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DEPARTMENT OF MINES AND RESOURCES

BUREAU OF MINES

CANADA

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Ottawa, January 16, 1947.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2166.

Investigation of Steels Suitable for Use as Rotter Impact Machine Anvils.

(Copy No. 5.)

Bureau of Mines

Mineral Dressing and Metallurgy Division

Physical Metallurgy Research Laboratories

CANADA

DEPARTMENT OF MINES AND RESOURCES

Mines and Geology Branch

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Origin and Object of Investigation:

In compliance with a verbal request received during December, 1946, from Mr. M. C. Fletcher, Acting Chief Explosives Chemist, Explosives Division, Bureau of Mines, N.R.C. Annex, Montreal Road, Eastview, Ontario, an investigation aimed at determining suitable steels, in the heat-treated condition, for use as anvils in the Rotter impact machine has been carried out. Anvils presently being used for this purpose are reported as proving unsatisfactory, in that failure usually occurs prematurely in service; it is thought that the trouble being experienced is largely attributable to the steel being used, hence the need for a steel (or steels) that will meet requirements.

PROCEDURE:

1. Material.

Three different alloy steels, all comparable from the standpoint of hardenability, were selected for this investigation. Chemical compositions of these three steels are given in Table I below:

TABLE I.

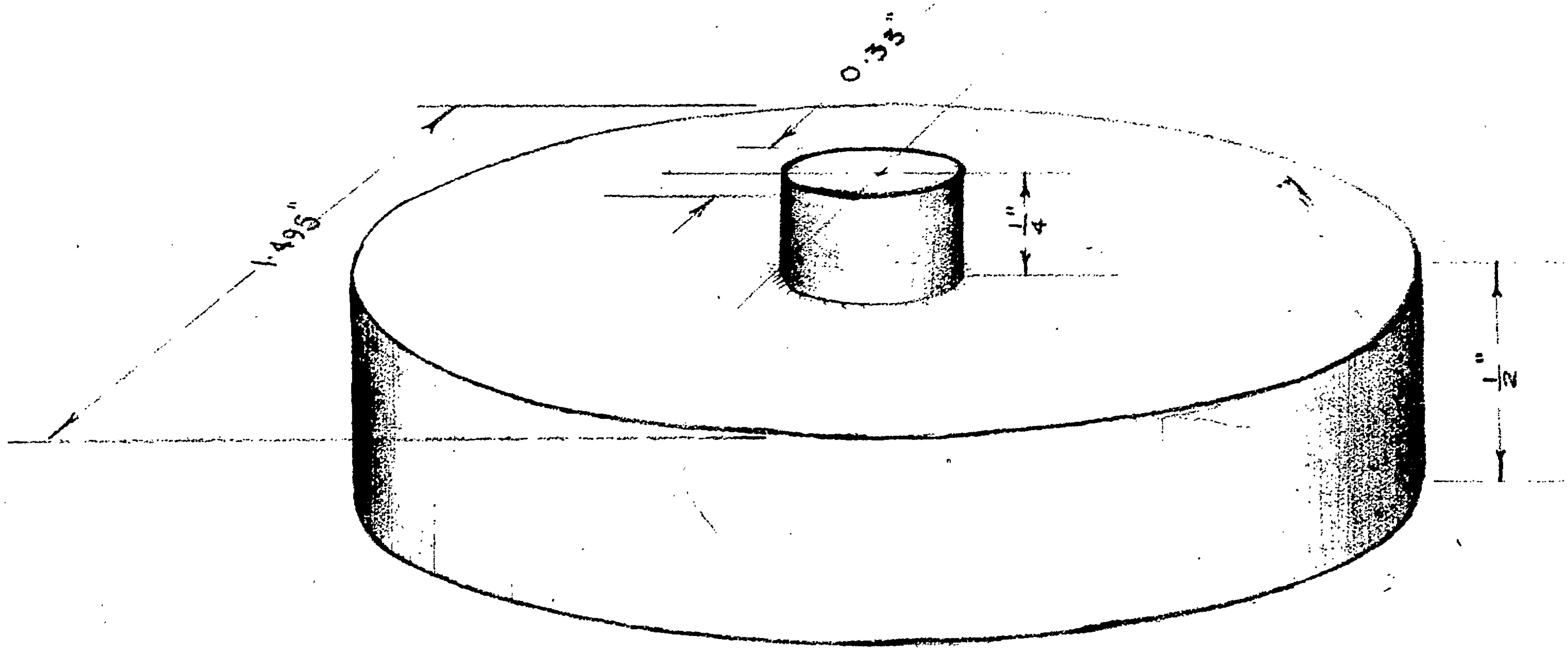
Alloy Steel	Chemical Composition (Per Cent)									
	C	Mn	Cr	Ni	Mo	Si	S	P	V	W
*SAE 4340 (Ultimo 4)	0.45	0.75	0.75	1.75	0.35	0.20	0.030	0.030		
A.P. (used for A.P. Shot)	0.70	0.80	0.70	1.00		0.30	<0.03	<0.03		
F6 (Falcon 6 Atlas Steel)	0.55	0.25	1.50						0.25	2.00

* Steels SAE 4340 and Ultimo 4 are of identical composition.

