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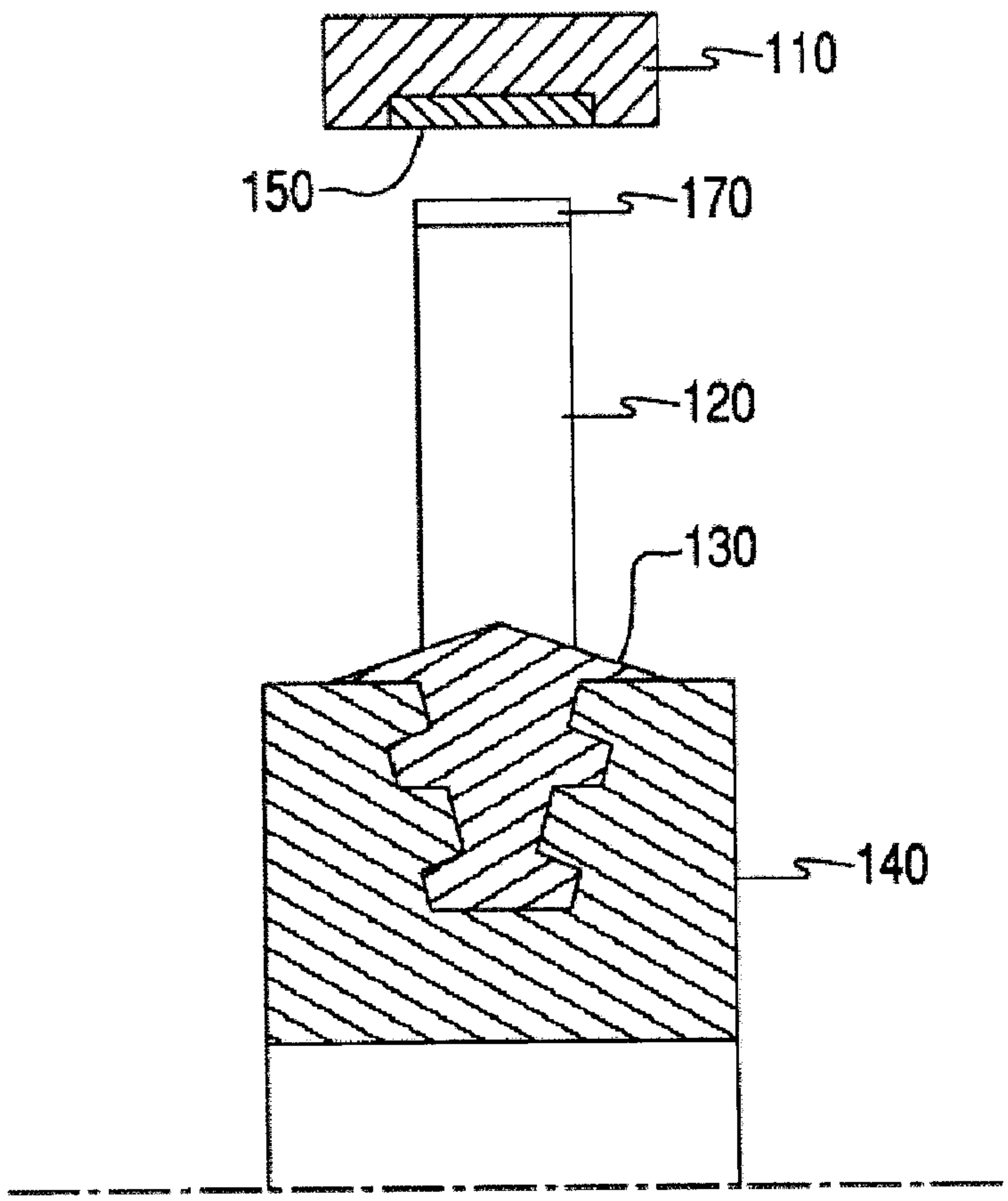
(72) **Inventeurs/Inventors:**
NICOLL, ANDREW, CH;
WILSON, SCOTT, CH

(73) **Propriétaire/Owner:**
SULZER METCO (US) INC., US

(74) **Agent:** GOWLING LAFLEUR HENDERSON LLP

(54) Titre : MATERIAU CERAMIQUE ABRADABLE CONTENANT UN DOPANT A BASE D'ALUMINE

(54) Title: CERAMIC ABRADABLE MATERIAL WITH ALUMINA DOPANT



(57) Abrégé/Abstract:

The invention provides an abradable ceramic seal material comprising yttria (Y_2O_3) stabilized zirconia (ZrQ_2) doped with alumina (Al_2O_3). Furthermore, the invention provides a gas turbine system, comprising at feast one turbine blade; an abrasive tip affixed on

(57) Abrégé(suite)/Abstract(continued):
a top surface of the at least one turbine blade; a shroud housing the at least one turbine blade; and an abradable seal deposited between the at least one turbine blade and the shroud, wherein the abradable seal includes yttria stabilized zirconia that is doped with 0.5 to 1 wt. % of alumina. In addition, the invention provides a method of forming a powder for abradable coatings.

Abstract

The invention provides an abradable ceramic seal material comprising yttria (Y_2O_3) stabilized zirconia (ZrO_2) doped with alumina (Al_2O_3). Furthermore, the invention provides a gas turbine system, comprising at least one turbine blade; an abrasive tip affixed on a top surface of the at least one turbine blade; a shroud housing the at least one turbine blade; and an abradable seal deposited between the at least one turbine blade and the shroud, wherein the abradable seal includes yttria stabilized zirconia that is doped with 0.5 to 1 wt. % of alumina. In addition, the invention provides a method of forming a powder for abradable coatings.

CERAMIC ABRADABLE MATERIAL WITH ALUMINA DOPANT

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The invention relates to ceramic clearance control (abradable) materials for high temperature applications, and more particularly to a ceramic abradable material that is doped with alumina, whereby the addition of alumina imparts a significant improvement in erosion resistance to the abradable compared to other commercially available ceramic abradables.

