CRITERION TO SELECT MATERIALS FOR SHOT PEENING AND ROLLING HARDENING

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ABSTRACT

The effect of residual stress forming during sholling peening and rolling was discussed. In this paper, We proved that attenuation of residual compression stress was relating to the compression yeild limit $\sigma_{s.c}$ and $\sigma_{s.t}$ of materials, and pressent that if effect of surface deformation hardening is judged by fatigue strength change rate $\Delta\sigma_{w}/\sigma_{w}$, σ_{bo}/σ_{sc} may be regarding as a criterion. The larger σ_{bo}/σ_{sc} is, the better the surface hardening effect upon the materials is. So it is convenient to select materials for shot-peening and rolling hardening by the date of static compression behaviour of materials, which is practically valuable.

KEYWORDS

Deformation Hardening, Attenuation of Residual Stress.

INTRODUCTION

The surface hardening technology such as shot peening and rolling has been proved very effective to enhance fatigue strength of materials. As it is widely applied in the industry, there are still some problems, i.e. what materials are more effective for the surface deformation hardening, and how to judge the effect of the surface hardenign upon materials. This paper give a study of these problems and put forward a criterion to select materials for shot peening and rolling.

MATERIALS AND EXPERIMENT METHODS

The steel and heat treatment adopted are shown in table 1. Another material is pearlite nodular iron, which the pearlite content is 80～85%, the degree of spherulite is 2A.
The bending fatigue test was conducted with Moorrotard endurance bending test machine, then the residual stress was determined by means of RIGAKU X-rays stress Analyzers. Tensile and compression tests were conducted with Instron test Machine.

ANALYSIS AND DISCUSSION

Based on following views, we present a criterion to select materials for the surface deformation hardening.
(a) After deformation hardening, the change of fatigue strength of material hardened by surface deformation results from changes of residual stress, degree of finish of surface and micro-structure. It has been dertermined (1.2) that, while the residual compression stress σ_r didn't attenuate more, the σ_r formed during deformation plays a primary role for enhancing fatigue strength.
(b) By k. Bahre [3], the rotary bending fatigue test was finished

for two groiups of smooth specimens, of which one existed quenching stress and another did not. The results shown that fatigue strength is relating to residual stress.

After 40 CrNi steel was quenched in salt water and in oil respectively, their moicrostructures were regarded same, but their residual stresses formed during quenching. Samilarly for 45# steel tempered at 690℃ cooling in water and in air. Their fatique strength and residual stress before and after fatique fests for four groups of specimens were determined and listed in Table 2.

It is shown in Table 2 that for 40CrNi temperod at low tempature the defference of residual stresses quenched in salt water and in oil is large fairly and attenate little after fatigue tests. fatique strength of that in salt water is double than that in oil. So we can say that effect of residual stress is obvious. Specimens of 45# steel tempered at 690℃ and then cooled in salt water had much residual stress before fatique tests, but it attenuate more after fatigue test. Though its fatigue strength 294 Mpa is slightly larger than 254.8 Mpa of that cooled in air, there is almost no difference. Thus we thought that attenuation of residual stress is dependent on whether residual stress play a primary rule for enhaning fatigue strength.

Bahre thought that fatrgue strength of smooth specimens isn't relating to residual stress, which was perhaps due to attenuation of residual stress.

(c) In the paper (4), we had proved that attenuation of residual compression stress was relating to the compression yield limit σ_{sc} and σ_{sc}/σ_{st} which the larger σ_{sc} and σ_{sc}/σ_{st} of specimens is, the uneasier to attenuate during symmetry fatigue. In Table 2, it was shown that σ_{sc} for 40 CrNi steel is much larger than 45# steel's, so is σ_{sc}/σ_{st}. It is same with general concept that the larger the tensile strength is, the larger σ_{sc} and σ_{sc}/σ_{st} are. Surface deformation hardening not only enhance σ_{sc}, but also increase σ_{sc}/σ_{st}, which is advantage to stop residual stress from attenuation.

