WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/634

Resistance of Light-Gauge Si-Ni-Cr-Mo and Cr-Mo-V Steels to Perforation by Fragment-Simulating Projectiles

BY

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DATE 18 May 1944

WATERTOWN ARSENAL
WATERTOWN, MASS.

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Eighth Partial Report on Problem R-8.2

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1. As part of a program of development of improved body armor components requested by the Office, Chief of Ordnance[1], there have been conducted at this arsenal several investigations of heat-treatable steels as possible substitutes for the Hadfield manganese steel currently used. In conjunction with this phase of the program samples of a Si-Ni-Cr-Mo steel and of a Cr-Mo-V steel were heat treated variously and subjected to ballistic test.

2. Both types of steel afforded greatest resistance to perforation by both caliber .45 (steel jacketed) ball projectiles and a light-weight fragment-simulating projectile, G-2[2] after being given a simple normalizing treatment to 49/51 Rockwell "C". When both types were austempered to Rockwell "C" 46 the Si-Ni-Cr-Mo steel exhibited superior resistance characteristics. The oil-quenched and tempered samples gave poorest results. The resistance of all samples, however, was considerably inferior to that of Hadfield manganese steel of the same weight.

3. Samples of a Si-Ni-Cr-Mo steel and of a Cr-Mo-V steel were received from the Ingersoll Steel and Disc Division of the Borg-Warner Corporation for development as body armor. Specimens of each chemical composition were subjected to three heat treatments. Samples were tested for hardness and clamped rigidly to wooden ballistic frames which allow an area 8"x8" to remain unsupported from the rear. Into these areas there were directed impacts of caliber .45 (steel jacketed) ball projectiles and caliber .22 fragment-simulating projectiles. The results of these tests and the chemical composition and heat treatment of the test samples are shown in Table I.

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1. O.O. 422.3/71(c) - Wtn 470.5/7443(c) dated 28 September 1943.

2. WAL Memorandum Report No. 762/253(c) - "Development of a Projectile, to Be Used in Testing Body Armor, to Simulate Fragments of a 20 mm. H.E. Projectile" - 7 January 1944.

4. Under impact of steel jacketed caliber .45 ball projectiles the resistance to perforation of the normalized samples (777 feet-per-second for the Cr-Mo-V and 783 feet-per-second for the Si-Ni-Cr-Mo) was considerably better than that of the austempered (560 feet-per-second and 613 feet-per-second, respectively) and oil quenched samples (510 feet-per-second and 532 feet-per-second, respectively). The resistance of Hadfield manganese steel of the same weight is about 900 feet-per-second.

5. Under impact of projectile G-2, the resistance of the normalized Cr-Mo-V sample (1322 feet-per-second) was greater than that of either austempered sample (1166 feet-per-second for the Cr-Mo-V and 1212 feet-per-second for the Si-Ni-Cr-Mo) or either oil quenched sample (1132 feet-per-second and 1089 feet-per-second, respectively). The normalized Si-Ni-Cr-Mo sample was not tested with this projectile because of its extreme brittleness under impact of the caliber .45 projectile. The resistance of no sample of either composition approached that of Hadfield manganese steel (1600 feet-per-second).

6. Of the austempered samples, the Si-Ni-Cr-Mo specimens offered greater resistance (613 feet-per-second and 1212 feet-per-second compared with 560 feet-per-second and 1166 feet-per-second) under both types of projectile attack. Because of differences in hardness or gauge precise comparison of the two compositions in the other heat-treated conditions could not be made.

7. Since the resistance of neither type of steel after any of these heat treatments compared favorably with that of Hadfield manganese steel little promise is seen for these compositions as prospective body armor components material.

8. Although there apparently is a correlation between resistance to perforation and hardness of these materials, it is considered that best resistance to flak and H.E. fragments will result from the use of a material which has a high percentage elongation prior to necking and is thus able to absorb energy over a wide area prior to local failure at the point of impact.

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Table I

Summary of Ballistic Tests Conducted at Watertown Arsenal on Light-Gauge Samples of Si-Ni-Cr-Mo Steel and Cr-Mo-V Steel

Samples	Chemical Compositions C	Mn	Si	Cr	Ni	Mo	V
843-1,2,3	.44	.57	.22	1.08	---	.90	.21
1739-1,2,3	.35	.81	.96	.75	.66	.25	---

Heat Treatment	Sample	Gauge	Hardness	Ballistic Limit G-2[1]	Cal. .45[2]
Oil Quench:					
1600°F - 10 min.	843-3	.041"	37 Rc	1132	510
Oil quench					
1050°F - 1 hour	1739-3	.041"	23 Rc	1089	532
Air cool					
Austemper:					
1600°F - 10 min.	843-1	.042"	46 Rc	1166	560
Quench in salt @ 600°F					
Hold 1 hour	1739-1	.042"	46 Rc	1212	613
Water quench					
Normalize:					
1600°F - 10 min.	843-2	.041"	51 Rc	1322	777
Air cool	1739-2	.040"	49 Rc	----	783
For Comparison:					
Hadfield manganese steel	---	.040"	88 Rb	1600	900

[1]Caliber .22 fragment-simulating projectile - 17 grains.

[2]Caliber .45 steel-jacketed ball projectile - 230 grains.

[redacted]

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ABSTRACT:
Samples of a Si-Ni-Cr-Mo steel and a Cr-Mo-V steel were heat treated and subjected to ballistics tests in an effort to find possible substitutes for the Hadfield manganese steel used for body armor. The samples were austempered, oil-quenched and normalized. Both types of steel gave best resistance to perforation by both steel jacketed caliber .45 ball projectiles and a light-weight fragment-simulating projectile when they were given a simple normalizing treatment to a 49/51 Rockwell C hardness. When both types were austempered to Rockwell C 46, the Si-Ni-Cr-Mo samples have superior resistance. The oil-quenched and tempered samples gave poorest results of all. However, the resistance of all samples was considerably inferior to that of Hadfield manganese steel of the same weight. A table of the summaries of the comparisons is given.

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