DEEP-DRAWING PERFORMANCE AND STRUCTURE-PROPERTY RELATIONS OF NIGERIA MILD STEEL

BY

ENO J. IBANGA
Department of Physics
University of Agriculture
P. M. B. 2373, Markudi, Nigeria.

AND

ANIEDI O. ETTE
Department of Mechanical Engineering
University of Agriculture
P. M. B. 2373, Markudi, Nigeria.

ABSTRACT:

Most inland rolling mills in Nigeria depend on Delta Steel Company (DSC), Aladja, Nigeria for their billets while the wire drawing companies depend on the rolling mills for their rods. The drawn products therefore owe their final properties to the production history of the billets and the drawing operations. Difficulties encountered by wire drawing companies using locally produced rods in deep drawing operations necessitated metallurgical charaterization on the rods. Investigation has revealed that a significant difference exists in the compositional characteristics of the locally produced mild steel rods compared to standard specifications of mild steels for wire drawing applications. The carbon content of the DSC steel is found to be higher than the standard requirements. The ductility was found to be within an acceptable range for mild steel but microstructural analysis revealed decarburization and grain growth during process annealing. Softening of products (wires and nails) was also observed and Brinell hardness number (BHN) was about 56.9% of the standard specification for 0.30% mild steel.

Keywords: Mild Steel, Deep-drawing, Failure, carbon content, annealing.

INTRODUCTION

Wire drawing industries in Nigeria have experienced increased demand on their products as a result of the difficulty in importing finished wire products under the present poor economic conditions in Nigeria. Wire rods form the raw materials for the wire industries and can either be sourced locally from the inland steel rolling mills or imported. Importation is made difficult by the huge foreign exchange requirements and also by government legislation. The situation encourages the use of the locally avilable rods produced by the inland steel rolling mills using billets from DSC, Aladja, Nigeria.

Most wire drawing companies in Nigeria utilizing locally produced rods experience premature failure during the drawing operations. bending of nails produced locally are also experienced while in use. Experience by the companies shows that imported rods exhibit less tendency to such failure given the same process treatment (1). The source of premature failure can generally be traced to the kind and quality of the raw materials (rod), the efficiency of the drawing operations and the process technology.

Physical defects in the rod will either cause failure in the drawing operation or remain as more minute defects in the wire. Compositional consistency is essential for appropriate tooling and processing of the rod. Acceptable composition of steel for wire drawing includes low carbon SAE Number (1006, 1008, 1010, 1012, 1108 and 1110), medium low carbon SAE Number (1013 to 1022, inclusive) and medium high carbon SAE Number (1025 to 1041, inclusive) (2). The DSC billets, which form the feed to the rolling mills, are classified as low carbon steel and should therefore satisfy process specifications for mild steel wire drawing operations. Significant differences should therefore not exist between the imported and locally sourced raw materials. However, failure experienced by local wire drawers can be reduced if physical and compositional defects are minimised and appropriate wire drawing technology, human resources and facilities utilized.

It is necessary to establish the source of the breakage experienced in wire drawing and the bending experienced in nails produced from locally available rods. Investigation has been carried out to establish the characteristics of the carbon steel produced locally for use in deep drawing operations. It is hoped that the parameters (physical and chemical) responsible for

the failure can be identified and recommendation for corrections made. These will enable the local industries to maximise the utilization of locally available raw material, minimize waste, be competitive and economically viable.

EXPERIMENTAL PROCEDURE

The wire products used for the experiment were obtained from the Nigerian Wire Industries Limited (NIWIL), Ikeja, Nigeria. The wire rods analysed were produced from billets of DSC, Aladja, Nigeria. Samples were made from rods drawn to various specifications in line with stages encountered in commercial wire production operations.

The wire samples were prepared for physical and mechanical tests including tensile, hardness, and metallographic analyses.. Tensile tests were carried out at the facilities of NIWIL while hardness and metallographic tests were conducted at the Laboratories of the Obafemi Awolowo University, Ile-Ife, Nigeria. Hardness and tensile values were compared with standard values documented for carbon steels of similar chemical composition.

Metallographic analysis were carried out to provide information on the physical characteristics of the rod as well as the heat treatment history/practices of the wire industry.

RESULTS AND DISCUSSIONS

PHYSICAL PROPERTIES

The certificate of analysis supplied by DSC, Aladja, Nigeria, in respect of F 70 x 6 gave the following values in table 1 for rolled products ready for dispatch.

