INVESTIGATIONS OF FORMULAS FOR THE STRENGTH OF THE IRON PARTS OF STEAM MACHINERY

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STEAM MACHINERY.

BY

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INTRODUCTION.

The following investigations formed part of a supplementary course in Applied Mechanics, given by the writer, in 1866-7-8, to the Engineer Class at the U. S. Naval Academy. They are submitted to the profession with the hope that they may prove convenient and of value.

The formulæ are founded upon the principle that the different parts of a machine should be *equally* strong, and they are developed in reference to the *ultimate* strength of the material in order to leave the choice of a *factor of safety* to the judgment of the designer. The pressure, therefore, wherever it occurs, is, unless specially noticed, the *rupturing* or *crippling* pressure, and is found by multiplying the *working pressure* by the factor of safety adopted.

The factor of safety generally adopted for wrought-iron by the best authorities lies between 6 and 8. The best practice in civil engineering suggests 6; but it is evident that when the forces act suddenly upon material the *resilience* and impressed work are greater than when they are gradually applied, and that the factor of safety, therefore, must be greater in the former than in the latter case. Again, where the material is subjected to a force both suddenly and continuously applied, it is equally evident that a still greater factor of safety should be used.

To illustrate the principle of *resilience*, let us suppose a bar of iron to be elongated by the force P, *suddenly applied*, *i.e.*, having its full intensity from the commencement of the elongation. Let the elongation corresponding to the *statical* force P be l; the *work* of the force P acting through the space l is then Pl, and is termed the *work of resilience*, and is, in general, the work which deflects, compresses, elongates, or ruptures the material, according to the circumstances of the case. Now, if the force P be *gradually* applied, little by little, beginning with an intensity *zero* and ending with an intensity P, the *mean* force will be $\frac{P}{2}$, and the elongation will still be due to P; the *work* will, therefore, be $\frac{Pl}{2}$. Hence the work of the suddenly applied force is *twice* that of the one gradually applied. The *work* of the former is, therefore, greater than is simply necessary to produce the elongation l, and will, therefore, cause an elongation greater than l, and the material will then either break or rebound and oscillate or vibrate, until, when rest ensues, the elongation will be that due to a force P, *statically* considered, unless a *set* should ensue, and then the elongation will be correspondingly greater.

The time during which a force acts has much to do with its destructive effects, but experiments have proved that there is no force, however slight, or for however short a time applied, which will not produce a certain amount of *permanent* distortion in the material. But there are limits beyond which it is unnecessary to consider these derangements of the material. In fact, within certain limits and in certain cases, the material may even be stronger after than before the derangement. The limit beyond which the material should not be strained may be thus defined: the *force applied must never be so great or so long applied as to produce a sensibly increasing set in the material.*

From such considerations as the above, the writer is led to recommend for wrought-iron that a factor of 8 be used in all cases where the forces are *suddenly* and *continuously* applied, and in all cases where the forces are *gradually* applied, that the factor be never less than 6. For steam engines the factor 8 is therefore recommended.