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(54) METHOD FOR INTRODUCING COMPRESSIVE STRESS IN AT LEAST ONE TARGET REGION

(57) The invention relates to a method (2) for introducing compressive stress in at least one target region (3) of a component (1). In this method, the component (1) is heated to a yield strength temperature in at least one sacrificial region (4) adjacent to the target region (3), is heated further to a maximum target temperature, and is cooled.

The invention also relates to the component (1) treated in the method (2).

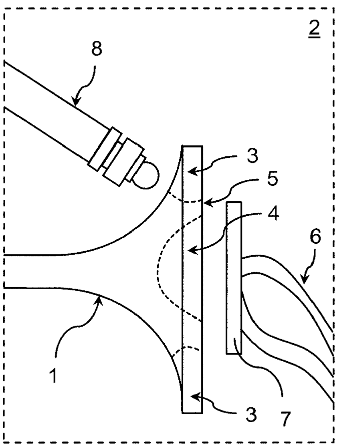

Fig. 1

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Description

[0001] The invention relates to a method for introducing compressive stress in at least one target region of a component according to the generic term of claim 1. The invention also relates to a component treated in the method.

[0002] A component can contain residual tensile stresses and/or residual compressive stresses in its material or on its body as a result of manufacturing - for example, due to mechanical and thermal treatments. The residual tensile stresses can lead to rapid failure of the component in heavily stressed regions of the component. The compressive stresses, on the other hand, can strengthen the component. However, it is difficult to influence the arrangement of the tensile stresses/compressive stresses in the component during production. Methods are known in which the tensile stresses in the component are almost completely relieved by subsequent treatment of the component. However, this does not achieve the beneficial effect of the compressive stresses.

[0003] It is therefore the object of the invention to provide an improved or at least alternative embodiment for a method of the type described, in which the disadvantages described are overcome. It is also the object of the invention to provide a component treated in the method.

[0004] This task is solved according to the invention by the object of the independent claims. Advantageous embodiments are the subject of the dependent claims.

[0005] The present invention is based on the general idea of introducing compressive stresses into certain target regions of a component by means of differential and plasticizing heat treatment, thereby reinforcing i.e. strengthening the component in these target regions.

[0006] The method according to the invention is provided for introducing compressive stress in at least one target region of a component. In the method, the component is first heated to a yield strength temperature in at least one sacrificial region adjacent i.e. close i.e. near to the respective target region. This increases the compressive stress in the respective sacrificial region and the tensile stress in the respective target region. Then, the component is heated to a maximum target temperature, thereby reaching the maximum compressive stress in the respective sacrificial region and the maximum tensile stress in the respective target region. Then, after reaching the maximum compressive stress in the respective sacrificial region and the maximum tensile stress in the respective target region, the component is cooled, thereby increasing the compressive stress in the respective target region and increasing the tensile stress in the respective sacrificial region. In the context of the present invention, the compressive stress and the tensile stress are the residual stresses of the component.

[0007] The method according to the invention is differential, whereby the respective target region is strengthened i.e. reinforced by increasing the compressive stress and the respective sacrificial region is not strengthened i.e. sacrificed by increasing the tensile stress. The respective target region can be, in particular, the region of the component which is high stressed when the component is used. The respective sacrificial region, on the other hand, can be the region of the component which is less strongly or weakly stressed when the component is used. The method can therefore be used to introduce the compressive stress specifically in the respective target region, thereby strengthening i.e. reinforcing the component in the respective target region. The component can also contain a plurality of target regions and a plurality of sacrificial regions. Accordingly, in the method, a single sacrificial region or several sacrificial regions can be used to reinforce a single target region or several target regions.

[0008] The respective target region and the respective sacrificial region can be adjacent i.e. close i.e. near to each other. Especially, the target region and the sacrificial region can be separated by a transition zone i.e. transition region. If the component is reinforced i.e. strengthened in several target regions in the method, the respective target regions are separated from each other by sacrificial regions. In other words, the individual target regions are not connected with each other. This also applies to the respective sacrificial regions. The respective target region differs from the respective sacrificial region by its use in the method. In other words, the respective target region can be arbitrarily defined in the component and reinforced in the method. Expediently, the respective target region can be located in the region of the component which contributes to improving the performance of the component. The respective sacrificial region, on the other hand, can be located in the region of the component that can compensate the compressive stresses in the respective target region without endangering the component itself.

