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WEARING DISCREPANCIES OF CYLINDER SLEEVES TREATED BY HONE FINISHING OR SURFACE PLASTIC DEFORMATION

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Abstract: *The magnitude of wearing in nineteen cross-sections of cylinder sleeves of internal-combustion engines treated by hone finishing or surface plastic deformation was investigated. The cylinder sleeves had worked in similar conditions hence they were placed in one and the same internal-combustion engine. The working regimes of the engine were cold and hot running-up, hot running-up with load, accelerated wearing tests and operational tests in real working medium.*

Key words: *internal-combustion engines, cylinder sleeves, hone finishing, surface plastic deformation, wear resistance.*

1. INTRODUCTION

Hone finishing is a classical finishing treatment during the production or the restoration up to repairing dimensions of cylinder sleeves of internal-combustion engines (ICE). An alternative finishing treatment is the surface plastic deformation (SPD) [1] which could be applied using multi-purpose metal-working machines with rotation major movement [2]. There are some reports concerning the successful applying of surface plastic deformation during repairing of cylinders and cylinder sleeves but there are no data confirming the wide use of this method in the general production or the restoration of ICE.

In this article the behaviour of cylinder sleeves working at identical conditions and treated with different finishing such as hone finishing or surface plastic deformation is considered.

2. EXPERIMENTAL TECHNIQUE

Four cylinder sleeves treated two by two by hone finishing and surface plastic deformation were put in four-cylinder internal-combustion engines. The sleeves treated by identical finishing were disposed one after the other. In this way the influence of the cylinder sleeve disposition on the wearing unevenness was diminished. This was done in two engines – ICE-1 and ICE-2. Both engines were worked out in laboratory conditions using brakes at regimes of cold running-up, hot running-up and hot running-up with load.

After the running-up the ICE-1 was put under wearing accelerated tests. The engine was working 76 hours using fuel with enhanced sulphur content (0.21 % instead of 0.05 % according the requirements of Bulgarian standards [4]) at lower temperature regime (70 ^{0}C below the optimal temperature) [3, 5-7]. After the finish of the accelerated tests the ICE-1 was mounted in a car which was driven mainly in the outlines of a town with 100 000 townspeople. The covered car run was 14 000 km till the end of the experiment. The dimensions of the cylinder sleeves were measured in nineteen cross-sections using co-ordinate measuring machine IOTA-1202. The measurements were done three times, one before the initial mount in the ICE, second after the wearing accelerated tests, and third after the real car exploitation in a town area with 14 000 km covered run. The measurements results are represented in Tables 1 – 4 and in Figs. 1 and 2. The designations in Table 1 are as following:

S is the cross-section of the cylinder sleeve;

l is the distance from the upper end of the cylinder sleeve;

Φ_N – the initial dimensions of a particular cross-section of the cylinder sleeve;

Φ_1 –dimensions of the cylinder sleeve after wearing accelerated tests;

Φ_2 is the dimension of the cylinder sleeve after working in real medium;

W_1 is the wearing of the cylinder sleeve after wearing accelerated tests;

Table 1

Dimensions of cylinder sleeve 1 treated by hone finishing and mounted in ICE-1

S №	l, mm	Φ_N, mm	Φ_1, mm	W_1, mm	Φ_2, mm	W_2, mm
1	8	83,004	83,024	0,020	83,053	0,049
2	13	83.000	83.007	0.007	83.015	0.015
3	18	82.997	83.008	0.011	83.013	0.016
4	23	82.998	83.005	0.007	83.008	0.010
5	28	82.998	83.004	0.006	83.008	0.010
6	33	82.999	83.009	0.010	83.013	0.014
7	38	83.002	83.012	0.010	83.010	0.008
8	43	83.003	83.010	0.007	83.011	0.008
9	48	83.004	83.009	0.005	83.014	0.010
10	53	83.001	83.010	0.009	83.012	0.011
11	58	83.003	83.005	0.002	83.012	0.009
12	63	83.002	83.005	0.003	83.016	0.014
13	68	83.001	83.009	0.008	83.013	0.012
14	73	83.004	83.005	0.001	83.011	0.007
15	78	83.004	83.007	0.002	83.007	0.002
16	83	83.002	83.007	0.005	83.008	0.006
17	88	83.002	83.012	0.010	83.011	0.009
18	93	82.997	83.005	0.008	83.004	0.007
19	98	82.995	82.997	0.002	82.996	0.001
x_{max}		83.005	83.024	0.020	83.053	0.049
x_{min}		83.995	83.997	0.001	82.996	0.001
$\bar{x}$		83.000	83.007	0.0072	83.012	0.0115

