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Method for manufacturing or for repairing a component of a rotary machine as well as a component manufactured or repaired using such a method

The invention relates to a method for manufacturing a component of a rotary machine according to the preamble of the independent patent claim 1. The invention further relates to a method for repairing a component of a rotary machine according to the preamble of the independent patent claim 12, as well as to a component of a rotary machine manufactured or repaired using such a method.

In the manufacturing of rotary machines such as e.g. pumps, turbines, compressors, compactors or expanders it is known to elaborate rotating rotors, pump impellers, impellers as well as stationary diffusers or guide wheels as a component out of a blank by a machining process or by a cutting process, for example by milling. In doing so, the blank can be present as a solid material or can already be preprocessed by a primary shaping process.

Such a method is known from EP-B-2 012 957, for example. The method proposed there is in particular characterized by allowing a machining manufacturing of the component, that is to say that the component is at least essentially brought into the desired final form as a whole out of the blank by means of a machining device. The assembling of preprocessed parts of the component, for example by means of welding, is no longer necessary with such an integral manufacturing. This is particularly advantageous because welding seams or other joints can be a weak spot at highly loaded parts of the component in the operating state, the weak spot can be the cause of a crack or another damage of the component, for example due to corrosion.

Hence a machining manufacturing without assembling individual parts is advantageous, in particular in the case of highly loaded components. That is why, such components as, for example rotors (impellers) of pumps are made of solid material, depending on the application, e.g. of high-strength stainless steels, super alloys, other suitable metals or metal alloys or also of non-metallic materials, for example ceramic materials, and the vanes and channels of the impeller are elaborated out of this material by cutting processes, for example by milling.

As already explained in EP-B-2 012 957, sometimes a machining manufacturing of the component as a whole is not possible for purely geometrical reasons. This can be the case, for example, when the rotors (impeller) are designed as covered or closed impellers. In such a design the impeller comprises a shroud, on which the vanes are arranged and also a cover plate covering the vanes completely or at least partially at the side facing away from the shroud. Hence, at least partially closed channels are formed between the vanes, the channels each extending from the center of the impeller to its outer radial limiting surface.

Even if considering that these channels could be milled out of the blank or processed by machining on both sides, respectively, that means from the interior of the impeller and also from its radial limiting surface by a machining device, it is obvious, that geometry is here subject to limits and in many cases a machining manufacturing as a whole is impossible or at least uneconomic.

In such cases, if it is no longer possible or practicable to mill the impeller as a whole out of solid material for purely geometrical reasons, it is the state of the art to elaborate initially the shroud and the vanes out of a blank by machining. Then, the channels between the vanes are completely open channels, which can be manufactured in a simple way. Afterward the cover plate is placed and joined to the shroud or the vanes, respectively, for example by welding.

Alternatively, it is also known, to manufacture the areas of the channels, which cannot be milled, by an eroding method, for example by electrical discharge machining (EDM: electrical discharge machining). However, these methods are generally comparatively slow and expensive.

It is also state of the art to manufacture such components having inner channels by casting, wherein the inner channels are manufactured by an appropriate design of the mold or of the casting core, respectively. However, a cast component has the disadvantage that defects can arise during casting, for example in the structural conditions, having negative effects on the resilience and the stability of the component. Additionally, the surface qualities that can be achieved as well as the dimensional accuracy of areas, which cannot be milled are normally limited during the casting process.

In EP-A-2 669 042 a method for a machining manufacturing of a closed impeller is proposed, dividing the component (impeller) to be processed in two sub-volumes, which meet at a separating surface. As a result, the sub-volumes are defined such, that the separating surface comprises or intersects no limiting surfaces of the channels and that the channels can be elaborated by means of a machining method, for example by milling, as a whole out of the first sub-volume later comprising the completed channels. The second sub-volume, being then only a part of the cover plate, is either manufactured as a separate part and joined to the first sub-volume after finishing or the second sub-volume is built on the first sub-volume by means of an additive processing method, for example, by build-up welding. Thus, it should be possible to manufacture the channels completely by a machining manufacturing. However, this method is still subject to geometrical limitations.

This problem explained by means of closed impellers is also present with other components having an inner channel, which position or geometry is such, that a

machining manufacturing as a whole is not possible and not practicable, in particular for geometrical reasons. Examples mentioned here are closed guide wheels, diffusors or also cooling channels in turbine blades, for example for cooling air.

Based on this state of the art, it is therefore an object of the invention proposing another method for manufacturing a component of a rotary machine, which component has at least one inner channel, by means of which method, in particular, such components can be manufactured which do not allow machining manufacturing of the channel as a whole for geometrical reasons. Furthermore the invention is expected to propose a corresponding component.

The objects of the invention meeting this problem are characterized by the features of the independent patent claim of the respective category.

According to the invention, a method for manufacturing a component of a rotary machine is proposed, the component extending in an axial direction as well as in a radial direction vertical thereto and having at least one inner channel, which extends from a first end in a center of the component to a second end at a radial limiting surface of the component and which is at least partially closed, wherein a blank is provided, comprising the center of the component and which blank is limited by an outer surface in the radial direction, wherein the maximum dimension of the outer surface in the radial direction is smaller than the dimension of the limiting surface in the radial direction, and in that further a first subtractive process step is performed wherein a part of the channel is manufactured by a machining process, with said part extending from the first end of the channel to the outer surface of the blank and in that afterwards the channel is finished by means of a build-up process on the blank.

