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(54) **A METHOD FOR SHOT PEENING**

KUGELSTRAHLVERFAHREN

PROCÉDÉ DE GRENAILLAGE

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EP 2 601 320 B1

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Description

Technical Field

[0001] The present invention relates to a method for shot peening. Specifically, it relates to a method for shot-peening a steel.

Background Art

[0002] Conventionally, shot peening has been known to produce compressive residual stresses to improve the fatigue strength of parts made of a steel (see authored by the Society of Shot Peening Technology of Japan; Fatigue of Metals and Shot Peening; published by Gendai Kogaku-sha; 2004). Further, it has been known that increasing the maximum value of compressive residual stresses is very effective in improving the fatigue strength of the parts (see Masahiko Mitsubayashi, Takashi Miyata, and Hideo Aihara; Prediction of Improvement in Fatigue Strength by Shot Peening and Selection of Most Effective Peening Conditions; Transactions of JSME, Vol. 61, No. 586 (June, 1995) pp. 28-34).

[0003] However, it is also known that the maximum value of compressive residual stresses produced by shot peening is approximately 60% of the yield strength at 0.2% offset (Hideki Okada, Akira Tange, and Kotoji Ando; Relationship among Specimen's Hardness, Residual Stress Distribution and Yield Stress on the Difference of Shot Peening Methods; Journal of High Pressure Institute of Japan, Vol. 41, No. 5 (2003) pp. 233-242). Thus by applying stress shot peening, i.e., shot-peening a part that is under a pre-stressed condition, a maximum compressive residual stress that exceeds 60% of the yield strength at 0.2% offset can be obtained (see the above reference).

[0004] Though the stress shot peening can be used for a part, like a spring that can be stressed while shot-peening it, there have been problems in that stress shot peening cannot be used for a part like a gear that cannot be stressed while shot-peening it.

[0005] US 4,415,378 discloses a method for work hardening the surface of a carburised steel part, whereby an amount of 10-30% residual austenite in the case layer is transformed to at least 5-20% of untempered martensite, to induce compressive residual stresses.

Disclosure of the Invention

[0006] The object of the present invention is to provide a method for shot peening for producing maximum compressive residual stresses that exceed 60% of the yield strength at 0.2% offset by controlling the properties of the material or the conditions for the heat treatment of the processed steel and the conditions for shot peening, without using the stress shot peening.

[0007] The method for shot peening of the first aspect of the present invention is to produce a compressive re-

sidual stress in a processed steel that has an amount of retained austenite in a range of 5 to 30%, by peening shot media onto the processed steel. The amount of retained austenite is controlled to keep the change in the amount within a range of 2 to 30% before and after the shot peening.

[0008] In the method for shot peening of the second aspect of the present invention, the shot peening is controlled to keep the change in the amount of retained austenite at the depth where the maximum compressive residual stress is generated at a range of 2 to 30% before and after the shot peening.

[0009] In the method for shot peening of the third aspect of the present invention the processed steel is a gas carburized steel.

[0010] By the method for shot peening of the first aspect, a maximum compressive residual stress can be obtained that exceeds 60% of the yield strength at 0.2% offset. Thus no jig for stressing the processed steel for the shot peening is required. Further, efficient shot peening can be used for a part such as a gear that has a complicated shape.

[0011] By the method for shot peening of the second aspect, the method for shot peening of the first aspect can always be performed.

[0012] By the method for shot peening of the third aspect, a processed steel that has a desired amount of retained austenite can be easily obtained by changing carburizing.

[0013] The present invention will become more fully understood from the detailed description given below. However, the detailed description and the specific embodiment are illustrations of desired embodiments of the present invention, and are described only for an explanation. Various possible changes and modifications will be apparent to those of ordinary skill in the art on the basis of the detailed description.

Brief Description of the Drawings

[0014]

Fig. 1 is a table showing the properties of the processed steels that were used in the embodiments of the present invention.

Fig. 2 is a table showing the conditions of the shot peening that were used in the embodiments of the present invention.