A set of fifteen anvils, the design and dimensions of which are illustrated in Figure 1, were machined from these three alloy steels.

(Figure I follows,)
(comprising Page 3)

FIG. I



SKETCH SHOWING DESIGN AND DIMENSIONS
OF ROTTER IMPACT MACHINE
ANVILS

Figure 1.

(Procedure, cont'd) -

2. Heat Treatment.

The anvils were subjected to various quenching and tempering heat treatments, as indicated in Table II. It is noted that quenching was done in oil at a temperature of about 120° F., also that five different tempering temperatures, namely 300°, 400°, 500°, 700° and 900° F., employed. Heating for quenching was done in a 55 K.W. Vapocarb furnace, and a Homo tempering furnace was employed in the tempering operation.

3. Hardness Tests.

Rockwell hardness tests were made on the quenched-and-drawn anvils, using the "C" scale. Readings were taken at three various locations on each anvil in order to ascertain whether or not the heat treatment had resulted in uniform hardening. Results are contained in Table III.

TABLE III. - Results of Hardness Tests on Rotter Impact Machine Anvils.

Steel	A.P.				SAE 4340			Ultimo 4					F6		
Anvil	A1	A2	A3	A4	1	2	3	1	2	3	4	5	1	2	3
Hardness Readings (Rockwell "C")	61	61	54	54	51	47	47	43	53	50	53	58	55	53	51
	61	61	54	55	52	48	48	44	52	50	54	56	55	54	51
	61	62	53	56	52	49	49	43	52	51	55	59	57	52	51
Average Hardness (Rockwell "C")	61	61	54	55	52	48	48	43	52	50	54	58	56	53	51

4. Practical Tests.

The anvils, after heat treatment, were used in actual explosive impact sensitivity tests at the Explosives Laboratories. Briefly, practical testing consists of fitting a brass cap over a small amount of explosive placed on the anvil, then dropping a known weight (5 kg.) from a specific

(Table II appears on Page 5. Text continues on Page 6.)

TABLE II. - Heat Treatment and Hardness Values of Rotter Impact Machine Anvils.

Steel	Anvil	Austenitizing		Quenching Medium	Tempering		Hardness (Rockwell "C")
		Temp., °F.	Time, in minutes		Temp., °F.	Time, in hours	
A.P.	A1	1500	30	Oil (120° F.)	300	2	61
"	A2	1500	30	Oil "	300	2	61
"	A3	1500	30	Oil "	500	2	54
"	A4	1500	30	Oil "	500	2	55
SAE 4340	4340-1	1500	30	Oil "	300	2	52
"	4340-2	1500	30	Oil "	400	2	48
"	4340-3	1500	30	Oil "	500	2	48
Ultimo 4	Ultimo 4-1	1500	30	Oil "	900	2	43
"	Ultimo 4-2	1500	30	Oil "	300	2	52
"	Ultimo 4-3	1500	30	Oil "	300	2	50
"	Ultimo 4-4	1500	30	Oil "	300	2	54
"	Ultimo 4-5	1500	30	Oil "	-	-	58
F6	F6-1	1625	5	Oil "	300	2	56
"	F6-2	1625	5	Oil "	500	2	53
"	F6-3	1625	5	Oil "	700	2	51

(Procedure, cont'd) -

height (50-200 cm.) onto the cap and observing the effect on the explosive. For practical purposes, a minimum of forty such "shots" is required of an anvil before spreading so that it will not take a brass cap. Results of these practical tests, which indicate the relative values of the various steels investigated for use as anvils, are recorded in Table IV.

TABLE IV. - Summary of Results of Impact Sensitivity Testing.

Steel	Anvil	(Rockwell "C")	Number of Shots	Remarks on Behaviour
A.P.	A1	61	68	Very good.
"	A2	61	56	Very good.
"	A3	54	38	Fair.
"	A4	55	38	Fair.
SAE 4340	4340-1	52	40	Fair.
"	4340-2	48	36	Fair.
"	4340-3	48	32	Unsuitable.
Ultimo 4	Ultimo 4-1	43	10	Unsuitable.
"	Ultimo 4-2	52	56	Very good.
"	Ultimo 4-3	50	24	Unsuitable.
"	Ultimo 4-4	54	30	Unsuitable.
"	Ultimo 4-5	58	40	Good.
F6	F6-1	56	54	Very good.
"	F6-2	53	36	Fair.
"	F6-3	51	28	Unsuitable.