Thus, the method according to the invention combines a subtractive

process, wherein material is removed from the blank, with an additive or build-up process, wherein material is applied, in an advantageous manner. In this case, only a part of the channel is manufactured by a machining process, as the rest of the channel is generated by a build-up process. Due to this combination, it is possible to generate a channel with - at least almost – any desired geometry.

Here a build-up process is a process, wherein the process takes place directly out of a shapeless or a neutrally shaped material, for example by melting.

As the dimension of the outer surface of the blank in the radial direction is smaller than the dimension of the limiting surface of the finished component in the radial direction, particularly the radial exterior parts of the component are manufactured by the build-up process, for example the part of the channel adjoining the limiting surface and which part comprises the second end of the channel. This build-up process in the radial direction has particularly the advantage, that then usually no or only slightly overlapping structures have to be manufactured during the build-up process, which is particularly advantageous regarding the procedural aspects.

As the blank has not to be processed by casting, the blank may advantageously consist of a forged material, which is then processed by machining. All advantages of the forged material are maintained by the machining process. In doing so, at least the port of the channel into the center of the component, that means its first end, as well as the port of the channel into the outer surface of the blank is manufactured by machining in the first subtractive process step.

Additionally, the part of the channel extending from the first end of the channel into the outer surface of the blank is manufactured by machining in the first subtractive process step. Hence only one part of the channel is finished after completing the first subtractive process step, the channel starting in the center of the blank or of

the component, respectively, and extending to the port into the outer surface of the blank. The first subtractive process step may either comprise a milling from the outer surface of the blank or a milling from the center of the blank. In particular it is also possible, that the first subtractive process step comprises both a milling or a machining process, respectively, out of the center and also a milling from the outer surface of the blank.

After completing the first subtractive process step, the channel is finished by a build-up process and the component is brought into its final form.

In a preferred embodiment, the component comprises a plurality of inner channels, each of which extending from a first end in the center of the component to a second end at the radial limiting surface of the component, wherein adjacent channels are respectively separated by a separating wall, wherein in each case one part of the channel is manufactured of each channel in the first subtractive process step, with said part extending from the respective first end of the channel into the outer surface of the blank and wherein each separating wall and each channel is only finished by means of the build-up process. Though it is particularly preferred if the port of each channel in the outer surface of the blank is designed that way in the first subtractive process step, that the port of the respective channel is already designed as a closed one. Then in each case these ports present all-site limited openings in the outer surface of the blank.

Preferably, the blank is a solid and in particular a rotationally symmetric body. But a cylindrical axial and through bore can preferably be provided in the center of the blank, which bore is used, for example, to fix the finished component on a shaft, e.g. on a driveshaft of a pump. I.e. the blank preferably has a central bore before the first subtractive process step, which bore is arranged radially inwardly such, that in the finished state of the component each first end of a channel being arranged in the center is separated from the central bore by an annular body.

According to a particularly preferred embodiment, the first subtractive process step is performed in such a manner, that after completing this step, the outer surface of the blank comprises a contiguous annular area covering the confluence of each channel into the outer surface. Then in each case these ports are all-site limited openings in the outer surface of the blank. This has the advantage, that in particular the contiguous annular area as well as the areas of the outer surface between the ports form a particular good basis, on which the build-up process can begin afterward.

The build-up process is preferably performed layer by layer. So it is possible, that each layer is vertically oriented to the radial direction. Of course, it is also possible to apply the layers in other orientations, in such a way, that the respective surface normal of the layer is obliquely oriented to the radial and / or axial direction. That is to say, the additive buildup on the blank is made by a successive application of material layers after finishing the first subtractive process step, until the component is finished. The application of material layers is made in a preferred variant that way, that the individual layers are rotationally symmetric. This is also possible, in particular, if the layers are vertically oriented to the radial direction, but also in a layer application in which the layers are obliquely oriented to the radial direction.

A further preferred measure is, that the build-up process comprises several additive process steps, in order to successively build up the component.

It is particularly preferred, if at least one further subtractive process step is performed between the additive process steps. In this further subtractive process step, the structure, which has been built up in the preceding additive process step, can be reprocessed, for example by milling, by grinding or by polishing. By means of this measure, a surface optimization can be realized or a particularly good geometric fidelity can be achieved.

It is especially preferred, that in each case one further subtractive process step is performed between two additive process steps. That is to say, the additive process steps and the further subtractive process steps are performed alternately. This allows a particularly high precision and surface quality of the component to be produced.

Nowadays processing devices are known, with which additive processes, for example laser build-up welding, as well as also subtractive processes, for example milling or grinding, can be performed. Such devices have different processing heads, for example, which are automatically changeable, wherein one processing head is designed for laser build-up welding, for example, whereas another processing head is designed for milling. Especially such processing devices allow a fast and easy change between subtractive and additive processing methods without the workpiece to be processed being re-clamped or transferred into another processing station. This allows a particularly rapid, cost-effective and high-quality manufacturing of components, which are processed very precisely.