Description of the Related Art

[0002] Gas turbine engines are used in a variety of applications, including aircraft engines and various other industrial applications where operating temperatures may be in the range of 1000 - 1200 degrees Celsius and higher. A gas turbine engine is an internal-combustion engine that is typically made up of an air compressor, combustion chamber, and turbine wheel that is turned by the expanding products of combustion. It essentially converts the chemical energy of a liquid fuel into mechanical energy by internal combustion. The operational efficiency of gas turbine engines increases with the rise in operational temperatures which can place components under increased stress as well as subject those components to thermal expansion.

[0003] In order to maximize efficiency in the operation of turbine engines, it is desirable to minimize the clearances between the turbine blade tips and the outer casing or shroud. Too large a clearance will result in poor fuel efficiency in order to provide the desired operational speeds, while too small of a clearance risks contact between the turbine blade tips and the outer casing which can result in component failure. To solve this problem, conventional gas turbine engines include an abradable coating or seal that is applied to the surface of the outer casing and/or seal. These abradable coatings or seals can be cut by the rotating turbine blades without damaging the turbine blades. In addition, the abradable coatings or seals must remain resistant to erosion that is caused by small solid particles and high gas flow rates present in the turbine. Erosion refers to wear caused by a stream of small particles and is analogous to abrasive wear.

[0004] The abradable coating or seal must also have good abradability, spall resistance, low gas permeability, a smooth surface, good aging properties and long term oxidation resistance.

[0005] Conventional gas turbine engines may utilize porous ceramic abradable materials, such as yttria stabilized zirconia (YSZ) (8 wt. % Y_2O_3, bal. ZrO_2). Although such YSZ materials are suited for use as abradable materials, they are relatively friable and susceptible to erosive wear effects. Thus, there is a continued need for superior abradables with acceptable abradability performance and erosion resistance so that tolerances can be optimized even further to achieve improved efficiency and performance.

SUMMARY

[0006] Accordingly, the invention is directed to a ceramic abradable material used for clearance control between turbine blade tips and the shroud or casing in gas turbine engines for industrial and/or aerospace applications. The ceramic abradable in accordance with the invention is a soft abradable material that provides for increased erosion resistance as well as the ability of the turbine blade tips to cut into the abradable without causing them damage. These properties allow for optimum tolerances within the gas turbine engine which results in superior efficiency and performance.

[0007] The invention provides a ceramic abradable material that includes an yttria stabilized zirconia (YSZ) that is doped in alumina (Al_2O_3). In accordance with one embodiment of the invention, about 0.5 to 1 wt. % of alumina is added to a standard yttria stabilized zirconia (e.g., about 8 wt. % Y_2O_3, balance ZrO_2). The abradable composition in accordance to the invention demonstrates a four- to five-fold improvement in the erosion resistance by solid particles and high gas flow rates as compared to conventional YSZ abradable materials.

[0008] In accordance with embodiments of the invention, the invention also provides for the application of the alumina doped yttria stabilized zirconia composition for sealing components in a gas turbine engine. This includes applying the abradable material as a seal between the turbine blades and the casing or shroud housing the gas turbine engine.

[0009] Thus, the invention provides a ceramic abradable having superior erosion resistance, abradability, spall resistance, low gas permeability, a smooth surface, good aging properties and long term oxidation resistance

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings are included to provide further understanding of the invention and are incorporated in and constitute a part of this specification. The accompanying drawings illustrate embodiments of the invention and together with the description serve to explain the principles of the invention. In the figures:

[0011] Fig. 1 illustrates a cross sectional view of a section of a gas turbine engine with the abradable material in accordance with the invention;

[0012] Fig. 2 shows the surface of a blade tip with a protective cubic boron nitride abrasive coating applied to its surface;

[0013] Fig. 3 illustrates a testing facility for testing the ceramic abradable material in accordance with an embodiment of the invention;

[0014] Fig. 4 illustrates a typical test matrix or "wear map" used for evaluating the abradability performance of ceramic abradable against cBN;

[0015] Fig. 5 provides a comparison chart of blade wear and erosion resistance for selected abradable seal materials; and

[0016] Fig. 6 provides a flow chart of a method for forming a powder for abradable coatings according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0018] Fig. 1 illustrates a cross-sectional view of a section of a gas turbine engine. Fig. 1 shows a blade 120 that is affixed to a blade root 130 and disc 140. The disc 140 is driven so as to impart rotational movement to the blade 120. The blade 120 also has an abrasive tip 170 that may be made of an abrasive material, such as cubic boron nitride (cBN) embedded in a creep resistant alloy matrix. Fig. 1 also shows the casing segment 110 or shroud which acts to cover or house the entire gas turbine engine. An abradable seal (material) 150 is provided between the abrasive tip 170 of the blade 120 and the casing segment 110. The abradable seal (material) 150 in accordance with the invention includes yttria stabilized zirconia that is doped with .5 to 1 wt. % of alumina. The yttria stabilized zirconia for use in embodiments of the present invention may be generally in the range of about 6-9 wt. % Y_2O_3, balance ZrO_2. Test results and descriptions below refer to an embodiment using yttria stabilized zirconia having about 8 wt. % Y_2O_3 and a balance of ZrO_2.

[0019] In operation, rotational movement is imparted by the disc 140 to the blade 120. The blade operates at very high rotational speeds and in a high temperature environment. In order to maximize efficiency and performance, the tolerances between the blade 120 and the casing segment 110 are very small and precise. The rotation of the blade 120 causes the abrasive tip 170 to come into repeated contact with the abradable seal 150. The abrasive tip 170 is able to cut into the abradable seal 150 which prevents damage to the blade 120 or to the casing segment 110. The abradable seal 150 in accordance with the invention is also resistant to erosion that may be caused by small solid particles and high gas flow rates.

[0020] Fig. 2 shows the surface of a conventional blade tip 35 that has a conventional protective cubic boron nitride abrasive coating 25 applied to its surface. The abrasive coating 25 material may be, for example, a commercially available cBN material. The blade tip 35 and abrasive coating 25 shown in Fig. 2 have been incursion tested against the alumina doped ceramic abradable according to embodiments of the present invention. Both the blade tip 35 and the coating 25 are shown to have no damage due to contact with a shroud coating made from ceramic abradable material in accordance with an embodiment of the invention.