TABLE 1 *DSC, Aladja Product certificate of analysis for F 70 x 6 steel (1985)*

Mechanical properties				
S/N	Heat No.	Y.S. Nmm^{-2}	T.S. Nmm^{-2}	Elongation %
F 70x6	410800	319.80	456.68	36.76
F 70x6	420638	322.32	455.41	38.02

Laddle Chemical Analysis in %						
C	Si	Mn	P	S	Cu	N_2 -
0.15	0.22	0.51	0.024	0.007	0.05	0.004
0.12	0.15	0.62	0.029	0.009	0.08	0.0039

Experimentally determined yield stress (Y.S.) and tensile strength (T.S.) for the 6.00 mm rod (as received) were found to be 330 Nmm^{-2} and 466 Nmm^{-2} respectively. It is of interest to note that the measured value of the yield stress and tensile strength compare favourably with the values determined by the DSC, Aladja (see Table 1). As observed by Sisco (3), the relationship between the carbon content and mechanical properties show that for a 0.15% C mild steel, the yield stress is 220.63 Nmm^{-2} and the tensile strength is 372.32 Nmm^{-2}.

Figure 1 represents a plot of the increase in tensile strength of plain carbon steel with increasing amount of cold working. Curve A - B representing data collected for wire materials drawn from DSC rods is superimposed on a standard plot for different ranges of carbon content (4). It can be observed that the general shape of curve A -B agrees with the standard plot and falls within the carbon range of 0.30 -0.60 per cent. Figure 2 also shows the effect of cold working on the ductility of plain carbon steel. Curve X-Y represents data from wire materials drawn from DSC, Aladja rods superimposed on a standard plot (2). The upper limit of the plot represents low carbon steel (% C <0.3) and the lower limit represents high carbon steel (%>0.3). From Figure 2, the curve X-Y is displaced towards the lower limit, thus suggesting higher carbon contents than obtainable in standard mild steel. Based on the results from Figures 1 and 2, composition sensitive properties were estimated using 0.15% C and 0.3% C of the as - rolled rod. The values obtained together with the measured values are displayed in Table 2.

TABLE 2: *Composition sensitive Properties of as - rolled plain Carbon Steel.*

Properties	Measured	DSC (at 0.15% C)	Sisco (1937)	
			0.15%C	0.3%C
Y.S Nmm^{-2}	330.0	319.80	220.6	303.4
T.S Nmm^{-2}	466.0	456.68	372.3	496.4
R.A%	60.8	-	68.0	52.0
BHN	91	-	136	160
Elongation%	27.4	36.76	37.0	29.0
%Pearlite	0.34	-	-	-

