# SHOCK WORKING OF STEEL

B. V. Voitsekhovskii, V. L. Istomin, A. D. Kryuchkova, and O. A. Maikov

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Thermomechanical processing has been tested on many classes of steel and has always been found advantageous [1]. Increase in yield point with retention of satisfactory plasticity is due to hardening of austenite during deformation and is a consequence of the increased dislocation density, which is retained after quenching.

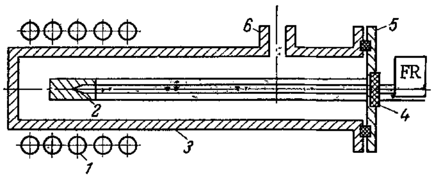


Fig. 1

All such processing schemes previously used have certain common features. Plastic deformation is produced largely statically, with a restricted range of deformation rates [2], and sometimes of degree of deformation. For instance, the maximum possible deformation rate is 1 m/sec in rolling, wire-drawing, and stamping, while the maximum possible degree of deformation in one working cycle ranges from 23–98%. The corresponding figures for extrusion, drop forging, and high-speed stamping are 50 m/sec and 98%.

It has been shown [3] that the strength has a complex relation to the delay after the end of hot deformation before quenching (incubation period), but this is often neglected. Even in 3 sec there is a sharp fall in yield point and marked rises in plasticity and grain size. The minimum delay has been reduced to 0.3 sec.

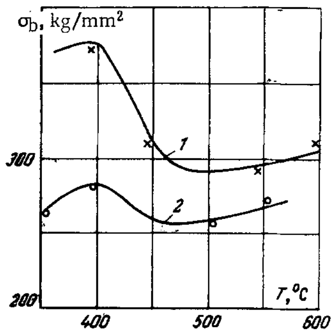


Fig. 2

Here we give some results on the effects of rapid bulk deformation, incubation period, and purity of the initial material on the maximum yield point in tension. The grades of martensite steel are denoted by (1)–(3), and the chemical compositions were as follows:

| | C, % | Si, % | Ni, % | Cr, % |
|---|---|---|---|---|
| (1) | 0.53 | 1.88 | 5.8 | 1.78 |
| (2) | 0.58 | 1.96 | 5.98 | 1.98 |
| (3) | 0.65 | 1.84 | 5.00 | 2.00 |

The steels were melted in zirconia crucibles of capacity 0.6 kg at 10 mm Hg in an MPV-3 oven. The alloys were made of technically pure and electrolytic materials.

The billets were crystallized under vacuum and were forged into rods. Oxidation was avoided by heating in the evacuated tube shown in Fig. 1, in which 1 is the heater, 2 is the specimen, 3 is the jacket, 4 are vacuum seals, 5 is an endplate, and 6 is a pumping part. The forged rods [FR] were cut up for specimens.

Shock hardening was performed as follows. The specimen was heated to 20–40° C above point $A_{c_3}$ in the above evacuated system

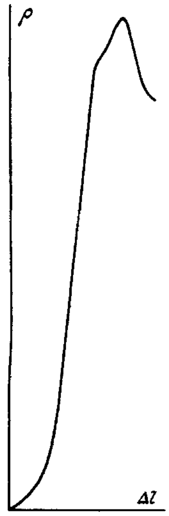


Fig. 3

and was kept there for 20–30 min. Austenitization was followed by immersion in an intermediate bath at the deformation temperature for 1.5–2 min. This temperature was chosen in the region of high stability for metastable austenite. Deformation at 3–4 km/sec was produced in a special machine, and the specimen was shot into the quenching medium within 0.2–0.3 msec. The quenching time was 2–2.5 sec, in accordance with the thickness.

The deformation time and incubation period were thus much less than the time of passage of the thermal wave during quenching. The shock hardening may be partly lost on account of the prolonged quenching time, which ought to be comparable with the other times. The products were cut in various directions with respect to the texture and were tested. Figure 2 shows the mean breaking point $\sigma_b$ as a function of deformation temperature for steel (1), in which curve 1 is for vacuum heating before deformation and curve 2 is for heating in air. The maximum value is $\sigma_b$ = 364 kg/mm² at a deformation temperature of 400° C.

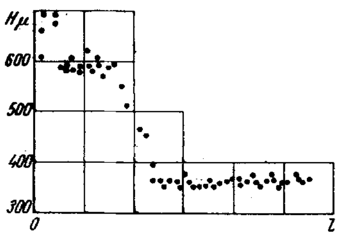


Fig. 4

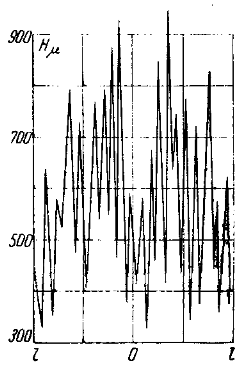


Fig. 5

Figure 2 illustrates the importance of purity, since heating in air reduces $\sigma_b$ by 15–25%.

The maximum $\sigma_b$ of 390–396 kg/mm$^2$ were produced in steels (1) and (2) by deformation at 400–420° C; classical heat treatment to maximum strength gives 230 kg/mm$^2$ for these steels. However, the results on $\sigma_b$ are not very reproducible, as the degree of deformation varies over the volume of the specimen.

Figure 3 illustrates the deformation in tension for this very hard steel. There is no plastic range, while the yield point approaches or equals the failure point.

The hardening can be determined qualitatively from the microhardness. The increase in hardness is greatest where the deformation is greatest.

Figure 4 shows the hardness plotted outwards from the center along a diameter for high-quality 30CrMnSi steel. There is a fall in hardness at the center and a plateau on the descending branch.

Steel (1) contains more carbon (0.53%), and here there is no region of constant hardness (Fig. 5). The hardness distribution is irregular, probably on account of deformation on certain planes rather than throughout the volume. Flow in this case produces hardening in a narrow region adjoining the slip plane and is seen as a peak on the hardness curve. A more plastic metal produces a wider region of slip, and consequently a region of constant hardness.

The shock method greatly reduces the deformation and incubation times, and so suppresses recovery and recrystallization. The failure point is thereby raised.

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