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(54) METHOD OF MANUFACTURING A METAL INJECTION MOLDED PART

(57) A green machining process comprises receiving a green body (30) made of powder injection molding material and engaging the green body (30) to a clamp pad (50) engaged to a fixture member (42) of a retaining fixture (40) of a machine tool. The clamp pad (50) has a surface hardness smaller than that of the green body (30). While the green body (30) is supported through the engagement of the clamp pad (50), the green body (30) is machined using the machine tool to obtain a machined green part. The machining operation may be followed by a debinding and a sintering step.

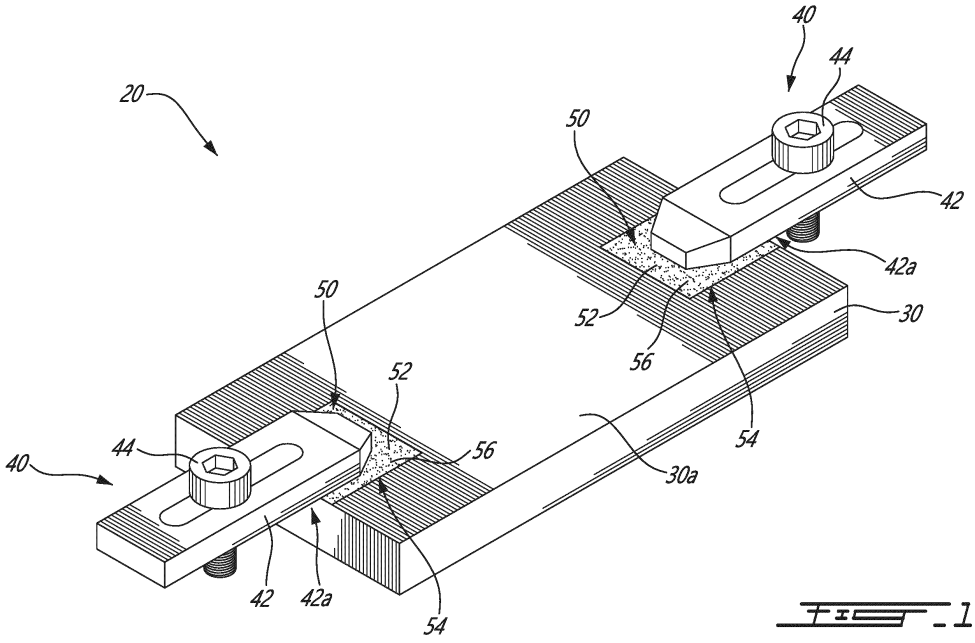

Fig. 1

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Description

TECHNICAL FIELD

[0001] The application relates generally to methods of manufacturing a part made using powder injection molding and, more particularly, to green part(s) obtained by metal injection molding.

BACKGROUND OF THE ART

[0002] Green machining involves the machining of metal bodies in the green state prior to sintering. Metal injection molded (MIM) parts in the green state are fragile. During green machining operation, the green body has to be held in place with enough load to handle the machining operation. However, because of its fragile state, there may be a risk of breaking or damaging the green body upon applying such load.

[0003] A standard process when machining a metallic part is to use a retaining fixture to hold the part in place. However, in some circumstances, the retaining fixture may slip on the part and therefore may not hold firmly the part in place which may result in either a scrap part or an out of tolerance part.

[0004] Accordingly, improvements in manufacturing methods for MIM parts are needed.

SUMMARY

[0005] In one aspect, there is provided a method of manufacturing a part, comprising: receiving a green body made of powder injection molding material, the powder injection molding material including a binder and a metallic powder material mixed with the binder, the green body having a first surface hardness; engaging the green body to a clamp pad engaged to a fixture member of a retaining fixture of a machine tool, the clamp pad having a second surface hardness smaller than the first surface hardness; while supporting the green body through the engagement of the clamp pad, machining the green body using the machine tool to obtain a machined green part; and debinding and sintering the machined green part.

[0006] The method as defined above and described herein may further include one or more of the following features/steps, in whole or in part, and in any combination.

[0007] In any of the aspects or embodiments described above and herein, the method may further comprise, prior to debinding and sintering, disengaging the clamp pad from the machined green part.

[0008] In any of the aspects or embodiments described above and herein, engaging the green body to the clamp pad may maintain the green body in a fixed position during the machining.

[0009] In any of the aspects or embodiments described above and herein, machining the green body may include rotating the green body with the clamp pad and the fixture member.

[0010] In any of the aspects or embodiments described above and herein, the method may further comprise connecting the clamp pad to the fixture member by engaging (e.g. by an interference fit or snuggly engaging) first and second complementary locating features with one another. The first locating feature may be provided on the clamp pad. The second locating feature may be provided on the fixture member.

[0011] In any of the aspects or embodiments described above and herein, the method may further comprise using a fastener to fasten the clamp pad to the fixture member.

[0012] In any of the aspects or embodiments described above and herein, the method may further comprise selecting the clamp pad from a set of clamp pads having different configurations of a green-body-engaging surface, the clamp pad being selected based on the green-body-engaging surface thereof and on a surface profile of the green body.

[0013] In any of the aspects or embodiments described above and herein, the method may further comprise selecting the clamp pad is based on a configuration of at least one of the fixture member and the machine tool.

[0014] In any of the aspects or embodiments described above and herein, during the supporting of the green body through the engagement of the clamp pad, the clamp pad may have a green-body-engaging surface engaging a surface of the green body, and a fixture-engaging surface engaging the fixture member. The green-body-engaging surface may have a first coefficient of friction greater than a second coefficient of friction of the surface of the green body engaging the green-body-engaging surface of the clamp pad.

[0015] In any of the aspects or embodiments described above and herein, the green-body-engaging surface may have a first coefficient of friction, the surface of the green body may have a second coefficient of friction, and the first coefficient of friction may be greater than the second coefficient of friction.

[0016] In any of the aspects or embodiments described above and herein, during the supporting of the green body through the engagement of the clamp pad, the clamp pad may spread a load applied by the fixture member over the green-body-engaging surface of the clamp pad.

[0017] In any of the aspects or embodiments described above and herein, during the supporting of the green body through the engagement of the clamp pad, the clamp pad may conform to the surface of the green body engaging the green-body-engaging surface.

[0018] In another aspect, there is provided an assembly comprising: a green body made of powder injection molding material, the powder injection molding material including a binder and a metallic powder material mixed with the binder, the green body having a first surface hardness; a retaining fixture of a machine tool, the retaining fixture including a fixture member having a sec-

ond surface hardness greater than the first surface hardness; and a clamp pad having a fixture-engaging surface engaged to the fixture member and a green-body-engaging surface engaged to the green body, the fixture-engaging surface having a third surface hardness smaller than the second surface hardness, and the green-body-engaging surface having a fourth surface hardness smaller than the first surface hardness and the second surface hardness.

