Lathe-cutting of certain alloy cast irons
by Wright K Gannett

a THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering
Montana State University

Abstract:
Alloy cast irons are widely used in industry. Yet little has been done to put their cutting on an engineering basis. The cutting of other metals, notably certain steels,, has-been carefully | investigated,, but the scientific Cutting of metals is still in its infancy. Among metals commonly cut, on which scientific cutting information is either meager or lacking, are the alloy cast irons used in this investigation. Concerning these irons, R. C. Deale, executive secretary of the A. S. M. E. Subcommittee on Metal-Cutting Data, states, ".... the work (of this investigation) should give data in a portion of the field where nothing is available and should be of very real value to industry. "1 The Subcommittee acts as a sort of clearing house for metal-cutting information and conducts a planned program of research. Mr. Deale directed this investigation as a part of that program.

Three compositions of cast iron were tested; one was ordinary base iron, while the other two were alloy irons* The bade iron acted as a convenient reference with which the cutting characteristics of the two alloy irons could be compared. Each iron was in the form of cylinder linings (sleeves) and was furnished by General Motors.

This investigation was concerned with the variation of tool life and of power input with different cutting speeds.

For each composition of iron the feed and the depth of cut were kept constant at values prescribed by Mr. Deale. The purpose of this investigation was to establish empirically—under the prescribed conditions—the mathematical relationships among the variables of (1) cutting speed, (2) tool life, and (3) power input, using formulas whose general form has been well-established by F.W. Taylor 3 and confirmed by later investigators. The data gathered served merely to find the values of certain constants in those formulas.

Since little information exists on the difference between the cutting characteristics of the skin and of the clean metal1, the data for these two types of cuts were kept separately. Those data made clear the extent to which the greater hardness and abrasiveness of the skin shorten tool life.

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A THESIS

Submitted to the Graduate Committee

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partial fulfillment of the requirements

for the degree of

Master of Science in Mechanical Engineering

at

Montana State College

Approved:

In Charge of Major Work

Chairman, Examining Committee

Chairman, Graduate Committee

Bozeman, Montana
June, 1939

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Introduction

According to F. W. Taylor [5] there are twelve principal variables involved in the cutting of metals. Combination of these variables as made by the machine operator is empirical and is based on practice which he never thinks to question. Modern industry in its scramble for profits is constantly placing itself under a more scientific economic management. Since the cutting of metals is one of the foremost processes of industry, it is important that the optimum economic combination of the variables of cutting for any given job be known. But such knowledge can be obtained only by careful and extensive research which establishes the emperical formulas that relate those variables. For all metals these formulas are of the same general exponential type and are commonly used to relate the more important variables of (1) tool life, (2) cutting speed, (3) power input, (4) feed, and (5) depth of cut. Altho this paper is limited to reporting on only the first three of those variables, further investigations from time to time are certain to help complete the picture of the cutting of these metals

Conditions under which this Investigation was made

The analyses of the three cast irons were:

	250 (Base Iron)	262	213 M
Silicon	1.99%	1.97%	1.92%
Total carbon	3.38	3.40	3.25
Nickel	0.36	2.00	0.30
Chromium	0.28	0.51	0.40
Molybdenum	----	----	0.60
Copper	0.35	0.50	0.20

And the physical properties were:

	250 (Base Iron)	262	213 M
Transverse	2,450	2,400	3,150
Deflection	0.20	0.26	0.28
Tensile (0.505" bar)	44,520	44,720	55,590
Brinell (average)			
(a) in skin	248	264	305
(b) at 1/8" depth	205	215	270
Type of fracture in tensile test	fine grain--gray carbide network	fine grain--gray	fine grain--gray

Except for the hardness values the above information was furnished by the International Nickel Company. The 250 base iron and the 262 iron were not dissimilar enough to produce very different cutting characteristics. Both cut far more easily than the 213 M.

There was available a total of twelve sleeves: four of each composition of iron. Since all cuts were 1/8" depth, the 3/8" walls of the sleeves allowed only two passes to be taken in each: one in the skin and one in the clean metal.

Since data for skin cuts were kept separately from those for clean metal, there were two sets of data for each composition of iron or six sets of data in all. The size of the sleeves and other factors made it impossible to get in each set of data more than about a dozen readings--much too few to establish a dependable average result. Therefore, the results of this investigation are not conclusive and should be regarded only as giving the approximate cutting characteristics of these irons.

