*Fracture by Compression.—*In compression tests of a plastic material, such as mild steel, a process of flow may go on without limit; the piece (which must of course be short, to avoid buckling) shortens and bulges out in the form of a cask. This is illustrated by fig. 23 (from one of Sir W. Fairbairn’s experi­ments), which shows the compres­sion of a round block of steel (the original height and diameter of which are shown by the dotted lines) by a load equal to 100 tons per sq. in. of original sectional area. The surface over which the stress is distributed becomes enlarged, and the total load must be increased in a corresponding degree to maintain the process of flow.@@1 The bulging often produces longitudinal cracks, as in the figure, especially when the material is fibrous as well as plastic (as in the case of wrought iron). A brittle material, such as cast iron, brick or stone, yields by shearing on inclined planes as in figs. 24 and 25, which are taken from

Hodgkinson’s experiments on cast iron.@@2 The simplest fracture of this kind is exemplified by fig. 24, where a single surface (approximately a plane) of shear divides the compressed block into two wedges. With cast iron the slope of the plane is such that this simplest mode of fracture can take place only if the height of the block is not less than about 3/2 the width of the base. When the height is less the action is more complex. Shearing must then take place over more than one plane, as in fig. 25, so that cones or wedges are formed by which the surrounding portions of the block are split off. The stress required to crush the block is consequently greater than if the height were sufficient for shearing in a single plane.

*Plane of Shear.—*The inclination of the surfaces of shear, when fracture takes place by shearing under a simple stress of pull or push, is a matter of much interest, throwing some light on the question of how the resistance which a material exerts to stress of one kind is affected by the presence of stress of another kind— a question scarcely touched by direct experiment. At the shorn surface there is, in the case of tension tests, a normal pull as well as a shearing stress, and in the case of compression tests a normal push as well as shearing stress. If this normal component were absent the material (assuming it to be isotropic) would shear in the surface of greatest shearing stress, which, as has already been shown, is a surface inclined at 45° to the axis. In fact, however, it does not shear on this surface. Hodgkinson’s experiments on the compression of cast iron give surfaces of shear whose normal is inclined at about 55° to the axis of stress, and Kirkaldy’s, on the tension of steel, show that when rupture of a rod under tension takes place by shear the normal to the surface is inclined at about 25° to the axis. These results show that normal pull diminishes resistance to shearing and normal push increases resistance to shearing. In the case of cast iron under compression, the material prefers to shear on a section

where the intensity of shearing stress is only 0·94 of its value on the surface of maximum shearing stress (inclined at 45°), but where the normal push is reduced to 0∙66 of the value which it has on the surface of maximum shearing stress.

*Lüders’s Lines.—*It is interesting to refer in this connexion to the phenomenon observed in 1859 by W. Lüders@@3 of Magdeburg and afterwards studied more fully by L. Hartmann.@@4 When a bar of plastic metal such as mild steel, preferably flat and with a polished surface, is extended a little beyond its elastic limit, markings appear on the surface in the form of narrow bands running transversely across it. These bands arc regions within which a shearing deformation has taken place, resulting from the tension, as has been explained with reference to fig. 1, and they are distinguished from the remainder of the bar because in the early stages of plastic strain the yielding is local. For the reason that has just been explained in speaking of surfaces of rupture, Lüders’s lines in a rod strained by direct pull are found to be inclined, not at 45°, but at an angle more nearly normal to the axis of pull (making about 65° with it). Their inclination shows that the metal prefers to elongate by shearing on a section where *pt* the shearing stress is not at its maximum, because *pn* the normal component—which is a pull—is greater there, and this can only mean that the presence of a normal component of the nature of a pull at any section reduces the resistance to yielding under the shearing stress which acts at that section, while similarly the presence of a normal component of the nature of a push increases the resistance to shear.

*Yielding under Compound Stress.—A* question of much theoretical interest and also of some practical importance is, what determines the yielding of a piece when it is subjected not to a simple pull or push alone but to a stress combined of two or of three principal stresses? According to one view, which in the absence of experimental data appears to have been taken by W. J. Μ. Rankine, the material yields when the greatest principal stress reaches a certain limit, irrespective of the existence of the other principal stresses. According to another view (Barré de Saint-Venant), it yields when the maximum strain reaches a certain limit, and as the strain depends in part on each of the three principal stresses this gives a different criterion. Neither the maximum stress theory nor the maximum strain theory can be regarded as satisfactory, and probably a much sounder view is that the material yields when the greatest shearing stress reaches a certain limit. Even this, however, requires some qualification in the light of what has just been said about the inclination of surfaces of shear and Lüders’s lines, for it is clear from these experimental indications that resistance to shear is affected by the presence of normal stress on the plane of shear, and conse­quently a theory which takes account of shearing stress only as the criterion of yielding cannot be completely correct. Accord­ing to the greatest shearing stress theory the yielding under compound stress depends directly on the difference between the greatest and least principal stress. In such cases of compound stress as have to be dealt with in engineering design this furnishes a criterion which though imperfect is certainly to be preferred to the criterion furnished by calculating the greatest principal stress.

*Experiments on Compound Stress.—*In experiments carried out by J. J. Guest *(Phil. Mag.,* 1900, vol. 50) the action of combined stresses in causing yielding was investigated by sub­jecting thin tubes to (1) tension alone, (2) tension and torque, (3) tension and internal (fluid) pressure, and (4) torque and internal pressure, while measurements were made of the axial strain and the twist so as to detect the first failure of elasticity. The general result of the experiments, so far as they went, was to support the view that yielding depends primarily on the greatest shearing stress, that is to say, on the difference between the greatest and least principal stresses.

*Fatigue of Metals.—*A matter of great practical as well as scientific interest is the destructive action which materials

@@@1 For examples, see Fairbairn’s experiments on steel, *Brit. Assoe. Rep.* (1867).

*@@@2 Report of the Royal Commissioners on the A pplication of Iron to Railway Structures* (1849); see also *Brit. Assoc. Rep.* (1837).

*@@@3 Dingier's Polytech. Journ.* (1860), 155, p. 18.

*@@@4 Bulletin de ta société d'encouragement* (1896 and 1897).