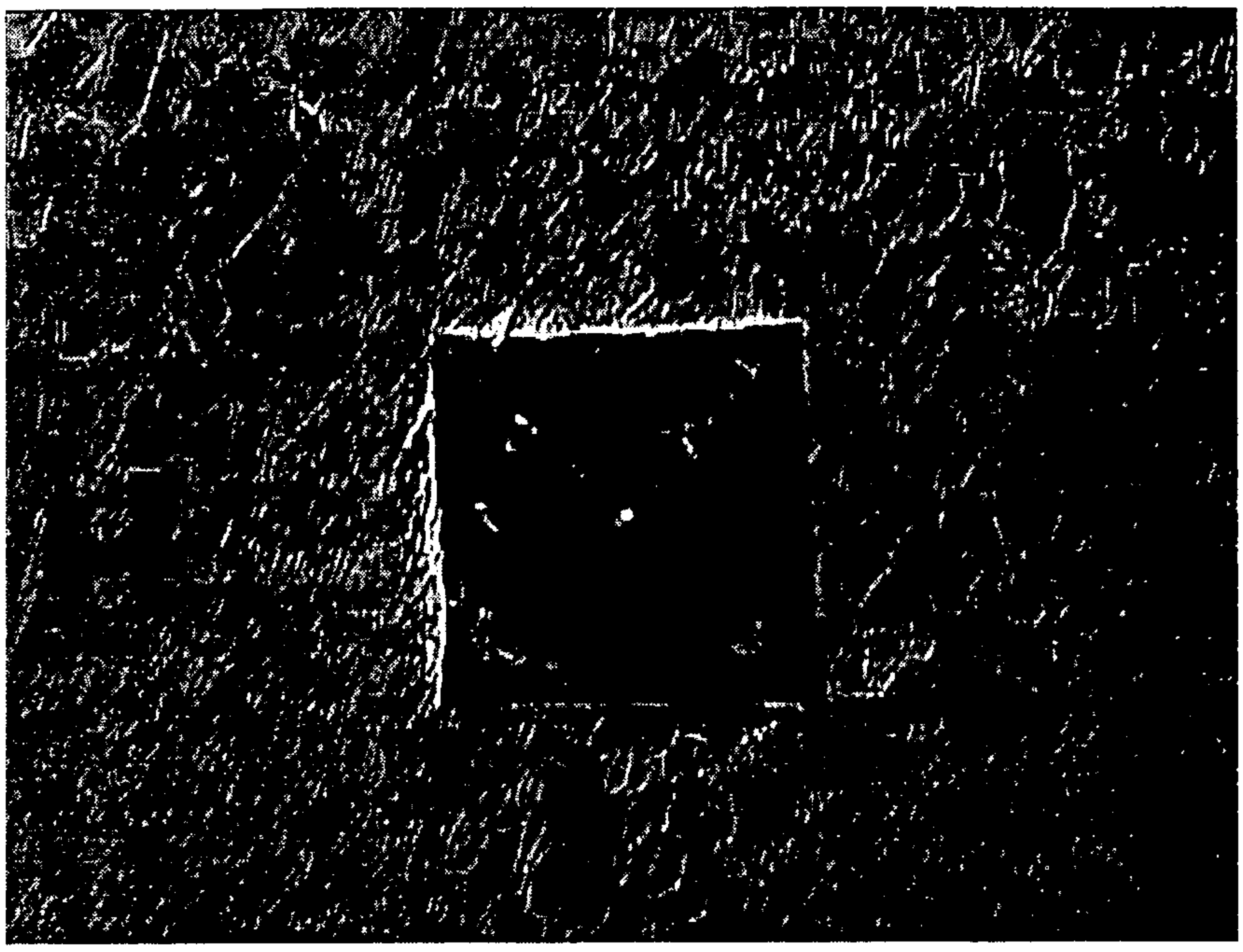

Fig.3