Fig. 3 is a table showing the properties of the processed steels after the shot peening.

Fig. 4 is a supplemental table giving data that are similar to those in Table 3.

Best Mode for Carrying Out the Invention

[0015] Below, the embodiments of the present invention are described with reference to the drawings.

[0016] Fig. 1 is a table showing the properties of the processed steels that were used in the embodiments of the present invention. Steel-A to Steel-G are prepared as the processed steels. The carbon contents (wt %), the conditions for heat treatment, and the yield strengths at 0.2% offset (MPa), as properties of the materials, and the tensile strengths (MPa), the hardness at the surfaces (HV0.3), and the amount of retained austenite $\gamma(\text{Gamma})_R$ (%),

are all shown in the table. The processed steels are prepared from the steels that are based on a chromium steel or a chromium-molybdenum steel and that have different carbon contents, i.e., between 0.2 and 0.8 wt%, and the steels that are based on a chromium-molybdenum steel that have a carbon content of 0.8 wt%, and that are tempered in different conditions. These processed steels are gas carburized steels.

[0017] Fig. 2 is a table showing the conditions of the shot peening that were used in the embodiments of the present invention. Two types of conditions for shot peening (the conditions for peening shot media onto the processed steels) were used. A compressive-air shot peening system was used in both types. The hardness (HV), the diameters (mm), and the air pressure for peening shot media are all shown in the table. The coverage, which represents the amount of shot media being peened, was 300% in all cases.

[0018] Fig. 3 is a table showing the properties of the processed steels after the shot peening. The table also shows the properties before the shot peening. It shows the properties of Steel-A to Steel-G in the upper and lower sides for two respective types of conditions for shot peening.

[0019] That table shows the maximum compressive residual stress $\sigma(\text{Sigma})_R$ (MPa), Gamma_R at the peak depth (%), $\text{Sigma}_R(\text{max})/\text{Sigma}_{0.2}$, and the rate of change in Gamma_R at the peak depth (%), as the properties of the processed steels after shot peening.

[0020] The maximum compressive residual stress Sigma_R (MPa) means the maximum value of the compressive residual stresses that are measured at various depths from the surface (since a compressive residual stress is generally expressed as a negative value, it is the maximum value in absolute values). The compressive residual stresses were measured by using a micro-stress analyzer that is available from Rigaku Corporation (X-ray tube: Cr-K α_{Alpha} ; diffractive surface: (220); stress constant: -318 MPa/deg; Bragg angle of the strain-free 2 θ : 156.4 °).

[0021] The Gamma_R at the peak depth (%) denotes the amount of retained austenite at the depth where the maximum compressive residual stress is generated. The

amounts of retained austenite were also measured by using a micro-stress analyzer that is available from Rigaku Corporation (X-ray tube: Cr-K α_{Alpha} ; diffractive surface: (220); Gamma-diffraction plane: (311); time for measuring on Alpha-plane: 60 sec; range of diffraction on Alpha-plane: 156.4 °).

[0022] The $\text{Sigma}_R(\text{max})/\text{Sigma}_{0.2}$ denotes the maximum compressive residual stress compared to the yield strength at 0.2% offset. The rate of change in Gamma_R at the peak depth (%) denotes a rate of change in the amount of retained austenite before and after the shot peening at the depth where the maximum compressive residual stress is generated.

[0023] As seen in Fig. 3, the $\text{Sigma}_R(\text{max})/\text{Sigma}_{0.2}$ exceeds 60%, which is the target value, for Steel-B, -C, -D, -E, and -G. Fig. 4 shows supplemental data for Fig. 3.

[0024] From these data, it was found that the processed steels that have the maximum compressive residual stress that exceeds 60% of yield strength at 0.2% offset can be obtained by the following process, i.e., peening shot media onto a processed steel that has the amount of retained austenite in a range between 5 to 30%. The rate of change (reduction) in the amount of retained austenite at the depth where the maximum compressive residual stress is generated is controlled to be in a range between 2 to 30%.