DISCUSSION:

Heat Treatment and Hardness Tests -

Results indicate that the heat treating procedures followed resulted in uniform hardening of anvils, an important consideration for any steel used in this application. From Table II, it is noted that a maximum hardness of Rockwell C-61 was obtained, this hardness being attained in the case of A.P. steel drawn for 2 hours at 300° F. It is also

(Discussion, cont'd) -

observed that the hardness of anvils investigated ranged from C-43 to C-61 Rockwell, the maximum being achieved as described above.

Practical Tests -

Results of practical tests indicate that A.P. steel drawn to 300° F. (C-61 Rockwell) and F6 steel drawn to 300° F. (C-55 Rockwell) are the most suitable, in that anvils made from these two steels and heat-treated to the hardness noted are stronger and have longer useful life than either the same two steels differently heat-treated or the other steels under test.

It is noted, in particular, that optimum results were obtained with steel of high hardness; material of low hardness is obviously of no practical use. From this, it is evident that the performance of anvils is to a great extent dependent upon the hardness of the material used; material of high hardness (55-60 Rockwell "C") must be used if satisfactory results are to be achieved.

Generally, failure was found to occur as cracking of the anvil, causing it to spread in such a manner as to render impossible the fitting of a brass cap. Figure 2 is an illustration of an anvil (A1) which stood up exceptionally well under test, in that no signs of failure were evident after a total of sixty-eight "shots," while in Figure 3 is illustrated an anvil (A2) in which failure occurred as cracking after fifty-six "shots."

(Figures 2 and 3)
(follow, on Page 8.)

(Discussion, cont'd) -

Figure 2.

ROTTER MACHINE IMPACT ANVIL.

This anvil (A1) shows no signs of failure after a total of sixty-eight "shots."

Figure 3.

ROTTER MACHINE IMPACT ANVIL.

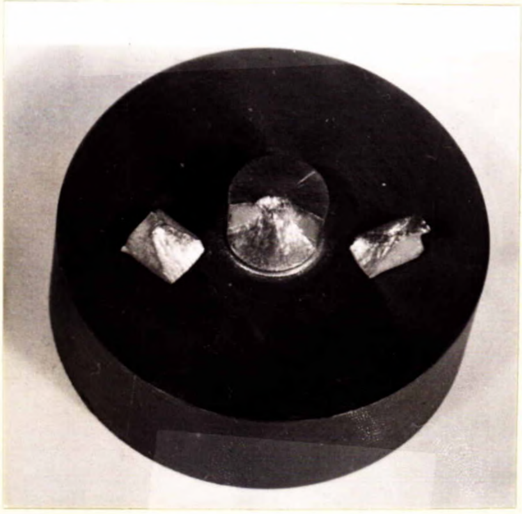
This anvil (A2) illustrates typical failure under test by cracking.

Another type of failure, in which obviously otherwise sound anvils failed in shear that started from the base, was observed (see Figure 4). This type of failure, it is thought, is attributable to the effect induced by the undoubtedly large stress concentration at the sharp base corner. As a means of remedying this, it was decided to incorporate an increased fillet radius in the design of

(Discussion, cont'd) -

these anvils; practical tests on this new design, using the two kinds of steel (A.P. and F6) which have given the most satisfactory results in this work, are presently under way.

Figure 4.



ROTTER IMPACT MACHINE ANVIL.

This anvil illustrates failure in shear originating at the base.

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CONCLUSIONS:

1. Test results disclose that the requirements of steel for Rotter impact machine anvils are somewhat similar to those for A.P. shot, in that a combination of high strength and good ductility is a prime requisite.

2. From the results obtained, it is concluded that the following two steels, heat treated to hardness values indicated, are suitable for use as Rotter impact machine anvils:

(1) A.P. steel drawn to 300° F. (C-61 Rockwell).

(2) F6 steel drawn to 300° F. (C-55 Rockwell).

3. Failure of anvils in shear originating at the base would appear to suggest that the large stress concen-

(Conclusions, cont'd) -

trations in that region, which are inherent in the present design, exert a deleterious effect upon the performance characteristics. Accordingly, it has been decided to carry out tests on a new design of anvil incorporating an increased fillet radius. In these tests, which are currently under way, the two steels (A.P. and F6) which gave the most satisfactory results in this work are being used.

4. Difficulty presently being experienced in regard to premature failure of anvils is quite likely attributable to both the type of steel and the design of anvil in use.

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