[0021] Fig. 3 illustrates a testing station 300 for testing the ceramic abradable material in accordance with an embodiment of the invention. In general, the testing station 300 includes a rotor 310, a movable specimen stage 320, and a heating device 330. As shown in Fig. 3, the rotor disc 310 is covered by an insulating casing 315 that allows for re-circulation of hot gases produced by flame combustion of the heating device 330. A blade or knife 318 is provided which is kept in an insulating hot environment for each rotation cycle. The ceramic abradable 360 can be heated up to temperatures of 1200 degrees Celsius and incursion tested against the blade 318 at tip speeds of up to 410 m/s and incursion rates ranging between 2 and 2000 microns per second. The testing station mimics the conditions of a gas turbine engine and the wear on the abradable material 360 can be analyzed.

[0022] Fig. 4 illustrates a typical test matrix or "wear map" used for incursion testing of the abradable material at different blade tip velocities and incursion rates in accordance with the invention. The test conditions illustrated on the wear map give an overview of the nominal blade tip incursion conditions that might be typically encountered in an aero or power turbine.

[0023] Table 1 below provides a descriptive a comparison of the abradable material in accordance with embodiments of the invention, designated "Al_2O_3 doped", as compared with conventional ceramic abradable materials (commercially available materials from Sulzer Metco, SM 2460 and XPT 395). As described earlier, the abradable in accordance with the invention provides for superior erosion resistance, which is discussed further in relation to Fig. 5.

Table 1

Designation	Descritpion	Function
SM 2460	8YSZ, Polyester Spray dried product, un-reacted prior to spraying	Standard ceramic abradable
XPT 395	Standard 8 YSZ, spray dried, HOSP treatment, blended with polyester & hBN and sprayed	Standard ceramic abradable
Al_2O_3 doped	Standard 8 YSZ with alumina addition, spray dried, HOSP treatment, blended with polyester and sprayed	Alumina: erosion resistance

[0024] Fig. 5 provides a comparison chart of blade wear and erosion resistance from testing on shroud seals with conventional ceramic abradable materials (SM 2460 and XPT 395) and those with materials in accordance with an embodiment of the invention (designated "Al_2O_3 doped" in the figure). Shroud coatings of each material were tested according to the procedures outlined above with respect to Fig. 3 and plotted as shown in Fig. 5. Generally, the data shows that use of material in accordance with embodiments of the invention results in up to a four- to five-fold improvement in the coatings resistance to erosion by solid particles, using a standard erosion test, without compromising abradability. The abradability of each coating is represented by the amount of blade wear experienced after an incursion test. The blade wear is measured as a percentage of the total incursion distance experienced by the blade tip during the test. For the three abradable coatings shown in Fig. 5, the percentage blade wear is either slightly positive where material has been removed from the blade tip, or negative, where material from the ceramic abradable has transferred to the blade tip during the cutting process, thereby "growing" it. In terms of erosion resistance, a GE erosion number greater than 1.0 sec/mil is indicative of acceptable erosion resistance for an engine. Both the standard abradables XPT 395 and SM 2460 exhibit GE erosion values of 1.2 and 0.7 sec/mil respectively. The alumina doped abradable has a considerably better erosion resistance at 6.3 sec/mil which, combined with its comparable abradability, makes for a better performing product compared to the two standard abradables.

[0025] Generally, the material according to embodiments of the present invention can be supplied in a number of conventional forms, such as partially stabilized powder form, as an agglomerated powder of the individual constituents, as a slurry of partially stabilized powder, or as a chemical solution. Referring to Fig. 6, a method 700 of forming a powder for abradable coatings is provided. Generally, the abradable composition in accordance with the invention may be manufactured by a conventional spray drying process where, in step 705 the yttria, zirconia and alumina are mixed in accordance with the weight percentages described earlier. In step 710, these materials may be mixed into a mixing tank along with binders, water and defoamants. The resulting mix can be pumped into a tank and fed through a nozzle creating droplets. In step 715, the droplets are sprayed into a high temperature environment which extracts the water, leaving microsized particles that agglomerate to form a precursor spray-dried powder in accordance with the invention. In step 720, the abradable powder may then undergo a further spherodizing (HOSP) process in which the particles are fed through a heavy duty plasma which fuses the material to produce hollow ceramic spherical particles that are a solid solution of the powder precursor constituents.

[0026] Prior to application of the abradable material, the HOSP'ed particles may, in step 725, be screened and blended together with a porosity generator phase (e.g., polyester) and then deposited on the shroud seal segment using plasma thermal spray process. The resulting abradable material may be applied using thermal spraying, in compositions similar to those described in related patent application U.S. Patent No. 6,887,530 and 5,530,050. In one embodiment, for example, blended powders may have a component of yttria stabilized zirconia doped with alumina and a component of ceramic coated plastic. The ceramic coated plastic component is made by attrition milling ceramic fine particles with plastic core particles, causing the ceramic fine particles to bind to the surface of the plastic core without the use of a binder. In another embodiment, a component of yttria stabilized zirconia doped with alumina may be combined with a solid lubricant and a matrix forming metal alloy used to form a three-phase abradable seal. Some commercially available ceramic abradables also employ the use of a hexagonal boron nitride "dislocator" phase to assist with particle removal during blade tip incursion into the coating microstructure, e.g., XPT 395. Similar techniques may also be used in aspects of the present invention.

We claim:

1. An abradable ceramic seal material for turbine seal applications, consisting of yttria (Y_2O_3) stabilized zirconia (ZrO_2) having 6-9 wt. % of yttria, characterized in that the seal material is doped with 0.5 to 1 wt.% alumina (Al_2O_3).

2. The abradable ceramic seal material of claim 1, wherein the material includes 8 wt.% yttria.

3. Use of the ceramic material of claim 1 or 2 for clearance control between turbine blade tips and a shroud in a gas turbine engine.

