THE SPRING RESEARCH & MANUFACTURERS' ASSOCIATION

# THE EFFECT OF SHOT PEENING EXPOSURE TIME ON THE FATIGUE AND RELAXATION PROPERTIES OF LOW CR-V VALVE SPRINGS

by

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Report No. 319

NOVEMBER 1979

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## SUMMARY

The effect of shot peening exposure time on the fatigue and relaxation properties of springs coiled from 2.5 mm diameter Oteva 60 low Cr-V valve spring wire has been evaluated.

It was hoped that shorter peening times might give improved fatigue resistance without giving the increase in relaxation usually associated with shot peening.

However, peening for only 5 minutes, with S330 music wire shot, gave as large an increase in relaxation as 40 minutes exposure. On the credit side, the improvement in fatigue properties was equally rapid - the fatigue limit of 750 $N/mm^2$ for the unpeened springs being raised to 875 $N/mm^2$ after only 5 minutes peening, while 40 minutes exposure gave only a further 25 $N/mm^2$ rise to 900 $N/mm^2$.



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November 1979

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## 1. INTRODUCTION

Shot peening of springs improves their fatigue performance but has a deleterious effect on relaxation resistance. Several reports on the effect of shot peening on the fatigue properties of various materials have already been produced at SRAMA, but only one report(1) has dealt with the effect of peening on relaxation properties. In that report(1) the effect of shot size on relaxation resistance was investigated. The present work has concentrated on the effect of peening time on both relaxation and fatigue properties for compression springs coiled from Oteva 60 low Cr-V valve spring wire.

## 2. MATERIALS

Oteva 60 2.5 mm diameter oil tempered low Cr-V valve spring wire has been used for this project. The results of chemical analysis of the wire complied with the specified composition (Table I).

## 3. TENSILE AND TORSIONAL PROPERTIES

An Amsler vertical multi-range tensile testing machine was used to determine the tensile properties of the wire both in the as-received condition and after low temperature heat treatment (LTHT) at 400°C for 30 minutes(2) (Table II). In both cases the $R_m$ values lay ~~within~~ the specified range of 1720-1860 $N/mm^2$.

The corresponding torsional properties were determined using a Tinius-Olsen horizontal multi-range torsion testing machine (Table III).

## 4. SPRING DESIGN AND MANUFACTURE

Four hundred helical compression springs were coiled from the Oteva 60 wire to the design shown in Table IV.

After coiling, the springs were given a LTHT at 400°C for 30 minutes[2] and then end ground.

## 5. EXPERIMENTAL PROCEDURES AND RESULTS

### 5.1 Shot Peening

A group of eighty springs were shot peened for 40 minutes, with further groups of sixty springs being peened for 5, 10 and 20 minutes. The Almen A2 arc rises[3] corresponding to these peening times are shown in Fig. 1.

Ballast springs were used to make up the groups of Oteva springs to a typical load, for shot peening in a Tilghmann Wheelabrator 'Tumblast' machine using S330 music wire shot and a wheel speed of 37.5 Hz. After shot peening all springs were stress-relieved for 30 minutes at 225°C[4].

### 5.2 Relaxation Tests

Ten springs from each peened group plus ten unpeened springs were cold prestressed to solid 20 times before being relaxation tested for 168 hours at 150°C. For each group of ten springs, five were tested at an applied stress of 400 $N/mm^2$ and five at 800 $N/mm^2$.

Tests were carried out using the standard 'nut and bolt' assembly[5,6] to hold the springs at a fixed length. The test results are expressed in Fig. 1 as a function of peening time.

5.3 Fatigue Tests

All springs were cold prestressed to solid 20 times before being fatigue tested. The tests were carried out on a forced motion multiple station fatigue testing machine using a minimum applied stress of 100 N/mm$^2$. For the unpeened and 40 minute peened springs S/N curves were produced (Figs. 2 and 3 respectively), four springs being tested at each maximum applied stress level.

Eight springs from each group of springs were tested at a maximum applied stress of 900 N/mm$^2$ (i.e. the fatigue limit of the 40 minute peened springs). The results of these tests are expressed as a function of peening time in Fig. 4.

As some springs in each of the 5,10 and 20 minute peened groups broke during the 900 N/mm$^2$ tests, four springs from each group were tested at 875 N/mm$^2$. The results of these extra tests established this maximum applied stress as the fatigue limit for these three groups of springs (all twelve springs survived beyond $10^7$ cycles).

