According to analytical calculations [1-3], at least two slip (break) lines can pass through any point in the incoherent zone. The conventional methods employed for the experimental determination of slip lines in nonporous materials cannot be applied to powders because of the latter's low mechanical properties.

The application of x-radiography, as used for defect detection, to free-flowing materials can give an accurate picture of regions of different densities in a strained particulate body in those cases where the plane macrodefects of the medium (slip and fracture planes, arches, and domes) are located in planes parallel to the direction of photography. For example, when the planes of macrodefects in a 60- to 120-mm-wide body being x-rayed are inclined at angles of 5-10° to the direction of photography, the width of resolved defects is 2.60-5.30 mm. In such a case, in the determination of the "thickness" of a macrodefect (or a slip line) photography must be performed at not fewer than two focal lengths. With single-focus-length photography, a slip line appears (because of the inclination of the slip plane to the direction of photography) as a slip band.

In a general case, x-ray photography gives an averaged picture of density distribution in a body being examined [4]. However, the macromechanism of powder deformation in the incoherent zone can be successfully studied by using a hopper with transparent walls. With this technique, macrodefects are photographed through transparent hopper walls, and the angle at which slip planes (macrodefects) are inclined to the walls is determined from the positions of their exit traces on the powder surface in the hopper and from the distribution of density in rolled strip at its maximum porosity [5].

In the work described below, the macrodeformation of powders was examined through transparent walls of hoppers on rolls of diameters \( D = 89.2, 180, \) and 500 mm. The initial hopper thicknesses \( H_0 \) were 1.5, 1, 0.5, and 0.25 \( D \), the hopper width in the majority of experiments being 60 mm. In some experiments use was made of a horizontal coordinate grid produced by dyeing different layers different colors. The objects of investigation were pairs of powders of different colors: an iron-copper mixture (20% Cu) - Fe and Cu - a copper-nickel mixture (70% Ni). The amounts of glycerin or oil in the mixtures were varied from 0.5 to 3%. The most "stable" slip lines were obtained by rolling an iron powder with an addition of 20 vol.% of 0.5- to 1-mm-diameter magnesium fibers; the fiber length-to-diameter ratio was 3.9:1.

The deformation of the powders was studied in the as-poured and tapped conditions and also with an additional load \( \Delta P = 10 \text{ GPa} \) applied to the powder surface in the hopper. A study was made of the initial nonsteady-state period of rolling [6]. After the rolls had turned through an angle of 10-40°, the slip lines were photographed and lined in. Each series of experiments was repeated two or three times. In all, more than 300 experiments involving stopping the rolls were carried out. In some cases, motion pictures of slip lines were taken with an RKD-200 camera.

Successive stages of macrodeformation development in the incoherent zone on 180- (\( H_0 = D \)) and 500-mm-diameter (\( H_0 = D/2 \)) rolls are depicted in Figs. 1 and 2. Analysis of experimental results revealed certain regularities in the deformation of powders in the incoherent zone. Stabilization of macrodeformation in rolling was attained earlier with coarse (70-200 \( \mu \text{m} \)) than with fine (less than 40 \( \mu \text{m} \)) powders. With all powders, the angle of stabilization of macrodeformation exceeded the angle of stabilization of the process [6].

Slip line generation and propagation commenced in a range of angles close to the rolling angles (8-12°). The upper region of slip lines extended up to angles \( \phi \approx 87-88° \). On each roll slip lines of a single family, di-

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*The component concentrations in mixtures are expressed in weight percentages.*

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context into the region of deformation, were generated. Slip lines of a second family (on each roll) formed as a result of the propagation of slip lines from the second roll. The bending of the slip lines was the greater, the larger their angle of initiation. The slip lines of one family acted as barriers hindering the propagation of the slip lines of the second family.

As a rule, on each roll there appeared between one and nine slip macrolines of a single family. The intersection of these lines led to the formation of macroregions. The number of slip lines generally grew with decreasing powder particle size.

The most stable slip lines were obtained when the strength of powders was increased by the addition of fibers. In such a case it was found, with all powders, that a single slip line formed on each roll. It was generated in the range of angles $\varphi \sim 70-85^\circ$ and emerged, after bending, on the other roll in the range of angles $\varphi \sim 40-50^\circ$. The mutual intersection of these lines (Fig. 3) divided the lag zone into characteristic macroregions. The decreasing distance between macroregions I and II (resulting from the narrowing of the *seat* of deformation) gave rise to the formation of macroarches. Less stable arches formed also in regions III and IV.

Inside the macroregions finer slip was observed, with the formation of submacroregions (due to the intersection of the slip lines). The intensity of the "fine" slip (number of lines in unit area) was greater in region...