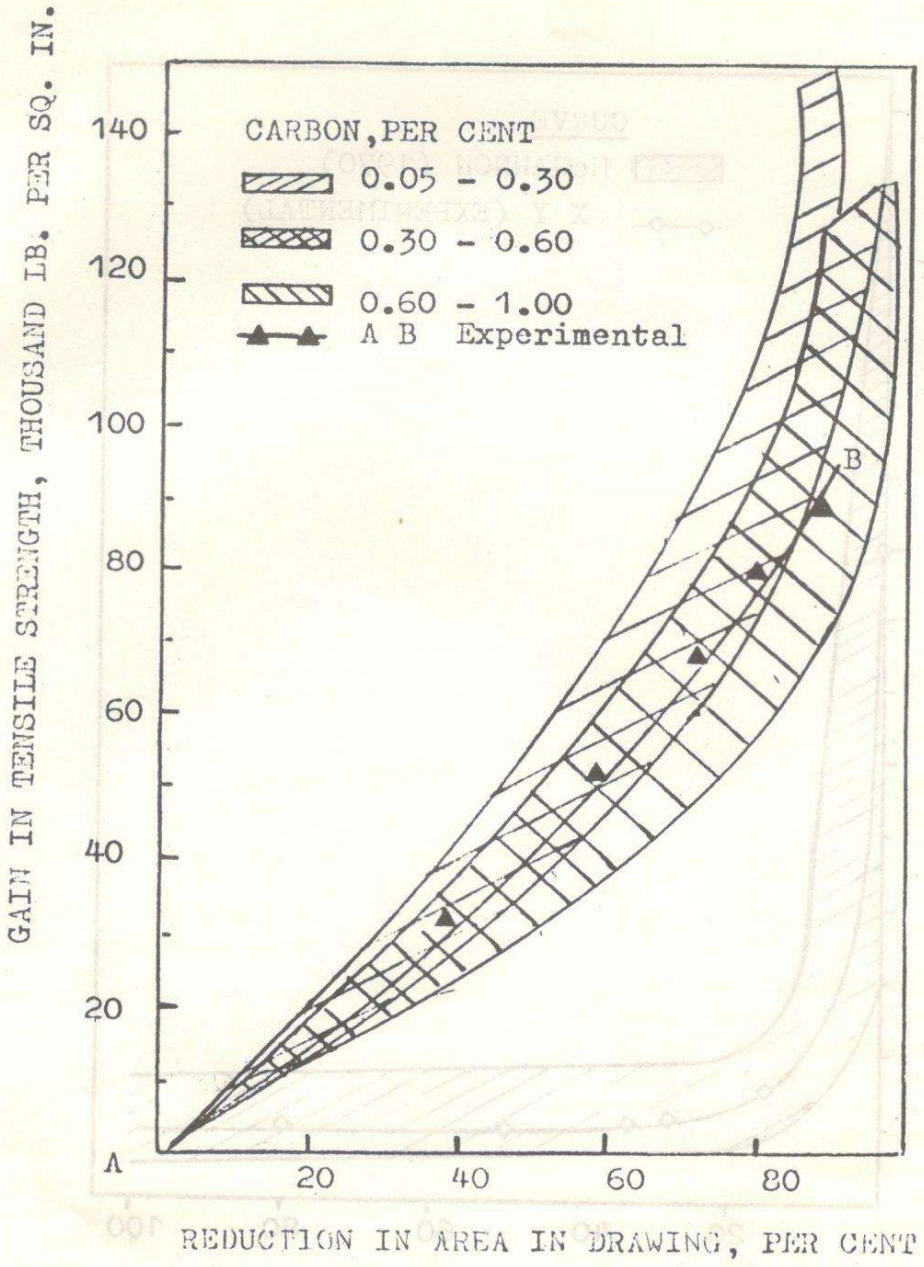


Figure 1 Increase of tensile strength of plain carbon steel with increasing amounts of cold working (From ASM 1977).

