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(54) **METHOD AND DEVICE ADJUSTING
TARGETED COMBINATIONS OF
PROPERTIES OF POLYPHASE STEEL**

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(57) **ABSTRACT**

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Compared to conventional steel products, polyphase steels have a significantly improved combination of resistance and ductility and are therefore becoming more and more important—especially for the automobile industry. The currently most important steel groups for the automobile industry are dual phase steels and TRIP steels. The production of different polyphase steel resistance categories, carried out directly on a hot strip, for meeting various requirements, requires a highly extensive know-how and firstly a corresponding adaptation of the alloy elements. According to the invention, a heat treatment (30) with a variable heating temperature and heating duration is carried out following the actual production of polyphase steels with a standard analysis and a standard process execution, whereby almost any combination of different materials or combination of properties (height of yield stress, level of tensile strength) can be adjusted.

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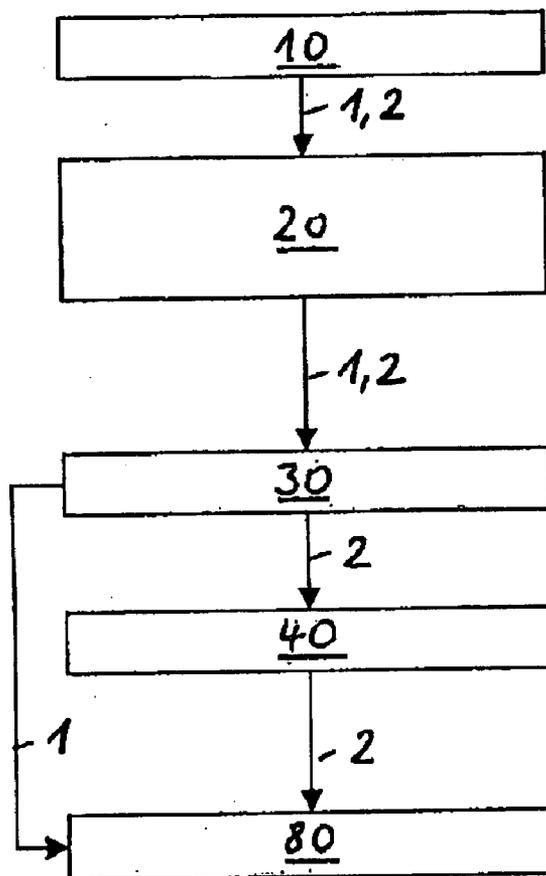
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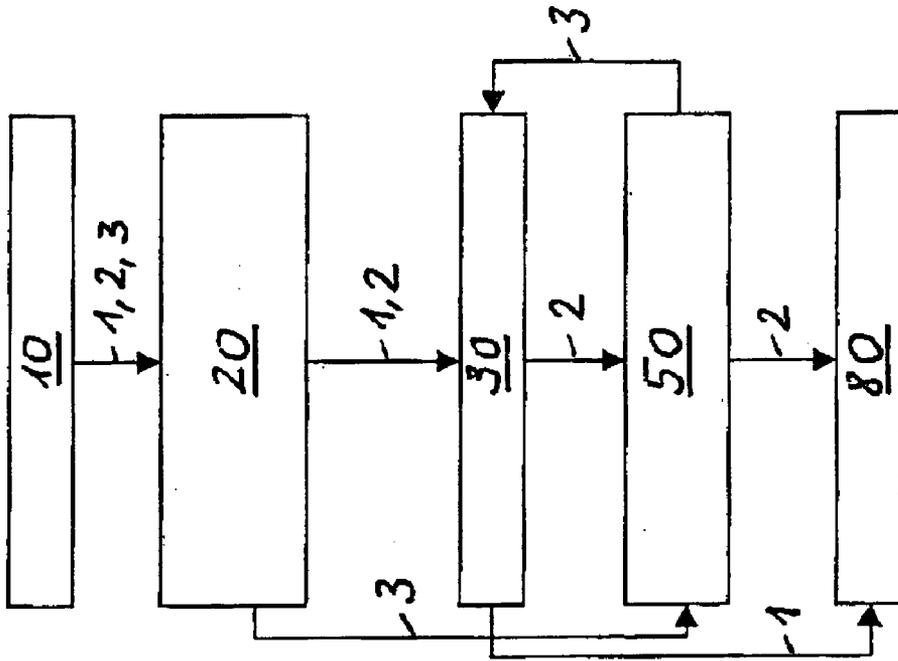