Table 2

Dimensions of cylinder sleeve 3 treated by hone finishing and mounted in ICE-1

S №	*L*, mm	Φ_N, mm	Φ_1, mm	W_1, mm	Φ_2, mm	W_2, mm
1	8	83.012	83.039	0.027	83.054	0.042
2	13	83.011	83.020	0.009	83.028	0.017
3	18	83.007	83.017	0.010	83.017	0.010
4	23	83.005	83.009	0.004	83.014	0.009
5	28	83.006	83.012	0.006	83.014	0.008
6	33	83.007	83.014	0.001	83.021	0.014
7	38	83.013	83.013	0.000	83.018	0.005
8	43	83.013	83.014	0.001	83.024	0.011
9	48	83.016	83.021	0.005	83.024	0.008
10	53	83.016	83.021	0.005	83.021	0.005
11	58	83.016	83.022	0.006	83.021	0.005
12	63	83.020	83.020	0.000	83.023	0.003
13	68	83.020	83.026	0.006	83.025	0.005
14	73	83.022	83.018	-0.004	83.027	0.005
15	78	83.019	83.023	0.004	83.022	0.003
16	83	83.015	83.022	0.007	83.028	0.013
17	88	83.015	83.025	0.010	83.024	0.009
18	93	83.016	83.018	0.002	83.018	0.002
19	98	83.009	82.015	0.006	83.014	0.005
x_{max}		83.022	83.039	0.027	83.054	0.042
x_{min}		83.005	83.009	0.000	83.014	0.002
$\overline{x}$		83.013	83.019	0.0058	83.023	0.0094

Table 3

Dimensions of cylinder sleeve 2 treated by surface plastic deformation and mounted in ICE-1

S №	L, mm	Φ_N, mm	Φ_1, mm	W_1, mm	Φ_2, mm	W_2, mm
1	8	83.046	83.059	0.013	83.073	0.027
2	13	83.046	83.056	0.010	83.062	0.016
3	18	83.042	83.051	0.009	83.063	0.021
4	23	83.042	83.054	0.012	83.058	0.016
5	28	83.038	83.051	0.013	83.053	0.015
6	33	83.046	83.054	0.008	83.058	0.012
7	38	83.048	83.053	0.005	83.058	0.010
8	43	83.052	83.054	0.002	83.054	0.002
9	48	83.054	83.056	0.002	83.056	0.002
10	53	83.055	83.055	0.000	83.055	0.000
11	58	83.052	83.054	0.002	83.061	0.009
12	63	83.054	83.057	0.003	83.057	0.003
13	68	83.052	83.060	0.008	83.055	0.003
14	73	83.056	83.059	0.003	83.060	0.004
15	78	83.056	83.060	0.004	83.057	0.001
16	83	83.057	83.061	0.004	83.060	0.003
17	88	83.053	83.054	0.001	83.058	0.005
18	93	83.056	83.053	-0.003	83.055	-0.001
19	98	83.055	82.056	0.001	83.055	0.000
x_{max}		83.057	83.061	0.013	83.073	0.027
x_{min}		83.038	83.051	0.000	83.054	0.000
$\overline{x}$		83.051	83.055	0.0054	83.058	0.0079

Table 4

Dimensions of cylinder sleeve 4 treated by surface plastic deformation and mounted in ICE-1