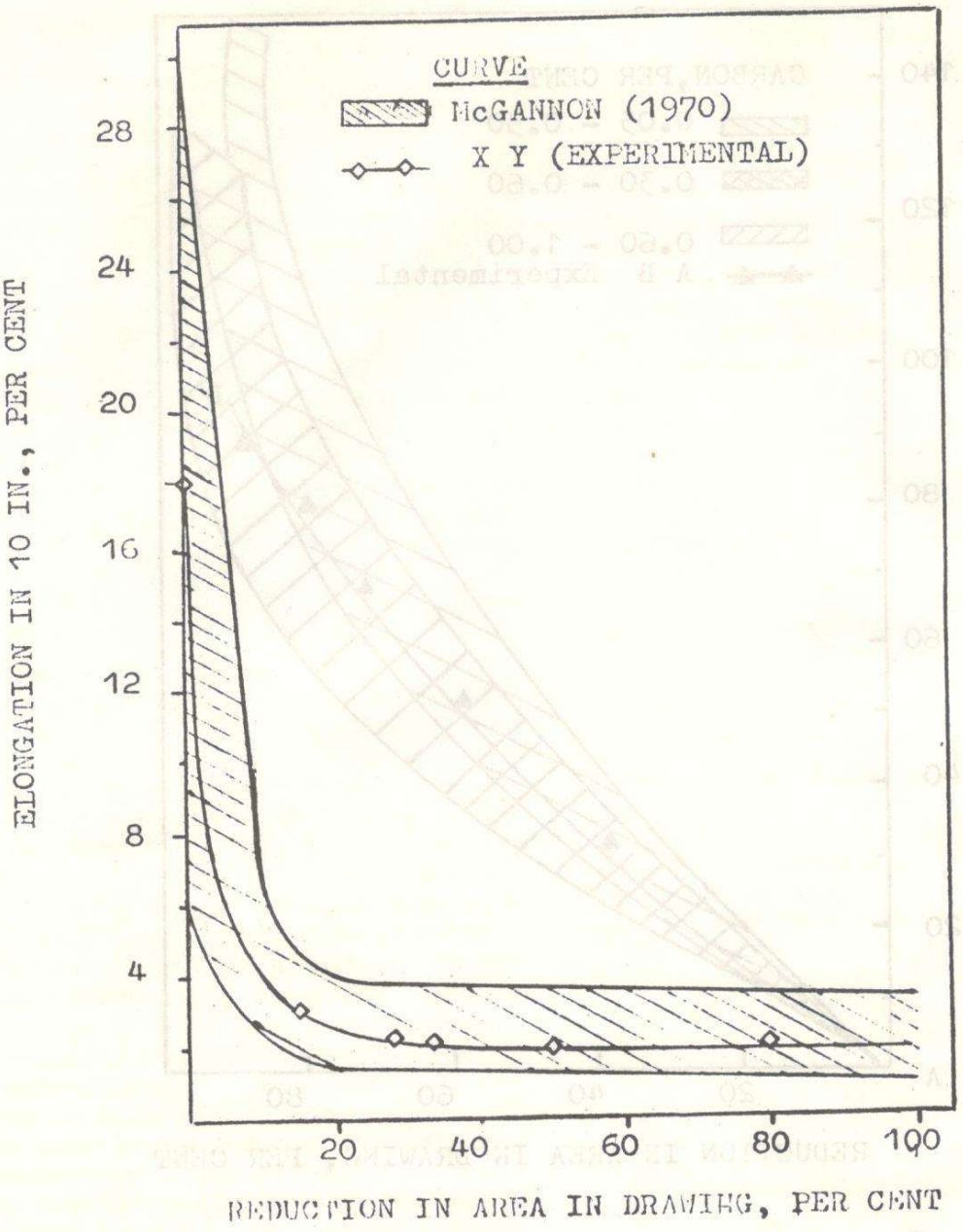


Figure 2 Effect of cold working on the ductility of plain carbon steel.

At 0.3% C, the values compare favourably with the experimental values and those quoted by DSC. However, the percentage elongation given by DSC corresponds to 0.15% C data. It is therefore obvious that the carbon content of the rod produced by the inland rolling mills using DSC billet is about 0.3% C. From Table 2, it can also be observed that the measured hardness value is 56.9% of the literature value at 0.3% C.

The problems encountered by wire drawers with the use of rods obtained from DSC billet have been: (1) premature failure during drafting; (softening of the final products (wire or nails). It was decided to investigate the effects of reduction of area and elogation on the product diameter. Figure 3 represents a plot of the reduction of area versus the guage diameter of the drawn products. Process annealing was carried out after each draft at 700°C. Curve A shows that continuous drawing from 6.05 mm (as - received) rod will result in failure at about 4.2mm. This confirms the report by Ibanga (5) that producers experience failure of the wire rod in the die between 4.0 mm and 5.0 mm when drawn from 6.0 mm guage. Curve B is obtained by applying one hour process anneal after each draft. It is seen that failure will occur at about 2.5 mm. By increasing the annealing time to 4 hours per draft, curve C was obtained. This shows that a guage of 1.5 mm could be attained be-fore failure. Figure 4 is the plot of the percentage elongation at fracture against the guage diameter. The right-hand portion of the curve shows decreasing elongation with reduction in guage diameter while the left hand-side shows an increase in elongation with decreasing gauge diameter. The result indicates that at short annealing time (right hand-side) the wire becomes harder with increased drawing and becomes softer at higher annealing time (left hand side) with decrease in wire diameter. The decrease in elongation could be attributed to grain refinement and work hardening while the softening occurs due to grain growth and decarburization. It is known that significant grain growth does not occur during process annealing for 7 hours at 650°C if the carbon content of the steel is between 0.04 - 0.12%. However, large grains persist when the carbon content is above 0.2% (2). The presence of large grains was observed when 4.75 mm gauge wire was annealed for 4 hours at 700°C.

MICROSTRUCTURAL PROPERTIES

The microstructure of the as - received wire rod drawn from DSC, Aladja billet is shown in figure 5. The average grain size of the rod was found to be 23.15 microns and the pearlite volume fraction of 0.34 was obtained using linear analysis method reported by Blank and Gladman (6). The measured pearlite fraction compares with the value of 0.36 calculated at 0.3% C by using the lever rule. At 0.15% C the calculated volume fraction of pearlite is 0.17 which is very low compared to the measured value.