FIG. 2

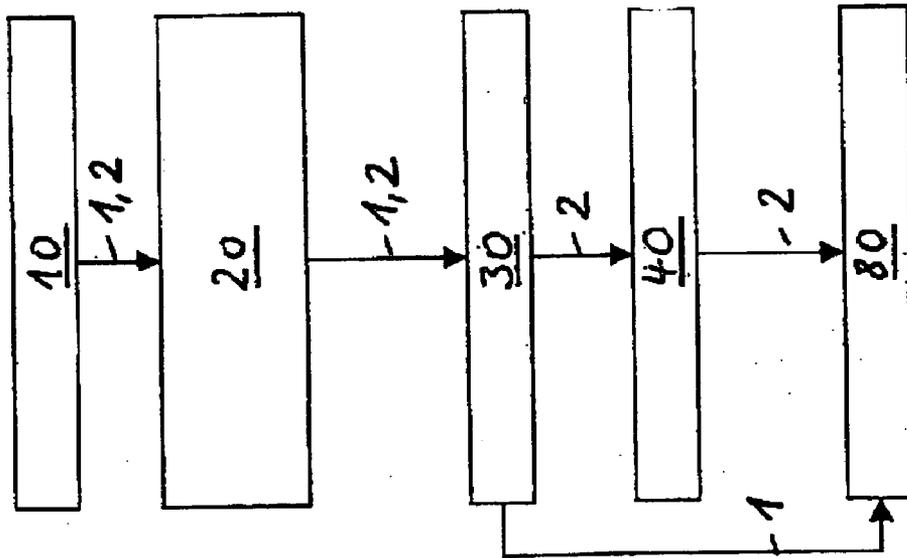


FIG. 1

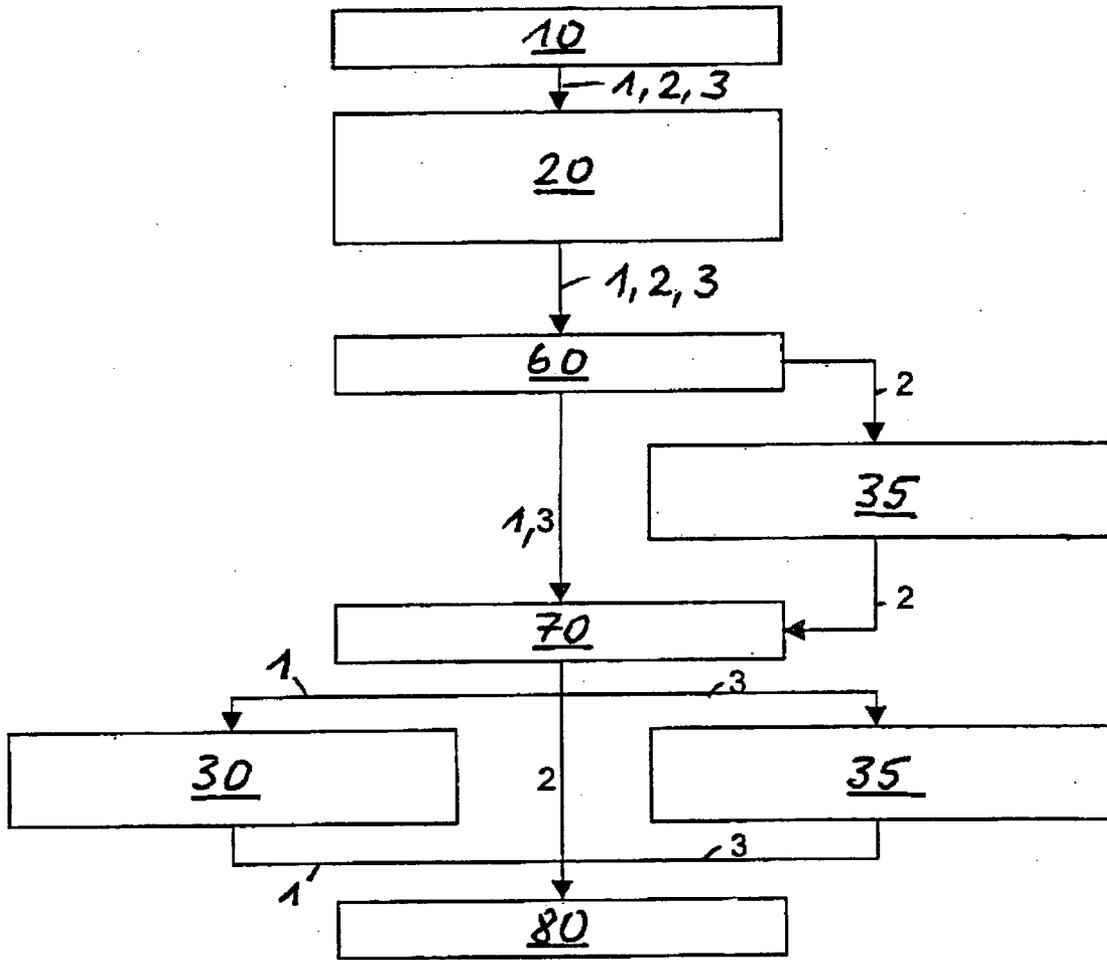


FIG. 3

**METHOD AND DEVICE ADJUSTING
TARGETED COMBINATIONS OF
PROPERTIES OF POLYPHASE STEEL**

[0001] The invention concerns a method and a device for adjusting targeted combinations of properties of hot-rolled multiphase steels, whose multiphase structure includes at least 30% ferrite and at most 50% martensite, for example, dual-phase steels and TRIP steels, which are produced with a standard analysis and standard process management in a conventional hot rolling mill train, a thin slab casting and rolling installation, or suitable narrow and medium strip mill trains, or a wire mill.

[0002] Compared to conventional steel grades, multiphase steels have a significantly improved combination of strength and ductility and therefore are becoming increasingly important, especially for use in the automotive industry. The most important groups of steel for automobile manufacturing at the present time are dual-phase steels and TRIP steels.

[0003] In this regard, due to the significantly lower production costs, the variant of production directly as hot strip offers economic advantages and thus has very strong potential for the future.

[0004] A characteristic feature of dual-phase steels is a low elastic limit-tensile strength ratio, which is generally 50-70%. Compared to HSLA steels, i.e., high-strength low-alloy structural steels, besides the lower yield point at the same level of tensile strength, significantly better elongation values are obtained. For some applications (for example, tubes), it may be desired that the elastic limit-tensile strength ratio must be adjusted to well-defined values, but nevertheless the elongation after fracture is as great as possible.