[0019] The assembly or method defined above and described herein may further include one or more of the following features, in whole or in part, and in any combination.

[0020] In any of the aspects or embodiments described above and herein, the retaining fixture may be a clamp.

[0021] In any of the aspects or embodiments described above and herein, the clamp pad may have the fixture-engaging surface parallel to the green-body-engaging surface.

[0022] In any of the aspects or embodiments described above and herein, the fixture-engaging surface may be skewed relative to (i.e. not parallel to) the green-body-engaging surface.

[0023] In any of the aspects or embodiments described above and herein, the retaining fixture may be a chuck jaw including a plurality of fixture members and each fixture member of the plurality of fixture members may have a corresponding clamp pad connected thereto and engaging the green body.

[0024] In any of the aspects or embodiments described above and herein, the fixture member may define an engagement surface embracing (conformally contacting) a surface profile of the green body on a portion thereof engaged by the green-body-engaging surface of the clamp pad.

[0025] In any of the aspects or embodiments described above and herein, the clamp pad may conform to (e.g., deform to or be conformal/complementary to) a surface profile of the green body.

[0026] In any of the aspects or embodiments described above and herein, the clamp pad may comprise a first locating feature and the fixture member may comprise a second locating feature. The second locating feature may be complementary shaped to the first locating feature for locating the first locating feature upon engaging (e.g. by an interference fit or snuggly engaging) the first and second locating features with one another.

[0027] In any of the aspects or embodiments described above and herein, a fastener may connect the clamp pad to the fixture member.

[0028] In any of the aspects or embodiments described above and herein, the green-body-engaging surface of the clamp pad may have a first coefficient of friction greater than a second coefficient of friction of a surface of the green body engaged to the green-body-engaging surface of the clamp pad.

DESCRIPTION OF THE DRAWINGS

[0029] Reference is now made to the accompanying figures in which:

Fig. 1 is a perspective view of a retaining fixture holding a MIM part in green state in accordance with a first implementation;

Fig. 2 is a perspective view of a retaining fixture holding a MIM part in green state in accordance with a second implementation;

Fig. 3 is a side view of the retaining fixture and MIM part of Fig. 2;

Fig. 4 is a front view of the retaining fixture and MIM part of Fig. 2;

Fig. 5 is a perspective view of a retaining fixture holding a MIM part in green state in accordance with a third implementation;

Fig. 6 is a perspective view taken from a top, front, right side of a retaining fixture holding a MIM part in accordance with a fourth implementation;

Fig. 7 is a perspective view taken from a bottom, front, left side of the retaining fixture of Fig. 6;

Fig. 8 is a flowchart of a method of manufacturing a part in accordance with one implementation.

DETAILED DESCRIPTION

[0030] In this description and the appended claims, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0031] The present application discusses a method of manufacturing a part made using metal injection molding (hereinafter "MIM") techniques. It is an object of the present technology to provide for a method of manufacturing a MIM part by which the MIM part is machined in green state after being molded and before the debinding and sintering steps are performed. The part in the green state is held in place during the machining operation(s) using a retaining fixture, and a clamp pad having a surface hardness that is different than that of the MIM part. Since the machining is carried out for the MIM part in the green state, which is softer as compared with the finally obtained sintered part, it is possible to carry out the machining while the part is in green state, thereby enabling improvement in dimensional precision and enabling the machining of complex and intricate shapes.

[0032] As is typical in MIM, a suitable feedstock is injected into a mold cavity to obtain a green part, also referred to herein as "green body". Such a feedstock can

include high temperature resistant powder metal alloys, such as a nickel superalloy. Other high temperature resistant material powders which may include one material or a mix of materials could be used as well. The feedstock is a mixture of the material powder and of a binder which may include one or more binding material(s). In a particular implementation, the binder includes an organic material which is molten above room temperature (20°C) but solid or substantially solid at room temperature. The binder may include various components such as surfactants which are known to assist the injection of the feedstock into the mold for production of the green body. In a particular implementation, the binder includes a mixture of binding materials, for example including a lower melting temperature polymer, such as a polymer having a melting temperature below 100°C (e.g. paraffin wax, polyethylene glycol, microcrystalline wax) and a higher melting temperature polymer or polymers, such as a polymer or polymers having a melting temperature above 100°C (e.g. polypropylene, polyethylene, polystyrene, polyvinyl chloride). Different combinations are also possible. In a particular implementation, the material powder is mixed with the molten binder and the suspension of injection powder and binder is injected into the mold cavity and cooled to a temperature below that of the melting point of the binder. "Green state", "green part" or "green body" as discussed herein refers to a molded part produced by the solidified binder that holds the injection powder together.

[0033] Since the feedstock is wax and/or polymer based, machining the green body can be performed with cutting feeds and speeds that are higher and cutting forces that are lower than typical feeds, speeds and forces for the machining of solid metal (for example the same metal as that found in powder form in the green body), and even when compared with "soft" metals such as aluminum. In a particular implementation, a machine tool that is designed for machining wax and plastics (e.g. small desktop CNC milling machine) is used to machine the green body. In a particular implementation, the cutting feeds and speeds are similar to that used during the machining of wax. In a particular implementation, the metal powder present in the green body provides for an increased material conductivity when compared to the binder material alone, which may help dissipate heat that may be generated during machining. When in the green state, the green body may have a surface hardness that is smaller than the surface hardness of the sintered part.

[0034] In a particular implementation, the method may be used for the rapid-prototyping of powder injection molding parts, for example to obtain a part for tests. This may allow the final part to be manufactured within a timeline in the order of days rather than months, allowing for quicker manufacture of parts available for testing. For example, shrinkage and deformations of the part until the end of the sintering process can be observed and measured, and a new green body with different dimensions can be produced by machining if the desired final dimensions are not obtained. Iterations in the green body design can thus be done by machining rather than by mold modifications, which in a particular implementation significantly reduces the development time and development cost for the part. Once the final design has been confirmed, a mold can be ordered for mass production.

[0035] In the following description, different assemblies 20, 120, 220, 320 adapted for the manufacturing of a part will be described.

[0036] Referring to Fig. 1, an assembly 20 includes a green body 30 having a substantially prismatic shape (i.e. block shape). The assembly 20 further includes two retaining fixtures 40, in the form of clamps, holding the green body 30 in place for machining operation(s). Each of the retaining fixtures 40 includes a fixture member 42 and a screw 44 adapted to engage a workbench (not shown) or other suitable support structure. In this case, screwing down the screws 44 cause the fixture members 42 to apply a downward load on the green body 30. Each of the fixture members 42 has an engagement surface 42a for engaging indirectly the green body 30. The engagement surface 42a has a surface hardness greater than the surface hardness of the green body 30.