4. A gas turbine system, comprising:
at least one turbine blade;
an abrasive tip affixed on an end surface of the at least one turbine blade;
a shroud housing the at least one turbine blade; and
an abradable seal deposited between the at least one turbine blade and the shroud,
characterized in that
the abradable seal includes yttria stabilized zirconia that is doped with 0.5 to 1 wt. % of alumina, and the yttria stabilized zirconia comprising 6-9 wt.% of yttria.

5. A method of forming a powder for use in a thermal spray process to produce abradable coatings, the method comprising:
providing a base material consisting of zirconia,
yttria and alumina, mixing the base material with a binder, water and defoamants to form a mixture, and
spray drying the mixture to form a spray-dried powder of micro-sized particles, characterized in that
the base material comprises 6-9 wt. % of yttria and 0.5 to 1 wt. % of alumina.

6. The method of claim 5, wherein the base material is in a partially stabilized powder form, or in the form of an agglomerated powder of the individual constituents,

or in the form of a slurry of partially stabilized powder, or in the form of a chemical solution.

7. The method of claim 5 or 6 further comprising the step of exposing the spray-dried powder to a plasma spherodizing process to produce hollow ceramic spherical particles.

8. The method of claim 7 further comprising the step of blending the hollow ceramic spherical particles with a porosity generator phase.

9. Use of the powder produced according to any one of claims 5 to 8 for applying an abradable seal on a shroud of a gas turbine system using a plasma thermal spray process.

10. A gas turbine system, comprising:
at least one turbine blade;
an abrasive tip affixed on an end surface of the at least one turbine blade;
a shroud housing the at least one turbine blade; and
an abradable seal deposited between the at least one turbine blade and the shroud,
characterized in that
the abradable seal includes yttria stabilized zirconia that is doped with 0.5 to 1 wt. % of alumina, and the yttria stabilized zirconia comprising 8 wt.% of yttria.

CA 02549600 2006-06-07

Application number/numéro de demande: 2549600

Figures: 2

Pages:

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Fig. 1

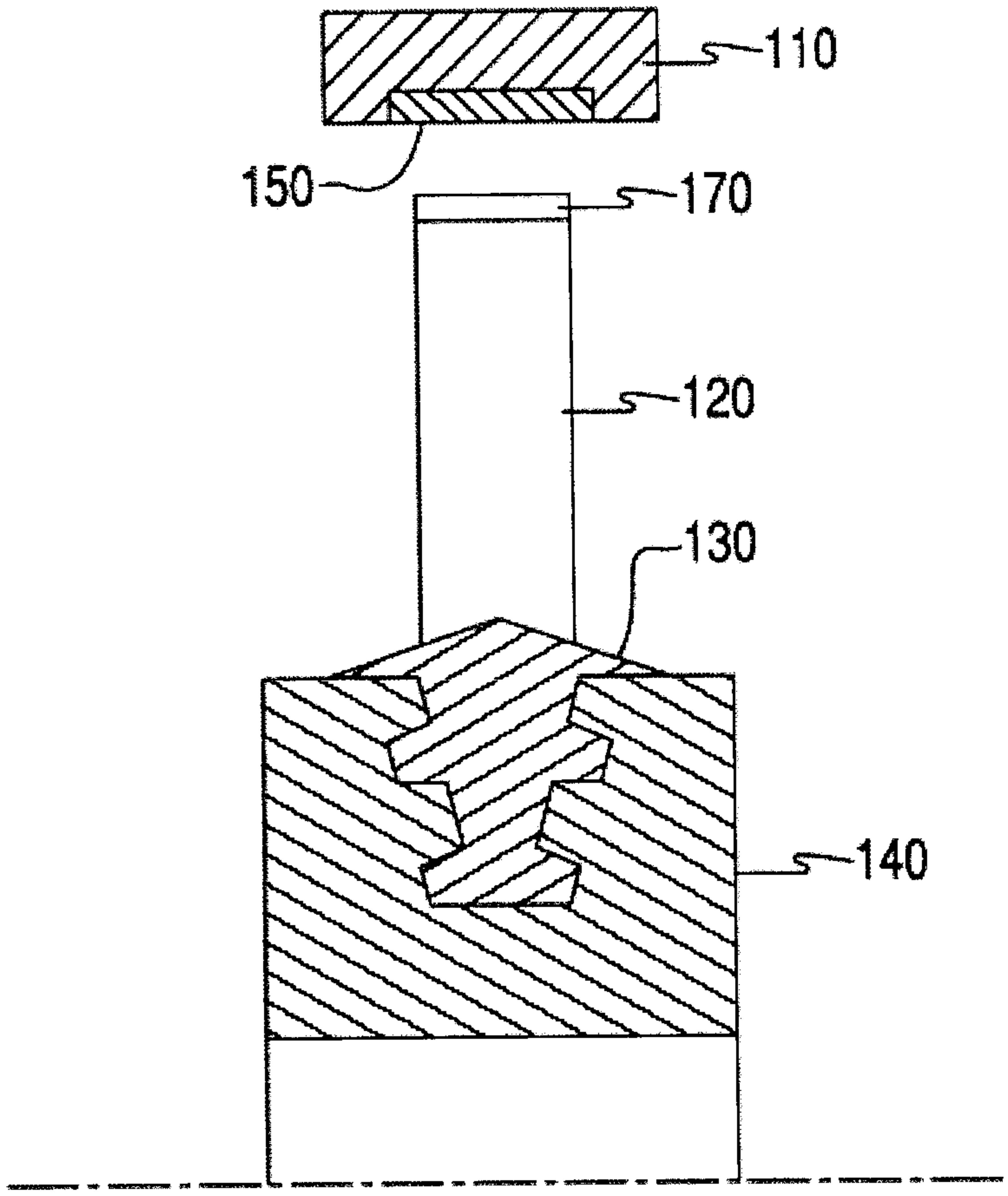


Fig. 3