[0005] Since the production of different strength classes directly in the hot-rolled strip requires very extensive process know-how, it is a prior art practice to adjust either the chemical analysis or the process management for each individual material, with TRIP steels basically having a somewhat higher elastic limit-tensile strength ratio than dual-phase steels.

[0006] EP 1 108 072 B1 discloses a method for producing dual-phase steels, in which after the finish rolling, a two-stage cooling is used to obtain a dual-phase microstructure that consists of 70-90% ferrite and 30-10% martensite. The first (slow) cooling is carried out in a cooling line in which the hot-rolled strip is cooled in a well-defined way at a cooling rate of 20-30 K/s by successive separated water cooling stations. In this cooling stage, the cooling is adjusted in such a way that the cooling curve enters the ferrite range at a temperature that is still high enough to allow rapid ferrite formation. This first cooling is continued until at least 70% of the austenite has been converted to ferrite, and then the further (rapid) cooling follows immediately without a pause.

[0007] The special effect of TRIP steels (transformation-induced plasticity) with a microstructure that comprises, for example, 40-70% ferrite, 15-40% bainite, and 5-20% residual austenite is the transformation of the metastable residual austenite to martensite when an external plastic deformation occurs. This transformation, which is accompanied by an increase in volume and plasticization of the ferritic matrix and which is supported not only by the austenite but also by the surrounding microstructural components, results in greater strain hardening and leads all together to higher plastic elongations. Steels produced in this way have an extraordinary

combination of high strength and high ductility, which makes them suitable especially for use in the automobile industry.