A possible variant is, that the component is built up part by part after the first subtractive process step, and wherein preferably first of all only each separating wall is completed. Thus, for example, after completing the first subtractive process step, at first all separating walls between the channels are completely built up and then the still missing parts are built up, e.g. those which turn the channels into closed channels.

It is particularly preferred for procedural reasons if the build-up process is performed by means of a laser. The method by laser build-up welding is particularly suited for the build-up process.

The applications are particularly relevant for practical use, if the component is designed as an impeller, as a guide wheel or as a diffusor of a rotary machine, in

particular of a pump, of a turbine, of a compressor, of a compactor or of an expander.

It has been shown, that the method, according to the invention, also can be very advantageously used in a corresponding similar manner for repairing damaged or worn out components of a rotary machine. According to this, the invention also proposes a method for repairing a component of a rotary machine, which component extending in an axial direction as well as in a radial direction vertical thereto, and comprising a plurality of inner channels, each of which extending from a first end in the center of the component to a second end at the radial limiting surface of the component, wherein adjacent channels are respectively separated by a separating wall, wherein damaged areas of the component at the limiting surface or at one of the channels or at one of the separating walls are identified, in that furthermore a blank is manufactured by a machining removal or by a separating removal of the damaged areas, the blank comprising the center of the component and wherein the removed damaged areas are replaced by means of a build-up process on the blank in order to manufacture the final form of the component.

Regarding the method, according to the invention, for repairing a component, a blank is manufactured in a corresponding similar manner as in the method for manufacturing a component, on which blank the missing parts or areas of the component subsequently are manufactured by means of a build-up process. Regarding the method for repairing, the blank is generated by removing the damaged areas of the component. After manufacturing the blank by removing the damaged areas, the blank corresponds to the blank manufactured by means of the method for manufacturing the component, in principle, after performing the first subtractive process step.

The component is a rotationally symmetric component for a plurality of applications. Regarding in particular the method for repairing, it is not necessary, that the blank, generated by removal of the damaged areas, is also rotationally symmetric. For example, it may be possible in the case of an impeller being the component, that the individual closed channels or the individual separating walls between said channels are damaged or worn out to a different degree, so that larger areas have to be removed for a first channel than for another second channel. Regarding this, the blank is no longer rotationally symmetric after removing all damaged areas.

The removal of the damaged areas can be made by a machining method, for example by milling or by turning. Alternatively or complementary, it is possible to remove the damaged parts by a separating process, for example by punching, by cutting, by torch cutting or by sawing.

A further advantageous measure for the method for manufacturing a component as well as for the method for repairing a component is, that at least one material is used for the build-up process, the material being different from the material the blank is consisting of. Regarding the build-up process, one ore more different materials or substances, respectively, can be used in order to optimize the properties of the component in its predetermined areas in a selective way. It is possible, for example, manufacturing those areas of the component which are exposed to highest loads in the operating state out of a particularly hard or of a particularly wear-resistant or of a particularly corrosion-resistant material. Regarding the impeller of a pump, those particularly overloaded areas, for example, are the radial exterior parts of the separating walls (vanes) between the channels, thus the trailing edges of the vanes as well as the area of the radial limiting surface of the impeller. These areas can be made of a particularly wear-resistant material in the build-up process.

Of course, it is also possible to change the material during the build-up process, thus, for example, initially to use a material during the build-up process, the material being the same as the material of the blank, for example, and then using a different material thereof, for example for the radial exterior areas of the component.

In this way it is also possible to generate a layer on individual parts by means of a build-up process, for example a wear protection coating.

Thus, due to this measure it is possible, for example, to realize a higher hardness of the component at wear surfaces of the component in a selective way. Hereby the service life of the component is increased. Regarding the impeller of a pump it is also in particular possible to do without a wear ring and to replace it by a coating, generated by means of the build-up process.

A component of a rotary machine is further proposed by the invention, the component being manufactured or repaired by a method according to the invention.

According to a preferred embodiment, each separating wall is designed as a vane.

The applications are particularly relevant for practical use, if the component is designed as an impeller, as a guide wheel or as a diffusor of a rotary machine, in particular of a pump, of a turbine, of a compressor, of a compactor or of an expander.

Further advantageous measures and designs of the invention result from the dependent claims.

The invention is explained in more detail below with reference to embodiments and to the drawing. The drawing illustrates:

Fig. 1: a perspective view of an embodiment of a component according to the invention, the component being manufactured according to an embodiment of a method according to the invention,

Fig. 2: a perspective view of an embodiment of a blank for performing an embodiment of a method according to the invention,

Fig. 3: a sectional view of the blank from Fig. 2 in a section in the axial direction,

Fig. 4: a perspective view of the blank from Fig. 2 after completing the first subtractive process step, and

Fig. 5: a sectional view of the blank from Fig. 4 in a section in the radial direction.