The dimensions of the sleeves were: 10 7/8" length, 5 1/2" outside diameter, and 4 3/4" inside diameter. The top end of each sleeve was thickened for about 1/4" in a collar equipped with two diametrically opposite lugs (for a positive driving grip). The bottom end of each sleeve, opposite the top (or collar) end, cooled first in the mold and as a result was chilled so hard that it had to be cut back about 1/2" before any "official" cuts could be taken. Further metal was made unavailable for cutting because of preliminary cuts. For example, a preliminary cut in the skin of sleeve 1-250-base was taken to check the approximate tool lives which the sleeves were expected to give. The tool cut the length of the sleeve without failing and showed the necessity of raising estimated speeds by more than 50%. Several tools on the last cut of a pass reached the end of the sleeve without failing. The preceding factors reduced the average length "officially" cut to considerably less than the total length of the sleeve.

Brinell hardness readings were taken in the skin and at 1/8" depth. A bolt and nut were cinched up inside the sleeves to help carry the 3,000 kg. load. No Brinell readings could be taken at 1/4" depth, because the 3,000 kg. load crushed thru, while the metal was not soft enough to be measured by the 500 kg. load. In both the skin and at 1/8" four readings equally spaced along the length "officially" cut were made. These readings were placed at random around the circumference of the sleeve. The Brinells showed a rather well-defined hardness gradient of about 20 B. H. N. units from the soft end to the hard bottom end, where the first cuts of each pass were started. No Brinells were taken in the chilled part of the hard end. This end in the 213-M sleeves was almost unmachinable with any tool softer than stellite, but the extreme hardness ended about 1/2" from the bottom end.

Cutting was done on a heavy-duty, cone-driven lathe 36" between centers and having a 26" swing (fig. 1). A 10-hp., D. C., adjustable-speed motor drove the lathe. Power input was measured by means of a voltmeter and an ammeter in the power circuit (fig. 2). The efficiency of the motor un-

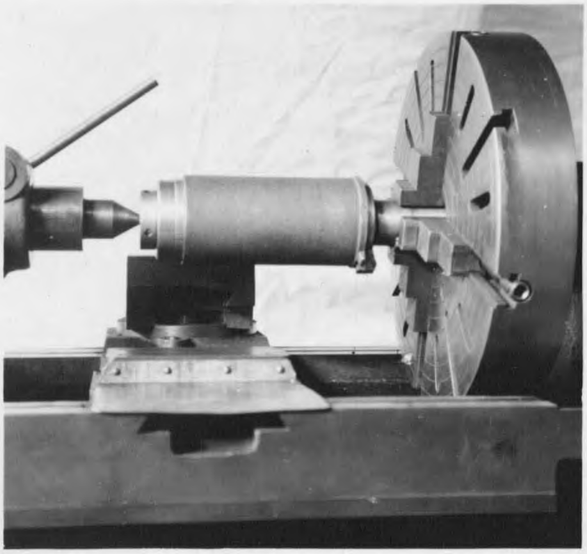

Fig. 1--Lathe with mandrel and sleeve.

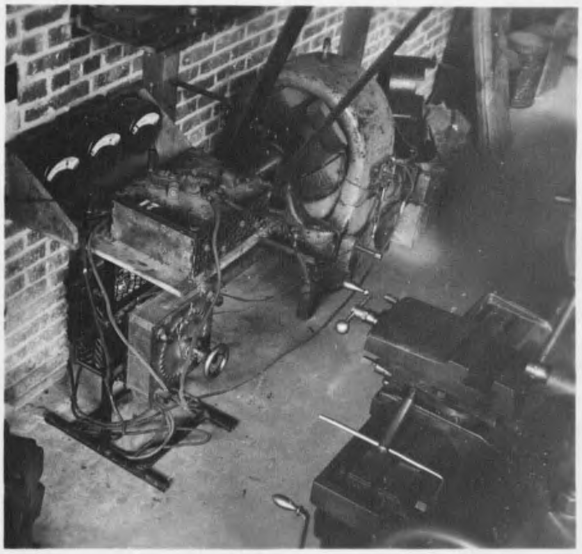

Fig. 2--D. C. motor and instruments.

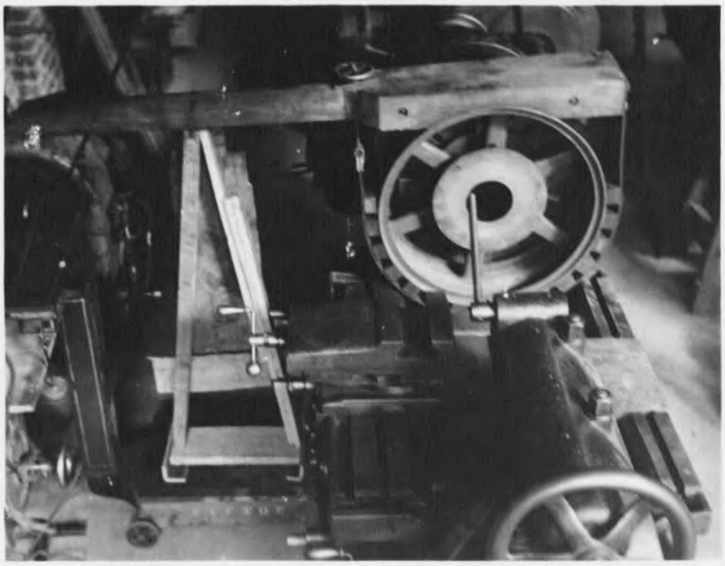

Fig. 3--Prony brake.

der various conditions of load had been determined previously with a prony brake (fig. 3), the efficiency readings including all friction losses up to the spindle of the lathe. Before any cuts were made the lathe was always allowed to run until the power readings became constant.