[0008] EP 1 396 549 A1 discloses a method for producing pearlite-free hot-rolled steel strip with TRIP properties, in which a steel melt, which contains, in addition to iron and unavoidable impurities, at least one of the elements Ti or Nb as an essential component and optionally one or more of the following elements in the amounts indicated: max. 0.8% Cr, max. 0.8% Cu, and max. 1.0% Ni, is cast into thin slabs, which are annealed at 1,000-1,200° C. for an annealing time of 10-60 minutes in an annealing furnace, starting from a run-in temperature of 850-1,050° C. After descaling, the thin slabs are then finish hot rolled in the range of 750-1,000° C. and then cooled to a coiling temperature of 300-530° C. in two stages at a controlled cooling rate of the first stage of at least 150 K/s and a cooling interruption of 4-8 seconds. Besides the prescribed process management, the presence of Ti and/or Nb is important, since these elements remain in solution until the start of the hot rolling and, upon their subsequent precipitation, improve, among other properties, the grain fineness of the hot-rolled strip and increase the residual austenite content and its stability.

[0009] Finally, EP 1 394 279 B1 discloses a method for producing a low-carbon steel of high strength and high ductility with a tensile strength of greater than 800 MPa, uniform elongation of greater than 5%, and elongation after fracture of greater than 20%. Starting from a hardened or hardened and tempered feedstock, a steel with 0.20% C, 1.60% Mn, and admixtures of boron and a martensite phase component of greater than 90%, and after a cold rolling that constitutes more than 20% of the total rolling, an annealing treatment is carried out at a temperature of 500-600° C., resulting in a microstructure with an ultrafine, crystalline, granular ferrite structure of 100-300 nm with iron carbides deposited in the ferrite.

[0010] Using this prior art as a point of departure, the objective of the invention is to specify a method and a device with which multiphase steels produced with a standard analysis and standard process management can be transformed to steel grades with almost any desired combinations of properties.

[0011] The objective of the invention with respect to a method is achieved with the characterizing features of claim 1 in such a way that following the cooling from the hot rolling or a later production step, for example, the production of components, the desired combinations of strengths and elastic limit-tensile strength ratios are adjusted in the multiphase steels by a subsequent or intermediate annealing treatment with variable annealing temperature and variable annealing time. A device for carrying out the method is characterized by the features of claim 8. Advantageous refinements of the invention are described in the dependent claims.

[0012] The annealing treatment of multiphase steels with a standard analysis and standard process management, which is to be carried out simply and with adaptation in accordance with the invention after the actual production process has been completed, makes it possible to adjust almost any desired combinations of different materials and combinations of properties (magnitude of the yield point, level of tensile strength). By contrast, the production of different multiphase steel strength classes directly in the hot-rolled strip requires very extensive process know-how and suitable adjustment of the alloying elements in advance.

[0013] In accordance with the invention, the annealing treatment is carried out at a variable annealing temperature of

$\leq 600^\circ\text{C}$. and a likewise variable annealing time of ≤ 120 s in such a way that the resulting microstructure consists of a ferritic base matrix and annealed martensite or bainite with 10-50% of the area fraction. In this regard, the annealing temperature affects primarily the magnitude of the yield point by finely distributed precipitation of carbides at the grain boundaries of the martensite or bainite, and the level of tensile strength can be adjusted by the annealing time.

[0014] In accordance with the invention, the annealing treatment can be carried out offline in a continuous annealing installation, independently of upstream or downstream process steps and adapted to existing circumstances, or it can be carried out online in an existing process line, for example, as part of a strip galvanizing operation in the heating stage of a galvanizing line before entry into the zinc bath.

[0015] In accordance with the invention, it is also possible to carry out the annealing treatment on components that have already been finish pressed (frame members, wheels, connecting elements, etc.), which results in subsequent improvement of the mechanical properties of these components. The advantage of this procedure is that the deformation into the component can be carried out on a nicely cold-workable material with a low elastic limit-tensile strength ratio with good elongation, and thus the tool wear is kept comparatively low. The annealing treatment that follows increases the strength of the components to values that otherwise would be difficult to preset, since then the pressing force of the shaping machines would not be sufficient.

[0016] In addition to the complete annealing treatment of a component, it is also possible, in accordance with the invention, to use a targeted zonal annealing treatment in locally limited sections of the component. The goal here is the partial replacement of welded tailor blanks. Where tailor blanks are concerned, steels of high strength are systematically welded onto specific sections of components in order to produce desired stiffness values of components. However, this welding operation could be eliminated if a zonal annealing treatment is carried out in the given sections instead.

