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RESULTS OF TESTS MADE TO ASCERTAIN EFFECT OF VARIOUS KINDS OF SHOT ON FATIGUE LIFE

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SECTION I.

ENDURANCE LIMIT OF HELICAL SPRINGS SHOT PEENED WITH DIFFERENT KINDS OF SHOT

Summary

This investigation was undertaken to find out how various shot hardness will affect the endurance life. As a matter of interest, attempts were made to determine the possibility of overpeening springs even using shot known to be large for the wire size in the spring.

On all tests almen strips were included with the springs. If correlation of the Almen arc height and spring life were possible, the tests run would establish this fact.

Six different lots of shot were used. These included one lot of P-46, one of P-28, and four of P-16. Of the P-16, one was steel, two were heat treated white cast iron, and one was white cast iron as were the P-46 and P-28. Physical and chemical tests were run on all of these types of shot.

The use of X-rays to determine the depth and magnitude of internal stresses was tried.

The springs were all from one coil of oil tempered valve spring wire. The springs were coiled, heated, ground and processed at the same time so as to insure a consistently uniform test specimen.

It will be noted that in one place we could only establish an endurance limit of less than a given figure while in another place we have given it as over a figure. In these instances we had insufficient springs to complete our tests.

The first thing to notice in the above table is that in every case the shot peening treatment has increased the endurance limit of the springs. For the lowest figures given we have increased the safe stress range 19.3%. For the highest endurance limit the increase in safe stress range is 56.7%.

It is at once apparent that the P-46 shot is too coarse for these springs. While it has increased the endurance limit over the springs which have not been shot peened, the values in the table are in almost every case lower than for any of the other shot. There would appear to be a tendency to over shot peen with this shot for long times of peening but the differences are hardly more than the experimental error in our testing.

In the case of the P-28 shot we have a value for our 15 min. run which appears low. Actually, for some reason we have not been able to determine, this was caused by the springs setting more than usual during the tests. The stress range is comparable to the other runs with the exception of the springs peened for two hours. The fact that this test is somewhat lower does not necessarily indicate much, because we have a ± 3000 psi possible machine and setup error. However, it might be well said that the springs are shot peened to the practical limit.

While our data on the various lots of P-16 shot are incomplete, it does appear that we are obtaining endurance limits with it that are strictly comparable to P-28 shot. It would also indicate that there is practically no difference as far as the endurance limits obtained are concerned whether, within the limits of the hardnesses used, we use hard or soft shot.

If we refer to the arc heights, which we obtained during the various shot peening operations, and compare them with the endurance limits determined for the springs which were peened with the Almen strips, it is readily apparent that in an investigation of this type there is absolutely no correlation between arc height and endurance limit. For example, we found almost exactly the same endurance limit for springs shot peened 15 minutes with P-16 shot, Lot 103, and with P-28 shot for 30 minutes. The arc height with the first lot of springs was 7 and that with the latter 24.2. It would therefore seem that arc height of itself does not mean much unless the shot used is specified as to size and hardness. Even then it would appear to be desirable to still set up a minimum arc height by running fatigue tests and attempting to secure some kind of correlation between arc height and endurance limit for the particular shot in question.

From our data there does not appear to be any tendency to over shot peen using the P-16 shot.

The depth of cold working with different size shot has not been completely worked out. If the larger shot does go deeper, then standards of shot size for various wire sizes should be considered. Also peening hot wound springs with some ferrite the heavier shot might then be an advantage. It is hoped that this data by X-ray (or other method) can be soon made available to all interested parties.

We know that the softer shot gives us lower maintenance of our equipment. Our tests here in 1939 - 1940, and reported to A.S.M. in 1941, showed equal fatigue life. These tests confirm the previous runs in that soft shot from an endurance point of view will produce results comparable with the hard shot. It is evident that an economy can be achieved using steel or a heat treated cast iron shot.

The breakdown or shot life tests were run by Mr. John C. Straub of The American Wheelabrator & Equipment Corporation. He tested the P-16 shot in two different ways, one was at constant wheel speed and the other at constant arc height on an Almen strip.