Cutting speed was gotten from the diameter of the work and the r. p. m. The latter was obtained in two ways: by measurement with a revolution counter and by calculation from the tool life, feed, and longitudinal length of work cut. When the two methods were not in exact agreement the greater weight was given to the revolution counter on very short cuts and to the computation method on longer cuts. The latter gave the average r. p. m. within ±1 revolution per time of tool life.

The 1/8" depth of cut, which was used both in the skin and in the clean metal for all three compositions of iron, was measured from the point of average runout for skin cuts. The feeds were as follows: for 250 base--0.0123"/rev., for 262--0.0123"/rev., and for 213 M--0.0185"/rev.

The sleeves were mounted with good concentricity and positive driving grip on a specially designed and constructed mandrel (fig. 4). Husky construction, including a 3"-diameter shaft, insured high rigidity. The mandrel is shown between centers on the lathe and holding a sleeve in fig. 1. Before the sleeves were mounted on the mandrel they were turned in a steady-rest and their inner ends were bored on a bevel so as to fit between the bevel rings on the mandrel. One ring was welded to the body of the mandrel, while the other was cinched up against the sleeve by means of a thick nut and washer. The lugs which furnish the positive driving grip can be seen in figs. 1 and 4.

Before starting skin cuts the average runout of each sleeve was measured and recorded. The average for the runouts of all sleeves was less than 1/32", while the runout of most single sleeves averaged near 1/32". The runout was partly caused by egg-shaped cross sections or by the sleeves' not being exactly straight from end to end. These same inaccuracies made it impossible to hold the sleeves for boring with perfect concentricity in the steady-rest. On all except one sleeve the runout was practically the same at all points along the length. For these sleeves the average runout was recorded. For the remaining sleeve the runouts were recorded cut by cut.

All tests were run dry, using sharp-nosed tool bits of a single shape, heat treatment, and composition. The tool blanks were heat treated by Brown & Sharpe and were of the 18-4-1 type and 5/8" square. Their analysis was: carbon 0.78-0.83%, manganese 0.20-0.25, phosphorous 0.025 max., sulphur

Fig. 4--Mandrel.

Fig. 6--Tool-holder.

0.03, chromium 3.50-4.00, tungsten 17.25-18.25, and vanadium 0.90-1.10. Their heat treatment was:

Operation	Temp. (deg. Fahr.)	Time (min.)	Atmosphere
Preheat	1,600	13	
Hardening	2,400	4 3/4	8-10% CO
Tempering	1,100	240	

The tools--of a shape approximating those in general use--were ground with no top rake, all top rake being provided by the 8-degree upslant of the tool-holder. Measured with respect to the tool shank the other angles were: 14 degrees side rake, 15 degrees front clearance, 6 degrees side clearance, 6 degrees front cutting-edge angle, and 20 degrees side cutting-edge angle (fig. 5). All tools were accurately ground on a Gisholt lathe-tool grinder and the burrs on the edges were carefully removed by honing. Care was taken not to burn the tool surfaces while grinding.

A specially built tool-holder (fig. 6) designed for rigidity and prevention of slippage was used. It was similar to the tool-holder used by H. J. French and T. G. Digges[2] in the rough turning of steel, in that a 3/8"-square trailer tool (not used in this investigation) can also be held in place if necessary. The main body of the tool-holder was a single piece of steel, to which the top piece was held by six cap screws. Between the main body and the top