The method according to the invention is used for manufacturing a component of a rotary machine, the component having at least one inner channel, extending out of a center to a limiting surface of the component and which channel is at least partially closed. Here a closed channel is a channel, which is completely closed, except for an inlet or an outlet, so the channel has a tubular shape, that is to say, the channel is limited by one wall or by several walls anywhere, vertical to its main direction of flow. In contrast, an open channel means a channel, which is not limited by a wall in a direction vertical to its main direction of flow, thus in a direction vertical to its longitudinal extension, but it is open. So, for example, a channel with an U-shaped or a V-shaped wall is an open channel. If the open side of the U-profile or of the V-profile were covered with a plate, the channel would be a closed channel.

A partially closed channel means a channel, which is partially designed as a closed channel and partially as an open channel.

In the following description of the invention it is referred to an important example for practice with an exemplary nature, wherein the component is a closed or a covered rotor (impeller), respectively, of a turbo engine, e.g. of a pump. For a better understanding, Fig. 1 illustrates a perspective view of an embodiment of a component according to the invention, the component being a closed impeller and which is entirely provided with the reference sign 1. The impeller 1 can be manufactured by means of a method according to the invention.

The component 1 or the impeller 1, respectively, extends in an axial direction A as well as in a radial direction R vertical thereto. The axial direction A usually means that direction which is determined by the axis of rotation of the rotary machine when the component 1 is installed in the rotary machine. The axis of rotation is that axis around which the rotor of the rotary machine rotates in the operating state.

The impeller 1 rotates around the axis of rotation in the operating state, which axis determines the axial direction A. A direction vertical to this axial direction A is described as radial direction R.

The impeller 1 is a rotationally symmetric component with respect to the axial direction A and comprises a shroud 2 in a manner known per se, with which the impeller 1 usually is mounted or fixed on an axis or a shaft, not shown here, and also a number of vanes 3, which are arranged on the shroud 2, as well as a cover plate 4 covering the vanes 3 at least partially at the side or edge, respectively, facing away from the shroud 2. According to the description (Fig. 1), the cover plate 4 extends higher than the shroud 2 with respect to the axial direction A.

As a result according to the description, an internal space 6 is formed above the vanes 3, the space being limited by the cover plate 4 with respect to the radial direction R. This internal space 6 presents the inlet in the operating state, through which the fluid flows to the impeller 1. An inner channel 7 exists in each case between two adjacent vanes 3, which channel is designed as an at least partially closed channel 7 and here as a closed channel 7.

Each channel 7 extends from a first end 72 in a center of the impeller 1, which is formed by the internal space 6, to a respective second end 71 in a limiting surface 42 of the impeller 1. The limiting surface 42 presents the radially outer surface of the impeller 1, which surface extending parallel to the axial direction A, that is to say, the surface limiting the impeller 1 outwards in the radial direction R. “Parallel to the axial direction A” means, that each vector of the surface normal of the limiting surface 42 is vertical on the axial direction A. The limiting surface 42 comprises the radially outer surfaces of the cover plate 4 and of the shroud 2 as well as the radially outer closing edges of the vanes 3, which are called trailing edges 31.

Thus adjacent channels 7 are each separated by a separating wall 3, each separating wall 3 forming in each case one vane 3 of the impeller 1.

Depending on the design of the impeller 1 it is also possible, that the closing edges of the vanes 3 are displaced backward with respect to the radial direction, that means they are not in the limiting surface 42. Then, the cover plate 4 and / or the shroud 2 protrude over the vanes 3 or the closing edges of the vanes 3, respectively, with respect to the radial direction R. Such a design particularly is also possible regarding a rotor of a turbine, where the outer closing edges of the vanes 3 usually are the leading edges.

Hence, each of the closed channel 7 is enclosed by a limiting surface 8, in each case composing of the surfaces of two adjacent vanes 3 facing each other, as well

as of the intermediate surface segments of the surfaces of the shroud 2 and of the cover plate 4 facing each other, which surface segments forming the bottom and the top of the respect channel 7. Thus the vanes 3 each form a separating wall between two adjacent inner channels 7. The second end 71 of each channel 7 comprises the port, with which the respective channel 7 joins the limiting surface 42. Adjacent second ends 71 in peripheral direction each are separated from each other by a trailing edge 31.

The impeller 1 also has a central through bore 9, which is used to receive a shaft or an axis, on which the impeller 1 is mounted.

An embodiment of the method according to the invention is explained in more detail below with reference to Fig. 2-5.

According to the method according to the invention a blank is firstly provided. Fig. 2 illustrates in a perspective view an embodiment of such a blank, which is entirely provided with the reference sign 10. This blank 10 is designed for manufacturing the impeller 1, illustrated in Fig. 1. For a better understanding, Fig. 3 illustrates a sectional view of the blank 10 from Fig. 2 in a section in the axial direction A.

The blank 10 is particularly preferred designed in a rotationally symmetric way with respect to the axial direction A, as also illustrated in Fig. 2 and Fig. 3.

The blank 10 has the central through bore 9, which is used to receive the shaft or the axis, on which the impeller 1 can be mounted. The bore 9 is limited in the area of its upper end (illustrated in Fig. 2) by an annular body 21, coaxially extending about the axial direction A. This annular body 21 forms a part of the shroud 2 in the finished state of the impeller 1.