[0017] In accordance with the invention, a device for adjusting targeted combinations of properties in hot-rolled multiphase steels by an annealing treatment is characterized by a thermal installation, which is located in a freely selectable place within the production plant or production line and in which an annealing treatment can be carried out at an annealing temperature of $\leq 600^\circ\text{C}$. and an annealing time of ≤ 120 s. This thermal installation can be a continuous annealing installation, in which the annealing treatment, for example, of components, is carried out offline, or it is arranged online in an existing process line, for example, as part of a strip galvanizing operation in the heating stage of a galvanizing line before entry into the zinc bath.

[0018] The mode of operation of the annealing treatment of the invention is made clear by the following example. Some dual-phase steels have anisotropic toughness properties in the direction of rolling and transversely to the direction of rolling. In a brief annealing treatment for 60 s at 500°C . carried out on a dual-phase steel produced as hot-rolled strip with a tensile strength of $980\text{-}1,035\text{ N/mm}^2$, this anisotropy of the properties can be evened out in the two different directions (isotropic properties). As the following table shows, the untreated hot-rolled strip (annealing time 0 s) has a significantly different development of the elongations after fracture in the longitudinal and transversal directions of rolling. As a result of the brief annealing treatment (annealing time 1 min), the

tensile strength declines somewhat, but the values for the elongation after fracture rise overall to a higher level:

Annealing Time (s)		$R_{p0.2}$ (MPa)	R_m (MPa)	$R_{p0.2}/R_m$	A (%)
0	longitudinal	473	1035	0.46	13.0
	transversal	469	981	0.48	7.8
60	longitudinal	503	839	0.60	17.7
	transversal	513	881	0.58	18.1

[0019] These relationships presented for the example of the dual-phase steel apply in the same way for TRIP steels as well.

[0020] Further details on the possible performance of the above-described annealing treatment of the invention are explained in greater detail below on the basis of the flowcharts shown in the accompanying schematic drawings.

[0021] FIG. 1 shows a flowchart of the annealing treatment of strip material.

[0022] FIG. 2 shows a flowchart of the annealing treatment of wire material.

[0023] FIG. 3 shows a flowchart of the annealing treatment of components.

[0024] In FIGS. 1 to 3, the individual process steps which, in accordance with the invention, are necessary for the annealing treatment of strip material (FIG. 1), wire material (FIG. 2), and components (FIG. 3) are shown in the form of flowcharts, with the respective process path labeled with numbered directional arrows. A common feature of all of the flowcharts presented here is that a hot rolling step is first carried out as the starting point, which is followed by a controlled cooling from the hot rolling operation to realize a multiphase microstructure. The further possible process steps and the time of the annealing treatment that is carried out for the different materials are described below.

[0025] FIG. 1 shows possible process paths 1, 2 for an annealing treatment of strip material before further processing. In process path 1, after the hot rolling 10 and the controlled cooling 20, an annealing treatment 30 is carried out, and then the strip material is sent for further processing 80 into the finished product. The annealing treatment 30 can be carried out online, and a suitable continuous furnace is to be installed in the existing process line for this purpose.

[0026] In the process path 2 indicated in FIG. 1, for example, strip galvanizing 40 of the hot-rolled strip is carried out, so that a continuous annealing treatment 30 can be carried out online before that in the heating stage of the galvanizing line. The strip galvanizing operation 40 is then followed by further processing 80 into the finished product.

[0027] FIG. 2 shows possible process paths 1, 2, 3 for an annealing treatment of wire material. In the illustrated process path 1, the hot rolling 10 and then the controlled cooling 20 are followed by the annealing treatment 30, which, as in the case of the strip material, can be carried out online. The annealing treatment 30 is followed directly by the step of further processing 80 into the finished product.

[0028] In the case of process path 2, the annealing treatment 30, which here too can be carried out online, is followed by another processing step, namely, the pressing 50 of connecting elements, before the wire material is sent for further processing 80 into the finished product.

[0029] Alternatively, this pressing 50 of connecting elements can be carried out before the annealing treatment 30, as indicated by process path 3. This then results in the following succession of process steps: hot rolling 10, controlled cooling 20, pressing 50 of connecting elements, annealing treatment 30 and finally the further processing 80 into the finished product.

[0030] FIG. 3 shows possible process paths 1, 2, 3 for an annealing treatment of components, such that for all three process paths, after the controlled cooling 20, an additional process step involving the production 60 of a blank is carried out first.

