Dr. John Convey, Director
Mines Branch

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 61-18

EVALUATION OF FOUR PLOUGHSHARE MATERIALS

by

R. K. BUHR

PHYSICAL METALLURGY DIVISION

15P

COPY NO. 16

FEBRUARY 28, 1961

929

Unclassified

Mines Branch Investigation Report IR 61-18

EVALUATION OF FOUR PLOUGHSHARE MATERIALS

by

R.K. Buhr*

SUMMARY OF RESULTS

The wear resistance of four compositions of ploughshare materials has been determined by field tests and the impact resistance of the same materials by laboratory tests. A high alloy cast iron is shown to possess the best wear resistance properties, but a mild steel ploughshare point hard surfaced on the wearing portions appears to possess the best combination of wear and impact resistance.

---

* Senior Scientific Officer, Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

At the request of The Canadian Federation of Agriculture, a program was initiated to evaluate different ploughshare materials. The wider use of tractor-drawn ploughs has resulted in reduced wear life in existing ploughshare materials and it was hoped that a superior material could be found as a result of this program.

The project was divided into three parts. Part One dealt with the composition, hardness and microstructure of commercially available ploughshare materials. Part Two consisted of wear-test data obtained for several different compositions of cultivator teeth. The results of these first two parts are reported in Mines Branch Investigation Report IR 59-103, November 16, 1959.

The final part of the program is reported herein and consists of data obtained on wear and drop-weight impact tests on ploughshare points made of four materials selected from Part Two of the project. The relative wear resistance of these compositions was determined by statistical methods. Impact resistance was determined by drop-weight tests carried out at the Physical Metallurgy Division.

EXPERIMENTAL PROCEDURE

The ploughshare points used in this investigation were all made in the experimental foundry of the Physical Metallurgy Division. Four different compositions were used; AISI 1080, normalized, AISI 1015 hard surfaced with Tube-Borium, AISI 5150, quenched and tempered to Rockwell 'C' 50 to 55, and a high alloy cast iron.

The statistical design employed in the wear testing program was a randomized block design. This type of design was considered best for testing four materials when only three could be tested at one time. (Only three-furrow ploughs were available for field tests). In this design, the materials are assigned randomly to each run for each position, that is, each material is tested the same number of times (twice) in each position but not in each run.

The castings were numbered in the sequence they were poured from each heat, and a table of random numbers was then used to select ploughshare points to be tested in the different positions and runs. Table 1. lists the compositions and ploughshare point numbers tested in the three positions, left - L, middle - M, and right - R.

TABLE 1

Ploughshare Points Tested in Three Positions and for Eight Runs in Randomized Block Design

Run	Ploughshare Point* to be Tested at Position		
	L	M	R
1	A3	C4	B9
2	D7	B8	A9
3	C10	D8	C8
4	A12	A1	D9
5	C3	C5	D12
6	D11	A4	C9
7	B6	B2	A10
8	B12	D10	B3

*A - AISI 1015, hard surfaced

B - AISI 1080, normalized

C - AISI 5150, quenched and tempered

D - High alloy cast iron

Impact resistance was determined by dropping a 50 lb weight from different heights onto the tip of the ploughshare point. The height which caused failure was used in calculating the impact resistance of the ploughshare material.

RESULTS

(a) Chemical Analyses

The chemical analyses for the four compositions tested are listed below in Table 2.

TABLE 2

Chemical Analyses of Four Test Compositions

Element	Composition Identification			
	A %	B %	C %	D %
C	0.14	0.76	0.49	3.79
Mn	0.39	0.79	1.09	0.99
Si	0.09	0.17	0.58	1.19
S	0.038	0.021	0.020	0.017
P	0.014	0.023	0.019	0.022
Cr	-	-	1.02	14.85
Mo	-	-	-	2.83

(b) Wear Testing

The data obtained from the wear tests are summarized in Table 3. In runs 6 and 8, the testing times were considerably shorter than in the other runs. The reason for this was that the under side of the right hand (front) point wore in such a manner as to make it extremely difficult to keep the point in the ground. Figure 1 is a photograph showing this wear pattern on one of these points and a second point in which this type of wear did not occur.