Dynamic relaxation measurements were made on all springs which survived beyond $10^7$ cycles, the mean value being ~ 4%. This value is too small to produce a significant error in the fatigue limit estimation .

## 6. DISCUSSION

The Almen A2 arc rise curve in Fig. 1 confirms the results of previous work on the variation of arc rise with peening time[1].

The relaxation vs peening time curves (Fig. 1) are somewhat similar in shape to the arc rise curve.

The initial increase in relaxation after 5 minutes peening (from 4.8% to 6.3% at 400 N/mm$^2$ stress and from 11.1% to 15.3% at 800 N/mm$^2$ stress)was followed by no further significant increase for the longer peening times.

The fatigue limit of 750 N/mm$^2$ for the unpeened springs was raised to 900 N/mm$^2$ after peening for 40 minutes (Figs. 2 and 3). However, tests at a maximum applied stress of 900 N/mm$^2$ on the other three groups of peened springs (Fig. 4) showed the fatigue limits to be slightly below 900 N/mm$^2$. Further tests confirmed the fatigue limits for these groups of springs to be 875 N/mm$^2$.

G.C. Bird's work(1) on the effect of shot size indicated that for optimum fatigue properties the shot size used should be ∿ 10% of the wire diameter. Therefore, for maximum fatigue life from shot peening of this 2.5 mm (0.098 in) diameter wire, S110 shot should have been used. However, the use of smaller size shot causes a smaller increase in relaxation and the effects of peening time on relaxation would have been less easily discernible.

Smaller shot gives better area coverage(3) than large shot but gives a smaller arc rise. Earlier work(3) into the effect of area coverage during peening as opposed to arc rise, indicated that even at a coverage as low as 30% a substantial increase in fatigue life can be obtained. The improvement in fatigue strength increases rapidly with coverage up to ∿80%. Above this point the rate of increase is reduced.

Obviously, with shot which is relatively large compared to the wire diameter quite a short exposure time will produce a large area of coverage giving a rapid increase in fatigue life. However, a much longer peening time would then be necessary to produce a further increase in coverage which would be large enough to increase this higher fatigue life significantly.

It appears, therefore, that there is no advantage in the form of improved relaxation to be gained from shortening shot peening times, and while even 5 minutes peening greatly improves fatigue resistance, more than 20 minutes peening is required for maximum effect.

## 7. CONCLUSIONS

1. Shot peening even for as short a time as 5 minutes produces a noticeable rise in relaxation. This rise is not significantly increased by peening for longer times i.e. up to 40 minutes.

2. The fatigue properties of the springs were considerably enhanced by shot peening even for 5 minutes, but for optimum improvement a peening time of greater than 20 minutes is necessary.

## 8. REFERENCES


1. Bird, G.C. "Shot peening and the effect of shot size on spring performance". SRAMA Report No. 267.

2. Hood, A.R. "The effect of the order of hot prestressing and shot peening on the fatigue and relaxation properties of low Cr-V valve springs". SRAMA Report No. 317.

3. "Shot Peening". Wheelabrator Corporation. 1962.

4. Bird, G.C. "The low temperature heat treatment of springs manufactured from patented cold drawn carbon steel wire". SRAMA Report No. 266.

5. Graves, G.B. "The stress-temperature relaxation properties of springs made from oil tempered and patented hard drawn wires". SRA Report No. 115.

6. Graves, G.B. "The stress-temperature relaxation and creep properties of some spring materials". SRA Report No. 143.

## TABLE I CHEMICAL COMPOSITION OF OTEVA 60 WIRE

| Element | C | Si | Mn | P | S | Cr | V |
|---|---|---|---|---|---|---|---|
| Specified % | 0.60-0.75 | 0.15-0.30 | 0.50 0.90 | 0.03 max | 0.025 max | 0.40-0.60 | 0.10 min |
| Actual % | 0.70 | 0.19 | 0.51 | 0.016 | 0.015 | 0.54 | 0.23 |