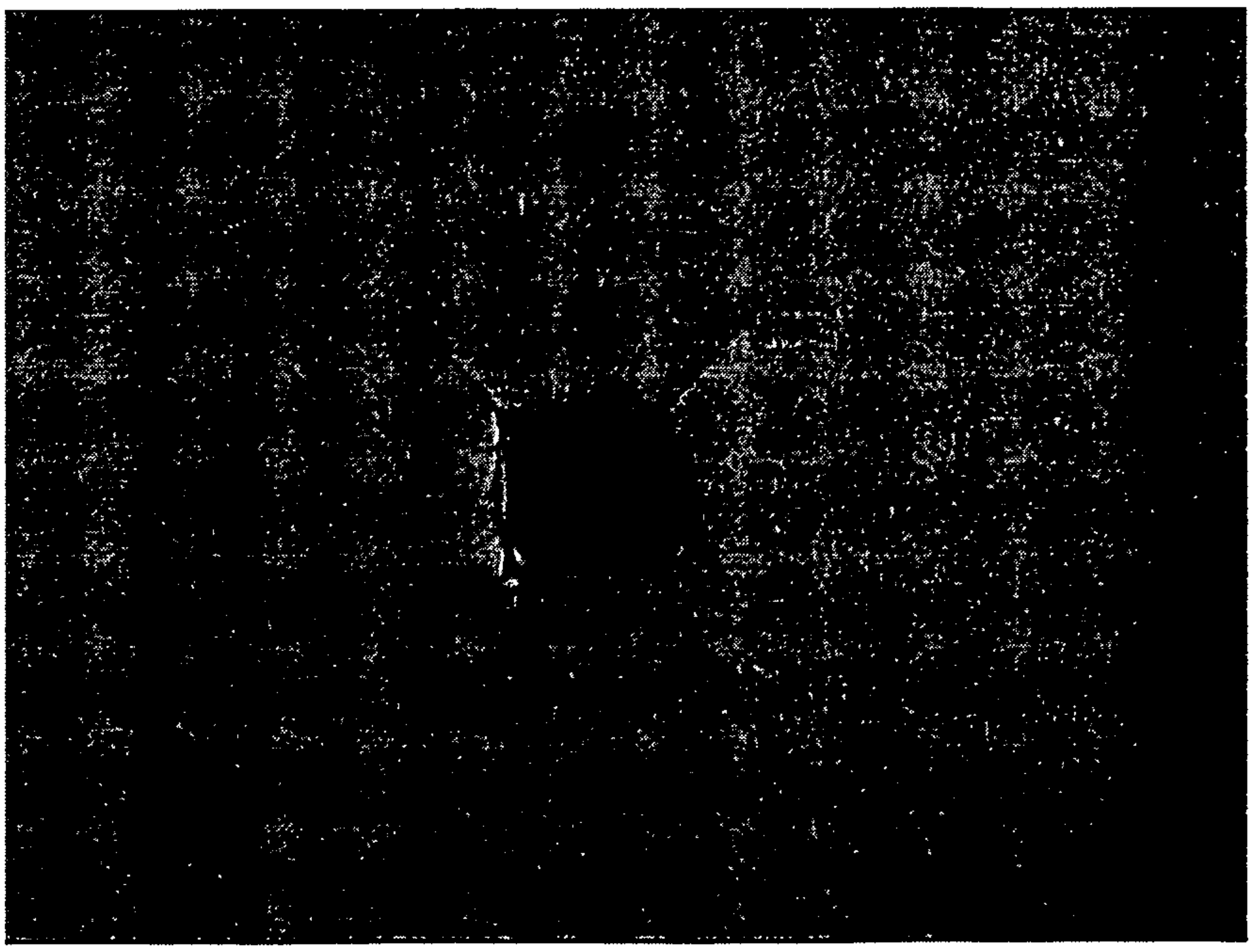

Fig.4