[0037] After molding, the green body 30 has a relatively low surface hardness provided by the powder material mixed with the solidified binder. In addition, the green body 30 is relatively fragile and brittle, but is rigid enough to be able to maintain its shape and handle some manipulation. In order to facilitate the machining thereof and in order to prevent damaging the green body 30 during the machining, the assembly 20 further includes a clamp pad 50 engaged to each of the retaining fixtures 40 and to the green body 30. According to some embodiments, each clamp pad 50 may have a fixture-engaging surface 52 engaged to the engagement surface 42a of the fixture member 42, and a green-body-engaging surface 54 engaged to the green body 30. The clamp pad 50 may be connected to the fixture member 42 via a fastener 56. In the present implementation, the fastener 56 is an adhesive provided on the fixture-engaging surface 52 of the clamp pad 50. Other fasteners 56, such as screws, collars or braces are contemplated to be used in other implementations for connecting the clamp pad 50 to the corresponding fixture member 42. According to some embodiments, no fastener may be used. In such cases, the clamp pad can be simply placed between the green part and the fixture and held in place by the clamping load of the fixture.

[0038] In the illustrated implementation, the green body 30 has a top surface 30a, and is held in place by the engagement of the top surface 30a with the green-body-engaging surface 54 of each clamp pad 50. The green-body-engaging surface 54 has a surface hardness that is smaller than the surface hardness of the engagement surface 42a of the fixture member 42, and smaller than the surface hardness of the top surface 30a of the green body 30. The clamp pads 50 are made of a rela-

tively soft and compliant material, such as a rubber-based or a silicon-based material. The clamp pads 50 have a thickness ranging between 30 thousandth of an inch (about 0.76 mm) and 3/8 inch (about 9.53mm). The thickness of the clamp pad 50 depends, among other factors, on the material forming the clamp pad 50 and on the load needed to be applied by the retaining fixture 40 for holding the green body 30 in place during machining operations.

[0039] Still referring to Fig. 1, each of the clamp pads 50 also has a prismatic shape. More particularly, the fixture-engaging surface 52 and the green-body-engaging surface 54 extend parallel to one another. Each of the clamp pads 50 may assist in spreading the load applied by the corresponding retaining fixture 40 over the top surface 30a of the green body 30. The material of the clamp pads 50 is also nonmarring and thus limits damages/prints over the top surface 30a of the green body 30 when the retaining fixtures 40 hold the green body 30 in place. In some implementations, the surfaces 52, 54 of the clamp pads 50 further have a coefficient of friction that is greater than a coefficient of friction of the engagement surface 42a of each of the fixture members 42 and/or of the surface of the green body 30 engaged by the clamp pad 50. This causes the clamp pad 50 to grip on the green body 30 and the corresponding fixture member 42, and maintains the green body 30 in a fixed position during machining operations without requiring to apply a clamping load with the retaining fixtures 40 that could damage and/or form prints on the green body 30. Put differently, the clamp pads 50 assist in limiting slipping movements of the green body 30 relative to the retaining fixtures 40 during machining operations while protecting the surface of the green body 30.

[0040] Referring now to Figs. 2 to 4, the assembly 120 will be described. The assembly 120 includes features that are the same as or similar to those of the assembly 20. Therefore, for simplicity, features of the assembly 120 that are the same as or similar to those of the assembly 20 have been labeled with the same reference numerals, but in the 100 series (for example, green body 30 corresponds to green body 130), and will not be described again in detail.

[0041] The green body 130 has a top surface 130a that is curved. The green body 130 has a wedge shape best seen in Fig. 3. In order to support the green body 130 for machining operations, a wedge-shaped clamp pad 150 is engaged between the top surface 130a of the green body 130 and the engagement surface 142a of the fixture member 142, being part of the retaining fixture 140 which is a clamp. Put differently, the clamp pad 150 has the fixture-engaging surface 152 skewed relative to the green-body-engaging surface 154, as best seen in Fig. 3. Hence, upon screwing down the screw 144, the retaining fixture 140 applies a downward load on the clamp pad 150, and the clamp pad 150 transmits the downward load to the green body 130. When the retaining fixture 140 applies the load and as best seen from double arrow 158 in Fig. 4, the clamp pad 150 conforms to the curved surface profile of the top surface 130a of the green body 130 engaging the green-body-engaging surface 154. In addition, the clamp pad 150 spreads the load applied by the retaining fixture 140 over the green-body-engaging surface 154. This causes the clamp pad 150 to grip on the green body 130, and maintains the green body 130 in a fixed position during machining operations without requiring to apply a clamping load with the retaining fixture 140 that could damage and/or form prints on the green body 130. Put differently, the clamp pad 150 assists in limiting slipping movements of the green body 130 relative to the fixture member 142 during machining operations while protecting the surface of the green body 130.

[0042] Turning now to Fig. 5, the assembly 220 will be described. The assembly 220 includes features that are the same as or similar to those of the assembly 20. Therefore, for simplicity, features of the assembly 220 that are the same as or similar to those of the assembly 20 have been labeled with the same reference numerals, but in the 200 series (for example, green body 30 corresponds to green body 230), and will not be described again in detail.

[0043] The green body 230 is cylindrically shaped, and has a surface 230a that is cylindrical. In order to support the green body 230 for machining operations, the retaining fixture 240 is a chuck jaw having three fixture members 242. The retaining fixture 240 is adapted to hold the green body 230 while rotating, for example, on a lathe during turning operations. The retaining fixture 240 is also configured for having a longitudinal axis 230b of the green body 230 coaxial with a central axis 240a of the retaining fixture 240. On each of the fixture members 242, a clamp pad 250 is engaged between the surface 230a of the green body 230 and the engagement surface 242a of the fixture member 242. A groove 246 is defined in the engagement surface 242a of each fixture member 242. The groove 246 extends parallel to the axes 230b, 240a. A ridge 248 projects from the fixture-engaging surface 252 of each clamp pad 250. The groove 246 and ridge 248 define locating features complementarily shaped for locating one another upon engagement to one another. In the implementation shown, the ridge 248 is a male locating feature projecting away from the clamp pad 250, and it is snuggly engaged (e.g., by an interference fit) within a corresponding female feature, e.g. the groove 246, defined in the fixture member 242. More than one pair of locating features may be used and/or the configurations of the locating features may vary, but are configured to allow for the clamp pad 250 to be engaged to the corresponding fixture member 242 with a known location. Other locating features, such as a pin and a complementarily shaped hole, are contemplated in other implementations. It is contemplated that in implementations having locating features on the clamp pad 250 and the fixture member 242, there is not necessarily a need for connecting the clamp pad 250 to the fixture member 242 using a fastener such as an adhesive.