S №	*L*, mm	Φ_N, mm	Φ_1, mm	W_1, mm	Φ_2, mm	W_2, mm
1	8	83.046	83.059	0.013	83.073	0.027
2	13	83.046	83.056	0.010	83.062	0.016
3	18	83.042	83.051	0.009	83.063	0.021
4	23	83.042	83.054	0.012	83.058	0.016
5	28	83.038	83.051	0.013	83.053	0.015
6	33	83.046	83.054	0.008	83.058	0.012
7	38	83.048	83.053	0.005	83.058	0.010
8	43	83.052	83.054	0.002	83.054	0.002
9	48	83.054	83.056	0.002	83.056	0.002
10	53	83.055	83.055	0.000	83.055	0.000
11	58	83.052	83.054	0.002	83.061	0.009
12	63	83.054	83.057	0.003	83.057	0.003
13	68	83.052	83.060	0.008	83.055	0.003
14	73	83.056	83.059	0.003	83.060	0.004
15	78	83.056	83.060	0.004	83.057	0.001
16	83	83.057	83.061	0.004	83.060	0.003
17	88	83.053	83.054	0.001	83.058	0.005
18	93	83.056	83.053	-0.003	83.055	-0.001
19	98	83.055	82.056	0.001	83.055	0.000
x_{max}		83.057	83.061	0.013	83.073	0.027
x_{min}		83.038	83.051	0.000	83.054	0.000
$\overline{x}$		83.051	83.055	0.0054	83.058	0.0079

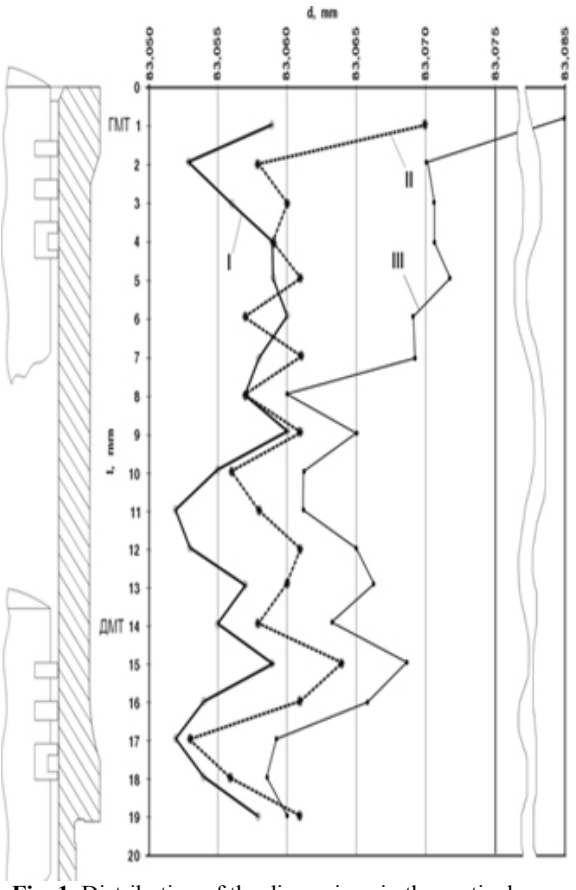

Fig. 1. Distribution of the dimensions in the particular cross-sections of cylinder sleeve 4 treated by surface plastic deformation and mounted in ICE-1. I – initial cylinder sleeve dimensions; II – cylinder sleeves dimensions after wearing accelerated tests; III - cylinder sleeve dimensions after working in real medium; U.D.C. and L.D.C - upper and lower dead centers;

