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ON THE ART OF CUTTING METALS

By FRED W. TAYLOR, PHILADELPHIA
Member of the Society

Part 1

For Index and Definitions, see end of Part 1

1 The experiments described in this paper were undertaken to obtain a part of the information necessary to establish in a machine shop our system of management, the central idea of which is:

2 (A) To give each workman each day in advance a definite task, with detailed written instructions, and an exact time allowance for each element of the work.

3 (B) To pay extraordinarily high wages to those who perform their tasks in the allotted time, and ordinary wages to those who take more than their time allowance.

4 There are three questions which must be answered each day in every machine shop by every machinist who is running a metal-cutting machine, such as a lathe, planer, drill press, milling machine, etc., namely:

- *a* WHAT TOOL SHALL I USE?
- *b* WHAT CUTTING SPEED SHALL I USE?
- *c* WHAT FEED SHALL I USE?

5 Our investigations, which were started 26 years ago with the definite purpose of finding the true answer to these questions under all the varying conditions of machine shop practice have been carried on up to the present time with this as the main object still in view.

6 The writer will confine himself almost exclusively to an attempted solution of this problem as it affects "roughing work"; *i. e.*, the preparation of the forgings or casting for the final finishing cut, which is taken only in those cases where great accuracy or high finish is called for. Fine finishing cuts will not be dealt with. Our principal object will be to describe the fundamental laws and principles which will enable us to do "roughing work" in the shortest time, whether the cuts are light or heavy, whether the work is rigid or elastic, and

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TENSILE STRENGTH POUNDS	ELASTIC LIMIT POUNDS	STRETCH PER CENT	CONTRACTION OF AREA PER CENT
115,000	58,000	15.6	31.4

CARBON PER CENT	SILICON PER CENT	PHOSPHORUS PER CENT	SULPHUR PER CENT	MANGANESE PER CENT	COPPER PER CENT
.555	.236	.049	.031	.981	.058

The Mushet and Midvale self-hardening tools showed an average gain of 30 per cent in cutting the same forging. From these figures it will be noted that as the cutting speeds of tools grow higher, the percentage of gain through the use of water for cooling the tool grows greater. This would seem to be due to the fact that (taking the two extremes) the noses of the modern high speed tools are very much hotter under the great friction caused by the high speed of the chip than are the old fashioned tempered tools with their slow speeds, and that therefore the water acts in a considerably more efficient manner in cooling the high speed tools than the slow speed tools.

CHATTER OF THE TOOL

633 The following are the general conclusions arrived at on the subject of chatter of the tool:

CHATTER CAUSED BY THE NATURE OF THE WORK

634 (A) Chatter is the most obscure and delicate of all problems facing the machinist, and in the case of castings and forgings of miscellaneous shapes probably no rules or formulæ can be devised which will accurately guide the machinist in taking the maximum cuts and speeds possible without producing chatter. (See paragraph 648)

635 (B) It is economical to use a steady rest in turning any piece of cylindrical work whose length is more than twelve times its diameter. (See paragraph 669)

CHATTER CAUSED BY THE METHOD OF DRIVING THE WORK

636 (C) Too small lathe-dogs or clamps or an imperfect bearing at the points at which the clamps are driven by face plate produce vibration. (See paragraph 659)

CHATTER CAUSED BY CUTTING TOOLS

637 (D) To avoid chatter, tools should have cutting edges with curved outlines and the radius of curvature of the cutting edge should

be small in proportion as the work to be operated on is small. The reason for this is that the tendency of chatter is much greater when the chip is uniform in thickness throughout, and that tools with curved cutting edges produce chips which vary in thickness, while those with straight cutting edges produce chips uniform in thickness. (See paragraph 661)

638 (E) Chatter can be avoided, even in tools with straight cutting edges by using two or more tools at the same time in the same machine. (See paragraphs 664 and 665)

639 (F) The bottom of the tool should have a true, solid bearing on the tool support which should extend forward almost directly beneath the cutting edge. (See paragraph 663)

640 (G) The body of the tool should be greater in depth than its width. (See paragraph 662)

CHATTER CONNECTED WITH THE DESIGN OF THE MACHINE

641 Chatter caused by modifications in the machine may be classified as follows:

642 (*H*) It is sometimes caused by badly made or fitted gears.

643 (*J*) Shafts may be too small in diameter or too great in length.

644 (*K*) Loose fits in the bearings and slides may occasion chatter.

645 (*L*) In order to absorb vibrations caused by high speeds, machine parts should be massive far beyond the metal required for strength. (See paragraph 656)

THE EFFECT OF CHATTER UPON THE CUTTING SPEED OF THE TOOL

646 (*M*) Chatter of the tool necessitates cutting speeds from 10 to 15 per cent slower than those taken without chatter, whether tools are run with or without water. (See paragraphs 671 to 677)

647 (*N*) Higher cutting speed can be used with an intermittent cut than with a steady cut. (See paragraphs 678 to 680)

648 Of all the difficulties met with by a machinist in cutting metals, the causes for the chatter of the tool are perhaps the most obscure and difficult to ascertain, and in many cases the remedy is only to be found after trying (almost at random) half a dozen expedients.

649 This paper is chiefly concerned with chatter as it is produced or modified by the cutting tool itself. Some of the other causes for chatter, however, may be briefly referred to. These may be divided into five groups: