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CREEP AND RELAXATION OF STEEL AT ROOM TEMPERATURE.

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Experiments on creep and relaxation have been performed, at a temperature of 21° ± 1° C, on a large variety of steel bars, ranging from mild steel to very hard cold-drawn steel wire, with tensile strenghts from 36 Kg/cm^2 to 210 Kg/cm^2. The bars were submitted to axial tension. Usual tensile tests were carried out for comparison.

Considering 10^{-6} as order of magnitude of the smallest perceivable permanent elongations, *experiments proved the statistical identity of the elastic limit, the creep limit and the relaxation limit (1) (2)*. Thus, the smallest stress producing the smallest perceivable permanent elongation has the same statistical value in the common short tensile test, the long creep test and the long relaxation test.

Calling *critical creep stress* the smallest sustained stress producing facture *(3), experiments proved that this critical stress is not much below the ordinary tensile strength*, special care being taken to reduce the scattering of this strength. The lowest figure was about 0,96 of the tensile strength and the delayed fracture occured not later than an hour after loading. Fracture was not reached for smaller sustained stresses, even after one year. After a long time creep with stresses of about 0,95 of the original tensile strength, an appreciable increase of the tensile strength was observed on the strained specimens, even on cold drawn wire. This involves that natural strain-ageing occurs after a rather small time, such as an hour, even in strongly cold-worked steel. It prevents the critical creep stress to fall well below the tensile strength. Details will be published later.

In the large interval of these two limits, which are not considerably depending of the duration for steel at the mentioned temperature, non reversible strains may be produced which, according to the experiments, are diversly influenced by the duration.

Considering the permanent strain for a certain stress in the usual tensile test, which will be called the instantaneous permanent strain, and the permanent creep for the same sustained stress after a definite time, experiments proved that in the case of steel without yield-point, *the value of the creep after a definite time is proportionnal to the instanteneous permanent strain for equal stress (2)*. The straight line which represents this relation starts from the common lower limit.

This property is disturbed by the existence of a yield point. For stresses lower or higher than the yield point, there are two different straight lines of which the lower one, rather inaccurate, starts from the common limit. The higher one is more accurate and roughly parallel to the first. Incidentally, the creep of such steel for stresses lower or higher than the yield point is rather small and quickly stabilised. The relaxation in the same conditions is small too and even sooner stabilised. *The constant ratio between the instantaneous permanent strain and the permanent creep after a definite time for the same stress depends considerably of the nature of the steel ;* it is much smaller for hard wire than for mild steel. *An empirical function has been established for this ratio from the comparison with the ordinary tensile test.* This question is developed in a thesis for a special doctors degree recently presented at the University of Liège, which is just under examination ; publication will appear later.

The linear relation between instantaneous permanent strain and creep enables to deduce a relaxation curve from a known creep curve, in function of the time. Hence, considering the relation established between the instantaneous permanent strains and the permanent creep, *it is theoretically possible to deduce a creep curve from a common tensile test.* Practically, it is useful for accuracy to refer to an experimental creep curve for the ten to fifty first hours, according to the kind of steel. As already stated, *a relaxation curve may be deduced from the creep curve, either experimental or deriving from a common tensile test.*

These results suggest the assumption that the permanent strain in a common tensile text and the permanent creep are of the same nature.

The yield of a steel bar presenting this phenomenon is influenced by the duration in a peculiar way. Experiments have shown that if such a steel bar has been submitted to a stress equal to the yield stress, in order that a permanent strain has been produced equal to a fraction of the total yield elongation, a large creep occurs afterwards under a sustained stress 10 to 20 % lower than the yield stress. It begins generally after about one or a few hours and continues for twenty to sixty hours or so *(7)*. Putting the creep ordinates in connection with the logarithms of time in abscisse, this large creep is marked by a steep part in the creep curve, preceded and followed by segments with a small slope, similar to the slope of all the creep curves unaffected by a yield point. *Thus, at the yield point, the creep curve has a peculiar S shape and the duration produces a decrease of the yield stress.*

If a steel bar is submitted to a permanent strain equal to a fraction of the yield elongation, a large relaxation occurs similarly, of the same order of magnitude of 10 to 20 % of the yield stress. This relaxation begins immediatly and develops rather quickly ; it seems stabilised after less than a day or a few days *(8)*.

This means a real but delayed decrease of the yield stress ; whose magnitude is defined by the mentioned relaxation.

This effect of the duration on the yield point is different from the phenomenon of the upper and the lower yield point, which occurs eventually in the ordinary tensile test, hence is instantaneous and depends of the conditions of the test, namely of the rigidity of the testing machine and of the speed of the loading *(4) (5)*. It is well known that when this speed is very high (impact), the yield stress is considerably increased and fracture may occur before yield *(6)*. The creep machines being of the roman balance type and the load and the load being permanent, there is no effect of rigidity of the machine nor of the speed of loading to consider.

The yield stress has thus largely variable values and is consequently not a limit. The french and german terms "limite apparente d'élasticité" and "Streckgrenze" are thus inadequate. But the yield elongation is significant and, if sufficiently large, allows the repetition of the mentioned delayed large creep or relaxation, till the total elongation is exhausted (publication on this subject will appear soon).

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