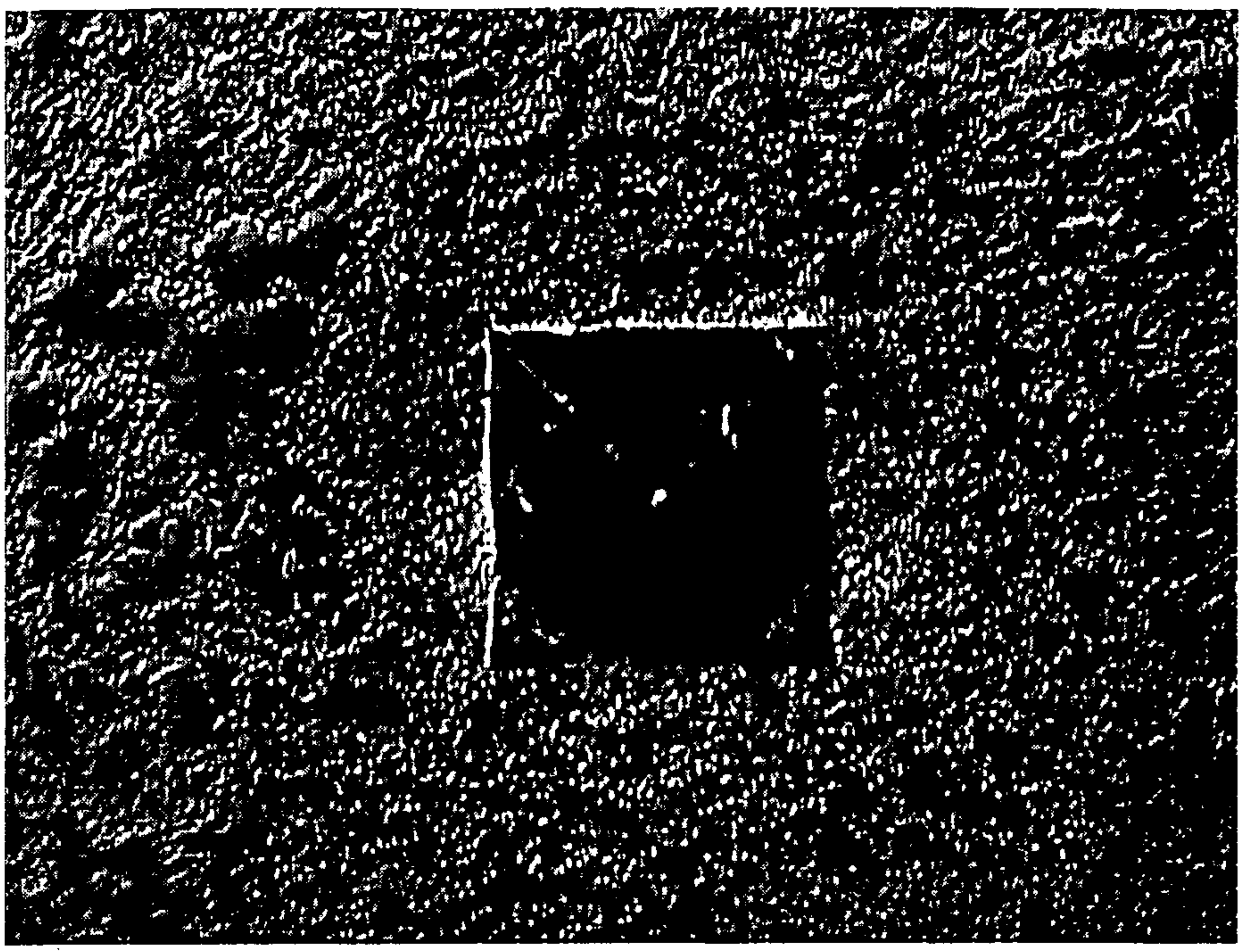

Fig.5