[0009] In the method, the component in the respective sacrificial region is first heated to the yield strength temperature. As a result, the component expands in the respective heated sacrificial region and the compressive stress is built up in the sacrificial region. The respective heated sacrificial region thereby induces the tensile stress in the non-heated target region. Accordingly, the compressive stress is increased in the respective sacrificial region and the tensile stress is increased in the respective target region. At the yield strength temperature, the elastic limit is reached. Below the yield strength temperature, the component can deform elastically and above the yield strength temperature, the component can deform elastically and plastically.

[0010] Then the component is heated in the method to the maximum target temperature which is higher than the yield strength temperature and in which plastic strain occurs. However, the difference between the yield strength temperature and the maximum target temperature can be negligibly small. In fact, the aim is to exceed the yield strength temperature and to maintain the plastic deformation in the sacrificial region of the component for the necessary time. For this purpose, the component can also be maintained at the yield strength temperature and/or at the maximum target temperature for a predetermined time. At the maximum target temperature, the maximum compressive stress in the respective sacrificial region and the maximum tensile stress in the respective target region are reached.

[0011] The component is then cooled after reaching the maximum compressive stress in the respective sacrificial region and the maximum tensile stress in the respective target region, thereby reducing the compressive stress in the respective sacrificial region and the tensile stress in the respective target region. As the component cools, it contracts. The contraction takes place in the direction of the respective sacrificial region and as a result the compressive stress is increased in the respective target region. In the respective sacrificial region, on the other hand, the tensile stress is built up. Overall, the compressive stress is increased in the respective target region and the tensile stress in the respective sacrificial region. By increasing of the compressive stress in the respective target region, the tensile stress in the respective target region is reduced and then the compressive stress is build up. By increasing of the tensile stress in the respective sacrificial region, the compressive stress in the respective sacrificial region is reduced and then the tensile stress is build up. In other words, the stresses which are achieved in the target and the sacrificial regions during heating are first reduced and lately inverted.

[0012] When comparing the component before applying the method i.e. the untreated component and the component after applying the method i.e. the treated component, the respective target region of the component exhibits the comparatively increased compressive stress i.e. the comparatively reduced tensile stress, and the respective sacrificial region exhibits the comparatively reduced compressive stress i.e. the comparatively increased tensile stress. After cooling, the component in the target region can have the compressive stress of at least 80 MPa, preferably of at least 100 MPa, in a compressive stress field having a minimum depth of at least 0.3 mm.

[0013] The component can have a thickness of at least 5 mm in the respective target region and/or in the respective sacrificial region. The component can be formed from an austenitic material, preferably from an austenitic steel. In the case of the austenitic material, no significant changes in the metallurgical properties of the component in the respective sacrificial region are to be expected after the method. However, there can possibly be a slight decrease in hardness and a slight increase in grain size.

[0014] In principle, the component can be heated in the respective sacrificial region by means of any devices and any methods. Preferably, the component in the respective sacrificial region can be inductively heated to the maximum target temperature by means of an inductive heating device. With inductive heating, particularly good penetration of the heat into the component i.e. targeted heating can be achieved.

[0015] The maximum target temperature understandably depends on the material of the component. In addition, the maximum target temperature depends on the compressive stress to be achieved in the respective target region and on the maximum tensile stress that can be generated i.e. the maximum permissible tensile stress in the respective sacrificial region. The component can exceed the yield strength at the yield strength temperature and deform plastically in the sacrificial region. However, after reaching the yield strength temperature, the component can be further heated in the sacrificial region to the maximum target temperature. The maximum target temperature is therefore higher than the yield strength temperature. The maximum target temperature can be, for example, between 60% and 80%, preferably at 70%, of the melting temperature of the material of the component. This allows to avoid strong grain growth, deformation of the component and high shear stress in the component.

[0016] In the method, the component can additionally be cooled outside the sacrificial region by means of air or liquid cooling when heating the sacrificial region. Thereby, the respective target region and/or a region outside the sacrificial region and the target region can be cooled. By cooling the component outside the sacrificial region, a thermal expansion gradient between the respective non-heated i.e. cold regions and the respective heated i.e. hot sacrificial region can be safely maintained. The component can be cooled not only when the sacrificial region is heated, but also when the sacrificial region is cooled by means of air or liquid cooling. The cooling of the component can be carried out until the component in the respective sacrificial region and/or in the respective target region and/or in a region outside the sacrificial region and the target region is cooled to a limit temperature of 200°C, for example.

