The mechanical properties of articles formed from powder alloy steels are lower than those formed from a rolled steel product of similar chemical composition; this is associated with reduced density, structural heterogeneity, and high contamination of the powder steels by nonmetallic inclusions [1]. These deficiencies are dictated by procedures of powder metallurgy with which the article is fabricated, varying the smelting and treatment of the melt by production additives to remove the harmful impurities. In this connection, the content of impurities and nonmetallic inclusions in the powder steels is one hundred times higher than that in cast steels. Thus, GOST 9849-86 regarding the iron powders PZhV3 and PZhV4, which are widely used at plants to fabricate various components, permits an oxygen content of up to 0.5-1.0% in the articles. The oxygen content normally does not exceed 0.005-0.01% in cast steels.

The structural homogeneity of the powder steels depends on the character of the charge and the production treatments. The simplest, most inexpensive, and widely employed method of producing powder alloy steels is the use of a mechanical mixture of the powders of iron, carbon, and alloying elements. This method, however, leads to significant segregation of the elements and to the formation of a heterogeneous structure, and, consequently, to low, unstable mechanical properties, and to degradation of machinability. It is known [1, 2] that powder nickel steels are characterized by a spotty nonuniform structure, which consists of undissolved nickel particles and a pearlite base. This makes it necessary to use high-temperature sintering (1300-1350°C), which requires special equipment, in the production.

A uniform structure can be obtained in powder steels using sprayed homogeneously alloyed powders [3]. There are, however, a number of reasons that limit the broad implementation of these powders: particles of homogeneously alloyed powders are rigid and hard after spraying; this reduces the material's pressibility and increases the wear of the pressing tool [4]; pressed blanks formed from homogeneously alloyed powders do not lend themselves well to production, and their strength is three times lower than that of blanks produced by the pressing of a mechanical mixture [5]; and, industry produces alloy powders of the given composition on a limited scale.

Use of partially alloyed powders is most effective. A positive quality of these powders is the local fixation of statically distributed alloying components in the powder mixture. Partially alloyed powder can be produced by introducing alloying components in the form of finely disperse readily reducible oxides, for example, NiO and MoO₃, with subsequent combined reducing annealing of the charge. This alloying makes it possible to produce a uniform structure and increased physical and mechanical properties of alloys at relatively low sintering temperatures [6]. The latter situation is extremely critical for sintering practice, since the procedure of low-temperature sintering is energy-efficient and tends to increase the operating time of industrial sintering furnaces.

The purpose of this study was to investigate the structure and mechanical properties of articles formed from partially alloyed iron powder with the use of nickel and molybdenum oxides, and for comparison, an alloy powder formed from a mechanical mixture of metallic nickel and molybdenum powders subjected to various production treatments.

The initial materials were the reduced iron powder PZh4M with a dispersity of 50-160 μm, a nickel oxide NiO and molybdenum oxide MoO₃ powder with a dispersity of less than 5 μm, the copper powder PMS-1 with a dispersity of less than 10 μm, and the pencil lead 0KI.
as well as nickel and molybdenum powders. Alloying of the charge in both variants was accomplished so that the powder steel corresponded to grade SP40N2D2M after sintering.

The charge was mixed in a ball mill and conical mixer with the subsequent introduction of alloying additives to the iron powder. The total mixing time was 8 h for both variants. After mixing, the charge with the nickel and molybdenum oxides was subjected to annealing in a reducing atmosphere at 720°C for 4 h. This annealing regime is optimal: the degree of oxide reduction is inadequate at lower temperatures, and a dense cake of charge is formed at higher temperatures. The degree of oxide reduction was monitored on the basis of the oxygen content in the charge, which should be less than 0.5%. In the comparison batch with the nickel and molybdenum powders, the iron powder was preannealed (prior to mixing) in accordance with a similar regime (720°C for 4 h) with an oxygen content of less than 0.5%.

Specimens were pressed from the reduced charge to a density of 6.9-7.1 g/cm³, and sintered in endogas and hydrogen at 800 and 1150°C. After this, some of the components were subjected to cold repressing in a hydraulic press to a density of 7.3-7.4 g/cm³ and were resintered at 1150°C, while the remaining portion of the components was subjected to hot stamping to a density of 7.7 g/cm³. The blanks were heated to the hot-pressing temperature of 1100°C in an inductor for 1.5-2 min. For protection from decarbonization and oxidation, the blanks were treated with a 15% graphite suspension in oil.

After hot stamping, the blanks were annealed at 600°C for 2 h to remove stresses and heal over microcracks, and were heat-treated additionally in accordance with the following regime: quenching from 840°C in oil, and tempering at 550°C. The results of mechanical