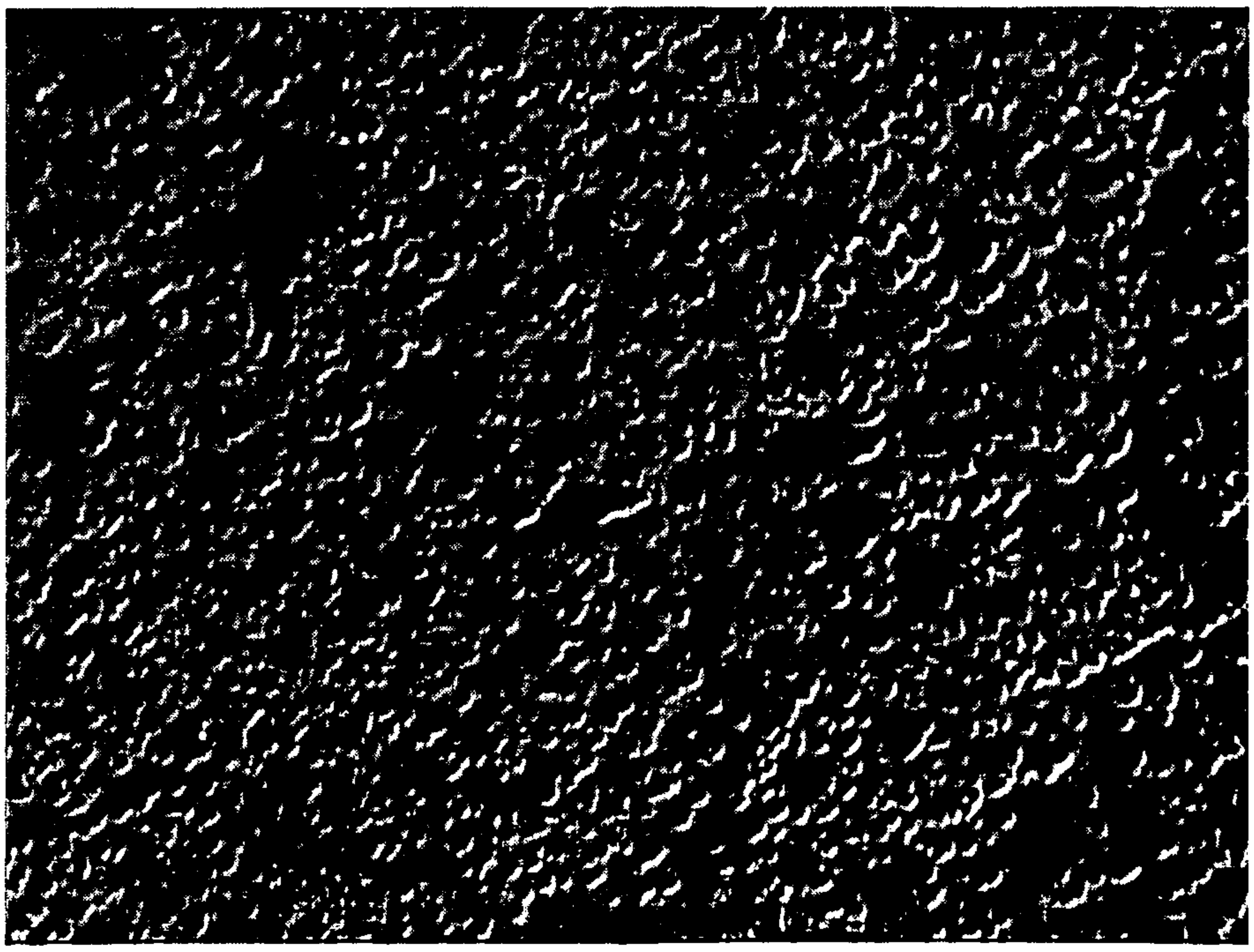

Fig.6