His results are given in the following table as are the results of two wheel speeds on the P-28 and P-46:

P-16 Shot

Sample No.	9800 r.p.m.		.007 A-2 arc height	
	arc height inches	av. life cycles	wheel speed r.p.m.	av. life cycles
100	.009	488	6500	1133
101	.014	6.9	3750	121
102	.010	53	5000	590
103	.007	135	9800	135

P-28 and P-46 Shot

Size	9800 r.p.m.		3000 r.p.m.	
	arc height inches	av. life cycles	arc height inches	~~av. life~~ cycles
P-28	.027	6.7	.012	235
P-46	-	4.4	.017	109

Testing the shot at the same wheel speed shows that the arc height of each lot for the P-16 shot bears a direct relationship to the hardness of the shot. The shot life for the cast iron shot is inversely proportional to the shot hardness. The steel shot has a much longer life than the iron shot. Since we only had one hardness to test, we have no data upon the relationship between shot life and hardness to test, we have no data upon the relationship between shot life and hardness for steel shot. Another interesting thing is that for the same wheel speed, 9800 r.p.m., there is not a great deal of difference in shot life for any of the hard white iron shots regardless of shot size (See P-16, P-46 and Lot 101). There was a slight tendency for shot life to decrease as shot size increased, but it was not very pronounced.

When the wheel speed was varied to obtain a constant arc height of .007 A-2, it would appear there is an optimum hardness for shot life. Lot 102 showed the longest life although it was not the softest shot. This applies, of course, to the iron shot. The steel shot had much the longest life, but the difference was not as pronounced as at constant wheel speed. Another thing, which might be expected, was that ot obtain a constant arc height with the various lots of P-16 shot the wheel speed had to be increased as the hardness of shot decreased.

minutes. A load of scrap springs was then placed in the machine and it was run an additional two hours with this load. Then two more Almen strips were placed in the machine and shot peened for two minutes without running the belt. The amount of dust collected during the entire run was then weighed to obtain an indication of how much the shot had broken up in the four-hour run.

SECTION V

INTENSITY OF SHOT PEENING AS MEASURED BY ALMEN A STRIPS

All Almen strips were Rockwelled before using. An average of the various Almen A2 readings for the different times for each lot of shot are given in the following table:

Time	P-46	P-28	P-16 Lot 100	P-16 Lot 101	P-16 Lot 102	P-16 Lot 103
2 min. no load belt stationary	38.5	21.5	7.7	9	10	8
5 min. with springs	28.1	20	8	9.2	7.5	4.2
15 min. with springs	38	23.5	7.5	11.7	9	7
30 min. with springs	39	24.2	9.2	12.7	11.5	8.5
120 min. with springs	46.5	26.7	12	15.5	14.7	13
2 min. no load belt stationary after 4 hrs. of running	15	12.5	8	5	10.2	6.7

It will be noticed that the arc height in each case reaches a fairly high value for the shot in question and then continues to rise very slowly with time. There is one exception to this on the 15 min. run of P-16 Lot 100 shot. In this case the strips for the 5 min. run were 45.5 Rockwell and for the 15 min. run 48. The lower the Rockwell hardness the higher is the Almen reading so this may partially explain this discrepancy. These tests show very conclusively that the Almen reading goes up as the shot size increases. It also shows that for the same size shot the Almen reading goes up somewhat as the shot hardness increases. In this case the difference appears to be somewhat more pronounced for the shorter peening times although it holds true in every instance in our tests.

The difference in the Almen readings taken before starting the shot peening of springs and after the finish of the peening tests, i.e., the 2 min. runs, must be attributed to breakdown of the shot. For the hard shot there is a great difference in the readings. For the two softer lots of shot there is none. In fact the last runs are a little higher than the first ones although we believe this can only be due to experimental error.

Shot Size in Inches	P-16 Lot 100	P-16 Lot 100A	P-16 Lot 101	P-16 Lot 101A	P-16 Lot 102	P-16 Lot 102A	P-16 Lot 103	P-16 Lot 103A	P-28	P-28A	P-46	P-46A
Under .011	0.3	0.6	0.2	81.5	0.1	4.5	0.2	0.2		37.7		16.8
.011 -.013	2.1	3.1	1.3	6.7	1.2	2.1	0.7	2.0		21.0		11.5
.013 -.016	27.3	39.9	25.6	6.5	24.5	25.3	13.6	27.6		20.5		16.7
.016 -.019	67.7	55.2	71.5	4.0	72.6	65.1	80.1	66.5		11.3		19.0
.019 -.023	(a) 2.6	1.0	(a) 1.4	0.7	(a) 1.6	2.6	5.3	3.4	(c) 1.0	5.0	(c) 1.0	16.9
.023 -.028		(b) 0.2		(b) 0.6		(b) 0.4	(b) 0.1	(b) 0.3	8.5	3.0	3.2	11.2
.028 -.033									89.4	(e) 1.5	13.0	5.2
.033 -.039									(d) 2.1		35.1	1.9
.039 -.046											41.2	0.6
.046 -.055											6.5	0.2

VALUES IN THE ABOVE TABLE ARE IN PERCENT

(a) over .019
(b) over .023
(c) under .023
(d) over .033
(e) over .028