[0044] Still referring to Fig. 5, the clamp pads 250 conform to the surface 230a of the green body 230, and spread the radially-applied load of the retaining fixture 240 over their respective green-body-engaging surface 254. This causes the clamp pad 250 to grip on the green body 230, and maintains the green body 230 in a fixed position relative to the retaining fixture 240 during machining operations without requiring to apply a clamping load with the fixture members 242 that could damage and/or form prints on the green body 230. Put differently, the clamp pads 250 assist in limiting slipping movements of the green body 230 relative to the retaining fixture 240 during machining operations.

[0045] Referring now to Figs. 6 and 7, the assembly 320 will be described. The assembly 320 includes features that are the same as or similar to those of the assembly 20. Therefore, for simplicity, features of the assembly 320 that are the same as or similar to those of the assembly 20 have been labeled with the same reference numerals, but in the 300 series (for example, green body 30 corresponds to green body 330), and will not be described again in detail.

[0046] The green body 330 has curved top surfaces 330a. In order to support the green body 330 for machining operations, arc-shaped clamp pads 350 are engaged to the top surfaces 330a of the green body 330 and to the engagement surface 342a of two arc-shaped fixture members 342 of the retaining fixture 340, which is a clamp. Each of the fixture members 342 has the engagement surface 342a embracing a surface profile of a corresponding one of the top surfaces 330a of the green body 330. Hence, the fixture members 342 apply a downward load on the clamp pads 350, and the clamp pads 350 transmit the downward load to the green body 330. Having the fixture members 342 and the clamp pads 350 embracing the surface profile of the green body 330 on the portion thereof that is engaged by the green-body-engaging surface 354 of each clamp pad 350 may limit stress concentration and assist in spreading the load applied by the retaining fixture 340.

[0047] As is apparent from the description of the assemblies 20, 120, 220, 320, the clamp pad may take different shapes and sizes. For example, the clamp pad is therefore selectable among a set of clamp pads having, for example, different configurations of green-body-engaging surface. The clamp pads of the set may also have different configurations for use with different fixture members, retaining fixtures and/or different machine tools. The selection of the clamp pad(s) can also be made based on a surface profile of the green body that is to be engaged by the clamp pad(s).

[0048] With reference to Figs. 1 and 8, an illustrative scenario of a method 400 of manufacturing a part using the assembly 20 will be described. At step 402, the green body 30 made of powder injection molding material is received. The green body 30 thus includes a binder and a metallic powder material mixed with the binder. The green body 30 has the top surface 30a having a relatively low surface hardness. At step 404, the clamp pads 50 are selected from a set of clamp pads including, and not limited to, clamp pads 50, 150, 250, 350 described above. The clamp pads 50 are selected based on their substantially flat green-body-engaging surface 54 in view of the prismatic shape of the green body 30 and the substantially flat surface profile of the top surface 30a of the green body. The clamp pads 50 are also selected based on the configuration of the fixture members 42 and the machine tool that will be used for machining the green body 30. At step 406, each of the clamp pads 50 is connected to the engagement surface 42a of the corresponding fixture member 42 using the adhesive 56. At step 408, the green body 30 is engaged to the clamp pads 50. The green body 30 is engaged to the clamp pads 50 upon screwing down the screws 44, thus applying a clamping load on the green body 30 that is spread over the green-body-engaging surface 54 of the clamp pads 50. At step 410, while supporting the green body 30 through the engagement of the clamp pads 50, the green body 30 is machined using the machine tool to obtain a machined green part. Put differently, machining operations are performed until the desired shape defining the machined green part is obtained. Different machining operations, such as drilling, boring, reaming, and milling are contemplated to be performed while the green body 30 is supported through the engagement of the clamp pads 50. In a particular implementation, the machining step 410 includes performing a first machining operation, then disengaging the machined green body from the retaining fixture 40 and re-engaging the machined green body in a different relative position and/or orientation before performing another machining operation using the same or a different tool, and/or using the same or a different retaining fixture. At step 412, the screws 44 are unscrewed and the clamp pads 50 are disengaged from the machined green part. At step 414, the machined green part undergoes debinding and sintering operations. The debinding operation removes most or all of the binder. The machined green part can be debound using various debinding solutions and/or heat treatments known in the art, to obtain a brown part. After the debinding operations, the brown part is sintered. The sintering operation can be done in an inert gas environment, a reducing atmosphere (H_2 for example), or a vacuum environment depending on the composition of material to be obtained. In a particular implementation, sintering is followed by a heat treatment also defined by the requirements of the material of the finished part. In some cases, it may be followed with hot isostatic pressing (HIP). Coining may also be performed to further refine the profile of the part. It is understood that the parameters of the sintering operation can vary depending on the composition of the feedstock, on the method of debinding and on the configuration of the part.

[0049] Although in the implementations shown the molded green body 30 is depicted as a block shape, i.e. having none of the features of the desired final shape for the part which are thus all obtained by machining, it is

understood that in other implementations the green body may be molded having some of the features of the desired final shape such that only part of the green body is machined, or with an intermediate shape between the block shape and the desired final shape, for example a rough shape approximating and larger than the desired final shape. The method 400 may also be used to perform secondary machining operations on molded parts in the green state, including the removal of gates created by the molding process, testing new/modified features on already molded parts (as opposed to directly molding the modified part using a new/modified mold), and machining difficult to mold features with easier to mold features being directly obtained in the molding step.

[0050] The method 400 may be used to shape any type of part that may be obtained by a metallic powder injection molding process, including, but not limited to, gas turbine engine elements such as pieces of fuel nozzles, combustor panels, brackets, vanes, vane segments, vane rings, heat shields, combustion air swirlers, shroud segments, bosses, flanges, tube fittings, adaptors, airfoils, blades, levers, etc.

[0051] It is understood that the machined green part may be assembled to one or more other green part(s) (whether machined or directly molded to shape) prior to debinding, and these parts may be assembled in their green state, connected using any type of suitable non-detachable connections or detachable connections, and debound and sintered to fuse them together to form the final element. In a particular implementation, the parts are fused during the debinding step. Alternately, the parts are joined after the debinding step and prior to the sintering step.

[0052] The implementations described in this document provide non-limiting examples of possible implementations of the present invention. Upon review of the present disclosure, a person of ordinary skill in the art will recognize that changes may be made to the implementations described herein without departing from the scope of the present technology. Yet further modifications could be implemented by a person of ordinary skill in the art in view of the present disclosure, which modifications would be within the scope of the claims.

Claims

1. A method of manufacturing a part, comprising:

receiving a green body (30; 130; 230; 330) made of powder injection molding material, the powder injection molding material including a binder and a metallic powder material mixed with the binder, the green body (30; 130; 230; 330) having a first surface hardness;
engaging the green body (30; 130; 230; 330) to a clamp pad (50; 150; 250; 350) engaged to a fixture member (42; 142; 242; 342) of a retaining fixture (40; 140; 240; 340) of a machine tool, the clamp pad (50; 150; 250; 350) having a second surface hardness smaller than the first surface hardness;
while supporting the green body (30; 130; 230; 330) through the engagement of the clamp pad (50; 150; 250; 350), machining the green body (30; 130; 230; 330) using the machine tool to obtain a machined green part; and
debinding and sintering the machined green part.