(d) It is well known that the σ_{bo} is the elastic limit under second loading when compression load is up to strength limit σ_{bc}. For both shot peening and rolling, specimens were hardened under going compression. If its compression loading adopted is up to compression strength limit σ_{bc}, the maximal yield limit of material is original σ_{bc} after shot peening and rolling, which the larger the difference between original σ_{sc} and σ_{bc} is, the larger σ_{sc} enhancing is after shoting peening and rolling, and the residual stress is not easy to attenuate, the fatigue limit enhance more by a wide range under condition of same residual stress. So · σ_{bc}/σ_{sc} may be regarded as a cirterion to select material for surface hardening. We sorted of data of fatigue test before and after rolling from papers (5.6) and then redetermined σ_{bc} and σ_{sc}, specimens of with same heat treatment condition as above Results is shown in Table 3. Results are as same as discussion above, i.e. the larger σ_{bc}/σ_{sc} is, the larger $\Delta\sigma_w/\sigma_w$ is. Regarding σ_{bc}/σ_{sc} as a criterion, it is convenient to select materials for deformation hardening by the date of static compression behaviour of materials, which is very practical.

Finally, it will be explained blow:

(a) σ_{bc} and σ_{sc} in the criterion are data from static test but dynamic yeild limit makes practically effect to attenuate residual stress. Hardening and softening behaviour durig fatigue process varies, but the dynamic yield limit can't be well determined up to now. It is a simple disposition that $(\sigma_{bc}/\sigma_{sc})_{static}$ take the place of $(\sigma_{bc}/\sigma_{sc})_{dynamic}$. The preceeding research has shown that the materials of low faulted energy isn't easier to sften than high faulted energy's, but, for those material having high faulted energry formed under large deformation, it isn't easy to soften. It is shown that the relation between $(\sigma_{sc})_{static}$ and $(\sigma_{sc})_{dynamic}$ is quite complex, and needs fruther research.

(b) Data of $\Delta\sigma_w'/\sigma_w$ adopted in this paper does not come from that under the rolling compression optimized, or we should found out the function between σ_{bc}/σ_{sc} and $\Delta\sigma_{w}'/\Delta\sigma_{w}$.

(c) For those soft materials which could not determine their compression strength, we had to determine σ_{bt}/σ_{st} instead of σ_{bc}/σ_{sc}, σ_{sc} of those materials adopted is close to σ_{st}, so it collnteract weaknesses itself yet.

(d) The σ_{bc} determined under axial compression loading, of cause, isn't equal to compression stress from shot peening and rolling, but difference will not affect the resonability of the criterion.

CONDUSION

If judging the deformation hardening effect by the fatigue strength change rate $\Delta\sigma_{w}/\sigma_{w}$, σ_{bc}/σ_{sc} may be regarding as a criterion to select materials for shot peening and rolling hardening. The larger σ_{bc}/σ_{sc}, the better the surface hardening effect upon the material is.

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Table 1 Materials and Their Heat Treatments

groups	steel	heat treatments
1	40CrNi	860°C OQ+200°C Temp.
2	40CrNi	860°C SWQ+200°C Temp.
3	45#	850°C SWQ+690°C Temp.+SWC
4	45#	850°C SWQ+690°C Temp.+AC
5	40Cr	860°C OQ+180°C Temp.
6	20Cr	900°C OQ+200°C Temp.

* OC: oil quenching
SWQ: salt water quenching
Temp.: tempering
AC: air cooling
SWC: salt water cooling

Table 2 Fatique Strength and Residual Stress Before and After Fatique Tests

Materials & Heat Treatments	σ_{-1} (MPA)	σ_r(MPA) A.F.	σ_r(MPA) B.F.	$\sigma_{s.c}$ (MPA)	$\sigma_{b.c}$ (MPA)	$\sigma_{b.c}/\sigma_{s.c}$
45# Steel 850°CQ +690°C/SWC	294	-287.1	-24.5	589	599.8	1.018
45# Steel 850°CQ +690°C/AC	254.8	-24.5	0	556.6	603.7	1.084
40CrNi Steel 860°C W+200°C Temp.	842.8	-415.5	-338.1	150.92	1799.3	1.192
40CrNi Steel 860°C SW+200°C Temp.	441	+155.8	+154.8	1593.5	1883.6	1.182

Note: A.F. and B.F. stand for after and before fatique, respectively.

Table 3 The Rate σ_b /σ and Its Fatique Strength Change Rate

Materials	$\sigma_{b.c}/\sigma_{s.c}$	$\frac{(\sigma_w)_r-(\sigma_w)_u}{(\sigma_w)_u}$
40Cr modified	1.086	26.9%
40Cr low-humidity temp.	1.22	33%
40Cr low-humidity temp.	1.45	45%
nodular cast iron	3.52	88%