TABLE 3

Results of Ploughshare Point Wear Tests

Run No.	Plough-point No.	Position	Initial Wt oz	Final Wt oz	Loss in Wt oz	Hours Tested	Wt Loss oz/hr
1	A3	L	132.0	131.0	1.0	12	0.0833
1	C4	M	124.5	123.0	1.5	12	0.1250
1	B9	R	120.25	117.75	2.5	12	0.2083
2	D7	L	122.5	122.0	0.5	16	0.0312
2	B8	M	119.5	115.0	4.5	16	0.2812
2	A9	R	130.0	128.0	2.0	16	0.1250
3	C10	L	125.5	123.5	2.0	15	0.1333
3	D8	M	116.5	116.0	0.5	15	0.0333
3	C8	R	124.0	121.0	3.0	15	0.2000
4	A12	L	130.25	128.75	1.5	15	0.1000
4	A1	M	129.5	127.25	2.25	15	0.1500
4	D9	R	118.0	116.75	1.25	15	0.0833
5	C3	L	123.0	120.5	2.5	15	0.1666
5	C5	M	123.25	119.5	3.75	15	0.2500
5	D12	R	118.75	118.0	0.75	15	0.0500
6	D11	L	122.0	121.75	0.25	6	0.0417
6	A4	M	131.0	129.5	1.5	6	0.2500
6	C9	R	125.5	123.25	2.25	6	0.3750
7	B6	L	124.0	121.5	2.5	15	0.1666
7	B2	M	121.5	117.5	4.0	15	0.2666
7	A10	R	128.5	126.75	1.75	15	0.1166
8	B12	L	122.5	121.0	1.50	9	0.1666
8	D10	M	119.0	118.5	0.50	9	0.0555
8	B3	R	122.0	119.5	2.50	9	0.2777

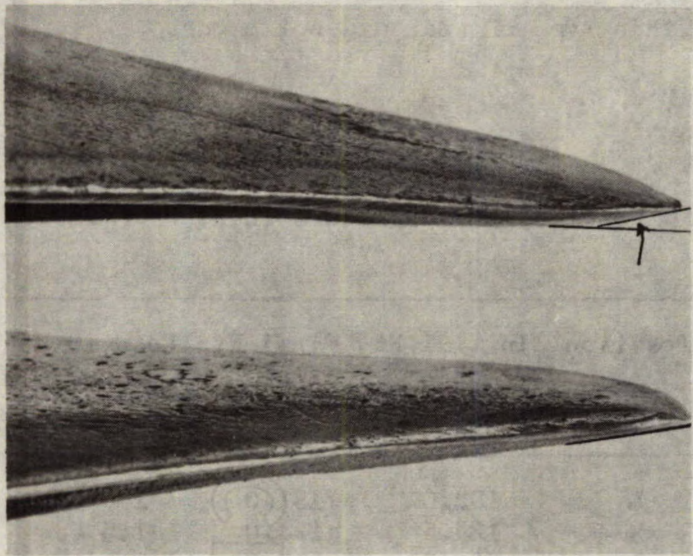


Figure 1. Photograph showing excessive wear on under side of ploughshare point tip (arrow), which causes the ploughshare point to tend to ride up. The ploughshare point shown at the bottom of the photograph did not display this type of wear.

The statistical analyses of the data in Table 3 revealed the information contained in Tables 4, 5 and 6.

TABLE 4

Ploughshare Point Wear Results (oz/hr)
Material vs Position

Position	Loss in Weight (oz/hr) for Material			
	A	B	C	D
Left	0.0833	0.1666	0.1333	0.0312
	0.1000	0.1666	0.1666	0.0417
Middle	0.1500	0.2812	0.1250	0.0333
	0.2500	0.2666	0.2500	0.0555
Right	0.1250	0.2083	0.2000	0.0833
	0.1166	0.2777	0.3750	0.0500
Total	0.8249	1.3670	1.2499	0.2950
Average	0.1375	0.2278	0.2083	0.0492

TABLE 5

Analysis of Variance

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square	F Value
Between Materials	0.117917	3	0.0393057	13.0*
Between Positions	0.023840	2	0.011920	3.95**
Between Runs	0.026394	7	0.003771	
Residual	0.027970	11	0.002543	
Total	0.196121	23		

* Statistically significant at the 1% level (one chance in a hundred that the result occurred through pure chance).

** Statistically significant at the 5% level.

TABLE 6

Mean Wear Loss and Relative Wear Resistance of Ploughshare Materials

Material	Mean Wear Loss (oz/hr)	Mean Relative Wear Resistance*	95% Confidence Interval for True Mean Wear Loss (oz/hr)
"D" (High Alloy Cast Iron)	0.049	4.6	0.002 - 0.096
"A" (AISI 1015 hard surfaced)	0.138	1.6	0.088 - 0.187
"C" (AISI 5150 R_c 50-55)	0.208	1.1	0.161 - 0.255
"B" (AISI 1080 normalized)	0.228	1.0	0.181 - 0.275

* The mean relative wear resistance of a material is the ratio of the mean wear loss of the standard material "B" divided by the mean wear loss of the material being rated.

(c) Drop Weight Impact Tests

The energy values required to fracture the tips off the ploughshare points in one blow are recorded in Table 7.