[0031] In process path 1, which involves the production of components with adjusted mechanical properties, the production 60 of the blank is followed by the pressing 70 of the components. The entire component is then subjected to an annealing treatment 30 and then to the further processing 80 into the finished product.

[0032] In process path 2, which involves the production of components with prior local annealing treatment of the blank, the production 60 of the blank is followed by a zonal annealing treatment 35, so that the pressing 70 of the components must be carried out on a blank that has already received a local heat treatment and thus on a blank that has locally altered mechanical properties.

[0033] Alternatively to process path 2, in process path 3, the components are produced with subsequent local alteration of the mechanical properties by a zonal annealing treatment 35 of the component after it has already been pressed, so that the pressing 70 of the components can be advantageously carried out on the still untreated blank. After this zonal annealing treatment 35, the component, which has thus undergone local alteration of its mechanical strength, can then be sent for further processing 80 into the finished product.

LIST OF REFERENCE NUMBERS

- [0034] 1,2,3 process path
- [0035] 10 hot rolling
- [0036] 20 controlled cooling
- [0037] 30 annealing treatment of the entire workpiece
- [0038] 35 zonal annealing treatment
- [0039] 40 strip galvanizing
- [0040] 50 pressing of connecting elements
- [0041] 60 production of the blank
- [0042] 70 pressing of the components
- [0043] 80 further processing into the finished product

1. A method for adjusting targeted combinations of properties of hot-rolled multiphase steels, whose multiphase structure includes at least 30% ferrite and at most 50% martensite, for example, dual-phase steels and TRIP steels, which are produced with a standard analysis and standard process management in a conventional hot rolling mill train, a thin slab casting and rolling installation or suitable narrow and medium strip mill trains, or a wire mill, wherein following the cooling from the hot rolling (10) or a later production step, for example, the production of components, the desired combi-

nations of strengths and elastic limit-tensile strength ratios are adjusted in the multiphase steels by a subsequent or intermediate annealing treatment (30, 35) with variable annealing temperature and variable annealing time.

2. A method in accordance with claim 1, wherein the annealing treatment (30, 35) is carried out in such a way that the resulting microstructure consists of a ferritic base matrix and annealed martensite or bainite with 10-50% of the area fraction, such that the annealing temperature affects primarily the magnitude of the yield point by finely distributed precipitation of carbides at the grain boundaries of the martensite or bainite, and such that the level of tensile strength can be adjusted by the annealing time.

3. A method in accordance with claim 1, wherein the annealing treatment (30, 35) is carried out at an annealing temperature of $\leq 600^{\circ}$ C. and an annealing time of ≤ 120 s.

4. A method in accordance with claim 1, wherein the annealing treatment (30, 35) is carried out offline in a continuous annealing installation.

5. A method in accordance with claim 1, wherein the annealing treatment (30) is carried out online as part of a strip galvanizing operation (40) in the heating stage of a galvanizing line before entry into the zinc bath.

6. A method in accordance with claim 1, wherein the annealing treatment (30, 35) is carried out on components that have already been finish pressed.

7. A method in accordance with claim 1, wherein the annealing treatment (35) is carried out as a targeted zonal treatment, i.e., in locally limited sections of a component.

8. A device for adjusting targeted combinations of properties of hot-rolled multiphase steels, whose multiphase structure includes at least 30% ferrite and at most 50% martensite, for example, dual-phase steels and TRIP steels, which are produced with a standard analysis and standard process management in a conventional hot rolling mill train, a thin slab casting and rolling installation or suitable narrow and medium strip mill trains, or a wire mill, especially for carrying out the method according to claim 1, wherein a thermal installation is located in a freely selectable place within the production plant or production line and that an annealing treatment (30, 35) can be carried out in this thermal installation at a variable annealing temperature of $\leq 600^{\circ}$ C. and a variable annealing time of ≤ 120 s.

9. A device in accordance with claim 8, wherein the thermal installation is a continuous furnace installed online in a galvanizing line.

10. A device in accordance with claim 8, wherein the thermal installation is a continuous annealing installation that is operated offline.

11. A device in accordance with claim 8, wherein the thermal installation is constructed in such a way that a zonal annealing treatment (35) can be carried out on locally limited sections of a component before or after its actual production as a finished product.

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