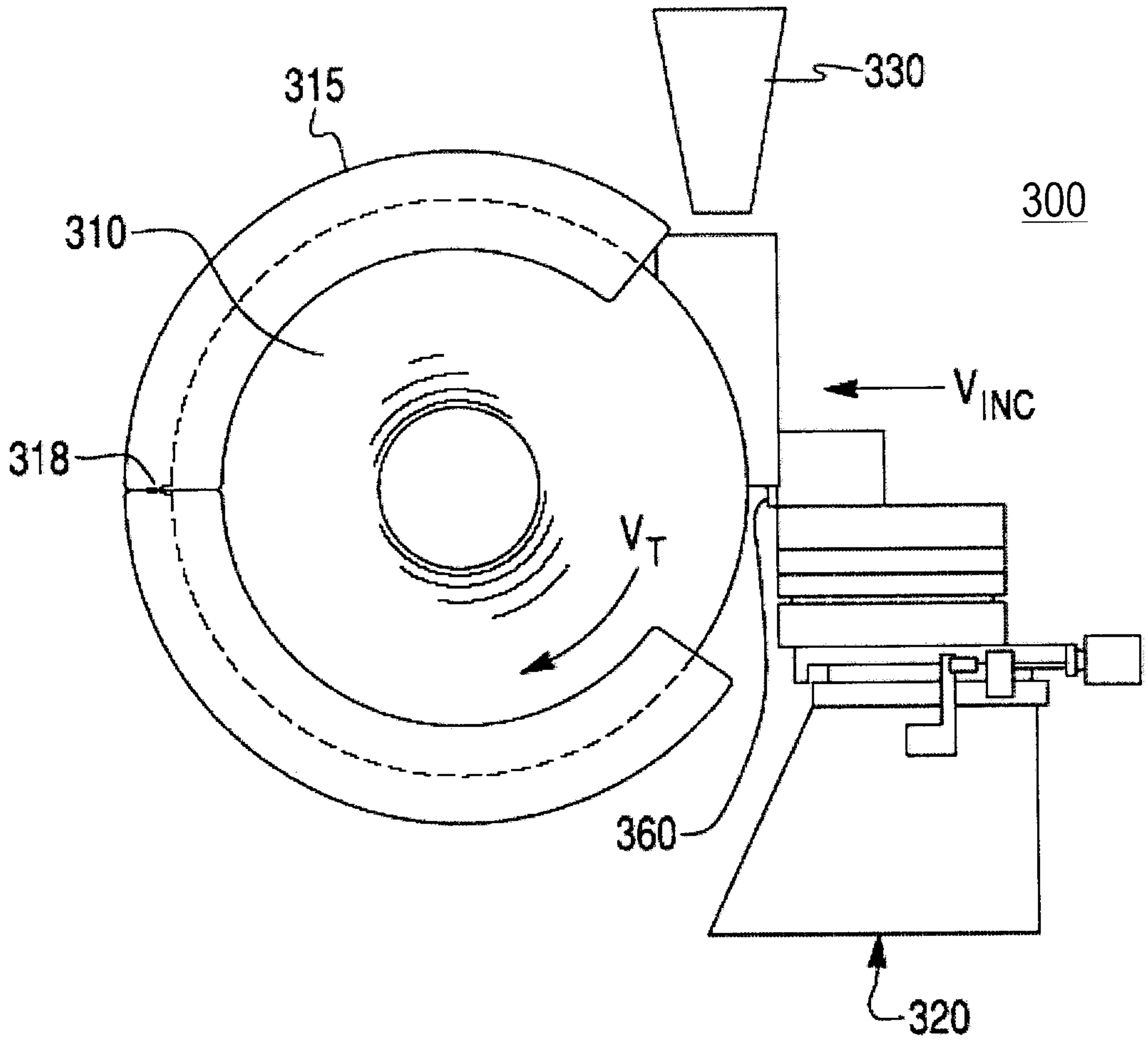
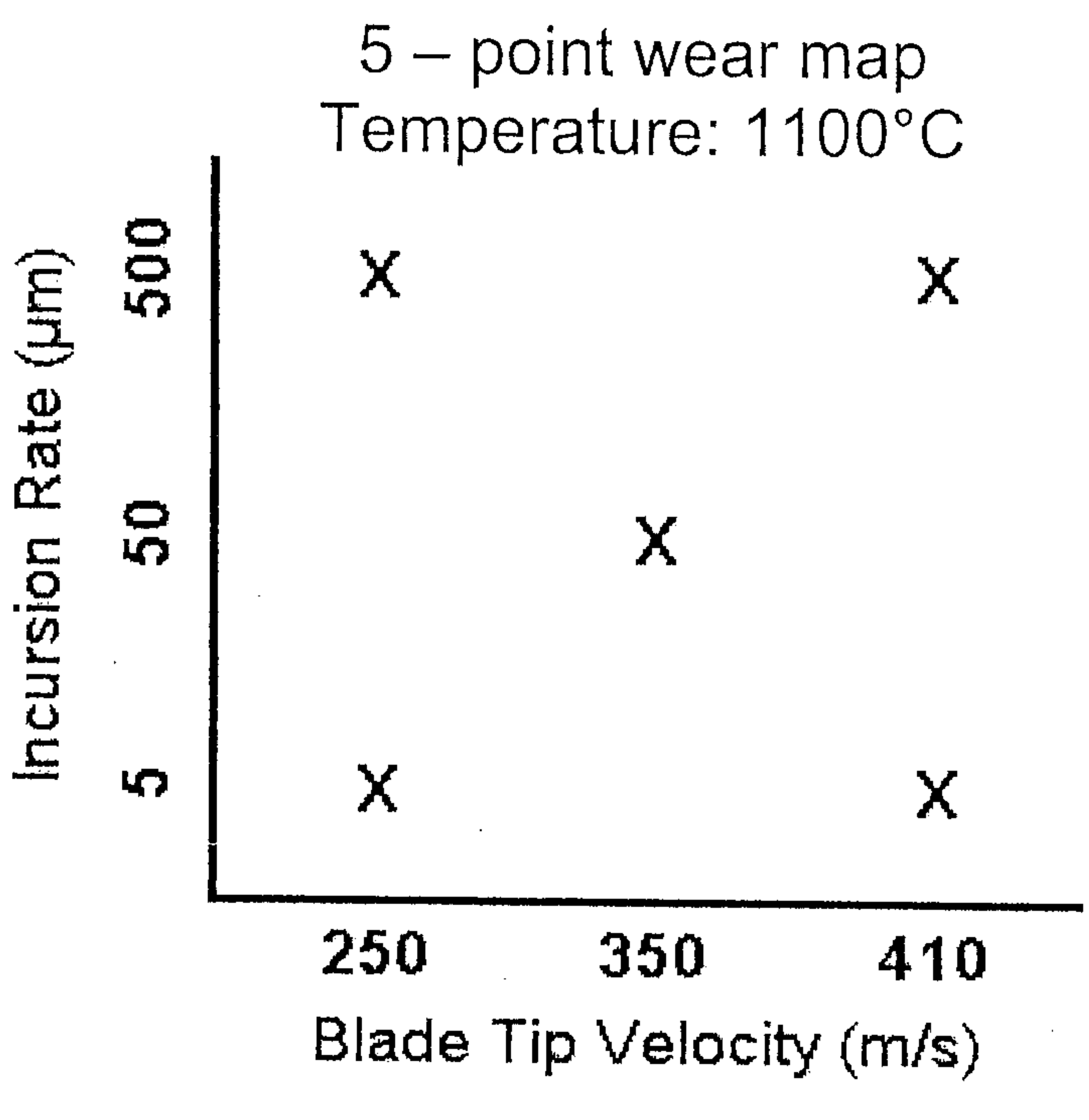
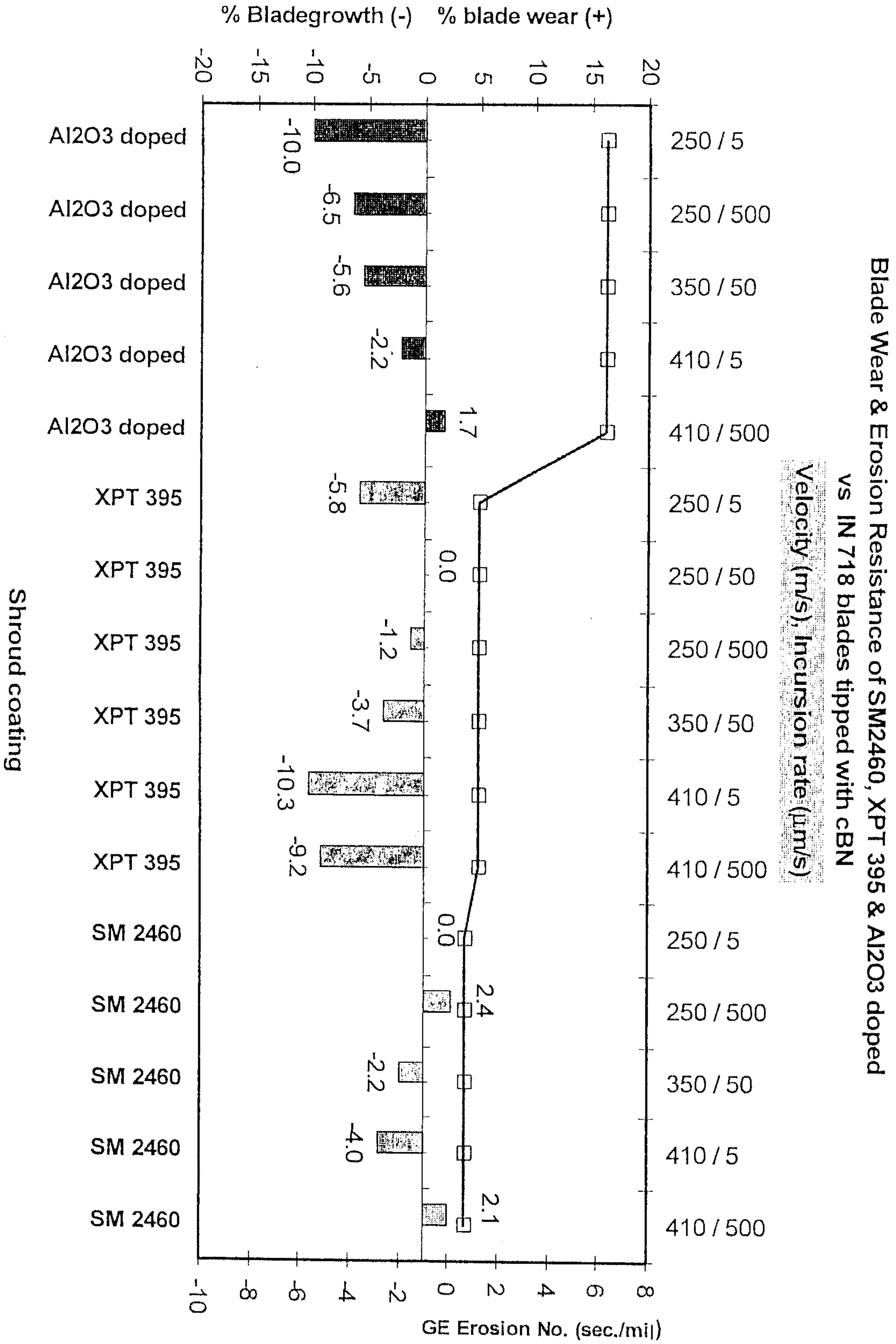