2. The method of claim 1, further comprising, prior to debinding and sintering, disengaging the clamp pad (50; 150; 250; 350) from the machined green part.

3. The method of any preceding claim, wherein engaging the green body (30; 130; 230; 330) to the clamp pad (50; 150; 250; 350) maintains the green body (30; 130; 230; 330) in a fixed position during the machining.

4. The method of any preceding claim, wherein machining the green body (30; 130; 230; 330) includes rotating the green body (30; 130; 230; 330) with the clamp pad (50; 150; 250; 350) and the fixture member (42; 142; 242; 342).

5. The method of any preceding claim, further comprising connecting the clamp pad (50; 150; 250; 350) to the fixture member (42; 142; 242; 342) by:

engaging first and second complementary locating features with one another, the first locating feature being provided on the clamp pad (50; 150; 250; 350) and the second locating feature being provided on the fixture member (42; 142; 242; 342); and/or
using a fastener (56) to fasten the clamp pad (50; 150; 250; 350) to the fixture member (42; 142; 242).

6. The method of any of the preceding claims, further comprising selecting the clamp pad (50; 150; 250; 350) from a set of clamp pads (50; 150; 250; 350) having different configurations of a green-body-engaging surface (54; 154; 254; 354), the clamp pad (50; 150; 250; 350) being selected based on the green-body-engaging surface (54; 154; 254; 354) thereof and on a surface profile of the green body (30; 130; 230; 330), optionally wherein:
selecting the clamp pad (50; 150; 250; 350) is based on a configuration of at least one of the fixture member (42; 142; 242; 342) and the machine tool.

7. The method of any of the preceding claims, wherein, during the supporting of the green body (30; 130; 230; 330) through the engagement of the clamp pad

(50; 150; 250; 350), the clamp pad (50; 150; 250; 350) has a or the green-body-engaging surface (54; 154; 254; 354) engaging a surface (30a; 130a; 230a; 330a) of the green body (30; 130; 230; 330), a fixture-engaging surface (52; 152; 252) engaging the fixture member (42; 142; 242; 342), and the green-body-engaging surface (54; 154; 254; 354) has a first coefficient of friction greater than a second coefficient of friction of the surface (30a; 130a; 230a; 330a) of the green body (30; 130; 230; 330) engaging the green-body-engaging surface (54; 154; 254; 354) of the clamp pad (50; 150; 250; 350).

8. The method of claim 7, wherein, during the supporting of the green body (30; 130; 230; 330) through the engagement of the clamp pad (50; 150; 250; 350):

the clamp pad (50; 150; 250; 350) spreads a load applied by the fixture member (42; 142; 242; 342) over the green-body-engaging surface (54; 154; 254; 354) of the clamp pad (50; 150; 250; 350); and/or
the clamp pad (50; 150; 250; 350) conforms to the surface (30a; 130a; 230a; 330a) of the green body (30; 130; 230; 330) engaging the green-body-engaging surface (54; 154; 254; 354).

9. An assembly (20; 120; 220; 320) comprising:

a green body (30; 130; 230; 330) made of powder injection molding material, wherein the powder injection molding material includes a binder and a metallic powder material mixed with the binder, and the green body (30; 130; 230; 330) has a first surface hardness;
a retaining fixture (40; 140; 240; 340) of a machine tool, wherein the retaining fixture (40; 140; 240; 340) includes a fixture member (42; 142; 242; 342) having a second surface hardness greater than the first surface hardness; and
a clamp pad (50; 150; 250; 350) having a fixture-engaging surface (52; 152; 252) engaged to the fixture member (42; 142; 242; 342) and a green-body-engaging surface (54; 154; 254; 354) engaged to the green body (30; 130; 230; 330), wherein the fixture-engaging surface (52; 152; 252) has a third surface hardness smaller than the second surface hardness, and the green-body-engaging surface (54; 154; 254; 354) has a fourth surface hardness smaller than the first surface hardness and the second surface hardness.

10. The assembly (20; 120; 220; 320) of claim 9, wherein the retaining fixture (40; 140; 240; 340) is a clamp, and the fixture-engaging surface (52; 152; 252) is:

parallel to the green-body-engaging surface (54; 154; 254; 354); or
skewed relative to the green-body-engaging surface (54; 154; 254; 354).

11. The assembly (220) of claim 9 or 10, wherein the retaining fixture (240) is a chuck jaw including a plurality of fixture members (242), and each fixture member (242) of the plurality of fixture members (242) has a corresponding clamp pad (250) connected thereto and engaging the green body (230).

12. The assembly (20; 120; 220; 320) of any of claims 9 to 11, wherein the fixture member (42; 142; 242) defines an engagement surface (42a; 142a; 242a; 342a) embracing a surface profile of the green body (30; 130; 230; 330) on a portion thereof engaged by the green-body-engaging surface (54; 154; 254; 354) of the clamp pad (50; 150; 250; 350).

13. The assembly (20; 120; 220; 320) of any of claims 9 to 12, wherein the clamp pad (50; 150; 250; 350) conforms to a surface profile of the green body (30; 130; 230; 330).

14. The assembly (220) of any of claims 9 to 13, wherein the clamp pad (250) comprises a first locating feature (248) and the fixture member (242) comprises a second, complementary shaped, locating feature (246) for locating the first locating feature (248) upon engaging the first and second complementary locating features (246; 248) with one another, and optionally wherein:
a fastener connects the clamp pad (250) to the fixture member (242).

15. The assembly (20; 120; 220; 320) of any of claims 9 to 14, wherein the green-body-engaging surface (54; 154; 254; 354) of the clamp pad (50; 150; 250; 350) has a first coefficient of friction greater than a second coefficient of friction of a surface (30a; 130a; 230a; 330a) of the green body (30; 130; 230; 330) engaged to the green-body-engaging surface (54; 154; 254; 354) of the clamp pad (50; 150; 250; 350).

