CLASSIC INVENTIONS: Reuleaux on Machine Design

Mechanics

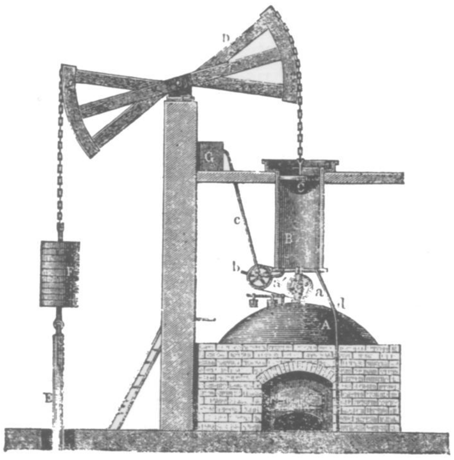
This section from a classic work on the theory of machines is offered in the hope that it may furnish suggestions of value to the amateur inventor, and may give others a new slant on the machine age in which we find ourselves.

THE KINEMATICS OF MACHINERY. Outlines of a Theory of Machines. By F. Reuleaux, translated and edited by Alex. B. W. Kennedy, C. E. London: 1876.

Growth of Modern Machinery

Modern machinery came into existence with the invention of the Steam Engine, and with it and by it has developed itself with a rapidity not even approached in former times. This has not been, in my opinion, by any sudden leap, by any discontinuousness in the sequence of ideas; it is due rather to an acceleration in the rate at which one has followed the other. The curve has risen suddenly, without any change occurring in the law according to which it is formed. We must here not forget how difficult it is in all cases to form an opinion about matters occurring in our own time, for we ourselves are subject to the influence of the time, and must judge it while we form part of it. The immense number of cases existing, on the other hand, and the exactness of our knowledge of them, here help us very greatly. An examination of the way in which the gradual perfecting of machines is today going on teaches us, however, one thing—as we shall presently see—namely, that the process of the replacement of force-closure by pair- and chain-closure goes on quietly extending itself further and further to this hour. We may therefore consider this process as showing the essential general tendency of the whole machine-development up to our time—we may even go further, and say that we must consider it as an essential characteristic of future machine-development.

In Newcomen's steam-engine, force-closure still predominated, and it remained thus through the whole eighteenth century. The machine was force-closed in its pit-work, in its beam-chains, in its steam-piston and in its valve-gear—although in the latter Potter's invention had substituted a machinal arrangement for the hand-gear. Watt introduced pair- and chain-closure by degrees into the machine. Thus, for instance, the force-closed beam-chains became the imperfect but still kinematically far more complete "parallel motion". Even to our own time the venerable pumping machinery used in our mines remains partly in the fetters of force-closure; it is only very lately that direct-acting steam pumping engines have begun to dispute its position. . . .



NEWCOMEN'S STEAM ENGINE, the crude, force-closed machine which was the fore-runner of the much more efficient power-plants of today

Traction Engines

In our various means of transport the change from force- to pair-closure has continued to the present time. After all had been done in improving the construction of the vehicle itself, furnishing it with a suitable fore-carriage, making better roads for it to move upon, etc., force-closure still remained, if nowhere else at least in the preservation of the direction of motion, which still demanded accustomed animals and an intelligent driver. Men naturally attempted to replace this force-closure by pair-closure. In the Railway the rails are paired with the wheels—force-closure is used only to neutralize vertical disturbing forces. The step thus made in the direction of machinal completeness—which it required half a century to make[1]— was a most important one—it was in reality no other than the uniting of the carriage and the road into a machine. The rail forms a part of this machine, it is the fixed element of the kinematic chain of which the mechanism really consists. The further improvement of the pair-closure, the removal of any remaining disturbing force-closure whether in the rails, in the axle-boxes, in the arrangement of the springs of carriages and of locomotives and so on, still engages most careful attention. In opposition to this we have the problem of steam locomotion on common roads, which has been so feverishly taken up again within the last few years, but the solutions of which seem doomed to eternal incompleteness, for they are self-contradictory. It is desired to make something which shall be a machine, but in which at the same time the special characteristic of the machine — the pairing of elements—may be disregarded. On the other hand, attempts have been made—as in Boydell's Traction Engine—to carry with the machine at least a portion of a transportable element which could be paired with the wheel, all indicating the general tendency towards the limitation of force-closure. Thomson's India-rubber tyres have essentially the same object—the inner side of the ring of vulcanized India-rubber, externally flattened upon the road, serves as a smooth uniform surface for the rigid tread to run upon—thus corresponding generally to the rail of the railway.[2]

The development of the Turbine has followed the same course—it has grown out of the primitive wheel of the Tyrolese and Swiss mountaineers in the hands of the mechanicians of our century. In the latter the water dashed and eddied against its irregular blades in vehement force-closure—in the Turbine it is already combined into a pair of elements with the accurately shaped wheel with very considerable completeness. . . .

Toothed wheels furnish us with another example. Although they have been known for thousands of years, their improvement today is still essentially in the direction of excluding force-closure, that especially which has remained with the "clearance" or "freedom" allowed between the surfaces of the teeth, and which has often enough made itself disagreeably felt. In the Chinese winding mill (gin) and in the similar machine used by the Egyptians, and worked by water (the Sakkiah), there is a large amount of play left between the teeth, which were merely such rough blocks as rendered it possible for one wheel to drive the other. But we see that during the Middle Ages, and in the last few centuries, the freedom has been more and more reduced, as greater care has been taken to find (*Turn to next page*)

[1]Wooden rails were in use at pits near Newcastle as early as 1676,—the first iron rails were laid down in 1738.

