PRECISION STEELS AND ALLOYS

EFFECT OF TUNGSTEN ON THE PROPERTIES OF AUSTENITIC DISPERSION-HARDENING SPRING ALLOYS

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The object of the present work is to improve the properties of an austenitic dispersion-hardening alloy, in the first place its strength, at normal and elevated temperatures (up to 400°C). For devising such an alloy we chose as base alloy an alloy type Kh13N36M5TYuBR (36NKhTYuM5) which has good technological properties and technological suitability up to 350°C. To improve its heat resistance, this material was alloyed with 2-4% W. It is known that the heat resistance of austenitic alloys improves when tungsten and molybdenum are simultaneously added to them [1, 2]. The chemical composition of the investigated alloys, which were produced in an open induction furnace, is presented in Table 1.

The investigations were carried out with specimens in the form of strips 0.3 × 5 × 100 mm in size which were heat-treated. Heating prior to quenching was carried out either in quartz ampuls evacuated to $133 \cdot 10^{-2}$ Pa or in a container through which argon was blown. Aging of the specimens was carried out in a vacuum furnace 1SNV-5.10.5/11.5 at rarefaction of 133×10^{-2}-$133 \cdot 10^{-4}$ Pa with subsequent cooling in air.

Figure 1 presents the results of the investigation of the process of hardening alloys type 13-36, additionally alloyed with 2-4% W while the molybdenum content was maintained at the level of 5%. We investigated the quenching temperature range 800-1100°C. It can be seen that heating to 1000-1050°C ensures fairly complete dissolution of the excess phases and saturation of the solid solution. This is indicated by the change of electric resistivity whose maximal value with all the investigated alloys was attained after quenching at 1000-1050°C. At the same time we also found that the alloys lose greatly in strength in consequence of the development of processes of recrystallization, decrease of the density of lattice defects. The grain size of the investigated alloys is 25-30 μm. When the quenching temperature is increased to 1100°C, it leads to a considerable growth of the grain (to 50-55 μm), probably as a result of the dissolution of carbide or carbonitride phases located along the grain boundaries. The ductility of alloys type 13-36 is sufficiently great for cold pressing or for making elastic elements with complex configuration. Even the most highly alloyed substance Kh13N36M5V4TYuBR has greater ductility than the alloy 36NKhTYuM8. After hardening at 1000-1050°C the alloy 36NKhTYuM8 has relative elongation 20-25% [3], and alloy Kh13N36M5V4TYuBR has 28%, in spite of its more complex alloying.

We also investigated the effect of aging on the properties of alloys type 13-36 additionally alloyed with tungsten. It follows from the data presented in Fig. 2 that maximal strengthening of the alloys is attained after aging at 750°C for 5-8 h. When tungsten is added, the forces of interatomic bond in the lattice of γ-solid solution increase, the processes of decomposition of the γ'-phase slow down in aging. The elasticity limit $\sigma_{0.002}$ of the alloy Kh13N36M5TYuBR and of the alloy with 2% W added attains the maximal value after 2-3 h,

TABLE 1

Alloy	Content of elements, %							
	C	Cr	Ni	Mo	W	Ti	Al	Nb
Kh13N36M5TYuBR	0,020	12,8	36,6	5,5	—	2,9	0,97	0,58
Kh13N36M5V2TYuBR	0,023	13,0	36,2	5,8	2,0	2,8	0,97	0,62
Kh13N36M5V3TYuBR	0,021	13,0	36,5	5,7	3,3	2,8	0,97	0,68
Kh13N36M5V4TYuBR	0,022	12,9	36,5	5,5	4,2	2,9	0,95	0,69

Note. In all steels the boron content was 0.002% (by calculation); the remainder is Fe.