## TABLE II TENSILE PROPERTIES OF OTEVA 60 WIRE

| Material Condition | $R_m$ (N/mm$^2$) | $R_p$ 0.2 (N/mm$^2$) | $R_p$ 0.1 (N/mm$^2$) | $R_p$ 0.05 (N/mm$^2$) | L of P (N/mm$^2$) | Elongation (%) | Reduction in Area (%) |
|---|---|---|---|---|---|---|---|
| As-Received | 1775<br>1785 | 1705<br>1705 | 1685<br>1695 | 1635<br>1640 | 715<br>720 | 6.0<br>6.0 | 48.6<br>48.0 |
| 400°C for 30 minutes | 1755<br>1755 | 1695<br>1680 | 1680<br>1660 | 1610<br>1620 | 965<br>960 | 6.2<br>6.2 | 49.8<br>49.8 |

## TABLE III TORSIONAL PROPERTIES OF OTEVA 60 WIRE

| Condition | Torsional Proof Stresses (N/mm$^2$) | | | L of P (N/mm$^2$) | G (x $10^4$) (N/mm$^2$) |
|---|---|---|---|---|---|
| | 0.5% | 0.2% | 0.1% | | |
| As-Received | 1195<br>1220 | 1120<br>1135 | 1045<br>1060 | 765<br>765 | 7.9<br>7.8 |
| 400°C/½ hr | 1160<br>1210 | 1085<br>1125 | 1035<br>1070 | 855<br>860 | 7.9<br>7.8 |

TABLE IV SPRING DESIGN

| Spring Parameter | Magnitude |
|---|---|
| Wire Diameter (mm) | 2.51 |
| Mean Coil Diameter (mm) | 22.0 |
| Total Coils | 5.5 |
| Active Coils | 3.5 |
| Free Length after grinding, LTHT and prestressing (mm) | 42.9 |
| Solid Stress ($N/mm^2$) | 1245 |
| Rm (as-received) $N/mm^2$) | 1780 |