The blank 10 further comprises the center formed by the internal space 6, which center presents the inlet of the impeller 1 in the operating state, through which the fluid flows to the impeller 1. The internal space 6 is designed as a cavity in the blank 10, which cavity rotationally symmetric and coaxially extending about the annular body 21. This cavity is radially inside limited by the annular body 21. Regarding the radial direction R external, the cavity forming the internal space 6 is limited by a cylindrical area 41, as well as by a substantially cone-mantle-shaped wall 61 joining the cylindrical area 41 below (illustrated in Fig. 3) in the axial direction A. The cylindrical area 41 as well as the wall 61 are coaxially arranged to the bore 9 and are rotationally symmetric regarding the axial direction A. The cylindrical area 41 forms a part of the cover plate 4 in the finished impeller 1 (see Fig. 1), namely that part limiting the internal space 6 in the radial direction.

The blank 10 is limited by an outer surface 11 in the radial direction R, which outer surface 11 is designed cylinder-mantle-shaped in this embodiment and which extends coaxially to the bore 9 about the axial direction A. Consequently, the dimension of the outer surface 11 in the radial direction R is the diameter D1 of the cylinder-mantle-shaped outer surface 11.

Naturally, such designs are also possible, wherein the radially external outer surface 11 of the blank 10 is not a cylinder mantle surface, but has another geometrical design, for example having the shape of a cone mantle surface or of a truncated cone mantle surface. In such cases, D1 indicates the maximum dimension of the outer surface 11 in the radial direction R, thus the maximum diameter, for example, which is enclosed by the outer surface 11.

The maximum dimension of the blank 10 in the axial direction A is described with the height H1. The height of the outer surface 11 of the blank 10 in the axial direction A may be smaller than or equal to this height H1.

The blank 10 is designed in such a way, that the diameter D1 of its outer surface 11 is smaller than the corresponding dimension of the limiting surface 42 in the radial direction R. The dimension of the limiting surface 42 in the radial direction R is the outer diameter D2 of the impeller 1 (see Fig. 1). Thus it is $D1 < D2$.

The height H2 of the impeller 1 in the axial direction A (see Fig. 1) is its maximum extension in the axial direction A.

In this embodiment, the height H1 of the blank 10 is measured such, that the height is equal to the height H2 of the finished impeller, thus it is $H1 = H2$.

Of course, it can also be advantageous to measure the height H1 of the blank 10 smaller than the height H2 of the finished impeller. For example, a suitable choice of H1 can be made on the basis of the criterion how much volume of the component 1 is to be manufactured by a build-up process and which parts of the component 1 are to be manufactured already in the first subtractive process step. Of course, this depends on the specific geometry of the component 1 to be manufactured and on economic factors.

The outer surface 11 of the blank 10 is preferably designed as a coherent surface having no openings.

Particularly preferred, the blank 10 is made of a forged material, which may be a metal or a metal alloy. Thus, for example, steel is suitable in its known embodiments or aluminum, titanium, nickel, a nickel or cobalt base alloy or a non-ferrous metal. Of course, other than forged materials are also possible, for example a cast material, a synthetic material or a composite or another machinable material.

The blank 10 is preferably manufactured or processed in such a way, that parts of the shroud 2 as well as of the cover plate 4 are already designed in its desired final form or at least substantially in its final form. In that regard, “substantially” means that, of course, post-processings can be performed at a later stage, as for example milling, turning, grinding, polishing or something similar, but the substantial design is already completed in the blank 10. Preferably, at least the following parts of the blank 10 are designed that way, that they substantially have the final form of the completed impeller: the central axial bore 9, the annular body 21 as a part of the shroud 2, the cylindrical area 41 as a part of the cover plate 4, the internal space 6, which forms the center and which is realized by the cavity in the blank 10. Furthermore, in the embodiment described here, the height H1 of the blank 10 is already substantially identical to the height H2 of the impeller 1.

Now a first subtractive process step is performed on this blank 10, which process step is explained below. Fig. 4 illustrates a perspective view of the blank 10 after finishing the first subtractive process step. Particularly, the first subtractive process step is performed by means of a machining process. For a better understanding, Fig. 5 additionally illustrates a sectional view of the blank from Fig. 4 in a section in the axial direction A.

A subtractive process step means, that material is cut or removed, respectively, from the workpiece - here from the blank 10 – in such a process step. As it is generally usual, a machining process means a process wherein excessive material is removed from the blank 10 or the workpiece, respectively, in the form of chips in order to achieve a desired geometrical form. For example, machining processes are milling, turning, drilling, planing, filing, grinding, honing or lapping, to mention only a few examples.

The first subtractive process step preferably comprises a milling by means of a

machining device, comprising, for example a computer-controlled milling tool. Particularly preferred, the machining device is designed at least as an five-axes-milling tool, with which the desired geometrical form is elaborated out of the blank 10. The milling tool is usually guided by a manipulator, the guide being computer-assisted.

One part is manufactured from each channel 7 in the first subtractive process step, which part extending from the first end 72 of the respective channel into the outer surface 11 of the blank 10. The first end 72 of each channel 7 joins the wall 61, limiting the internal space 6.