[0025] The threshold value of the amount of retained austenite, i.e., 5 to 30%, is determined based on the maximum value in the range that is representative for industrial materials. The upper limit for the rate of change in the amount of retained austenite, i.e., 30%, is specified based on the maximum value of the amount of retained austenite. The lower limit for the rate of change in the amount of retained austenite, i.e., 2%, is determined by plotting the $\text{Sigma}_R(\text{max})/\text{Sigma}_{0.2}$ in relation to the rate of change in Gamma_R at the peak depth (%) and drawing an approximate curve by the least square method.

[0026] If the rate of change (reduction) in the amount of retained austenite of the processed steel at the depth where the maximum compressive residual stress is generated is controlled to be in a range between 2 to 30%, the maximum compressive residual stress becomes over 60% of the yield strength at 0.2% offset. This is because the retained austenite expands by the deformation-induced martensitic transformation and thus the mechanical properties improve by the expansion of the retained austenite.

[0027] As discussed above, in the embodiments of the present invention processed steels that have the amount of retained austenite in a range between 5 to 30% are subject to shot peening. The change in the amount of retained austenite before and after shot peening is controlled to be in a range of 2 to 30%, so as to produce the compressive residual stress in the processed steel. Thus, a maximum compressive residual stress that exceeds 60% of the yield strength at 0.2% offset can be produced. Therefore, no jig for stressing the processed steel for the stress shot peening is required. Further, a part such as

a gear, which has a complicated shape, can be efficiently shot-peened.

[0028] Further, by changing the amount of retained austenite at the depth where the maximum compressive residual stress is in the range between 2 to 30% before and after shot peening, a maximum compressive residual stress that exceeds 60% of the yield strength at 0.2% offset can always be produced.

[0029] Further, since the processed material is a gas carburized steel, a processed steel that has a desired amount of retained austenite can be easily obtained by adjusting the conditions for carburizing.

[0030] Any steels can be used for the processed steels, but a gas carburized steel that has a large amount of retained austenite is preferable.

dans lequel de la grenaille est projetée sur un acier traité qui a une quantité d'austénite résiduelle dans une plage entre 5 à 30%, et

dans lequel un changement de la quantité d'austénite résiduelle à la profondeur où la contrainte de compression résiduelle maximum est générée est maîtrisé pour être dans une plage de 2 à 30% avant et après grenaillage pour produire une contrainte de compression résiduelle dans l'acier traité qui excède 60% de limite d'élasticité à 0,2% de déformation.

2. Procédé de grenaillage selon la revendication 1, dans lequel l'acier traité est un acier carburé au gaz.

Claims

1. A method for shot peening, wherein shot media are peened onto a processed steel that has an amount of retained austenite in a range between 5 to 30%, and wherein a change in the amount of retained austenite at the depth where the maximum compressive residual stress is generated is controlled to be in a range of 2 to 30% before and after shot peening to produce a compressive residual stress in the processed steel that exceeds 60% of yield strength at 0.2% offset.
2. The method for shot peening of claim 1, wherein the processed steel is a gas carburized steel.

Patentansprüche

1. Verfahren zum Kugelstrahlen, wobei Strahlmaterialien auf einen verarbeiteten Stahl gestrahlt werden, der eine Menge von eingeschlossenem Austenit in einem Bereich von 5 bis 30% aufweist, und wobei eine Änderung in der Menge des eingeschlossenen Austenits in einer Tiefe, an der die maximale Druckeigenspannung erzeugt wird, auf einen Bereich von 2 bis 30 % vor und nach dem Kugelstrahlen gesteuert wird, um eine Druckeigenspannung in dem verarbeiteten Stahl zu erzeugen, die 60% der Streckfestigkeit bei 0,2% Dehnung überschreitet.
2. Verfahren zum Kugelstrahlen Anspruch 1, wobei der verarbeitete Stahl ein aufgekohlter Stahl ist.