Fig. 4


5 – point wear map
Temperature: 1100°C
Incursion Rate (μm)
500
50
5
X
X
X
X
X
250
350
410
Blade Tip Velocity (m/s)


Blade Wear & Erosion Resistance of SM2460, XPT 395 & Al2O3 doped
vs IN 718 blades tipped with cBN
Velocity (m/s), Incursion rate (µm/s)
% Bladegrowth (-) % blade wear (+)
GE Erosion No. (sec./mil)
Shroud coating
Al2O3 doped
XPT 395
SM 2460
250 / 5
250 / 500
350 / 50
410 / 5
410 / 500
250 / 50
-10.0
-6.5
-5.6
-2.2
1.7
-5.8
0.0
-1.2
-3.7
-10.3
-9.2
0.0
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2.1

Fig. 5

Fig. 6

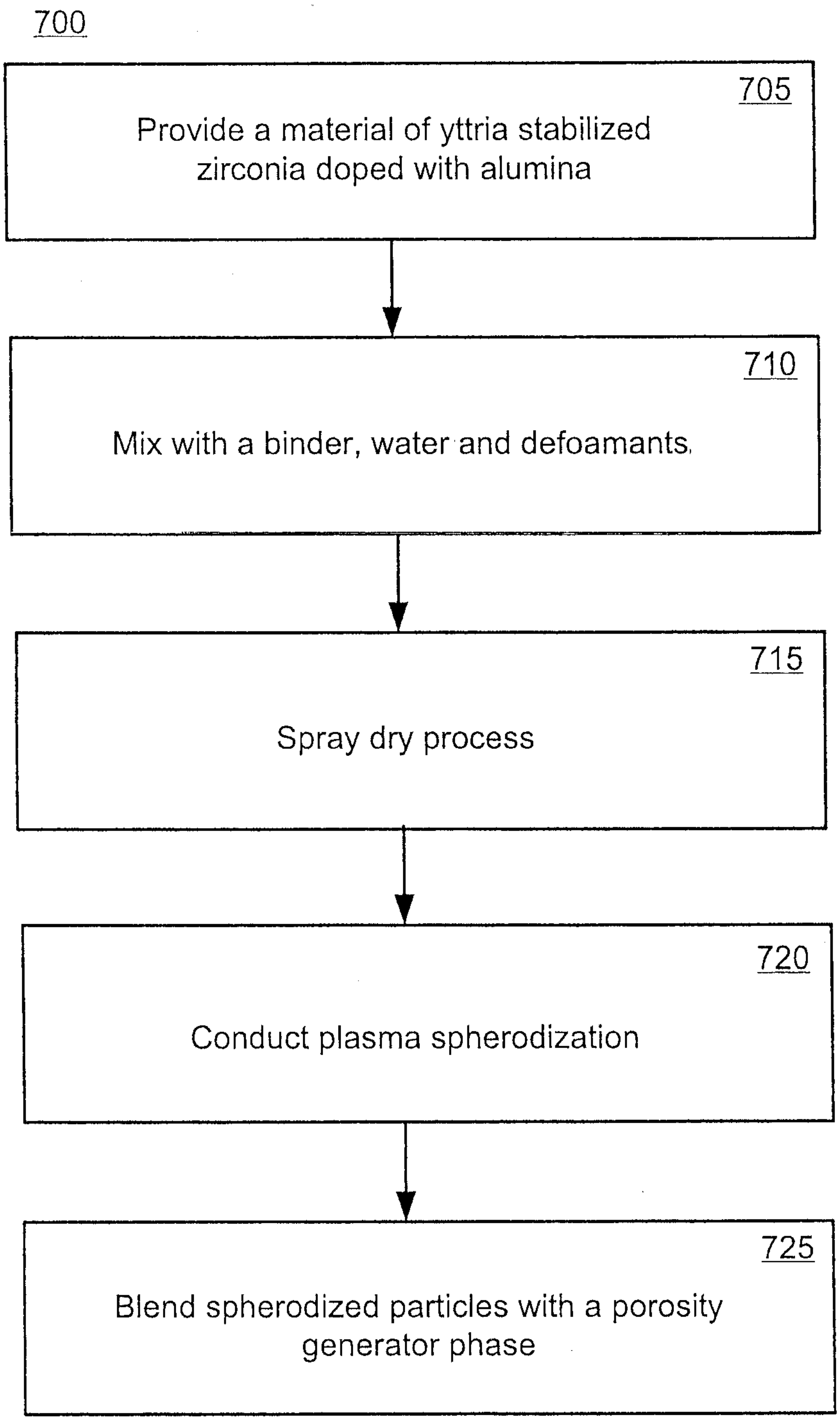
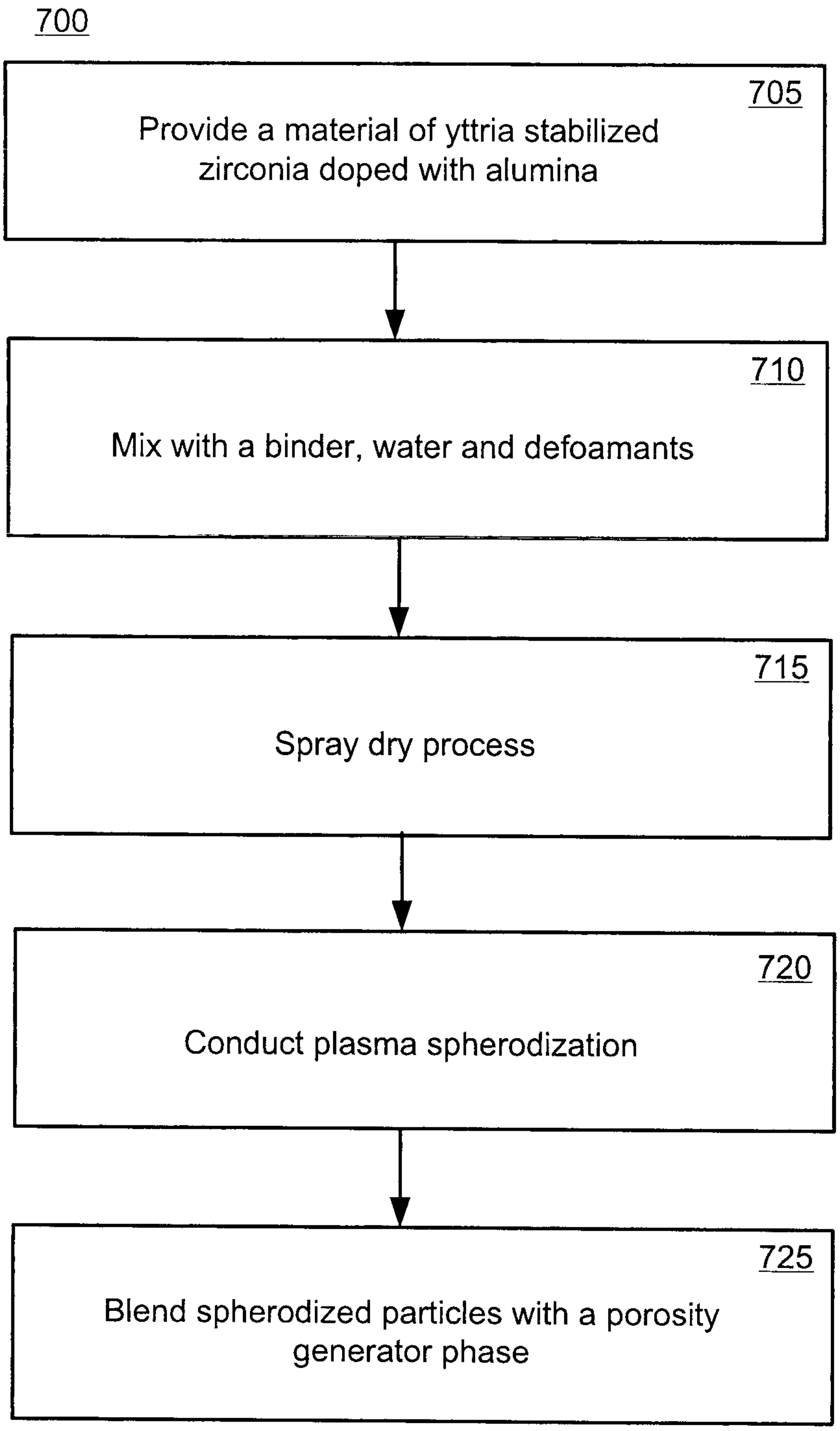