As it particularly is illustrates in Fig. 4, the area of the port of each channel 7 into the outer surface 11 is designed as a closed channel section. These ports are each milled into the outer surface 11, wherein adjacent ports each are separated from each other by an edge 32 of the incomplete separating walls 3.

After the ports of the channels 7 into the outer surface 11 of the blank 10 have been finished, the outer surface 11 has a coherent annular area 12 covering the port of each channel 7 into the outer surface 11. Thus, all channels 7 are closed by the annular area. That is, after finishing the first subtractive process step (see Fig. 4), the outer surface 11 of the blank 10 comprises the annular area 12, which surface is designed as annular coherent area having no openings, and thus being consistent with respect to the peripheral direction, and which area covering all ports of the channels 7 into the outer surface 11.

The parts of each channel 7 being manufactured in the first subtractive process step, that means in each case the channel section from the first end 72 of the channel in the wall 61 of the internal space 6 to the port of the respective channel into the outer surface 11 of the blank 10, are preferably manufactured in such a way, that they substantially have at least their final form.

After finishing the first subtractive process step (see Fig. 4, Fig. 5) the blank 10 has the following form: the center formed by the internal space 6, the bore 9, the annular body 21 and the cylindrical area 41 of the cover plate 4 substantially have at least their final form.That part of each channel 7 is completed, i.e. substantially in its final form, which extends from its first end 72 joining the internal space 6 to the port into the outer surface 11 of the blank 10. Thus, the blank 10 already has at least substantially the final form of the completed impeller 1 apart from those areas of the impeller 1, which are arranged radially external with respect to the outer surface 11 of the blank 10.

It is understood, that the first subtractive process step can comprise a milling from the wall 61 or from the internal space 6, respectively, as well as a milling from the outer surface 11. Of course, it is also possible, to mill or to process by machining, respectively, only from the internal space 6 or only from the outer surface 11 in the first subtractive process step depending on the component.

It is an advantage of the purely machining process, that a blank 10 made of a forged material retains all positive properties of the forged material.

It is understood, that the diameter D1 of the blank 10, which in principle is a freely selectable parameter within wide limits, preferably is chosen such in the respective application, that these parts of the channels 7 manufactured in the first subtractive process step can be elaborated out of the blank 10 by machining without any problem, for example by milling, in particular with respect to the geometry.

After finishing the first subtractive process step (see Fig. 4, Fig. 5), the still missing parts of the component 1 are manufactured by means of a build-up process and the component 1 is brought in its final form. Fig. 1 illustrates in a perspective view the finished component 1, here the covered impeller 1, which is manufactured out of the blank 10, illustrated in Fig. 4 and 5.

A build-up process means a process, wherein a shapeless or a neutrally shaped material is applied. In doing so, the shapeless material, for example a powder, or the neutrally shaped material, for example a strap-shaped material, usually is melted in order to build up the still missing parts of the component 1 on the blank or on the already existing structure, respectively. Thus, a build-up process is a process out of a shapeless or a neutrally shaped material.

The build-up manufacturing comprises one or several additive process step(s). An additive process step or an additive manufacturing, which is also referred to as generative manufacturing, respectively, means a process step, wherein material is added or applied on the workpiece, here the blank 10. The desired structures usually are generated, for example by a build-up process on a workpiece, in an additive manufacturing out of a shapeless material, for example liquids or powders, or out of a neutrally shaped material, for example strap-shaped or wire-shaped material, by means of chemical and / or physical processes. Additive manufacturing methods known per se for metallic workpieces are , for example build-up welding methods, in particular inert gas methods as tungsten inert gas welding (TIG) or laser build-up welding or plasma methods or selective laser melting (SLM selective laser melting) or selective laser sintering (SLS).

After finishing the first subtractive process step the still missing areas of the component 1 are generated by means of a build-up process, in particular these are the radial exterior parts of the separating walls 3 and of the channels 7, parts of the cover plate 4 as well as parts of the shroud 2.

In a preferred embodiment, the still missing parts are generated in the build-up process by means of laser build up welding. The method of laser build-up welding with its different variants is well known to the person skilled in the art and, thus, no further explanations are required.

Hence, it is possible to perform the build-up process of the blank 10 layer by layer, in particular by using the rotationally symmetric design.

Another also preferred embodiment is to build up the component 1 part by part in the build-up process, i.e. the individual parts of the component 1 as e.g. the separating walls 3 or the covers of the channels 7 are successively built up in this sense, that first a part, e.g. the separating walls, is completely built up to its final state and then the next part is completely built up. This process is repeated until the component is finished.

Furthermore, it is possible, that the individual parts of the component 1 are not completely built up, but only part by part, in other words first a part of the separating walls 3 is built up, then a part of the covers of the channels 7, then a part of the separating walls 3 again and so on. In doing so, a further subtractive process step can preferably be performed after a partial build up.

As already mentioned, according to a preferred embodiment the build-up process can comprise several additive process steps to build up the component 1 in a successive manner. Regarding this, it is particularly preferred performing at least one further subtractive process step between the additive process steps.

Deviations from the desired geometry can be compensated in such a further subtractive process step, for example by a machining process, which deviations have arised in the preceding additive process step. Thus, for example, milling or grinding works can be performed in this further subtractive process step, in order to remove such material which was applied too much in the additive process step or in order to equalize or to grind junctions between adjacent layers or the like.

