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Morrison W B. The effect of grain size on the stress-strain relationship in low-carbon steel. *Trans. ASM* 59:824-46, 1966.
[Edgar C. Bain Lab. for Fundamental Research, US Steel Corp., Monroeville, PA]

Techniques to obtain an extremely wide grain size range in low-carbon steels are briefly described. The influence of grain size on the yield stress and the strain hardening behaviour is then discussed in terms of empirical equations previously only applied to data from steels having a relatively narrow grain size range. [The *SCI*® indicates that this paper has been cited in over 105 publications since 1966.]

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"In the 1950s and early 1960s, much effort was devoted to studies of the relation between the strength of low-carbon steel and the grain size. The catalyst for such research was the discovery by E.O. Hall[1] and N.J. Petch[2,3] of a quantitative relationship between the lower yield stress and the inverse of the square root of the grain diameter. My first research project carried out at Sheffield University in 1959 was a study of the structure-property relationship in commercial high strength, low alloy steels using the Hall-Petch equation. This led to a better understanding of the factors influencing strength and toughness in this important class of steels.

"However, in those days the applicability of the Hall-Petch equation was demonstrated only over a relatively small range in grain size in iron and steel. Although a great deal of theoretical work was going on, there remained a dearth of good experimental data. My opportunity to supply such data came when I joined the E.C. Bain Laboratory for Fundamental Research (now defunct) of US Steel Corporation at Monroeville, Pennsylvania, in 1964. There, I had complete freedom to pursue any research project I chose with full support from many of my gifted colleagues. One of these colleagues, Ray Grange, had recently developed several novel thermodynamic treatments for refining the grain size of steel. By utilising adaptations of these, I was able to obtain the finest grain size yet seen in commercial low-carbon steels. A detailed study was then carried out of the strength and work hardening behaviour of the steels over an extremely wide grain size range backed up by optical and electron microscopy. The Hall-Petch equation was shown to be correct over the entire grain size range and single n and double n work hardening behaviour was revealed.

"The paper was timely in the sense that grain refinement was being recognised as an important step in the production of commercial high strength, low alloy steels and the data contained in the paper aided in the development of such steels. The main reason for the paper being highly cited is related to the fact that it contains a large body of experimental data and results in such a form that the reader can easily utilise them for his own application. I remember that there was opposition from one of the referees to the inclusion of such detailed experimental data but I was certain that good basic experimental data would stand the test of time. This has proved to be correct and the paper still contains probably the best data of its type, of relevance to the study of structure-property relationships in present-day steels."

1. **Hall E O.** The deformation and ageing of mild steel: III. Discussion of results. *Proc. Phys. Soc. B* 64:747-53, 1951. (Cited 260 times since 1955.)
2. **Petch N J.** The cleavage strength of polycrystals. *J. Iron Steel Inst.* 174:25-8, 1953.
3. ----------. Citation Classic. Commentary on *J. Iron Steel Inst.* 174:25-8, 1953. *Current Contents/Engineering, Technology & Applied Sciences* 13(19):24, 10 May 1982.