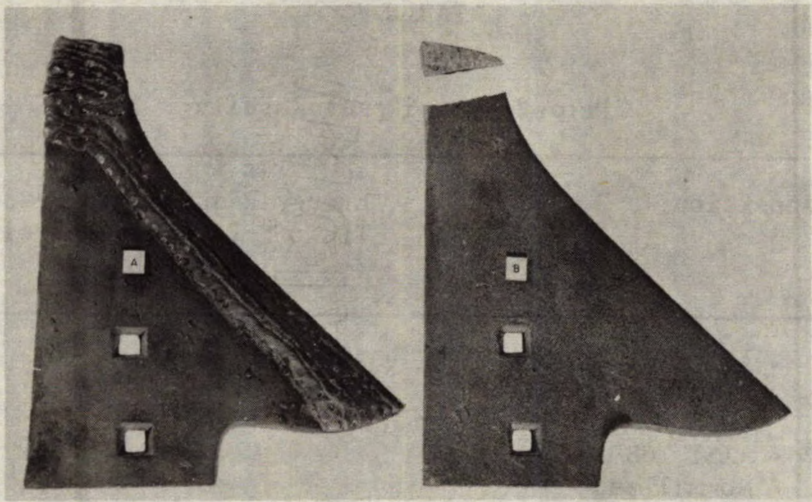
TABLE 7

Drop-Weight Impact Results

Composition	Energy Required to Fracture Tip off Ploughshare Point ft-lb
"A" - AISI 1015 Steel Hard Surfaced	425*
"B" - AISI 1080 Steel Normalized	425
"C" - AISI 5150 Steel R_C 50-55	150
"D" - High Alloy Cast Iron	50

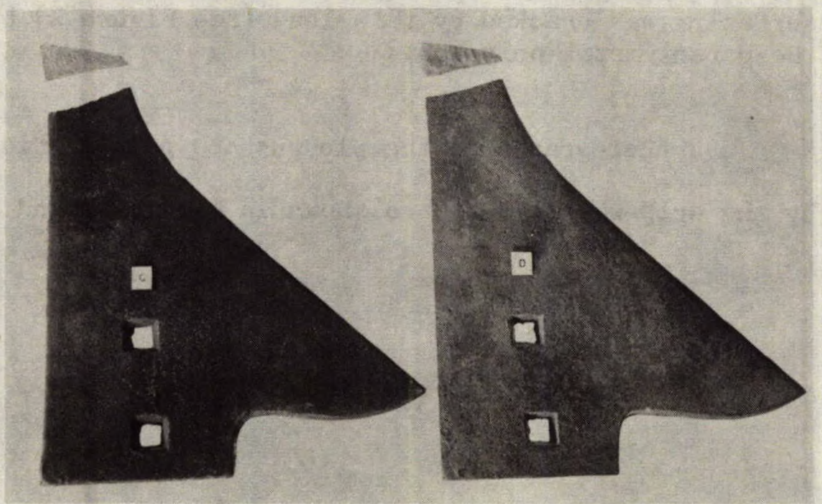
* The capacity of the apparatus was 425 ft-lb. The hard surfacing was cracked by this load (see Figure 2) but the parent metal only bent.

Photographs of the ploughshare points after testing by the drop-weight test are shown in Figures 2 and 3.



Approx. 1/5 actual size

Figure 2. Photograph of ploughshare points "A" and "B" after a drop-weight impact load of 425 ft-lb. The hard surface layer on "A" has cracked but the parent metal has only bent. Note also the pattern employed in the deposition of the hard surface material.



Approx. 1/5 actual size

Figure 3. Photograph of ploughshare points "C" and "D" after a drop-weight impact load of 150 and 50 ft-lb, respectively.

DISCUSSION

Although the high alloy cast iron displays the best wear resistance properties of the materials tested, the AISI 1015 steel ploughshare point, hard surfaced with Tube-Borium, has the best combination of wear resistance and impact resistance. This type of ploughshare point also has the additional advantage of reclamation after the hard surface layer has worn away.

The poor wear resistance of the AISI 5150 steel points was not expected and is difficult to explain, as its hardness of R_c 50-55 would be expected to result in good wear resistance. It may be that longer testing times would give a better relative rating of the ploughshare materials, although their order would not be expected to change. It is felt, however, that both compositions "A" and "C" are more superior to the standard "B" composition than is indicated by the "Mean Relative Wear Resistance" in Table 6 because of the hardness of the wearing material*. This, of course, can only be checked by carrying out more extensive testing than was possible for this program.

Part One of this investigation showed the steel ploughshare point to be fabricated. The blade material was AISI 1080 steel and the sole was made of AISI 1010 steel, the two pieces being welded together. It is felt that this type of construction is unnecessarily complex and costly, and that steel ploughshare points could be made much more economically by casting rather than fabricating. This aspect should be looked into with a view to

---

* In general, wear resistance increases as the hardness increases. Also, for the same hardness, a uniform microstructure (quenched and tempered) has better wear resistance than a mixed microstructure (normalized).

prices for the cast ploughshare points. It should be noted, however, that a possible reason for the type of construction of the fabricated steel ploughshare points could be that the low carbon "sole" of the point would wear faster. This may act to maintain the proper contour of the tip so that it will not tend to "ride up" as was noted in runs 6 and 8 in the wear testing series.