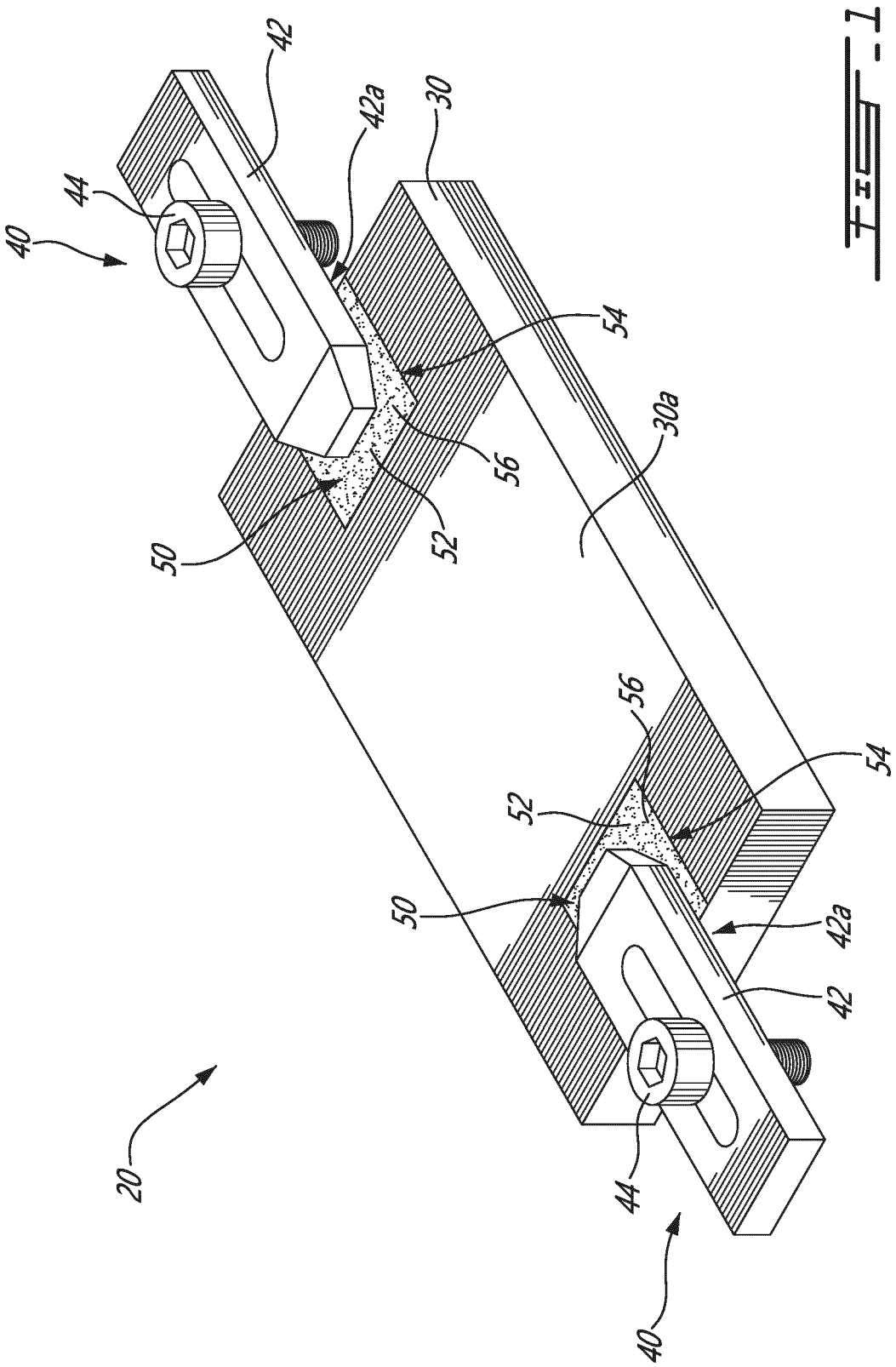

Fig. 1

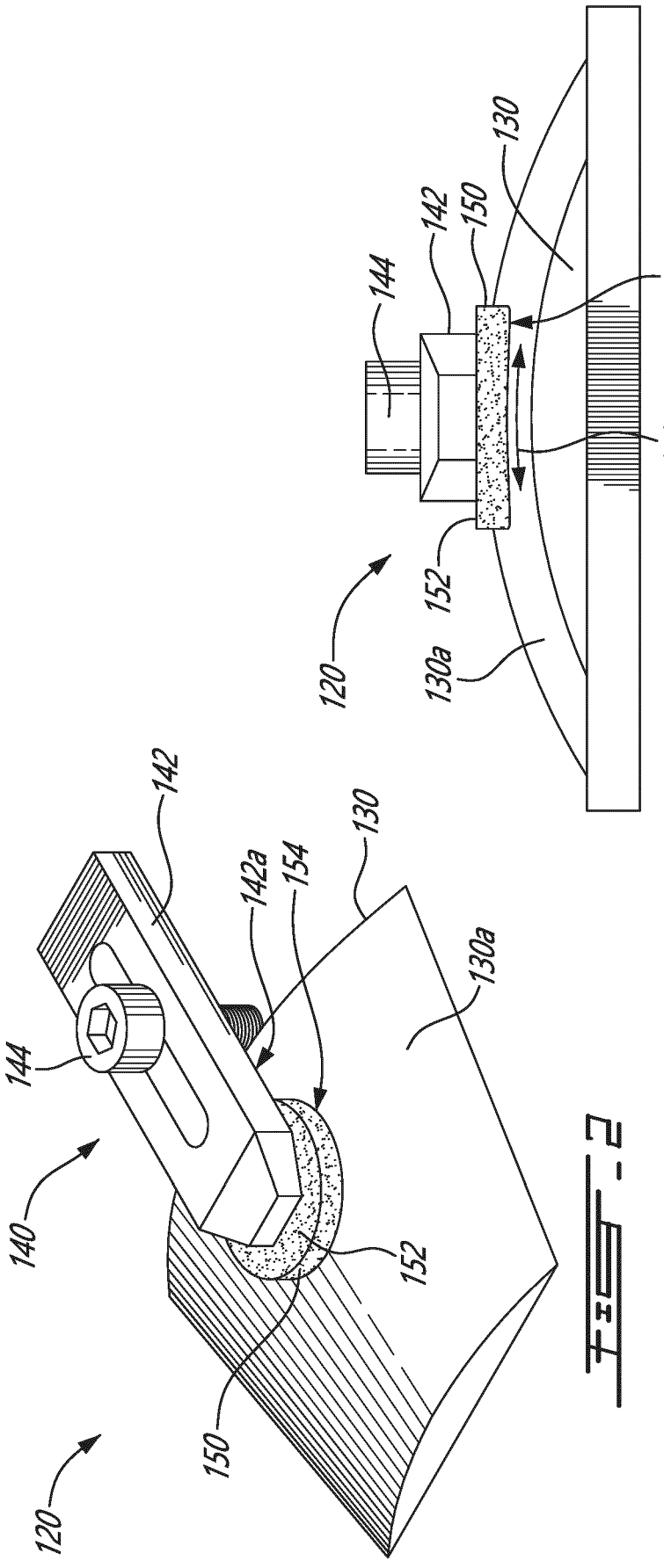

Fig. 2

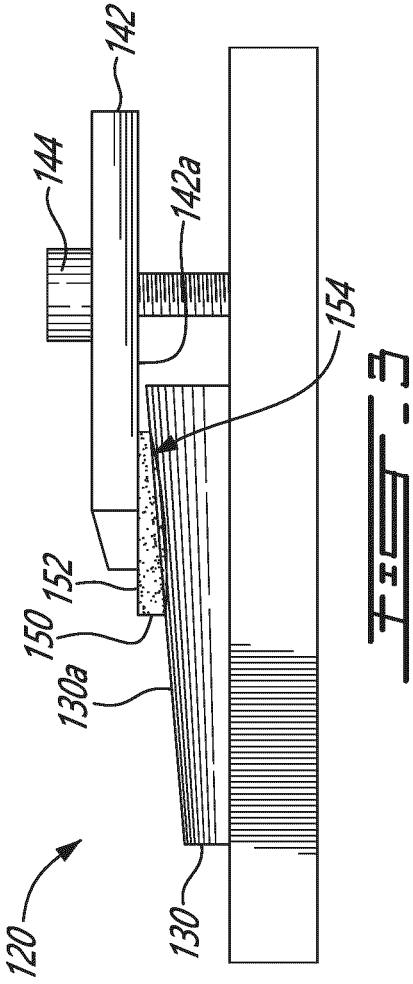