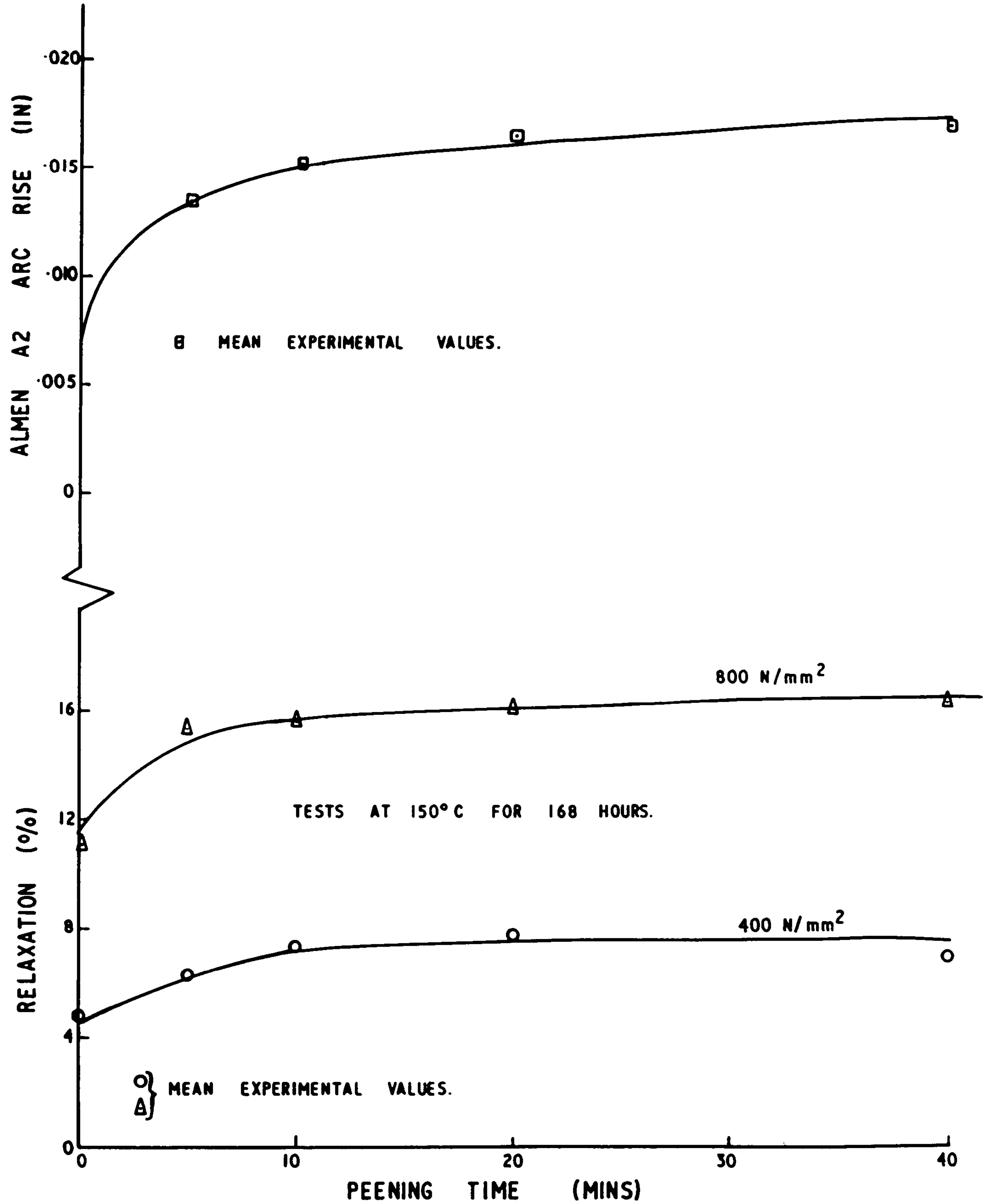


FIG. 1. VARIATION OF RELAXATION AND ALMEN ARC RISE WITH PEENING TIME.