It is particularly preferred performing a further subtractive process step in each case between two additive process steps, i.e. the additive process steps and the further subtractive process steps are performed alternately or in turns, respectively. This ensures a particularly high quality and precision of the component 1.

Nowadays modern processing machines are known, with which subtractive process steps as well as additive process steps can be performed in the same process chamber without need to re-clamp the blank 10 or the component 1, respectively, or to put them into another holder. The blank 10 is only once clamped into a holder and then, the blank can be processed selectively or alternately in a subtractive or additive manner. Such processing machines comprise several processing heads for this purpose, at least one of them being designed for a subtractive process, for example as a milling tool, and at least one of them being designed for the additive process, for example as a device for laser build up welding. After finishing an additive process step, for example, the processing machine automatically changes the processing head and then it can perform a subtractive process step and vice versa. In doing so, a particularly fast and very precise manufacturing of the component 1 is possible.

Deviating from the embodiment described above, it is also possible, according to another also preferred variant, that parts of the annular body 21 and / or of the cylindrical area 41 are only manufactured in the additive process.

Thus, it is possible, for example, to manufacture the upper zone according to the illustration (Fig. 5) of the cylindrical area 41 only after the first subtractive process step in regard to the build-up process, having the advantage, that parts of the channel 7, which are to be elaborated in the first subtractive process step, are more accessible to the tool. The “upper zone” means that part of the cylindrical

area 41, which is, according to the illustration, above the first ends 72 of the channels 7 with respect to the axial direction A.

Alternatively or additionally, it is also possible, that a part of the annular body 21 is only manufactured in regard to the build-up process. This also makes it possible to ensure a better accessibility to the ports of the channels 7 in the first subtractive process step, which channels are elaborated out of the blank 10 in this first subtractive process step.

The invention also proposes an analogously same method for repairing damaged or worn out components of a rotary machine. Regarding the method for repairing a components 1 of a rotary machine, for example the impeller 1 of a pump, it is proceeded in the analogously same manner as described above, but the blank 10 is generated out of a damaged or worn out, respectively, impeller 1. For example, this can be an impeller 1, whose trailing edges 31 of the vanes 3 or of the separating walls 3, respectively, or the radially outer areas of the channels 7 are damaged. The method according to the invention for repairing the component is particularly characterized in that damaged areas of the component 1 are identified at the limiting area 42 or at the channels 7 or at a separating wall, that further a blank 10 is manufactured by a machining or by a separating removal of the damaged areas, which blank comprising the center of the component 1, and that the removed damaged areas are replaced by means of a build-up process on the blank in order to manufacture the final form of the component 1.

Regarding the method according to the invention for repairing a component the blank 10 is manufactured in an analogously same manner as in the method for manufacturing a component, on which blank the still missing parts or areas of the component 1 are subsequently manufactured by means of a build-up process.

Regarding the method for repairing, here the blank 10 is generated by removing the damaged areas of the component. After manufacturing the blank 10 by removing the damaged areas, the blank corresponds in principle to the blank 10 manufactured by the method for manufacturing the component after performing the first subtractive process step (see Fig. 4 and Fig. 5).

Regarding the method for repairing, it is particularly not necessary, that the blank generated by removing the damaged areas is rotationally symmetric. For example, in the case of an impeller 1 being the component, it can be possible, that the individual closed channels 7 or the individual separating walls 3 between them are differently damaged or worn out, so that larger areas have to be removed from a first channel 7 than from another second channel 7. In this case, the blank 10 is no longer rotationally symmetric after removing all damaged areas.

The removal of the damaged areas can be performed by a machining method, for example by milling. Alternatively or additionally, it is also possible to remove the damaged areas by a separating process, as for example punching, cutting, torch cutting or sawing.

The illustrations regarding the method for manufacturing the component 1 including the advantageous measures and variants are also valid in a same or in an analogously same manner for the method for repairing the component 1.

Regarding the method according to the invention for manufacturing a component as well as the method according to the invention for repairing a component, it is possible to use one ore several materials for the build-up process, the materials being different from the material of which the blank is consisting. Of course, it is also possible to change the material during the build-up process, thus using different materials for the build-up process, for example up to four different materials. Thus, for example, a first material can be used for a first additive

process step, the material being equal or different from the material of the blank 10 and then using a second material for a further additive process step, the material being different from the first material.

In this way, layers can be generated, for example wear protective coatings for protecting particularly such areas of the component where the highest loads arise in the operating state. Here such coatings can be generated directly on areas, which are manufactured in the subtractive process step, as well as on areas, which are generated in a preceding additive process step.

In this way, areas of the component can be optimized specifically with respect to hardness, wear resistance, corrosion resistance and so on.

Regarding the impeller of a pump it is possible, for example, the radially external areas of the separating walls (vanes) between the channels, hence the trailing edges of the vanes as well as the area of the radial limiting surface of the impeller. Then, these areas can be manufactured out of a particularly wear-resistant material in the build-up process.