Fig. 3

Fig. 4

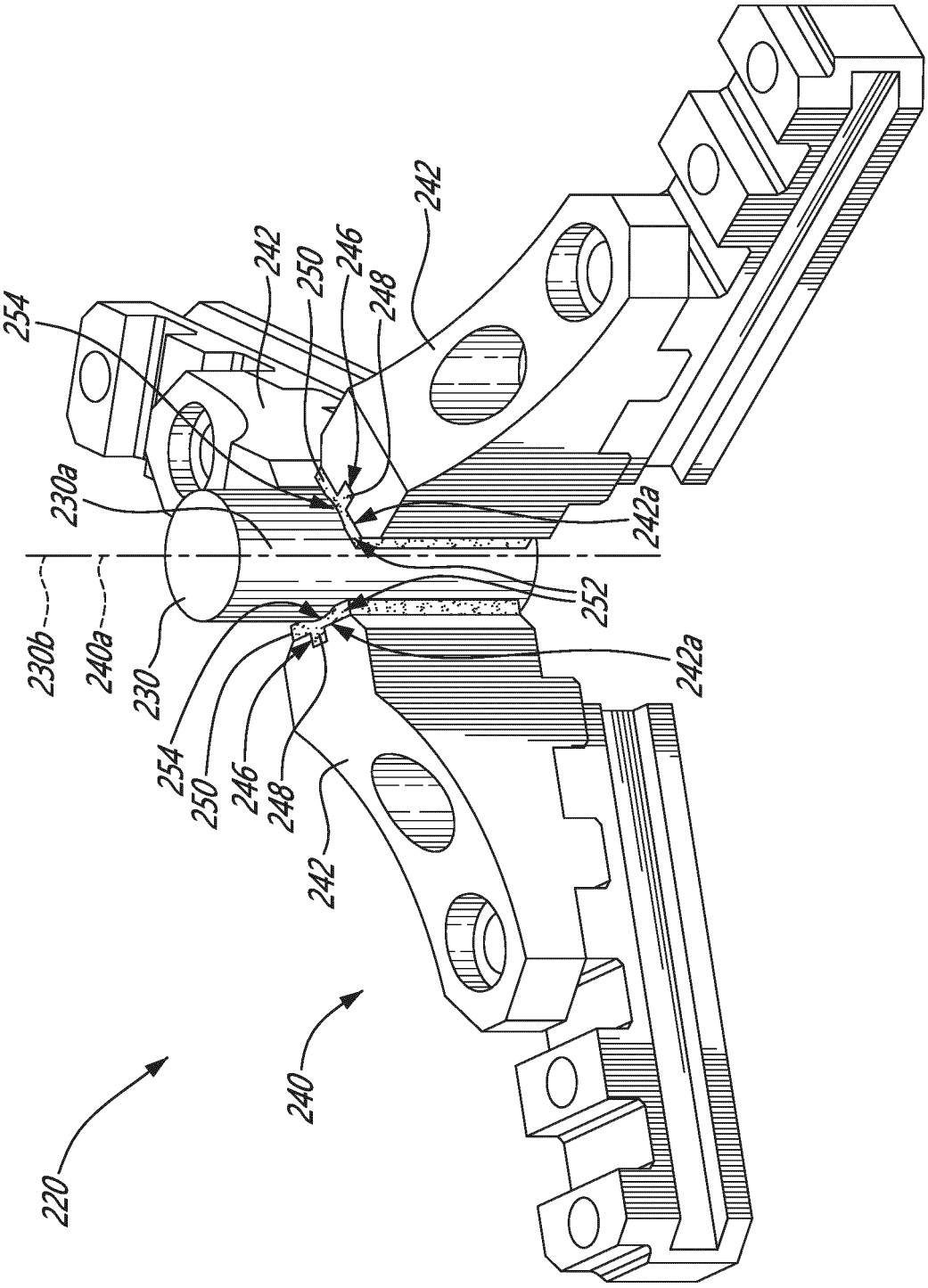
254
242
250
246
248
242
230a
242a
230b
240a
230
252
242a
254
250
246
248
242
240
220