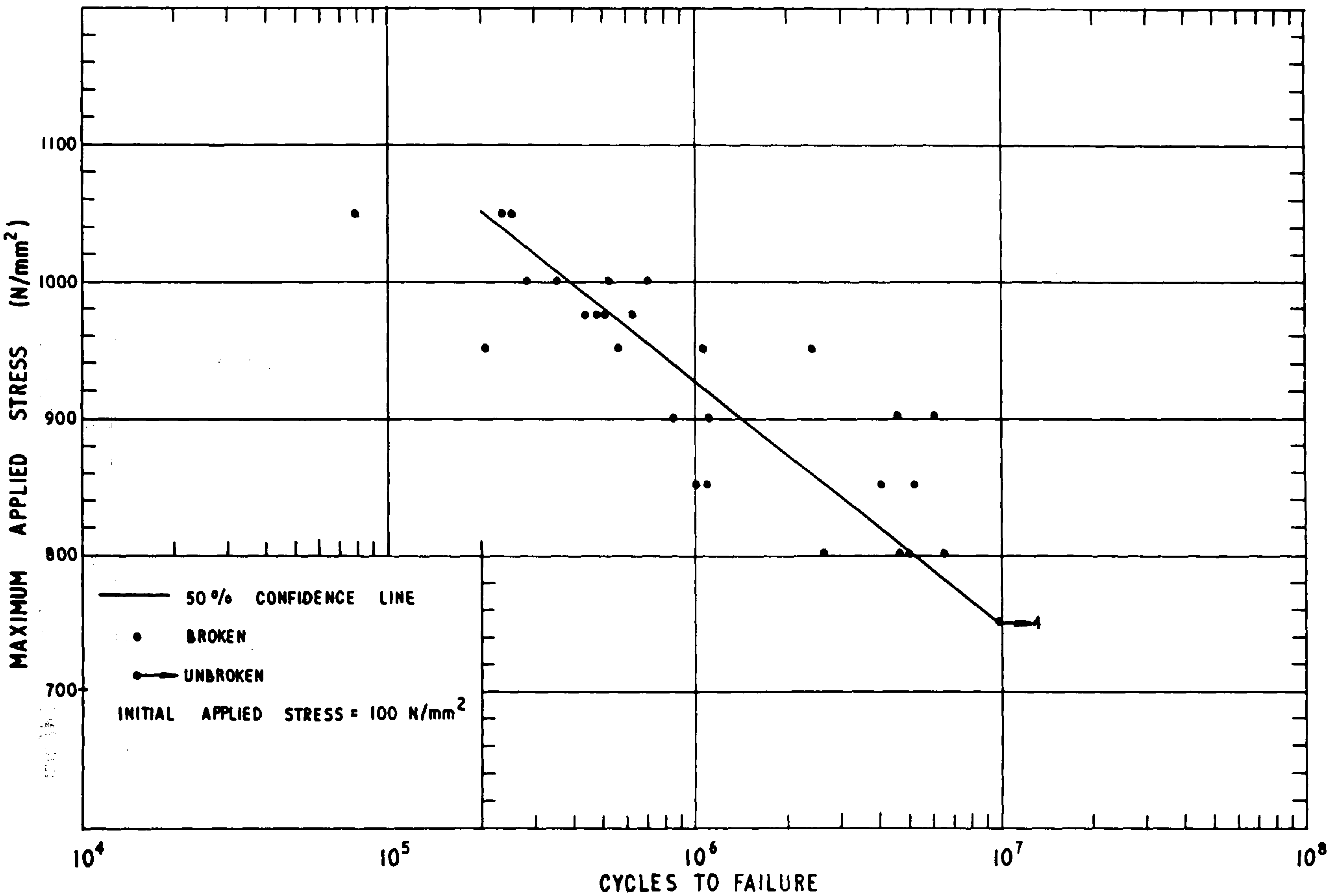


FIG. 2. S/N CURVE FOR UNPEENED OTEVA 60 SPRINGS.

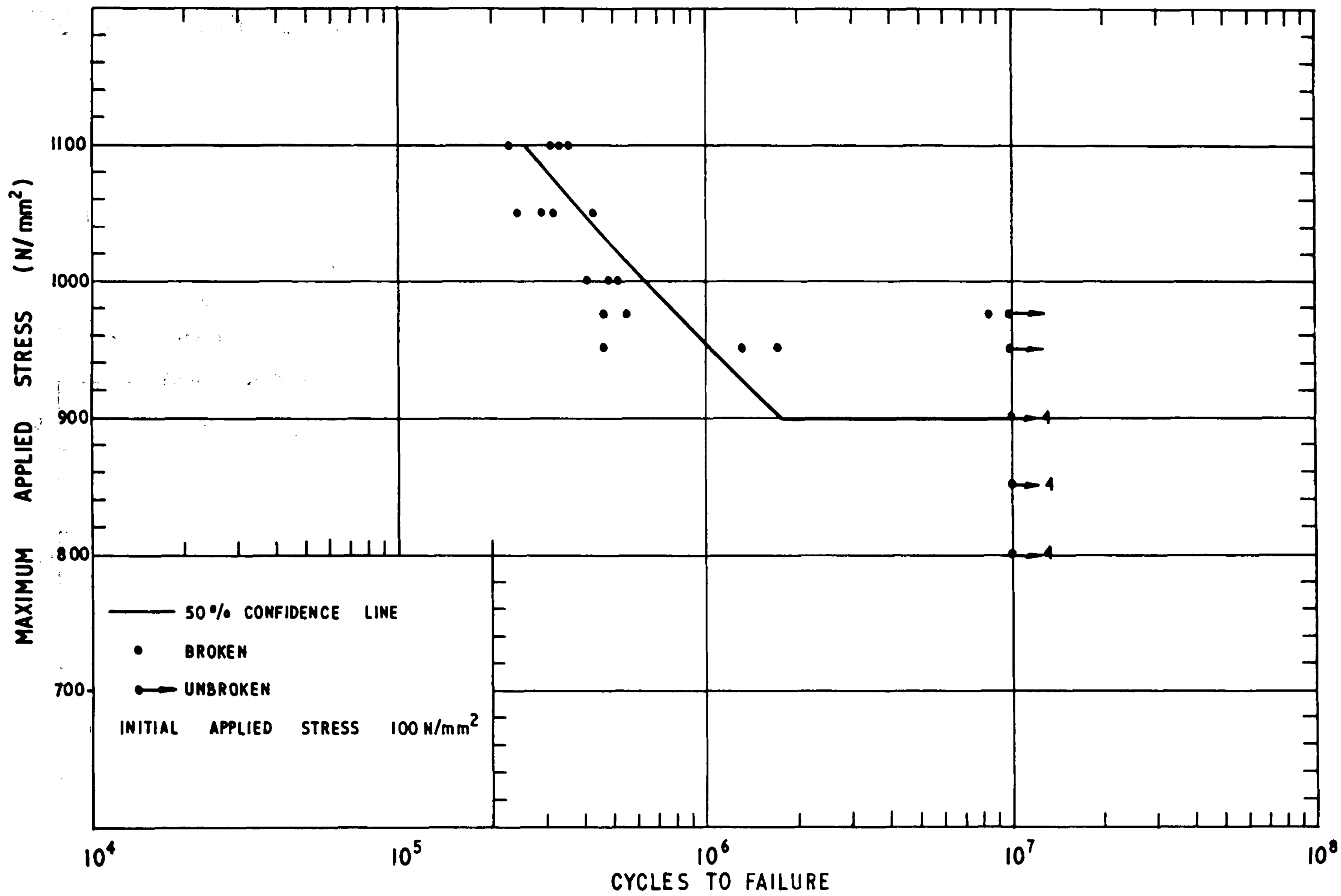


FIG. 3 S/N CURVE FOR OTEVA 60 SPRINGS SHOT PEENED FOR 40 MINUTES.