[2]It was this action unfortunately, the motion of the tread inside the tyre, which caused the failure of many of these engines. The excessive wear which took place in the India-rubber made the cost of repairs enormous.

the kinematic condition to be fulfilled by the form of the teeth-profiles, until we have now succeeded in reducing it to a very small fraction of the pitch. During the last century, the wheel and its teeth gradually came to be understood as forming together one whole, and the teeth-profiles were then looked at in a new light. I believe that in a few decades it will be the rule to employ spur-wheels working without any clearance between the teeth. . . .

Putting in a few words the results of our examination in their relation to the fundamental idea laid down at the beginning of the chapter, we may say that the limitation of force-closure has essentially been the means by which machines have been made capable of better carrying out their own share of work. This limitation led gradually from the make-shift first attempts at machines to the accurately working pairs of elements and the simpler mechanisms. This at the same time creates the possibility, and becomes the cause, of further extension of the limits within which the machine acts—of obtaining larger results by human intellect,—or as we expressed it before, of making the share of the machine a larger fraction of the whole problem.

The endeavors after this lead to the invention of new mechanisms and in these again force-closure—which seems always to be nearest to our hands—is at first employed. This shows itself every day, especially in machines invented by workmen or others whose knowledge of their subject is merely empirical. Of such machines we have many; not infrequently they have been pioneers to open up a new region. They contain such a combination of weights, springs, tappets, catches, stamps, fly-wheels and so on, clattering and jerking in their force-closed working, that they might be a little representation of all the steps in the development of the machine seen through a reversed telescope. The experienced and scientific designer sets them aside with a smile, and replaces them with accurately working elements. But in spite of his experience and knowledge, if the same man have to design an entirely new machine, he too will at first employ force-closure in many places where he might better have used pair-closure, and where in time he will use it. The Corliss valve-gear is a capital example of this; in its earliest form it was everywhere force-closed, and all the subsequent improvements have been unconsciously in the direction of the replacement of this by something better. In the intensive growth of the machine we thus see that the removal of force-closure is also continually going on, by restricting its employment within narrow limits, so distinctly that we cannot wish, nor indeed dare, to attempt to return again to its use.

Systematic Constrainment

We must not overlook the fact that to a certain extent the general development of the machine has hitherto gone on unconsciously, and that this unconsciousness which has characterized the older method of production has left its special mark, it prevents that method indeed from being distinctly understood. The way in which the modern machine is designed is different, lying as it does from the beginning in the hands of experienced and more or less scientific men. Here some things at least, if not a large number, are closely and deliberately grasped. Here we do not so much see the improvement of old and defective arrangements as the bringing into existence of new ones, enabling the machine to perform operations which had previously been considered quite beyond its province. The mechanism, although new, is presented to us complete—a faultlessly constrained and closed system of bodies—ready to be put to practical proof; as we see, for instance, in sewing-machines, in the new guns and projectiles, and so on. There can be no doubt that in some of these there are tokens of a new tendency, a very striking one, very distinctly differing from that which gave us the older machines. The difference somewhat resembles that between the processes of integration and differentiation. Formerly the fundamental idea of alteration or extension was improvement, a word which says much in itself of the nature of the process. Now, on the other hand, we have a direct production of new things, a sudden bringing into being of so far complete machines. We see the beginnings of a perception which will some day apparently be universal among those who have to do with all classes of machinery. Upon this growing sense I believe that our polytechnic machine-instruction should act with increasing certainty. The nature of men's talents meanwhile remains as a whole unaltered. The idea must be developed in each individual afresh microkosmically from its beginning onwards. For this reason, and also because incomplete solutions may still be real solutions, the existing antagonism between pair- and force-closure will never become quite extinct.

The whole inner nature of the machine is, as our investigations have gradually made clear, the result of a systematic restriction; its completeness indicates the increasingly skilful constrainment of motion until all indefiniteness is entirely removed. Mankind has worked for ages in developing this limitation. If we look for a parallel to it elsewhere we may find it in the great problem of human civilization. In this the development of machinery forms indeed but one factor, but its outline is sufficiently distinct to stand out separately before us. Just as the poet contrasts the gentle and lovable Odyssean wanderers with the untamable Cyclops, the "lawless-thoughted monsters", so appears to us the unrestrained power of natural forces, acting and reacting in limitless freedom, bringing forth from the struggle of all against all their inevitable but unknown results, compared with the action of forces in the machine, carefully constrained and guided so as to produce the single result aimed at. Wise restriction creates the State, by it alone can its capacities receive their full development; by restriction in the machine we have gradually become masters of the most tremendous forces, and brought them completely under our control.

Franz Reuleaux (1829-1905) came of a family long distinguished in the engineering profession in Germany. He had practical instruction in shops in his youth, and studied for four years at Karlsruhe, Bonn and Berlin. After some practical experience in Cologne, he began teaching mechanics and technics in Zürich, at the age of 27. Later he taught in technical schools in Berlin and Charlottenburg. He published "Theoretischen Kinematik" at the age of 46. The English translation from which this extract is taken appeared the next year. Reuleaux also served on the juries of nearly all the great international exhibitions of the time.

It is an odd coincidence that this year is the 200th anniversary of the death of Thomas Newcomen, inventor of the first practical steam engine, and the 100th anniversary of the birth of Reuleaux, one of the greatest masters of design of the machines which sprang into being so rapidly after the appearance of the steam engine.

Science News-Letter, November 23, 1929

A radish contains 91 per cent. of water; turnip roots, 89 per cent., and celery 84 per cent., as compared with bread only 35 per cent.