METALLURGY

Trick Metals to Improve Steel

The monocrystalline structure of certain metals used in research gives them unique properties. Yet due to atomic flaws these single crystal metals are very weak.

By J. G. FEINBERG

See Front Cover

➤ SILVER rods which bend like lead, but cannot be unbent. Metal wires which can be pulled out as easily as a piece of taffy—once, but not a second time.

Those are the sort of trick metals to be found in the laboratory of Prof. E. N. daC. Andrade, world authority on metallurgy, at London's University College, who will soon become director of the Royal Institution.

The rods that bend and wires that stretch are single crystals several inches in length. By contrast, the ordinary piece of metal is made up of a myriad of microscopic crystals. They are polycrystalline. The monocrystalline structure of Prof. Andrade's metals gives them their unique properties.

Of what practical value is this work with forms of metals which exist only in specialized laboratories? The ultimate practical gains may be great, says Prof. Andrade. It is well known that even the toughest steel our steel-makers can turn out of their furnaces today is only 1/40th as strong as it theoretically could be. There are theoretical possibilities of vastly increased strength of materials.

"Where so many of the dreams of inventors are clearly impossible on simple grounds of energy and such-like fundamental considerations, gigantic advances are here, at any rate, not inherently ruled out," Prof. Andrade declares.

Unusual Characteristics

These single crystals of metals possess unusual and unexpected characteristics. On the basis of theoretical calculations, it was expected that single crystal metals would be much stronger and tougher than the ordinary polycrystalline forms. Prof. Andrade was amazed, therefore, to find that they were softer and much less resistant to stress.

A one-half inch single crystal wire can be stretched by pulls of, depending on the metal, between two and 20 pounds. A child could stretch the softer of the metals.

But, once the wire is pulled, or the rod bent, the metal undergoes a strange toughening. A single crystal copper wire can easily be pulled to twice its original length, but having reached this maximum length, it then takes 80 times as much force to stretch it any farther. X-ray analysis indicates that the reason for this is that stretching destroys the single crystal structure of the metal. The length to which one of these trick metals can be drawn is shown on cover, contrasted with an undrawn single crystal.

Another unusual characteristic of single crystal metals is that, regardless of the direction of the pull, they insist on stretching in directions of their own choice. Nor does the wire stretch uniformly. Rather it elongates in spurts along certain very definite planes. In scientific language, mono-crystalline wires are said to have definite glide-directions and glide-planes.

The result of these innate predilections is, on stretching, a peculiar flattening of the wire, accompanied by curious steplike ridges, as if the crystal had slipped in layers. These steps are called slip-bands and can clearly be seen with the naked eye. The distance between the bands varies with the different metals and with the temperature. Sometimes a single crystal will exhibit several slip planes at angles to each other and frequently twinning occurs, with two sets of bands which are mirror images of each other.

Twinning Occurs

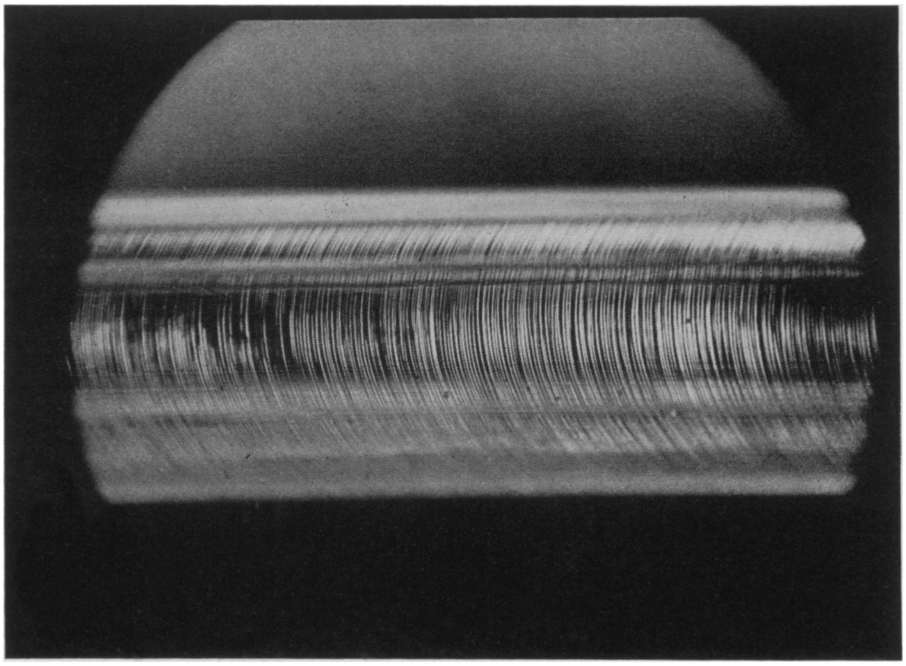
Twinning is a phenomenon which is not yet clearly understood, but for the other peculiarities of single crystal metals Prof. Andrade has reasonable explanations based on his own experimental work and deduced by analogy from the behavior of other substances.

The softness and gliding properties of his single crystal wires Prof. Andrade explains on the basis of imperfections in the surface layers of atoms, to ultra-microscopic "cracks" in the atomic "skin" of the crystal. Thus, a coating of oxide only 20 atoms thick will increase by 50% the force required to stretch a 0.5 millimeter wire, while thicker films will double the stress required. Also, bombarding a wire with alpha particles (hearts of helium atoms) while it is stretching very much increases the rate of flow of single crystal cadmium in the early stages, when fresh glide planes are being formed. Since the alpha particles have practically no penetrating power, this can only be a surface effect.