[0017] The invention also relates to a component which contain at least one target region with compressive stress and at least one sacrificial region with tensile stress. In accordance with the invention, the component is treated in the method described above. Compared to a non-treated component, the treated component can have the comparatively high compressive stress in the respective target region and the comparatively low compressive stress in the respective sacrificial region. After cooling, the component can have the compressive stress of at least 80 MPa, preferably at least 100 MPa, in the target region in a compressive stress field with a depth of at least 0.3 mm.

[0018] Further important features and advantages of the invention are apparent from the subclaims, from the drawings, and from the accompanying figure description based on the drawings.

[0019] It is understood that the above features and those to be explained below can be used not only in the combination indicated in each case, but also in other combinations or on their own, without departing from the scope of the present invention.

[0020] Preferred embodiments of the invention are shown in the drawings and will be explained in more detail in the following description, wherein identical reference signs refer to identical or similar or functionally identical components.

[0021] It shows, each schematically

Figs. 1 and 2	a side view and a top view of a component according to the invention during a method according to the invention;
Fig. 3	a view of the component treated in the method according to the invention with distribution of the residual stress in the component;
Fig. 4	a view of the component treated in the method according to the invention with distribution of the residual stress in the component with measuring points;
Fig. 5 to 8	distribution of the residual stress in the component at measuring points shown in Fig. 4.

[0022] Fig. 1 shows a side view and Fig. 2 shows a top view of a component 1 according to the invention during a method 2 according to the invention. In this embodiment, the component 1 is an intake/exhaust valve for a motor vehicle and is formed from an austenitic material. For the method 2, a target region 3 and a sacrificial region 4 adjacent to the target region 3 are defined in the component 1. The target region 3 and the sacrificial region 4 are defined in such a way that the target region 3 can be reinforced by introducing of the compressive stress and the sacrificial region 4 can be weakened uncritically by introducing of the tensile stress in the method 2.

[0023] In the method 2, the component 1 is inductively heated in the sacrificial region 4 to a maximum target temperature by an inductive heating device 6 with a heating coil 7. The maximum target temperature is between 60% and 80%, preferably 70%, of the melting temperature of the material of the component 1. At the same time, the target region 3 is cooled by means of air or liquid cooling 8. The component 1 expands in the sacrificial region 4 by heating, wherein compressive stress is build up in the sacrificial region 4 and tensile stress is build up in the target region 3. The air or liquid cooling 8 increases a temperature gradient between the target region 3 and the sacrificial region 4 and reinforces the described method.

[0024] If a yield strength temperature which is smaller than the maximum target temperature is reached in the sacrificial region 4, the component 1 exceeds the yield point in the sacrificial region 4 because of the reached compressive stress and deforms plastically in the sacrificial region 4.

[0025] The component 1 is then cooled. The component 1 contracts towards the sacrificial region 4 by cooling, wherein the compressive stress is build up in the target region 3 and the tensile stress is build up in the sacrificial region 4. Hereby, the stresses which are achieved in the target and the sacrificial regions during heating are first reduced and lately inverted. As a result, the compressive stress is introduced into the target region 3 and the latter is reinforced. When the component 1 is cooled, the heating device 6 is turned off and the component 1 is further cooled with the air or liquid cooling 8 until the component 1 reaches a limit temperature of 200°C in the sacrificial region 4 or in the target region 3.

[0026] Fig. 3 shows a view of the component 1 treated in the method 2 with distribution of the residual stress in the component 1. The component 1 is shown here in section and in addition the size scales x and y are shown in mm.

[0027] Fig. 4 shows a view of the component 1 treated in the method 2 with distribution of the residual stress in the component 1. In addition, a total of four measuring points MT, A, B and C are shown, each with a measuring direction indicated by an arrow. At the measuring point MT, the residual stress is measured along a surface 5 as indicated by the arrow. At the measuring point A, the residual stress is measured at a distance i.e. height of 2.7 mm from the edge of component 1 from the surface of component 1 into component 1 as indicated by arrow. At measuring points B and C, the residual stress is measured at a distance i.e. height of 30 mm and 50 mm from the surface 5 of component 1 from the surface of component 1 into component 1 as indicated by arrow.