The effect of process annealing on the microstructure of 4.75 mm hard drawn wire is shown in Figure 6 and 7. Figure 6 is the hard - drawn wire before annealing. It can be seen that significant grain refinement occured due to the cold work. The hard - drawn specimen was annealed at 700°C for 4 hours in line with industrical practice. Figure 7 shows two interesting features compared to Figure 6: (1) the presence of extensive grain growth and (2) the near absence of pearlite regions. These results confirm the observed reduction in strength experienced with nail products of shank diameter less than 4.75 mm. The near absence of pearlite region indicates decarburization problem. The wire drawers over-anneal their materials to avoid failure during the drawing operations. This practice results in softening of the final product and the associated in-use problems.

CONCLUSIONS

1] The wire rods produced using DSC, Aladja billets contain about 0.3% C and have an average grain size of 23.15 microns. Using the 6mm rod, premature failure occurs on hard - drawn wires before the gauge of 4.0 mm is attained. Process annealing at 700° C for 4 hours enabled the production of rods of about 1.5 mm before failure. However, the annealing process gave rise to severe decarburization and grain growth which resulted in the softening of the draw products. This softening results in the wire failure in the die and the bending of nails due to accelerated loading.

2] Lower annealing temperature (570 - 630°C) for 3 hours should be employed to rods produced from DSC, Aladja billets used in wire drawingduring process annealing to relieve the stress and prevent excessive grain growth. Atmosphere control in the furnace during the annealing treatment using any of the following gases: nitrogen, coke oven gas, natural gas, propane or butane should be employed.

***N.B.** The repeat of this article earlier published in the Jan-March 1994 edition of Vol. 29 No. 1 was necessitated by some printers devil noted therein. To avoid misreading or interpretations of the data we had to reprint. Editor.*

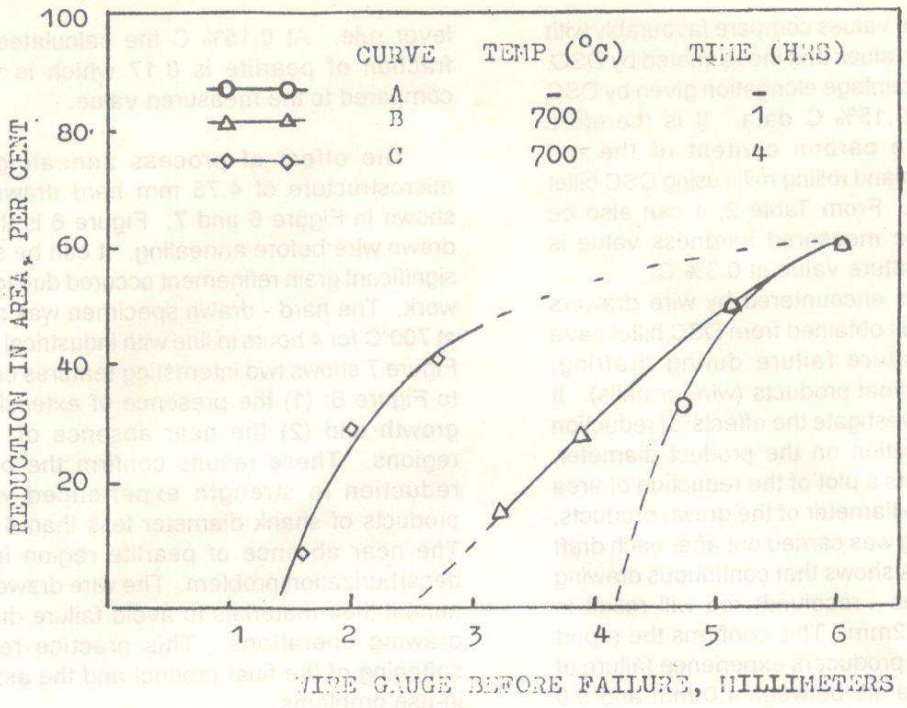


Figure 3 The effect of process annealing on the reduction in area and gauge before failure for F 70x6 steel.