Revendications

1. Procédé de grenaillage,

[Fig. 1]

Fig. 1

Steel	Carbon Content (wt%)	Heat Treatment	Properties of Steels			
			Yield Strength at 0.2% Offset (Mpa)	Tensile Strength (Mpa)	Hardness at Surface	γ_R (%)
A	0.2	Vacuum Quenching - Tempering at 180 °C	1224	1510	485	3
B	0.4	Vacuum Quenching - Tempering at 180 °C	1488	2062	609	4.9
C	0.6	Vacuum Quenching - Tempering at 180 °C	1470	2473	697	9
D	0.8	Vacuum Quenching - Tempering at 180 °C	1093	2046	737	19.7
E	0.8	Vacuum Quenching - Tempering at 180 °C	1131	1808	717	21.2
F	0.8	Vacuum Quenching - Tempering at 300 °C	1833	2083	623	1.6
G	0.8	Vacuum Quenching	1131	1225	802	24.2

[Fig. 2]

Fig. 2

Conditions for Shot Peening	Type of Peening	Hardness (HV)	Diameters (mm)	Air Pressure (MPa)	Coverage (%)
①	Compressive Air	700	0.6	0.3	300
②	Compressive Air	950	0.3	0.5	300

[Fig. 3]

Steel	Conditions for Shot Peening	Properties before Shot Peening			Properties after Shot Peening			
		Yield Strength at 0.2% Offset (Mpa)	Tensile Strength (Mpa)	γ_R (%)	Maximum σ_R (Mpa)	γ_R at Peak Depth (%)	$\sigma_R(\max) / \sigma_{0.2}$	Rate of Change in γ_R at Peak Depth
A	①	1224	1510	3	-683.63	1.6	55.9%	1.40
B		1488	2062	4.9	-1259.4	1.3	84.6%	3.60
C		1470	2473	9	-1456.09	4	99.1%	5.00
D		1093	2046	19.7	-1354.21	12.2	123.9%	7.50
E		1131	1808	21.2	-1451.51	6.3	128.3%	14.90
F		1833	2083	1.6	-1178.26	0.7	64.3%	0.90
G		1131	1225	24.2	-1107.79	6.9	97.9%	17.30
Steel	Conditions for Shot Peening	Yield Strength at 0.2% Offset (Mpa)	Tensile Strength (Mpa)	γ_R (%)	Maximum σ_R (Mpa)	γ_R at Peak Depth (%)	$\sigma_R(\max) / \sigma_{0.2}$	Rate of Change in γ_R at Peak Depth
A	②	1224	1510	3	-724.72	1.5	59.2%	1.50
B		1488	2062	4.9	-1354.5	0.7	91.0%	4.20
C		1470	2473	9	-1416.32	1.6	96.3%	7.40
D		1093	2046	19.7	-1650.28	3.7	151.0%	16.00
E		1131	1808	21.2	-1623.46	4.5	143.5%	16.70
F		1833	2083	1.6	-1111.43	1.6	60.6%	0.00
G		1131	1225	24.2	-1781.15	1.2	157.5%	23.00

[Fig. 4]

Fig. 4

Specification	Shot Media	Hardness (HV)	Diameters (MM)	Pressure for Peening	Steel	Maximum σ_R (Mpa)	Change in γ_R (%)
①	Steel	700	0.60	0.10	A	-1294.01	8.90
②	Steel	800	0.60	0.30		-1421.00	5.00
③	Steel	930	0.30	0.50		-1749.72	18.20
④	Steel	930	1.00	0.10		-1850.49	18.90
⑤	Ceramics	1000	0.35	0.10	B	-1278.68	5.00
⑥	Ceramics	1000	0.35	0.50		-1823.34	8.50
⑦	Steel	1250	0.08	0.10		-1934.01	8.30
⑧	Steel	800	0.03	0.50	C	-1965.69	4.80
⑨	Steel	900	0.05	0.50		-2010.40	3.40

Steel	Material	Heat Treatment
A	SCM420H	Gas Caburized Quenching - Tempering at 180 °C
B		Vacuum Caburized Quenching - Tempering at 180 °C
C		Vacuum Caburized Quenching - Tempering at 140 °C

REFERENCES CITED IN THE DESCRIPTION

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