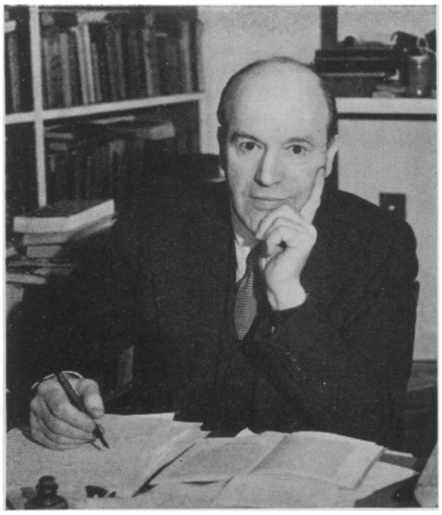
Surface Has Defects

It is possible that internal flaws may play a part, admits Prof. Andrade, but he feels that "surface defects are the only ones whose effect has so far been definitely proved in the case of metals."

Analogous deductions can be made from the experimental weakness of non-metals like glass, quartz and rock salt as compared with their theoretical strengths. In each of these cases it has been shown that the weakness lies in minute cracks in their surfaces, cracks which can be made visible



STRETCHED SINGLE CRYSTAL—The slip bands in a solid mercury single crystal which has been stretched are pictured.



METALLURGY AUTHORITY—Prof. E. N. daC. Andrade prepares papers which tell of his research with single crystal metals.

by exposing them to sodium vapor. In the case of sheet mica, the surface of which is remarkably free of flaws except at the very edges, it has been shown that the strength of such sheets is ten times greater when the stress is kept solely on the perfect surface than when it extends to the imperfect edges.

Making Crystals

To make his single crystals, Prof. Andrade encloses an ordinary wire of many crystals in a glass tube in which it fits loosely and from which all the air has been evacuated. He then runs a traveling furnace slowly, at about the rate of half or an inch an hour, over the tube. The wire melts locally and then re-solidifies as the furnace moves along, resulting in a single crystal. In the case of metals with melting points higher than that of glass, Prof. Andrade employs molds made of carbon.

The first specimens ever seen of the single crystal forms of some metals were prepared by Prof. Andrade as long ago as 1913. Since then he has devoted his energies to their study. So interesting and novel were the properties of single crystal metals that between the wars they were studied extensively by scientists in England, Russia and Germany, but for some reason the subject has not attracted American investigators.

Atomic Flaws Weaken Crystals

One lesson learned from the study of the single crystals is that, because of atomic flaws, the individual metal crystals are exceedingly weak. The greater strength of every day metals lies in their haphazard polycrystalline structure, with the glide-planes and glide-directions of the crystals oriented at random. Thus each crystal is hemmed in by other crystals which will not readily give in the same direction or plane in which it gives most easily. This is much like the principle of the girder, in which the planes of several sheets of metal are fixed at right angles to each other.

Prof. Andrade believes his experimental results point two tasks for the practical metallurgist:

1. To see if the atomic flaws in metal surfaces can be eliminated.

2. If not, to see how the polycrystalline nature of metals can be increased.

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ENGINEERING

Electric Discharge Prints Instrument Chart Paper

➤ CHART paper for use particularly with commercial facsimile telegraphy, but usable in many types of recording instruments, has a coating of electrosensitive material which is "printed" by an electric current passing to it from a simple wire stylus.

The new paper, dubbed Teledeltos, was developed by the Western Union Telegraph Company and was revealed at the annual meeting of the Society for Experimental Stress Analysis by Grosvenor Hotchkiss of the company. It meets the requirement in facsimile recording by being instantaneous, dry and permanent. The coated paper is light grey in color. The current flowing through it produces a black mark.

In previous facsimile transmission, the record was made photographically by a beam of light on photo-sensitive paper. Facsimile is a system, now coming into wider usage, in which an entire printed page, letter, message or photograph is sent by radio waves or through wire connections from a transmitter to distant receivers. In the transmitter, the copy is rapidly scanned by a beam of light that passes over it in successive lines, each close to the one above. The reflected light, varying with the variations in the markings on the surface being scanned, operates a photoelectric cell from which varying electrical energy is emitted.

At the receiving end, the process is in reverse. The electrical energy causes variation in the beam of light from a photoelectric cell. The varying intensity of the light reproduces an exact copy of the original on sensitized paper. With this new paper, the record made requires no finishing or fixing. The paper is usable for automatic train position recorders, recording chronographs and galvanometers, wave pattern recorders and other instruments.

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NUTRITION

Dairy Products Improved By Ion-Exchange Milk

➤ SMOOTHER ice cream, improved quality of baked goods and improvements of various other dairy products by the use of ion-exchange milk are foreseen by Dr. C. W. Gehrke of the University of Missouri at Columbia, Mo., and Dr. E. F. Almy, of Ohio State University at Columbus.

Ion-exchange milk is milk that has been modified by the use of certain artificial resinous materials. Reporting on their joint researches at Ohio State University in the scientific journal, SCIENCE (Nov. 25), Drs. Gehrke and Almy state that these materials seem to "offer a variety of possibilities for modifying the mineral components of milk," either by removing ions, such as calcium, or substituting other ions for those normally present or by both operations.

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