[0028] Fig. 5 to Fig. 8 show diagrams of the residual stress in component 1 at the measuring points MT, A, B and C. Results are shown for two components 1, where for one component 1 the maximum target temperature was 1050°C and for the other component 1 the maximum target temperature was 850°C reached in 35 seconds in each case. In the diagram in Fig. 5, the residual stress along the surface 5 of the component 1 is plotted in the measurement direction indicated by arrows in Fig. 4. In the diagrams in Figs. 6-8, the residual stress is plotted in each case against the distance from the surface of the component 1 in the measurement direction indicated by arrows in Fig. 4. The residual stress is indicated in MPa and the distance in mm. The component 1 treated in the method 2 exhibits in the target region 3 the compressive stress of at least 100 MPa in a compressive stress field with a depth of at least 0.3 mm.

Claims

1. Method (2) for introducing compressive stress in at least one target region (3) of a component (1),

   - wherein the component (1) is heated to a yield strength temperature in at least one sacrificial region (4) close to the target region (3), thereby

increasing the compressive stress in the respective sacrificial region (4) and the tensile stress in the respective target region (3),
- wherein the component (1) is heated in the respective sacrificial region (4) to a maximum target temperature, thereby reaching the maximum compressive stress in the respective sacrificial region (4) and the maximum tensile stress in the respective target region (3),
- wherein the component (1) is cooled after reaching the maximum compressive stress in the respective sacrificial region (4) and the maximum tensile stress in the respective target region (3), thereby increasing the compressive stress in the respective target region (3) and the tensile stress in the respective sacrificial region (4).

2. Method according to claim 1,
characterized
in that the component (1) exceeds the yield point at the yield strength temperature and deforms plastically in the respective sacrificial region (4).

3. Method according to claim 1 or 2,
characterized
in that the maximum target temperature is between 60% and 80%, preferably at 70%, of the melting temperature of the material of the component (1).

4. Method according to any of the preceding claims,
characterized
in that the component (1) in the respective sacrificial region (4) is inductively heated to the maximum target temperature by means of an inductive heating device (6).

5. Method according to any of the preceding claims,
characterized
in that the component (1) is cooled outside the sacrificial region (3) by means of air or liquid cooling (8) during heating of the respective sacrificial region (4).

6. Method according to any one of the preceding claims,
characterized
in that the respective target region (3) is cooled by means of air or liquid cooling (8) during cooling of the component (1).

7. Method according to claim 6,
characterized
in that the respective target region (3) is cooled until the component (1) in the respective sacrificial region (4) and/or in the respective target region (3) and/or in a region outside the sacrificial region (4) and the target region (3) achieves a limit temperature.

8. Method according to claim 7,
characterized in that
that the limit temperature is 200°C.

9. Method according to any one of the preceding claims,
characterized

- **in that** the component (1) has a thickness of at least 5 mm in the respective target region (3) and/or in the respective sacrificial region (4), and/or
- **in that** the component (1) is formed from an austenitic material, preferably an austenitic steel, and/or
- **in that**, after cooling, the component (1) has the compressive stress of at least 80 MPa, preferably at least 100 MPa, in a compressive stress field with a diameter of at least 0.3 mm in the respective target region (3).

10. Component (1) comprising at least one target region (3) with the compressive stress and at least one sacrificial region (4) with the tensile stress, wherein the component (1) is treated in the method (2) according to one of the preceding claims.