Of course, it is also possible to change the material during the build-up process, thus, for example, initially using a material during the build-up process, the material being the same as the material of the blank, for example, and then using a different material, for example for the radially exterior areas of the component.

In this way, it is also possible to generate a layer on individual parts or areas of the component by means of a build-up process, for example a wear protection coating.

Thus, due to this measure it is possible, for example, to realize a higher hardness of the component at wear surfaces of the component in a selective way. Hereby

the service life of the component is increased. Regarding the impeller of a pump it is also in particular possible to do without a wear ring, which may be provided on the impeller, and to replace the wear ring by a coating, generated by means in regard of the build-up process.

Although the invention has been explained with reference to manufacturing or repairing, respectively, an impeller 1, the invention is, of course, not limited to such components 1 or their manufacturing or their repairing, respectively, but the invention is suitable for a plurality of other components 1, in particular for such components 1 where at least one inner channel 7 is provided, which geometry does not allow to elaborate that channel by machining or subtractively out of a blank 10 with a reasonable expenditure.

In particular, the component 1 can also be designed as an impeller or as a diffusor of a rotary machine, wherein the rotary machine can be in particular a pump or a turbine or a compressor or a compactor or an expander.

The inner channel can also be, for example, a cooling channel, e.g. in a turbine blade, for example a cooling air channel.

Patent Claims

1. A method for manufacturing a component of a rotary machine, the component extending in an axial direction as well as in a radial direction perpendicular to the axial direction, the component having at least one inner channel, which extends from a first end in a center of the component to a second end at a radial limiting surface of the component and which is at least partially closed, said method comprising:

providing a blank comprising the center of the component, wherein the blank is limited by an outer surface in the radial direction, and the maximum dimension of the outer surface in the radial direction is smaller than the dimension of the radial limiting surface in the radial direction;

performing a first subtractive process step during which a radially-inner part of the at least one inner channel is manufactured by a machining process, with said radially-inner part extending from the first end of the channel to the outer surface of the blank; and

finishing the at least one inner channel by creating a radially-outer part of the channel using an additive manufacturing process step performed on the blank by applying a shapeless or a neutrally shaped material that is shaped into the radially-outer part of the channel.

2. A method according to claim 1, wherein the component comprises a plurality of inner channels, each of which extending from a first end in the center of the component to a second end at the radial limiting surface of the component, wherein adjacent channels are respectively separated by a separating wall, wherein in each case one part of the channel is manufactured of each channel in the first subtractive process step, with said part extending from the respective first end of the channel into the outer

surface of the blank, and wherein each separating wall and each channel is only finished by means of the additive manufacturing process.

3. A method according to claim 1 or 2, wherein the component is built up part by part after the first subtractive process step.

4. A method according to claim 3 when dependent from claim 2, wherein, after the first subtractive process step, the additive manufacturing process comprises first completing only each separating wall.

5. A method according to anyone of the preceding claims, wherein the blank has a central bore before the first subtractive process step, said bore being arranged radially inwardly such that, in the finished state of the component, each first end of a channel arranged in the center is separated from the central bore by an annular body.

6. A method according to anyone of the preceding claims, wherein the first subtractive process step is performed in such that, after finishing the first subtractive process step, the outer surface of the blank comprises a contiguous annular area covering the confluence of each channel into the outer surface.

7. A method according to anyone of the preceding claims, wherein the additive manufacturing process is performed layer by layer.

8. A method according to any one of the preceding claims, wherein the additive manufacturing process comprises several additive process steps to successively build up the component.

9. A method according to claim 8, wherein at least one further subtractive process step is performed between the additive process steps.

10. A method according to claim 8 or 9, wherein in each case one further subtractive process step is performed between two additive process steps.

11. A method according to any one of the preceding claims, wherein the additive manufacturing process is performed by means of a laser.

12. A method according to any one of the preceding claims, wherein the component is designed as an impeller, as a guide wheel or as a diffusor of a rotary machine.

13. A method according to claim 12, wherein the rotary machine is a pump, a turbine, a compressor, a compactor, or an expander.

14. A method for repairing a component of a rotary machine, the component extending in an axial direction as well as in a radial direction perpendicular to the axial direction, the component comprising a plurality of inner channels, each of which extend from a first end in the center of the component to a second end at the radial limiting surface of the component, wherein adjacent channels are respectively separated by a separating wall, said method comprising:

identifying damaged areas of the component at the radial limiting surface or at one of the channels or at one of the separating walls;

manufacturing a blank by a machining removal or by a separating removal of the damaged areas, the blank comprising the center of the component and being limited by an outer surface in the radial direction, wherein the maximum dimension of the outer surface in the radial direction is smaller than the dimension of the radial limiting surface in the radial direction, the blank further comprising a radially-inner part of the channels extending from

the first end of the channels to the outer surface of the blank; and

replacing the removed damaged areas by means of an additive manufacturing process on the blank in order to obtain the final form of the component, the additive manufacturing process being effected directly from a shapeless or a neutrally shaped material applied to the blank.

15. A method according to anyone of the preceding claims, wherein at least one material is used for the additive manufacturing process, said material being different from the material of which the blank consists.

16. A method according to any one of the preceding claims, wherein the or each inner channel has an open end at the first end and has another open end at the second end.