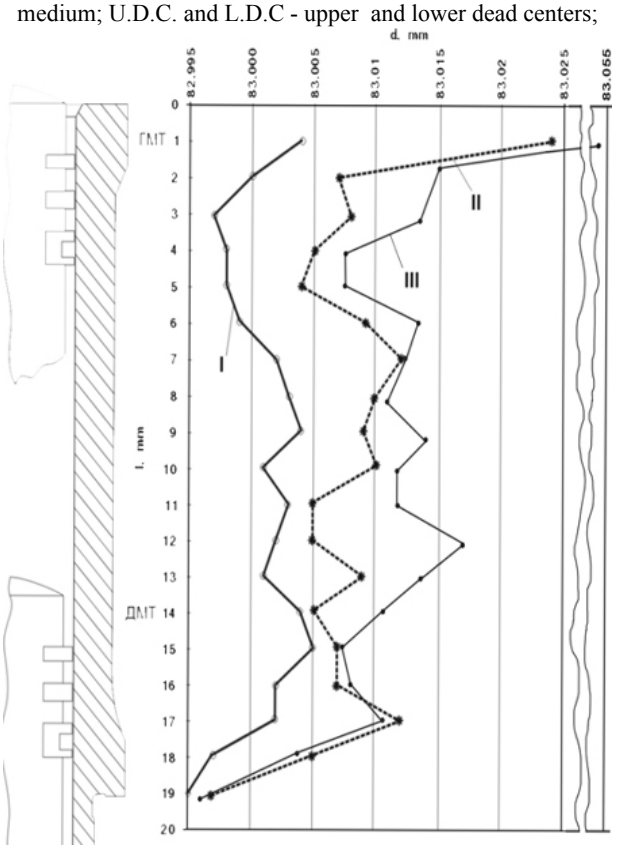

Fig. 2. Distribution of the dimensions in the particular cross-sections of cylinder sleeve 4 treated by hone finishing and mounted in ICE-1.

Table 5

Dimensions of cylinder sleeves 1 and 3 treated by surface plastic deformation and mounted in ICE-2

S №	cylinder sleeve 1			cylinder sleeve 3		
	Φ_n, mm	Φ_1, mm	W_2, mm	Φ_n, mm	Φ_1, mm	W_2, mm
1	82.546	82.555	0.009	82.549	82.559	0.010
2	82.545	82.555	0.010	82.550	82.558	0.008
3	82.545	82.557	0.012	82.549	82.560	0.011
4	82.550	82.563	0.013	82.550	82.560	0.010
5	82.552	82.562	0.010	82.548	82.554	0.006
6	82.551	82.559	0.008	82.551	82.559	0.008
7	82.552	82.558	0.008	82.549	82.553	0.004
8	82.551	82.558	0.007	82.551	82.553	0.002
9	82.550	82.555	0.005	82.548	82.551	0.003
10	82.553	82.557	0.004	82.550	82.555	0.005
11	82.546	82.552	0.006	82.551	82.557	0.006
12	82.552	82.555	0.003	82.547	82.551	0.004
13	82.545	82.551	0.006	82.544	82.549	0.005
14	82.542	82.847	0.005	82.541	82.547	0.006
15	82.543	82.551	0.008	82.551	82.558	0.007
16	82.546	82.553	0.007	82.550	82.558	0.008
17	82.546	82.550	0.004	82.544	82.549	0.005
18	82.537	82.540	0.003	82.547	82.549	0.009
19	82.548	82.550	0.002	82.540	82.550	0.002
x_{max}	82.553	82.563	0.013	82.551	82.560	0.011
x_{min}	82.537	82.540	0.002	82.540	82.543	0.002
$\bar{x}$	82.547	82.554	0.0067	82.548	82.554	0.0050

Table 6

Dimensions of cylinder sleeves 2 and 4 treated by hone finishing and mounted in ICE-2

S №	cylinder sleeve 2			cylinder sleeve 4		
	Φ_n, mm	Φ_1, mm	W_2, mm	Φ_n, mm	Φ_1, mm	W_2, mm
1	82.560	82.572	0.012	82.538	82.550	0.012
2	82.550	82.573	0.013	82.537	82.548	0.011
3	82.559	82.575	0.016	82.544	82.556	0.012
4	82.563	82.583	0.020	82.544	82.560	0.016
5	82.563	82.576	0.013	82.542	82.551	0.009
6	82.556	82.569	0.013	82.542	82.550	0.008
7	82.560	82.574	0.014	82.549	82.556	0.007
8	82.554	82.571	0.017	82.547	82.553	0.006
9	82.557	82.573	0.016	82.550	82.555	0.005
10	82.568	82.575	0.007	82.547	82.554	0.007
11	82.562	82.570	0.008	82.545	82.553	0.008
12	82.565	82.576	0.011	82.547	82.556	0.009
13	82.567	82.577	0.010	82.549	82.557	0.008
14	82.558	82.571	0.013	82.552	82.563	0.011
15	82.556	82.573	0.017	82.551	82.558	0.007
16	82.563	82.577	0.014	82.547	82.554	0.007
17	82.564	82.577	0.013	82.558	82.566	0.008
18	82.560	82.567	0.007	82.553	82.556	0.003
19	82.560	82.565	0.005	82.552	82.555	0.003
x_{max}	82.5	82.583	0.020	82.558	82.566	0.016
x_{min}	82.5	82.565	0.005	82.537	82.548	0.003
$\bar{x}$	82.5	82.573	0.0126	82.547	82.555	0.0083

W_2 is the wearing of the cylinder sleeve after working in real medium.