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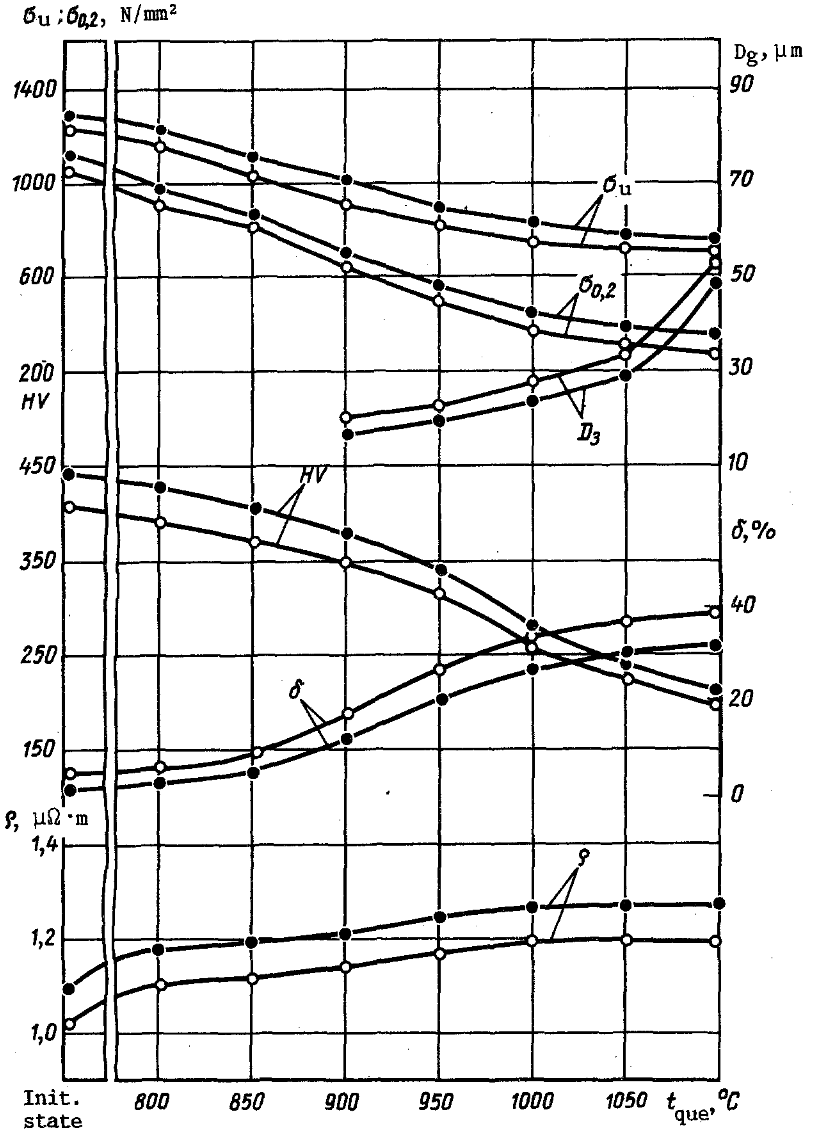

Fig. 1. Effect of the quenching temperature on the properties of alloys type Kh13N36M5TYuBR (○) and Kh13N36M5V4TYuBR (●). Initial state: cold plastic deformation with ε = 70%.

TABLE 2

Alloy	σ_u	$\sigma_{0,2}$	$\sigma_{0,002}$	δ, %	HV
	N/mm²				
Kh13N36M5TYuBR	1270	1080	700	17,2	385
Kh13N36M5V2TYuBR	1320	1100	740	16,3	405
Kh13N36M5V3TYuBR	1370	1140	780	15,6	420
Kh13N36M5V4TYuBR	1420	1200	800	15,0	440

Note. Presented are the properties of the alloys after quenching at 1100°C and aging at 750°C 8 h (hardness was measured with a load of 50 N).

and of alloys with 3-4% W added after 4-5 h. Besides, judging by the change of electric resistivity, the degree of decomposition of γ-solid solution that is maximal at the given aging temperature is attained in an alloy with added tungsten after longer holding than in alloy without tungsten. For instance, after aging at 750°C this state is attained in the former alloy after 5 h, in the latter after 2 h. This effect of slowing down the decomposition manfests itself also in the rate of change of the strength properties in aging; it can be explained by the fact that tungsten reduces the diffusional mobility of atoms of the alloying