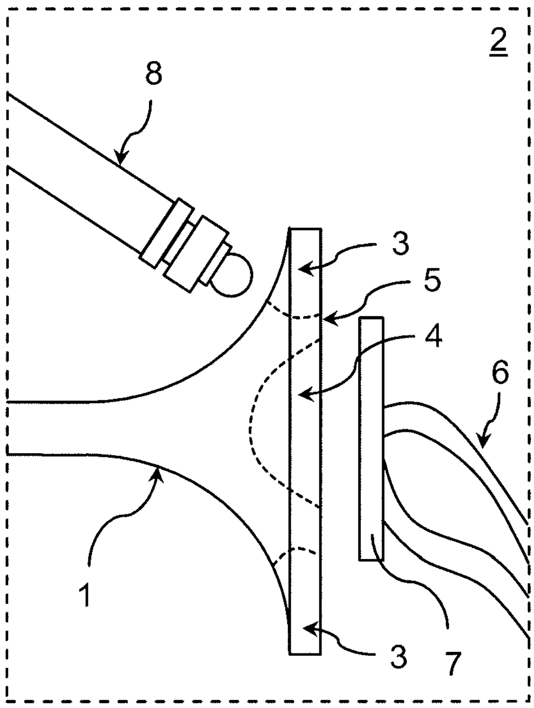


Fig. 1

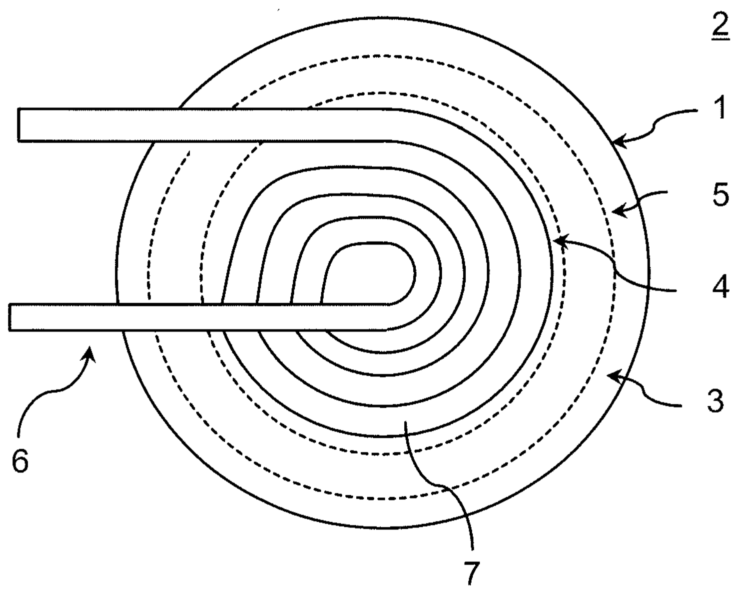


Fig. 2

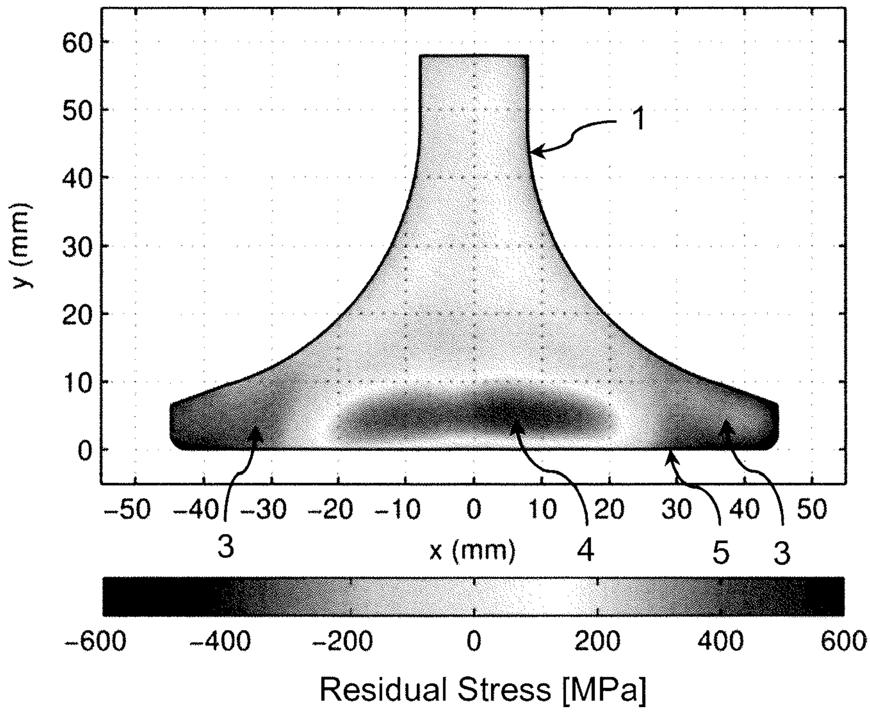

60
50
40
30
20
10
0
y (mm)
1
−50 −40 −30 −20 −10 0 10 20 30 40 50
x (mm)
3
4
5
3
−600 −400 −200 0 200 400 600
Residual Stress [MPa]