ICE-2 was put under stand wearing accelerated tests. On working out in laboratory conditions the engine was mounted in a car which was driven for 48 000 km mixed covered run – urban and interurban. The dimensions of the cylinder sleeves were twice measured using co-ordinate measuring machine UTA-1202 – first before the mount in the car, and second – after the 48 000 km mixed covered run. These results are represented in Tables 5-6.

3. RESULTS AND DISCUSSION

The examination of cylinder sleeves dimensions of ICE-1 put under wearing accelerated tests showed that the wearing in the area of U.D.C. of the first packing ring for the cylinder sleeves treated by surface plastic deformation, i.e. cylinder sleeves 2 and 4, was with 45-53 % less than the wearing of cylinder sleeves 1 and 3 treated by hone finishing. The mean values of the wearing of cylinder sleeves treated by hone finishing were 0.0058 mm and 0.0072 mm for sleeves 3 and 1, respectively. For the cylinder sleeves treated by surface plastic deformation the mean values of the wearing were 0.0033 mm and 0.0054 mm for sleeves 4 and 2, respectively. The surface layer formed after the surface plastic deformation treatment was probably more resistant to the predominant in this case corrosion-mechanical wearing. The dimensions of the cylinder sleeves after ICE-1 had worked in real medium showed that the wearing in the area of U.D.C. of the first packing ring for the cylinder sleeves treated by surface plastic deformation, i.e. cylinder sleeves 2 and 4, was with 36-47 % less than the wearing of cylinder sleeves 1 and 3 treated by hone finishing.

The examination of cylinder sleeves dimensions put in ICE-2 who had worked in real medium showed a different wearing behaviour in comparison with ICE-1. The wearing in the area of the first packaging ring for both kinds of finishing treatment was not dominant over the wearing in the other sections. A wearing maximum was observed sooner in the area of U.D.C. of the oil scraper piston ring as it was stressed for the cylinder sleeves treated by hone finishing. The maximum wearing values in that area for the cylinder sleeves 1 and 3 treated by surface plastic deformation was with 25-40 % less than that of the sleeves treated by hone finishing. The mean wearing values of the cylinder sleeves treated by hone finishing for ICE-2 were 0.0126 mm and 0.0083 mm for sleeves 2 and 4, respectively. For the cylinder sleeves

treated by surface plastic deformation the wearing was 0.0067 mm and 0.0059 mm for sleeves 1 and 3.

The carrying up of wearing accelerated tests in laboratory conditions possesses certain priorities over the operational tests, for example:

- continuous control of the engine status and working regimes;
- possibility for matching of testing regimes in order a certain kind of wearing to be dominant;
- reduction in the data dispersion;
- iteration of tests at keeping the given condition of working regimes.

Besides the discrepancies in the wearing behaviour of cylinder sleeves during wearing accelerated tests and working in real experimental medium the cylinder sleeves treated by surface plastic deformation showed better wearing resistance than those treated by hone finishing.

4. CONCLUSIONS

The carried out investigations and the obtained results allow the following conclusions to be done:

1. Experimentally by wearing accelerated tests of ICE-1 was found that the wearing of cylinder sleeves treated by surface plastic deformation was with 45-53 % less than the wearing of cylinder sleeves treated by hone finishing.

2. By operational tests of ICE-1 and ICE-2 was found that the wearing of cylinder sleeves treated by surface plastic deformation was with 25-47 % less than the wearing of cylinder sleeves treated by hone finishing.

3. A discrepancy in the wearing behaviour of cylinder sleeves was found at the conditions of wearing accelerated tests and working in real working medium.

4. Besides the discrepancies in the wearing behaviour the cylinder sleeves treated by surface plastic deformation showed better wear resistance than that of cylinder sleeves treated by hone finishing.

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