## III.—True Surfaces and Accurate Measurements. By D. W. Robb, A. S. M. E., *Amherst, N. S.*

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That absolute truth is almost unattainable, becomes apparent to the skillful mechanic as well as to the thoughtful scientist, and the degree of success of each may be measured by the nearness of approach to absolute accuracy, whether it be in the result of the scientist's reasoning, or the more material product of the mechanic's hands.

For the production of flat surfaces of metal, the mechanic uses an instrument called the "surface plate," which is simply a plate of cast iron well stiffened by ribs and resting upon three points of support to prevent springing, the upper side of which is carefully scraped by hand until its surface is approximately true. When one of a pair of such "surface plates" is placed with its trued surface above the other it will not immediately come in contact with the lower plate, but will for a time float upon the air confined between the surfaces, because the air can only escape at the edges, and, as the plates come closer together, it will do so more slowly so that a noticeable time, depending upon the truth of the surfaces, weight and size of plates, will elapse before the plates will really touch each other. When the air is fully excluded, or as fully as the truth of the surfaces will allow, the plates will adhere, or rather the atmospheric pressure on the outside will press them together.

It is evident that, if we interpose between the surface plates a fluid, more viscid than air, such as oil, it will require a longer time and greater weight to expel it, and we may move the upper plate back and forth for a long time before the plates come into direct contact, the particles of fluid forming a perfect system of rollers, upon which the metal will roll with very slight friction. If we provide means whereby the oil will be renewed, the iron will never come into contact, provided the pressure of the upper plate is not sufficient to overcome the capillary attraction, and force the oil out. It will at once be recognized that this is the principle upon which all lubricated bearings or journals of machinery, whether flat or round, are constructed. This somewhat minute and elementary explanation is given in order to show the importance of truth in the surfaces of the bearings of machinery, to have flat bearings truly flat and round bearings truly round. If such surfaces are uneven, as they will be when made by the ordinary method of turning or planing, owing to the springing of the cutting tools and uneven texture of the metal, lumps will be produced which will project through the oil, and the metals will touch each other producing, when moving past each other at a high rate of speed, friction and wear so common in machinery. But it has been proved by experiment that, if the surfaces be made nearly true, so that the lubricant will completely separate the metals, and the bearing sufficient in area to withstand the weight imposed without forcing the oil out, such journals may be run without wear, and that the rate of speed, within practicable limits, makes no difference. The question will at once suggest itself: Why not make all the bearings of machinery perfectly true, sufficiently large in surface, provide continuous lubrication, and prevent wear entirely? I may say that a very great advance has been made in this direction. In the higher grades of machinery, manufacturers use delicate grinding and scraping processes to produce smooth and true surfaces, with the result that many machines, such as electric dynamos and steam engines, which run at a high rate of speed, have practically no wear in their journals, but it is just here the mechanic learns how hard it is to obtain absolute perfection. He may be able to produce a sufficiently true surface, but he finds he cannot overcome the distortion of metals, due to unequal pressure, or heat. As he approaches greater refinement in producing true surfaces, he will learn that it is impossible to get them to remain true when subjected to the strains incident to the conditions under which they work. He finds that, if he lifts his surface plate by one corner it is less true, if I may be allowed the expression, than when resting upon its three supports, or that his straight edge, which was about straight when resting upon the surface plate, bends slightly when he lifts it by the ends. A machine designed and constructed with the greatest care and skill, when subjected to the necessary strain of belts, or the inertia of its own rapidly moving parts, will spring so that the bearings, which have been made nearly perfect in surface and alignment, are thrown slightly awry, causing the strain to be borne by a decreased area, and forcing the lubricant out. The skill of machine designers is shown in designing a machine so that the journal and its seat will spring together, thus preserving the adjustment of bearing surfaces. We hear and see much in these days of ball bearings. The success of the modern bicycle depends upon this ingenious device, and has induced almost a mania for using hardened steel balls for bearings of all kinds. Those engaged in mechanical work often forget that the old and tried oil lubrication is really a ball bearing composed of such perfectly formed balls as only nature can produce, and with the advantage that they may be replaced or renewed as often as desired with very slight trouble. Steel balls are undoubtedly better suited to a bicycle than ordinary bearings lubricated by oil, because it is impossible to get a machine light enough for the purpose and have the bearing surfaces large and parts sufficiently rigid to keep the surfaces in correct alignment; but in heavy machinery where the strain on bearings is so much greater, steel balls, with their small surface of contact and tendency to crush, are not as suitable as the minute spheres of a fluid such as oil. In this connection may be mentioned a point which is also closely connected with the second part of this subject, accurate measurements, viz., that it is necessary in the construction of bearings of machinery to allow sufficient space for the oil between the metals. If a shaft be made as perfectly round and smooth as possible, and of the exact size of the bushing or box in which it is to work, which is also true, there will be no room for the lubricant. The writer has seen this fact well illustrated by a bar which was intended to carry revolving cutters in a machine for boring cylinders, both the bar and the bush were made as carefully as possible and to fit closely. The bar fitted the bush so well that while it could be shoved into its place when free and clean from oil, when oil was applied it refused to move except by using considerable force, showing that there was not room for the oil. The shaft required to be reduced 2/1000″ in size to make room for the lubricant. Heating of journals is frequently caused by neglect of this point. In many kinds of machinery no attempt is made to true the surfaces carefully, or indeed to do more than get them approximately round or flat, as the case may be, or to make them to any exact size nearer than can be measured by the eye or an ordinary box wood rule. The result is that journals and seats have to work out their own salvation or destruction, by wearing the high parts down until the low parts approach near enough for the oil to support the whole journal, consequently, much care and patience must be exercised in working new machinery until it is worn to a bearing, otherwise the metals will abrade and heat by friction until the surfaces are completely destroyed.

The foregoing will emphasize the importance of being able to make minute and accurate measurements, as much depends upon the certainty with which the mechanic can measure the inaccuracies of his work in order to bring it to the necessary state of perfection. The ordinary system of measuring by a rule graduated to 16ths, 32nds or perhaps the 64ths of an inch, the use of which leaves room for an error which is too great for the production of good machinery, has been superseded in machine shops, where accuracy is aimed at, by the "Micrometer Caliper" and hardened steel gauges of various kinds, by means of which measurements of 1/4000 of an inch can be made as easily as 1/16 inch can be measured by the ordinary rule.

"The Interchangeable System," first used by American workmen in the production of watches, fire arms, and other machines, having a number of small parts, any one of which should fit any other, has done much to introduce refined and rapid methods of measurements. Steel gauges, which are hardened and then ground, are now produced by manufacturers of tools which are guaranteed to be accurate within 1/10000 of an inch, and when such gauges are applied to a piece of machinery there is no difficulty in producing work rapidly and uniformly correct within 1/4000 or 1/5000 of an inch.

In addition to the evident advantage this system has over the old "Cut and Try System," by which each part of a machine was fitted especially to the other part, it eliminates the individual factor to a considerable extent, so that perfection of product is not so much dependent upon the individual whose skill has been acquired by long years of experience, and who must have produced much inferior work before he attained his present deftness. The manufacturer is enabled to furnish plans of each machine giving the exact sizes, marked in thousandths of an inch, and each mechanic is able, by the aid of his gauges, to produce any number of parts which are exactly alike, and will fit any other part of similar machines. By preserving this uuiformity in all the machines he produces, the manufacturer is able to determine accurately from the machines in use where imperfections exist, and can record and store up his accumulated experience and make corrections and improvements as required.