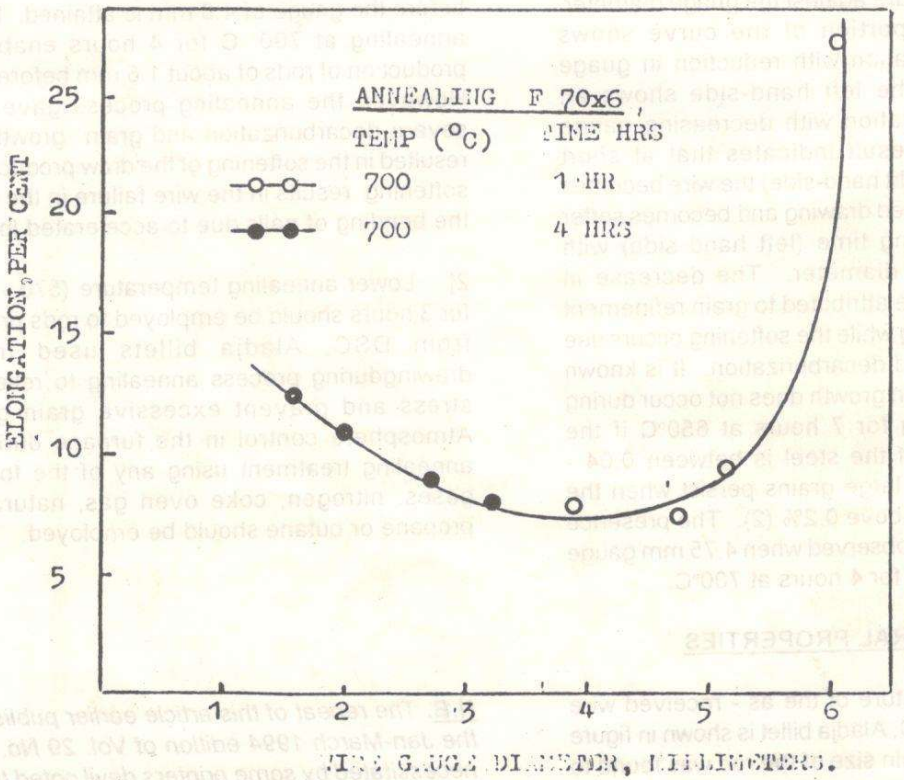


Figure.4 Effect of process annealing on the elongation and gauge diameter.

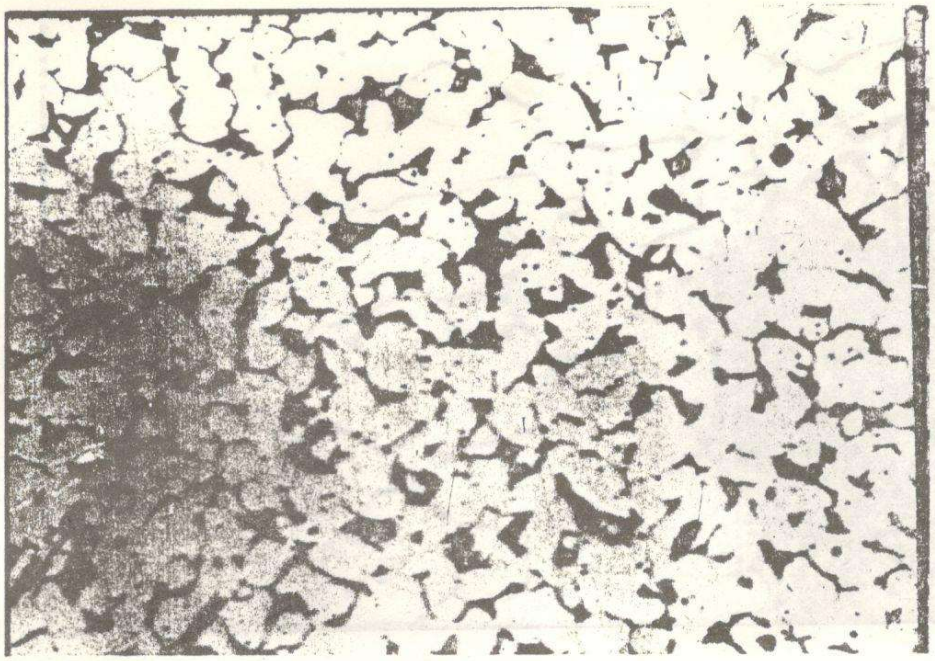


Figure 5. Photomicrograph of as-received 6.05mm diameter wire rod. Magnification: 330X