Fig. 3

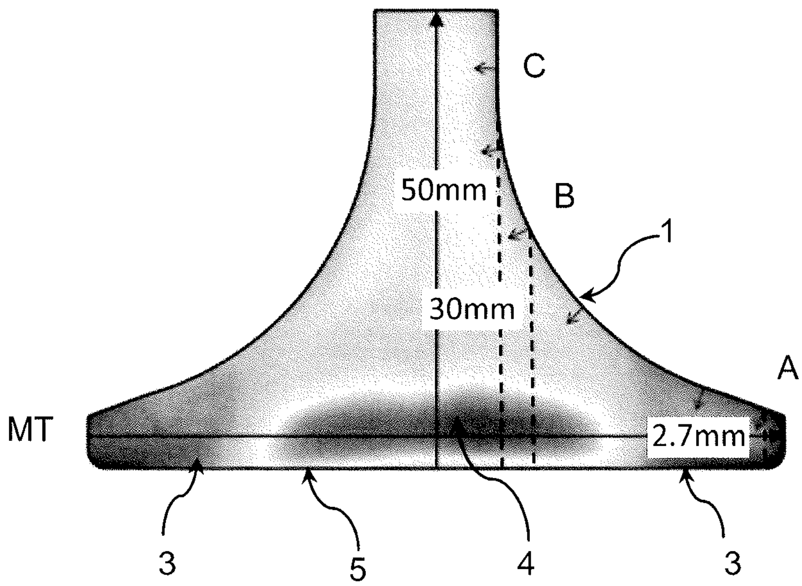
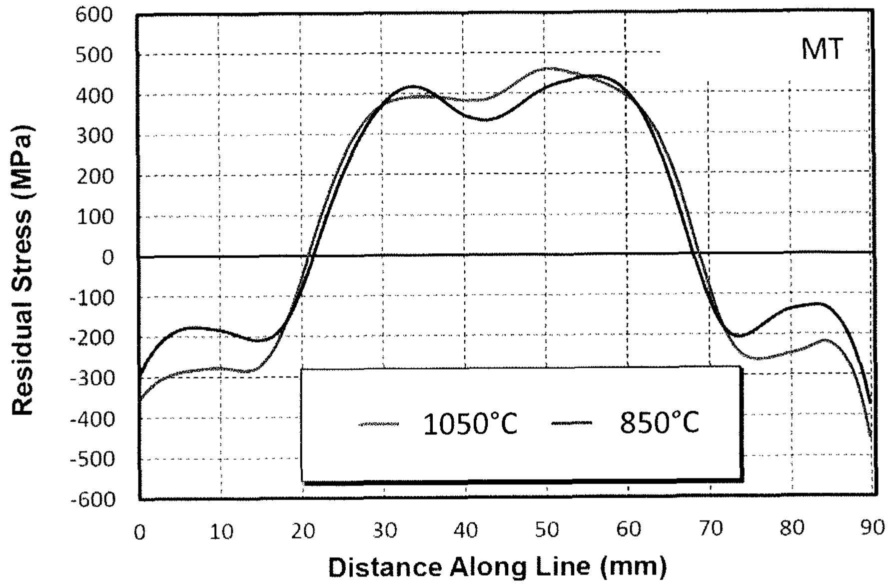
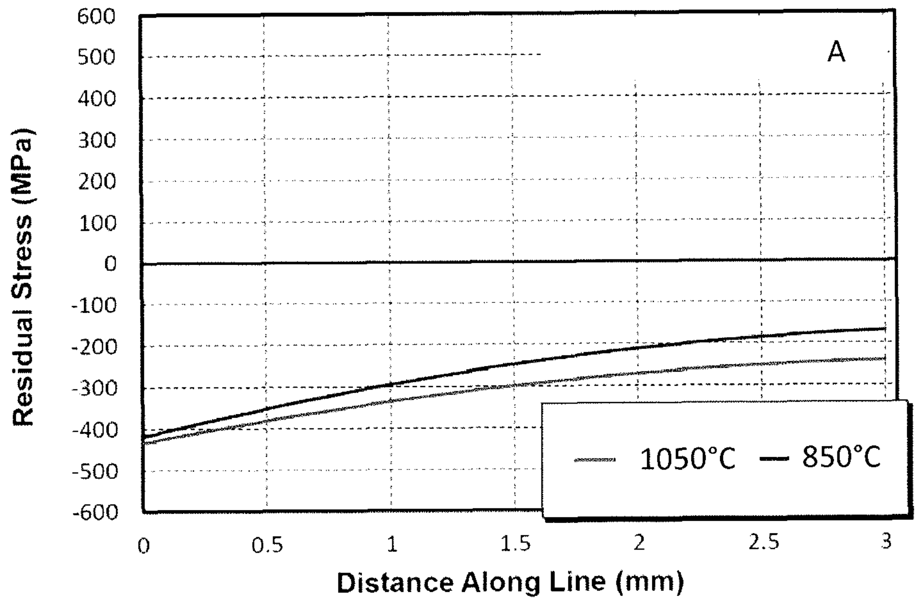

