degree of nicety only when pre-determined conditions are adhered to. Any change of load, speed, steam pressure, etc., especially in those automatic engines depending on a single valve for admission and exhaust, will produce disturbance which cannot be counteracted except by altering the weight of the reciprocating parts and counterbalance to harmonize with the effect of a greater or less admission and compression.

It is mainly by the action of the steam in the cylinder that the reciprocating parts of a high speed engine can be properly counterbalanced. The work of counterbalancing is partly, through this elastic medium, transmitted to the frame or non-reciprocating parts, and must be counterweight in a measure by placing its equivalent in effect opposite the crank-pin. The cylinder and frame form the opposite element, on the one side, to the accelerating and retarding force necessary in effecting this balancing; and the requirement of a counterweight, for horizontal balancing, diminishes as the ratio of required accelerating force to the inert mass of frame, cylinder etc., is increased.

In all easy-running engines the tendency of the reciprocating parts and of the counterweight will be in the same direction while the crank is on and passing either center. At these points the counterweight can have no effect on the reciprocating parts, and hence, its centrifugal effort, if sufficient to neutralize the initial accelerating force, would produce all that is needed. But we should none the less take into account the relation between the reciprocating and non-reciprocating masses of the entire engine: "Action and reaction are equal and opposite;" so, if we shoot a wedge between the cylinder head and the piston, and an equivalent in effect of the steam entering, the tendency of the wedge to shoot the reciprocating parts in one direction, and the cylinder, frame, etc., in the opposite direction, will be as the relative masses. At the initial point the horizontal movement of the reciprocating parts is opposed by the main bearing, but the tendency, with proper accelerating force, is there none the less, and (if repetition be allowed), the tendency of the counterweight being in the same direction, its effort should be just sufficient to neutralize the effort made by the frame to move in the direction opposite.

The recoiling effect of compression and admission in the engine is analogous to the action of a cannon. The greater the ratio between mass of shot and gun for any given velocity, the less the recoil; and the greater the ratio between the mass of reciprocating mass of engine, for any given speed, the less recoil, and therefore the need of a counterweight to pull in the opposite direction at the same time.

An engine of the Corliss type, with a simple unbalanced crank, and with cylinder and frame of sufficient weight to secure strength and stiffness, will run quite as steadily as an ordinary high speed engine, with a crank disk balanced in the usual way, to secure good results. Not that balancing at high speed is sovery difficult, but simply because it is difficult to get a builder to construct, or a customer to pay for, an engine with sufficient metal in the framing to secure the same ration between the work of reciprocation and the inertia of the non-reciprocating mass in one case that there is in the other. So long as builders will insist on making light engines, and running them at high speeds, just so long will we have engines demanding the closest attention and the best of lubricants while they are making an effort to shake, even the unshakable.

In no case should the non-reciprocating mass (the shaft and wheel must be left out) be less than five times the initial accelerating force. Designed in this way, the weight and proportion of the engine will bear special reference to the speed it is intended to run at—the reciprocating mass, in case of high rotative speed, being fixed with reference to crank effort.

Ordinarily, we may make the frame, cylinder, etc., of mill engines of the Corliss type about fifteen times the weight of the reciprocating parts, and secure good results in running.

In counterbalancing, if we place a weight opposite the crank equal to the crank and pin (the reciprocating mass multiplied by the initial accelerating force and divided by the non-reciprocating mass) good running will result, and the main bearing will be free from the abuse commonly received by overbalancing.—*Am. Mach.*

ACCORDING to the Jewelers' *Circular* French clocks represent the highest perfection in the way of decorative clock cases. English clockmakers claim and deserve the reputation of producing the most accurate timekeepers, while to the American manufacturers belongs the credit of making the best timekeepers at the least possible cost.

DR. SANG ON THE FORTH BRIDGE.

We fear that the worthy and venerable secretary of the Scottish Society of Arts must have unintentionally caused a flutter of alarm in the minds of the City clerks and other readers of a recent issue of an evening paper, wherein it was stated on his authority that "from a geometer's point of view" the construction of the Forth Bridge was "inadmissable," because amongst other enigmatical reasons as "no collection of even numbers could make an odd number, there must be either deficiency or redundancy." Commenting on the "elaborate paper which Dr. Sang read in three portions before the Royal Scottish Society of Arts," a leading Highland journal observed: "It is rather alarming to find a scientific man of Dr. Sang's eminence and responsibility, declaring that the Forth Bridge is being built on unsound principles. He would not say it was unsafe, but then his principle is that a structure which is theoretically unsound is practically unsafe, even although by waste or redundancy of material the margin of strength over and above its power to hold itself together may make it practically of use for the purpose intended. The paper will, no doubt, receive attention from scientific men." It is quite possible that it may. Frequenters of the London parks can hardly have failed to notice that guardsmen, for some reason seem to derive a pleasure from watching the evolutions of an undrilled squad of volunteers, and the same touch of nature may no doubt make scientific engineers regard for a few moments with interest the secretary's "Elementary view of the strains on the Forth Bridge due to the shifting load."

Dr. Sang devoted his first evening to proving to the Fellows of the Society that if one end of a balanced double contilever be loaded, a compensating weight must be applied somewhere on the opposite side of the fulcrum, in other words he conclusively demonstrated that if a weight be placed in one pan of a pair of scales an equivalent mass of matter must be loaded into the opposite pan, or balance will not be attained. Applying this principle to the central pier of the Forth Bridge he found that "an amount of ballast must be heaped upon" the central to prevent the cantilever tipping under the possible contingency foreseen by him of the train covering one cantilever only. Had Dr. Sang any knowledge of the subject-matter of his paper or of bridge building of any kind, he would have known that unfortunately the dead weight of steel required for the construction of a 1700 ft. span bridge must necessarily be so considerable that no "ballast" or holding-down bolts could be required at the central pier to balance merely the unequally distributed and comparatively insignificant weight of a train.

The investigation having been advanced so far the first evening, Dr. Sang next directed the attention of the Fellows to the "Geometry of the Cantilever Truss," and on a subsequent evening to the "Statics of the Cantilever Truss," or rather of the central or Inch Garvie tower, which rests on four piers arranged at the corners of a rectangle 260 ft. by 120 ft. In dealing with this part of his subject, Dr. Sang's troubles very quickly commenced. "The tower," said he "cannot terminate in a single point; it would make the bridge stand on three feet. When there were four struts converging, and when some known pressure is applied thereto, it is *impossible to tell* what share of that strain is borne by each." Again, with a rectangular top, certain struts or ties are "redundant, and *therefore dangerous*. . . . The presence of the other member changes matter entirely; it creates strains rising toward infinity. *Unless the compressions and distensions of the parts be sufficient*, the strains must come to exceed the capabilities of any material. Our minds cannot grasp the idea of infinity; let us come down to finitude," and so on, with a continued repetition of "no one can compute the strains." and "no one can tell," until the bewildered investigator at last frankly confessed that these elements "create an unneeded, an intolerable, anxiety." It is to be regretted that the estimable secretary of the Scottish Society of Arts should have subjected himself to this "unneeded, intolerable, anxiety," but probable the same result would have followed his acceptance of the command of the Channel Fleet or any other important duty outside of his own experience.

Engineers will at once see that the cause of all Dr. Sang's troubles is his ignorance of the fact that the problems he sets himself to solve require for their solution a knowledge of the laws of elasticity, that is to say, of the laws which connect the stresses on a body with the alterations of dimensions the parts simultaneously undergo. His difficulty is the same in kind as that the schoolboy experiences when facing his first quadratic