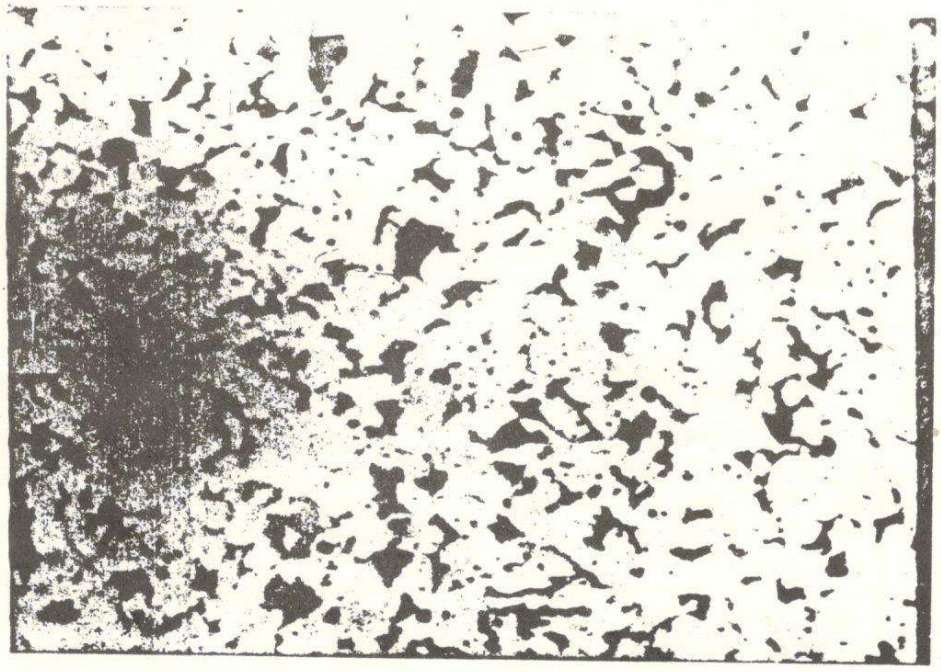


Figure 6. Photomicrograph of hard -drawn 4.75mm diameter wire rod. Magnification: 330X

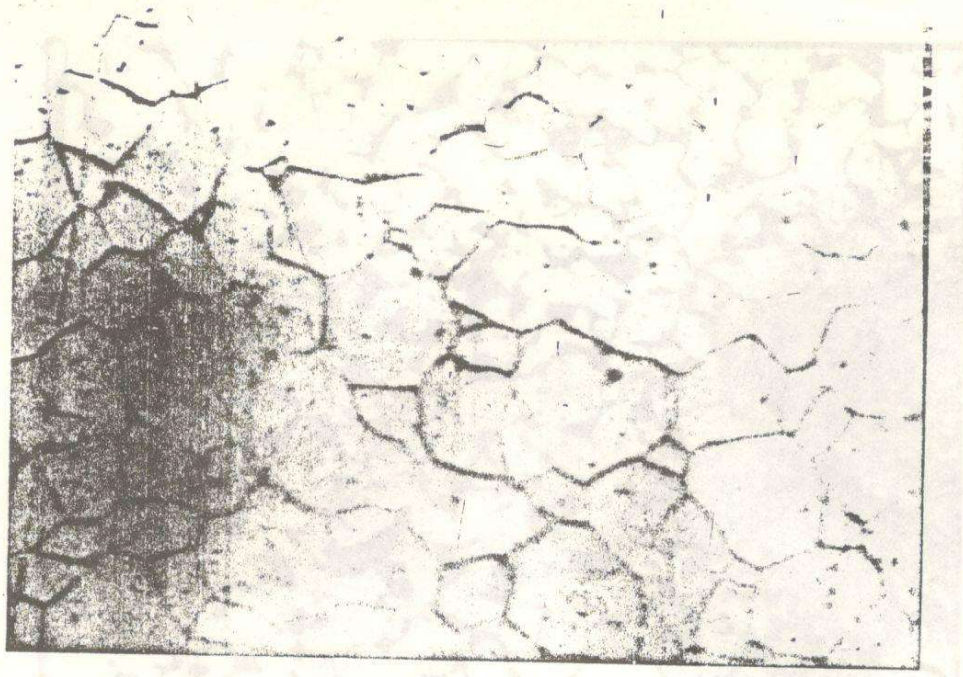


Figure 7. Photomicrograph of annealed 4.75mm diameter wire rod.
Magnification: 330X