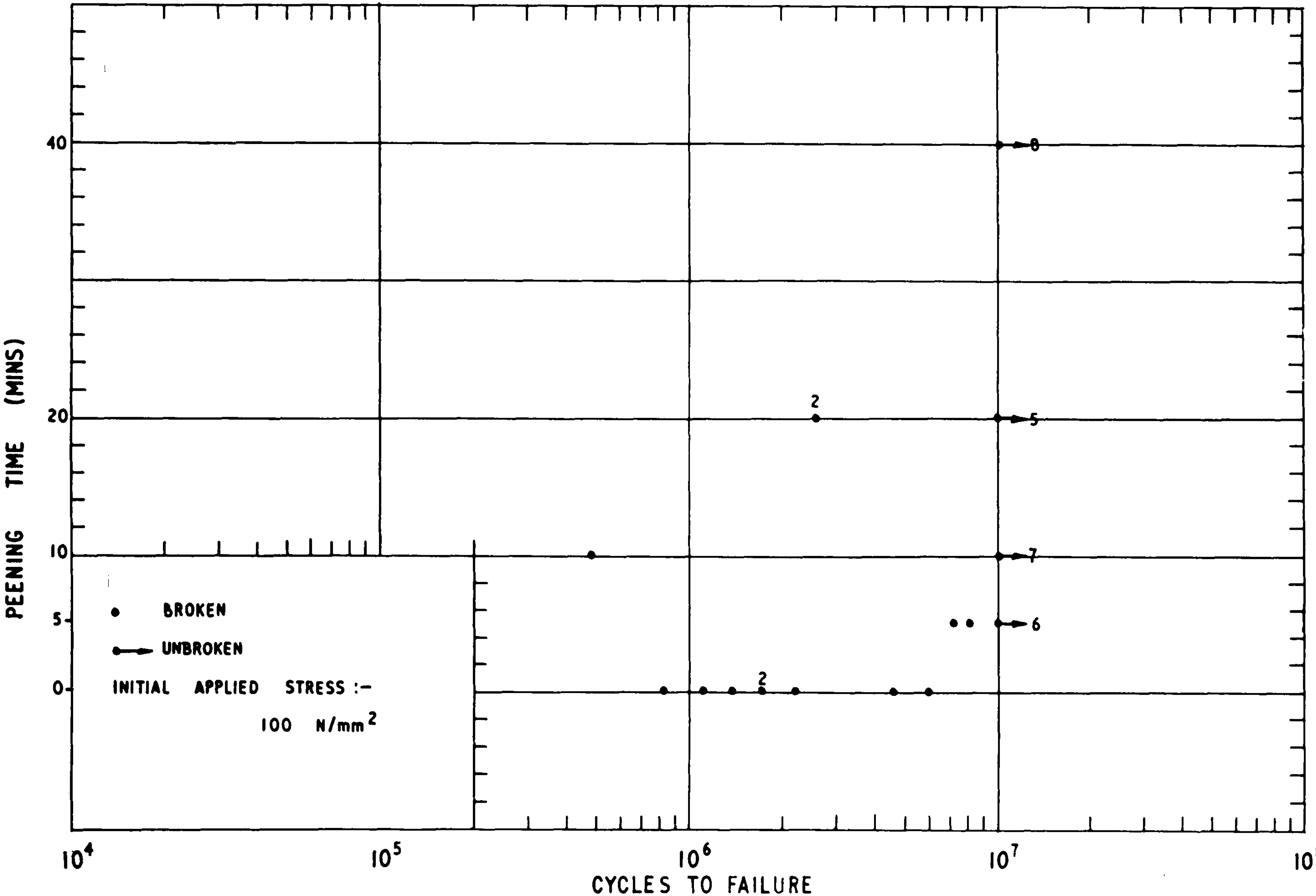


FIG. 4. EFFECT OF PEENING TIME ON FATIGUE LIFE AT A MAXIMUM APPLIED STRESS OF 900 $N/mm^2$