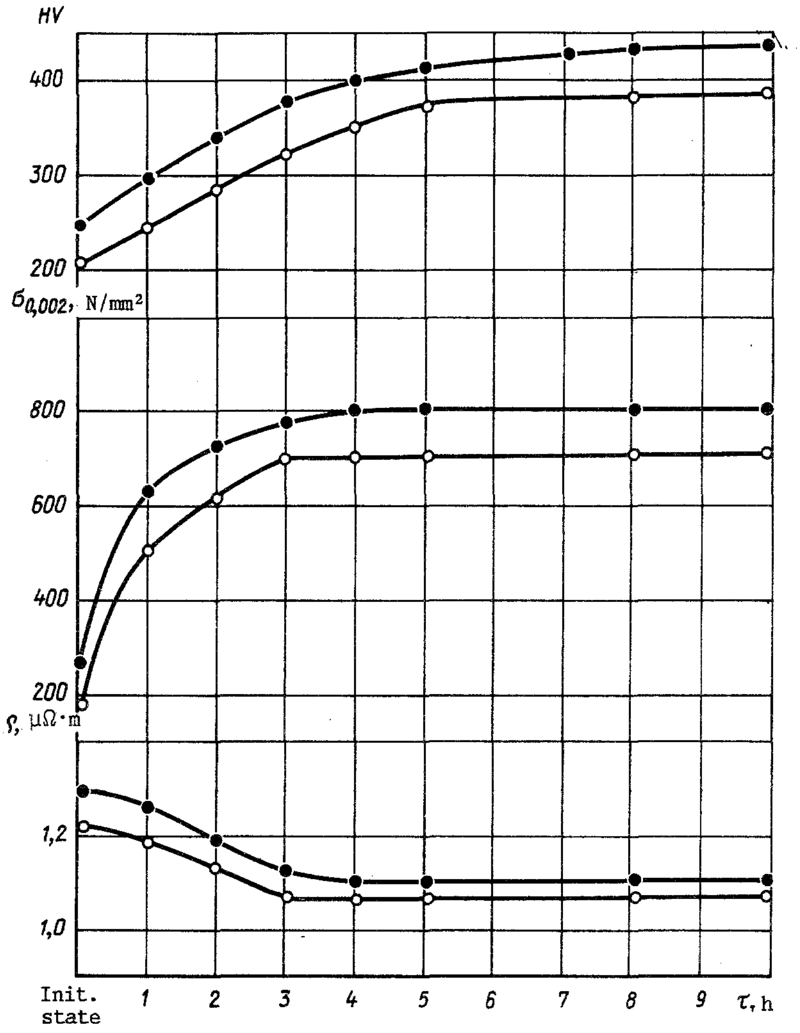

Fig. 2. Change of properties of alloys Kh13N36M5TYuBR (○) and Kh13N36M5V4TYuBR (•) in the process of aging at 750°C. Initial state: quenched at 1050°C.

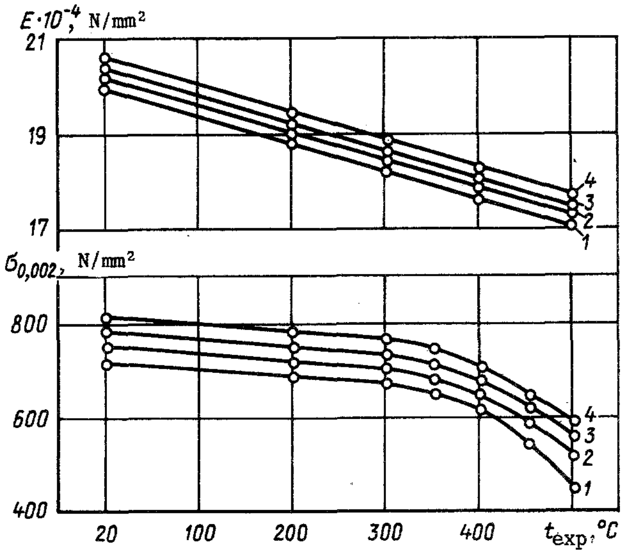

Fig. 3. Effect of the test temperature on the properties of alloys. Initial state: quenched at 1050°C, aging at 750°C 8 h: 1) Kh13N36M5TYuBR; 2) Kh13N36M5V2TYuBR; 3) Kh13N36M5V3-TYuBR; 4)Kh13N36M5V4TYuBR.

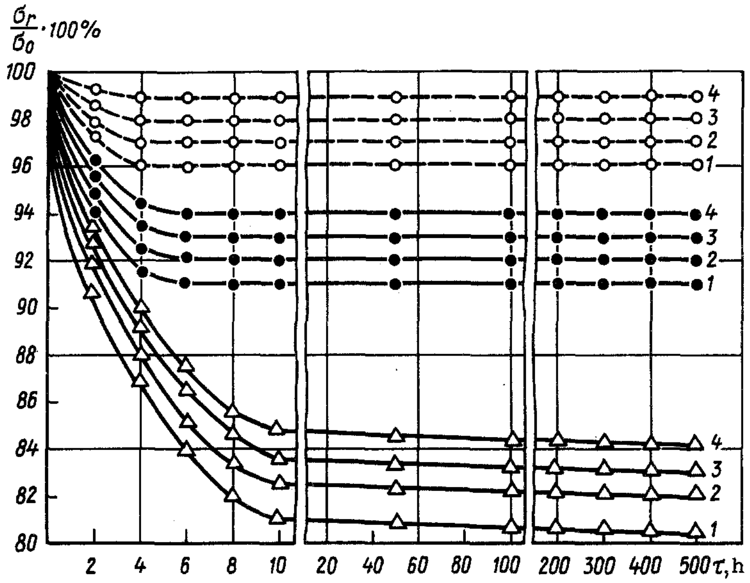

Fig. 4. Resistance to relaxation of alloys. Initial treatment: quenching at 1050°C, aging at 750°C 8 h: 1) Kh13N36M5TYuBR; 2) Kh13N36M5V2TYuBR; 3) Kh13N36M5V3TYuBR; 4) Kh13N36M5V4TYuBR: o) $\sigma_0 = \sigma_{0.002} = 800$ N/mm² ($t_{expt} = 20$°C); •) $\sigma_0 = 1000$ N/mm² ($t_{exp} = 20$°C); Δ) $\sigma_0 = 600$ N/mm² ($t_{exp} = 450$°C).