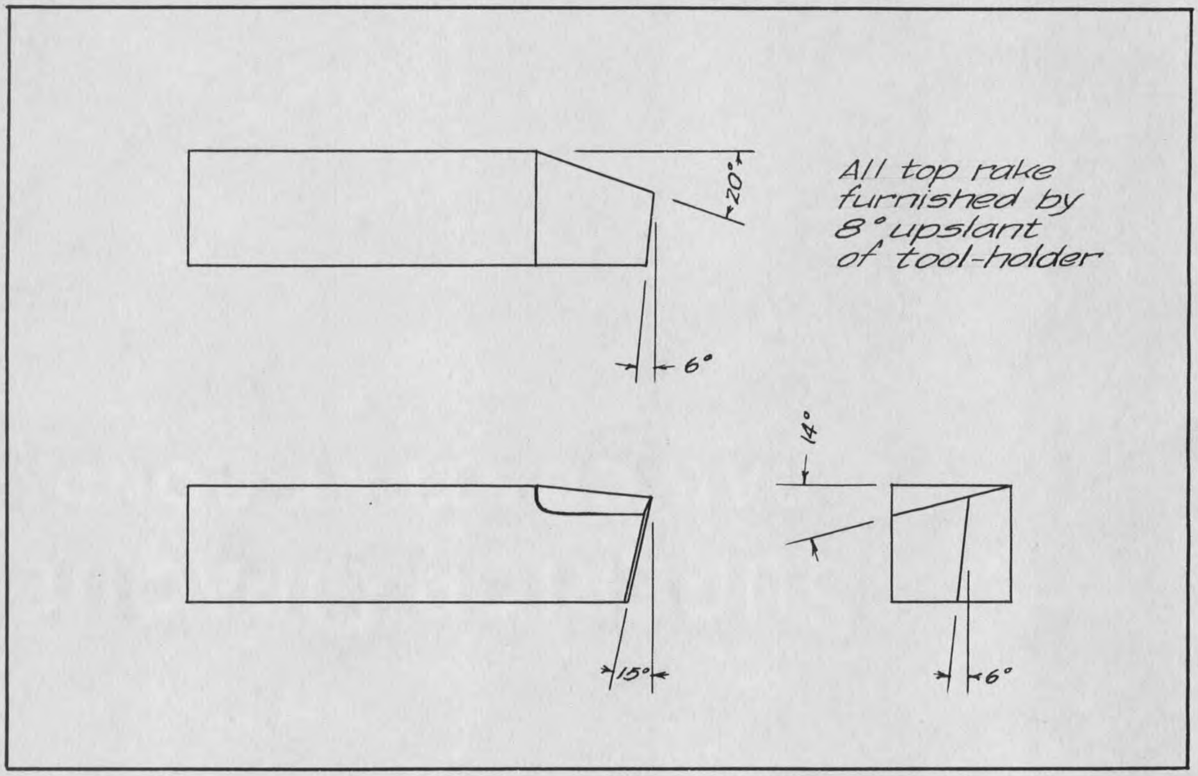

FIG. 5 — TOOL SHAPE

piece were grooves for the cutting tool and for the trailer tool. The tool bits were held in place by set screws and backed up by bolts provided with lock nuts.

Tool Failure

The exact time of tool failure was never clear-cut and had to be set somewhat arbitrarily. The type of failure was characteristic of a sharp-nosed tool, being of a slowly progressive rather than of a more "instantaneous" nature. Cutting conditions would remain constant up to the point where failure started. The first stage of the progressive failure consisted of infinitesimal specks of metal adhering to the corner of the cut. Next an almost imperceptible fuzz would appear, the corner of the cut becoming less well-defined. Then the fuzz would grow into what I called a "definite fuzz". The latter I took as the criterion of failure. Naming the instant at which the fuzz became "definite" was rather arbitrary. Certainly the accuracy could not have been much closer than $\pm$ 30 seconds for a tool life of, say, four minutes. Incidentally, the fuzzy appearance at the corner of the cut was partly illusory due to the rotation of the work.

In gathering each of the six sets of data no tool bit was used more than twice. Thus, any possible peculiarities of single tool bits were minimized.

A failed tool had a slightly rounded-off nose, while the cutting edge at contact with the periphery of the work was brightly but negligibly abraded——even for skin cuts. The top of the tool, where the chip rubbed, was burned and also slightly roughened by specks of metal welded to it. Except for the degree of rounding of the nose, a tool appeared the same whether removed shortly before or shortly after the "definite-fuzz" point. Neither the face of the cut nor the surface of the work underwent any apparent change before failure. But the "definite-fuzz" point seems a proper indication of failure, because it was there that both power input and the diameter of the work started to increase. Several times after failure a new tool was inserted and used to make a longitudinal scratch in the surface of the work. These scratches became minutely deeper in the neighborhood of the "definite-fuzz" point, revealing a small increase in the diameter of the work.

Two cuts, each of about a two-minute tool life, were run past failure. The resulting increase in fuzz was enormous. About three minutes past failure the corner of the cut, resembling iron filings clustered to a magnet, became a complete mess and power input went up abruptly. I called this the "let-go" point. The tool upon removal had a bluntly flattened nose, seemingly sheared off. Welded "wings" on each side of the nose and considerable burning evidenced the heat generated. Probably the failure of a round-nosed tool would correspond more closely to the "let-go" point than to the "definite-fuzz"