C
50mm
B
1
30mm
A
MT
2.7mm
3
5
4
3

Fig. 4



600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
Residual Stress (MPa)
MT
1050°C
850°C
0
10
20
30
40
50
60
70
80
90
Distance Along Line (mm)

Fig. 5



600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
Residual Stress (MPa)
A
1050°C
850°C
0
0.5
1
1.5
2
2.5
3
Distance Along Line (mm)

Fig. 6

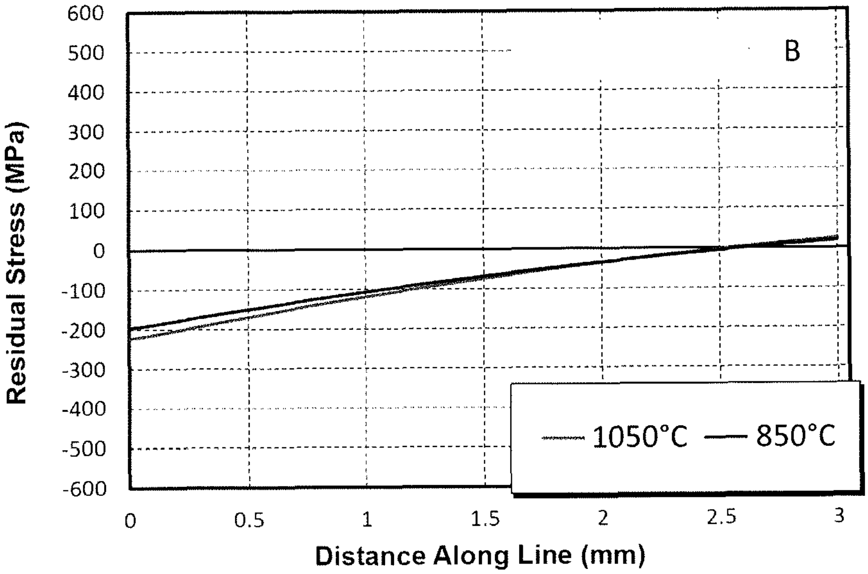

B
Residual Stress (MPa)
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
0
0.5
1
1.5
2
2.5
3
Distance Along Line (mm)
1050°C
850°C

Fig. 7

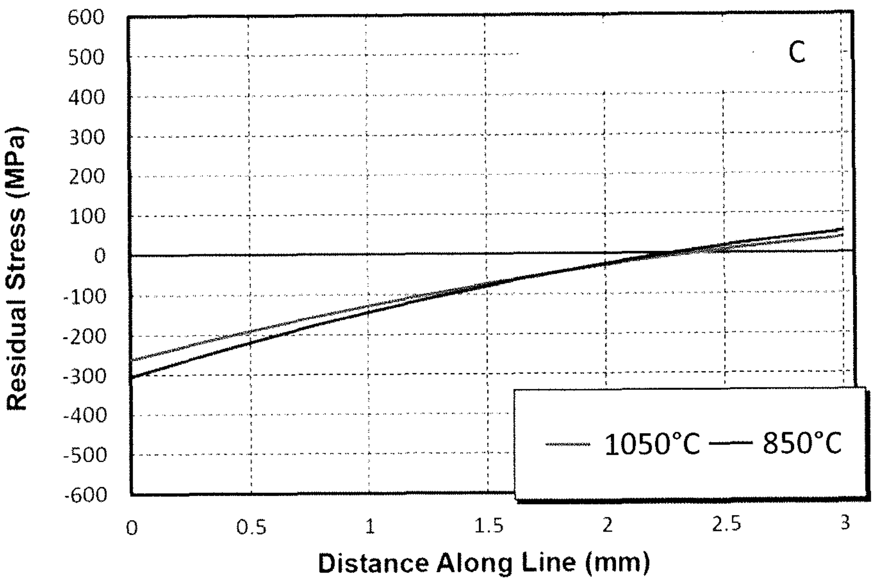

C
Residual Stress (MPa)
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
0
0.5
1
1.5
2
2.5
3
Distance Along Line (mm)
1050°C
850°C

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 22 20 9822

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

C21D
F01L

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 April 2023	Kreutzer, Ingo

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