FIG. 5

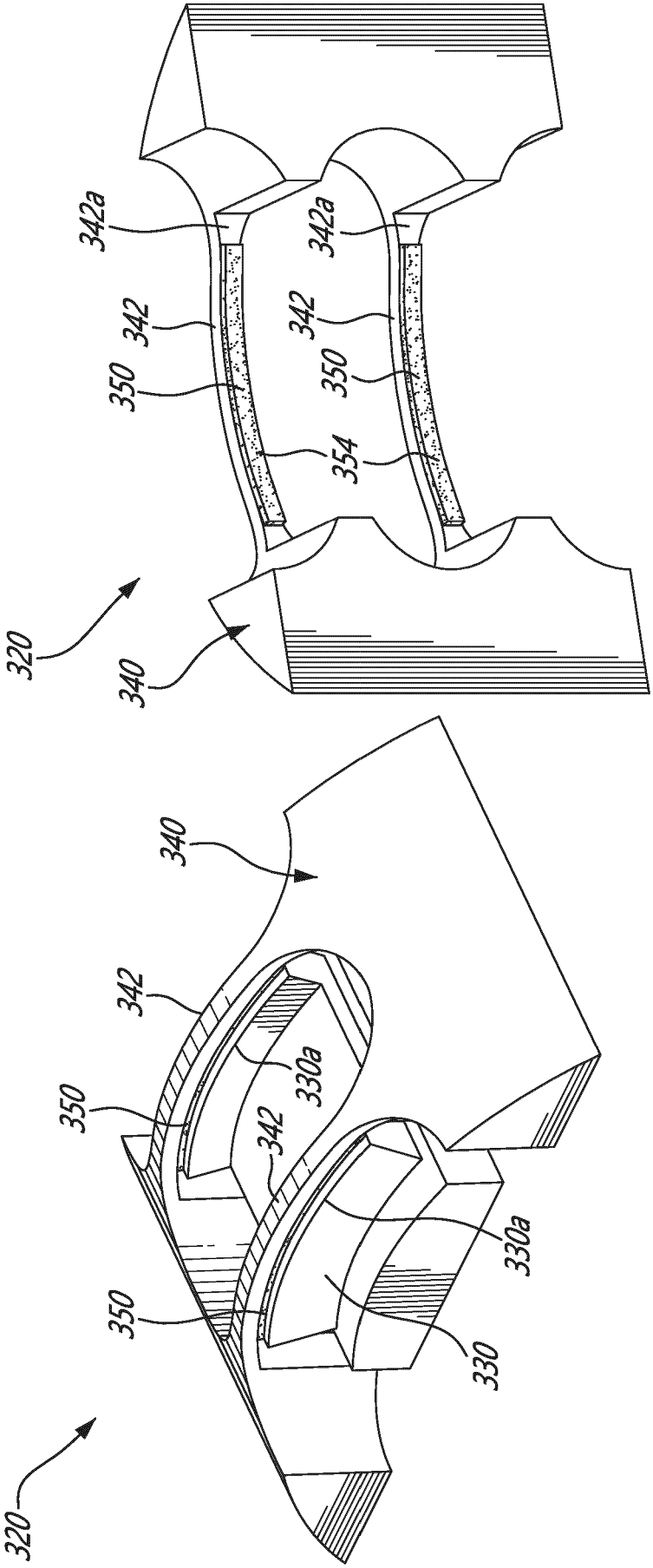
342a
342a
342
342
350
350
354
320
340

Fig. 7

340
342
330a
350
342
330a
350
330
320

Fig. 8

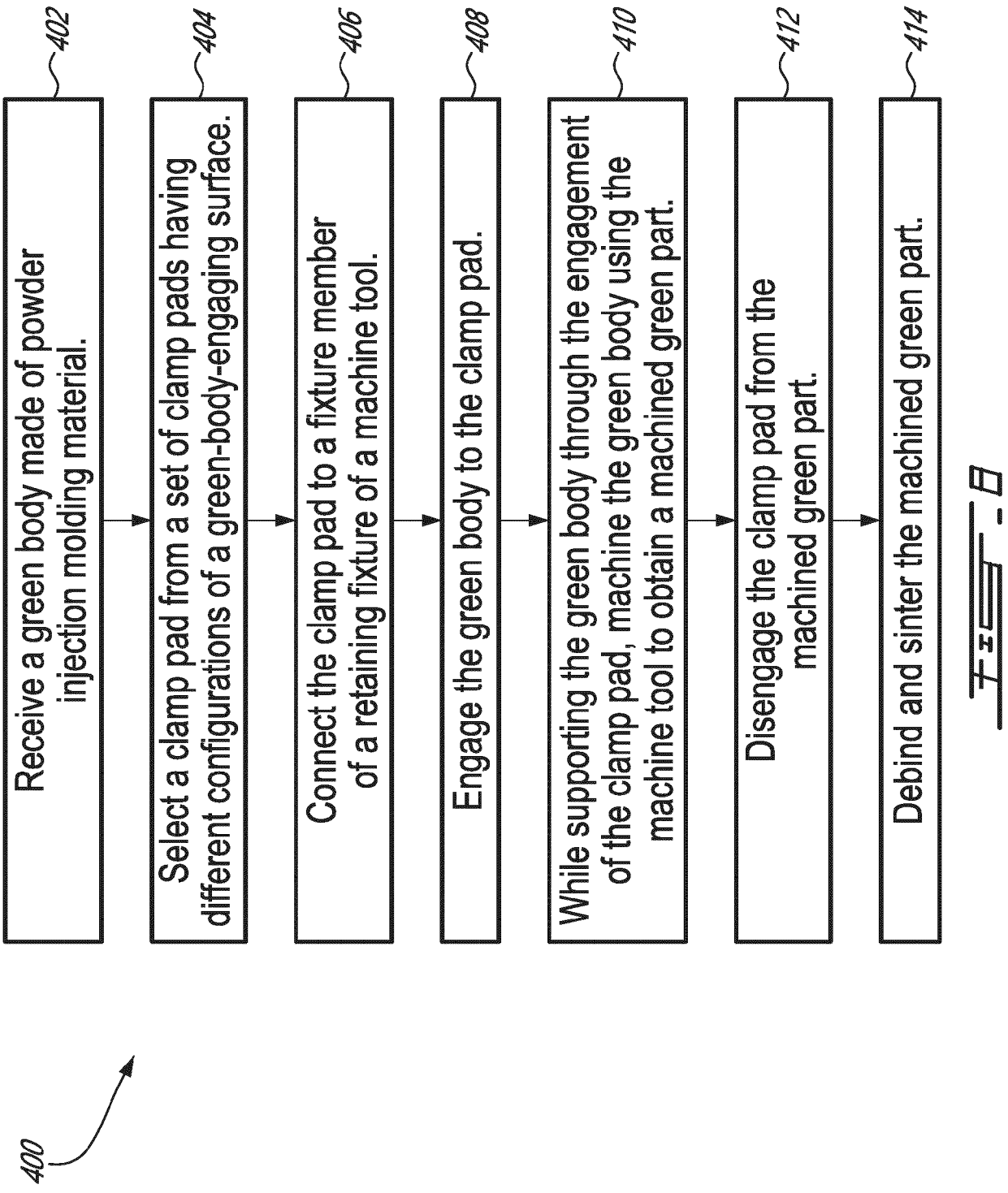
400
402
Receive a green body made of powder injection molding material.
404
Select a clamp pad from a set of clamp pads having different configurations of a green-body-engaging surface.
406
Connect the clamp pad to a fixture member of a retaining fixture of a machine tool.
408
Engage the green body to the clamp pad.
410
While supporting the green body through the engagement of the clamp pad, machine the green body using the machine tool to obtain a machined green part.
412
Disengage the clamp pad from the machined green part.
414
Debind and sinter the machined green part.

FIG. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 24 20 0113

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	CN 208 428 055 U (SHENZHEN ZHENGHE ZHONGXIN PRECISION TECH CO LTD) 25 January 2019 (2019-01-25) * figure 1 * * paragraph [0004] * * paragraph [0008] * * paragraph [0020] * * claim 1 * * abstract *	1-3, 5-10, 12-15 4,11	INV. B22F1/10 B22F3/10 B22F3/22 B22F3/24 B22F3/16 B22F7/08
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A	US 2010/094420 A1 (GROHOWSKI JR JOSEPH A [US]) 15 April 2010 (2010-04-15) * figures 10-16 * * paragraph [0114] - paragraph [0124] *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

B22F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	28 January 2025	Godino Martinez, M

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

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28-01-2025

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