700
705
Provide a material of yttria stabilized zirconia doped with alumina
710
Mix with a binder, water and defoamants.
715
Spray dry process
720
Conduct plasma spherodization
725
Blend spherodized particles with a porosity generator phase

Fig. 7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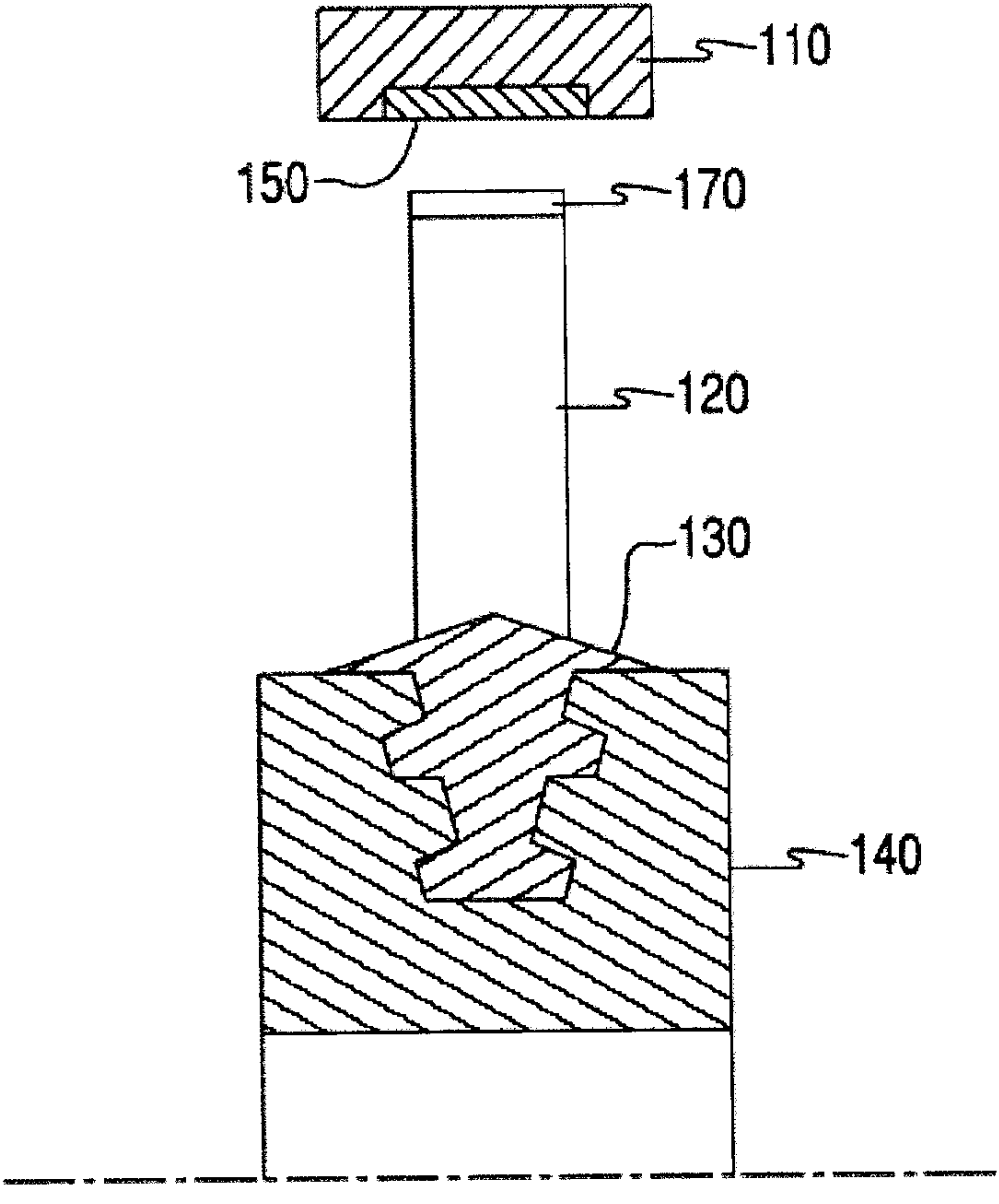
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