elements, especially in the presence of molybdenum, because the effect of each of these high melting elements is reinforced when they are jointly added to the alloy [4]. It should be noted that the greater tungsten content is, the greater is also the effect of dispersion hardending in the process of aging at 750°C (Table 2). During aging the decomposition of γ-solid solution proceeds by a continuous mechanism, and this is ensured when the alloy contains molybdenum and tungsten. These elements bind vacancies, as a result their sink flow to the grain boundaries is greatly slowed down, and therefore the rate of diffusion in the near-boundary zones decreases correspondingly.

The alloy Kh13N36M5V4TYuBR (Table 2) has strength properties at the level of the properties of the high alloy 36NKhTYuM8 but in distinction to it is more ductile. On the basis of this it may be concluded that form the point of view of strength properties and ductility, similar alloys are much more effectively alloyed with molybdenum and tungsten than with molybdenum alone, even when this involves large quantities (up to 8%).

Figure 3 presents the results of the determination of the dependence of the modulus of elasticity and of the elasticity limit on the temperature of alloys type 13-36 additionally alloyed with tungsten. It can be seen that with rising heating temperature the elasticity limit ($\sigma_{0.002}$) of the alloys becomes lower, but to a smaller extent, the higher the tungsten content of the alloys is. For an alloy type Kh13N36M5V4TYuBR a decrease of the elasticity limit by 5% corresponds to 300°C. However, the elasticity limits remain at a fairly high level up to 400°C.

When we compute the test results we may conclude that adding molybdenum and tungsten to alloys type 13-36 increases their elasticity limit when they are heated.

Figure 4 shows the dependence of the resistance to relaxation (σ_r/σ_0) of alloys type 13-36 on the tungsten content. The alloy with 4% W (Kh13N36M5V4TYuBR) has the greatest resistance to relaxation.

The decrease of the relaxed stress of alloy type Kh13N36M5V4TYuBR after being tested for 500 h amounted to 16%, which is somewhat more than of alloy 36KhNTYuM8 but less than of alloys types 17-40 to which tungsten was added [1].

CONCLUSIONS

1. Quenching alloys type Kh13N36M5TYuBR with 2-4% W at the optimal temperature (1050°C) ensures sufficiently fine grain, good ductility, practically the maximal degree of supersaturation of the solid solution.

2. The optimal aging regime (750°C 5-8 h) does not depend on the tungsten content of the alloys. The absolute magnitude of strengthening increases with the lowering of the quenching temperature to 1000°C, but at the same time ductility is impaired.

3. When tungsten is added to austenitic alloys, the degree of their strengthening increases and so does their resistance to relaxation. When tungsten is added to this type of alloy, their resistance to relxation is increased at temperatures up to 450°C whereas an alloy without tungsten is stable up to 350°C. Alloy Kh13N36M5V4TYuBR has better ductile properties than alloy 36NKhTYuM8.

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EFFECT OF THE HEAT-TREATMENT REGIME OF ALLOY 44NKhMT ON THE TEMPERATURE COEFFICIENT OF DELAY OF ULTRASOUND

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Alloy 44NKhMT is used for making sound ducts of different elements for automation and computers including sound ducts of ultrasonic delay lines, ultrasonic displacement sensors, etc. The material of sound ducts has to have a low temperature coefficient of delay of ultrasound (TCD) and be characterized by a certain speed of propagation of ultrasound in it.

The low TCD inherent in the alloy 44NKhMT change considerably in dependence on the heat treatment regime [1, 2].

In the present work we determined the effect of heat treatment on the TCD of ultrasound and on its speed in alloy 44NKhMT. The sound duct (cold-formed wire 1 mm thick, 280 mm long, degree of work-hardening 75%) was heat-treated: holding in a muffle furnace at t = 550, 600, 650°C for 10-60 min, cooling in air.

To determine the TCD we used an installation with an ultrasound sensor utilizing direct and reflected ultrasonic waves. A block diagram of the experimental installation is shown in Fig. 1.

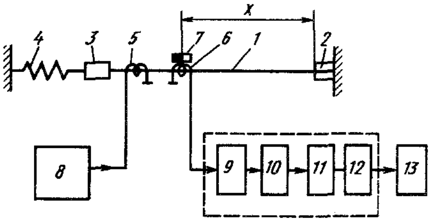

Fig. 1. Block diagram of the experimental installation.

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