The 1960 prices for ploughshare points from five different manufacturers are listed below.

Manufacturer	Steel Ploughshare Points	Cast Iron Ploughshare Points	Nodular Iron Ploughshare Points
1	$8.00 each	$2.40 each	-
2	7.84 "	2.49 "	$2.98 each
3	6.80 "	2.60 "	-
4	8.50 "	3.95 "	-
5	7.65 "	3.15 "	-

On a per pound basis, taking the average weight of ploughshare points to be 8 lb, the cheapest steel point would be 85¢ per lb, cast iron 30¢ per lb, and nodular iron 37¢ per lb. The price of 85¢ per lb for steel ploughshare points appears to be excessive, especially in view of the poor wear resistance of this composition shown in these tests.

The drop-weight impact tests give a qualitative indication of relative impact resistance of the test materials. It is likely that these ratings would be found substantially correct in actual service, that is, hard surfaced AISI 1015 would have the best impact resistance. It does not necessarily follow, however, that the differences between the test materials shown in this laboratory test would be the same in service.

It is not possible to state what the cost would be for ploughshare points made in the test compositions. However, the mean relative wear resistance figures shown in Table 6 can be used as a rough guide, using the price for standard AISI 1080 steel ploughshare points as a base, that is, one could pay 1.6 times the price of the standard ploughshare point for a hard-surfaced AISI 1015 ploughshare point with no increase in cost per acre ploughed. As previously mentioned, compositions "A" and "C" (AISI 1015 hard-surfaced, and AISI 5150, respectively) are thought to be better than is indicated by the mean relative wear resistance ratings. Consequently, it is felt that these ratings are on the conservative side.

One point in regard to the hard-surfaced ploughshare points should be noted. The amount of hard surfacing material deposited on these ploughshare points (approximately 7 oz per point) could be reduced. The test points were hard surfaced all along the leading edge and on both the upper and lower surfaces of the tip, (see Figure 2). It is the writer's opinion that only the tip needs be hard surfaced (both upper and lower surfaces), and the leading edge could be left as it is, or at most only one bead of hard surfacing would be required. The cost of the hard surfacing rod used in these tests is 96¢ per point. This could be reduced to an estimated 60¢ per point. This figure does not include labour or fixed operating costs for the welding operation. The actual cost of hard surfacing would have to be determined separately.

Information recently obtained on the high alloy cast iron composition indicates that improved impact resistance, with no loss in wear resistance, can be obtained by slight revisions to the composition, and by use of a complete heat treatment rather than the low temperature stress-relief treatment given the "D" ploughshare points. It is conceivable, therefore, that this type of ploughshare point made to the revised composition and heat treatment would prove to be the most useful and economical of the materials tested. Again, however, additional testing would be required to verify this.

CONCLUSIONS

As a result of the testing program, the following can be concluded.

1) A reasonably satisfactory method for evaluating ploughshare points has been found.

2) Of the materials tested, the high alloy cast iron shows the best wear resistance properties. However, mild steel ploughshare points hard surfaced with Tube-Borium appear to have the best combination of wear and impact resistance.

3) More extensive field tests would be required to determine whether or not the high alloy cast iron material has sufficient impact resistance for this application. In the tests carried out, no breakage of the high alloy cast iron occurred. A revision to the composition and heat treatment of this alloy may also prove to be beneficial.

4) As would be expected, impact resistance varies as the hardness of the material, a high hardness resulting in low impact resistance. In general, the reverse is true for wear resistance.

5) Fabrication of steel ploughshare points is thought to be needlessly expensive. Economies should be realized if steel ploughshare points were cast.

6) The ploughshare materials have been statistically rated with respect to AISI 1080 cast steel ploughshare points. These indicate AISI 5150 quenched and tempered ploughshare points to be rated at 1.1, AISI 1015 hard surfaced ploughshare points at 1.6, and the high alloy cast iron at 4.6. However, longer testing times would likely change this relative rating to indicate greater superiority for the AISI 5150 and AISI 1015 compositions than these figures indicate.

ACKNOWLEDGEMENT

The field testing of the ploughshare points was carried out by the Research Branch of the Canadian Department of Agriculture, and the help and cooperation of Mr. W. Kalbfleisch and Mr. J.C. Kemp, in carrying out this work are gratefully acknowledged. The statistical design and analysis of the results were carried out by Mr. D.K. Faurschou, Liaison Officer, Mines Branch, Department of Mines and Technical Surveys, and his contribution to this project is also gratefully acknowledged.

RKB:ac