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Interim-report on low cycle fatigue investigations with ship structural components made of higher strength steel.

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Report no. **SSL 178**

INTERIM-REPORT ON LOW CYCLE FATIGUE INVESTIGATIONS WITH SHIP STRUCTURAL COMPONENTS MADE OF HIGHER STRENGTH STEEL

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Interim-report of Dutch part in the - EGKS program 6210-55/2/162 - of the Committee "Fatigue et Construction Type".

Prepared for the meeting at Liege in October 1973.

1. Introduction.

This second interim-report is restricted to the progress since May 1973 of the low-cycle fatigue investigation at Delft on ship structural components made of higher strength steel, corresponding to the EGKS-program 6210-55/2/162.

As already mentioned in the first interim-report /1/ the investigation has not been limited to the original program /2/ of low-cycle fatigue but also the influence of low temperature upon fatigue and the possibility of brittle crack initiation have been included.
This of course meant a complication for the test procedures and caused time delay.

Regarding the total progress of the Dutch part of the investigation, the testing of the last specimen is expected to be finished at the end of October 1973.

With regard to the results as reported in the first interim-report, a further analysis of the crack surfaces was made. Together with the data of specimens 6, 7 and 8 these crack analyses led to the necessity of preparing a new diagram as presented in this report.

With respect to the investigations carried out in Belgium, France, Germany and Italy it was not possible to compare already these results in a more detailed way with the results of the full-scale test carried out in Delft, or to build them in by further analysis into the results of the full-scale specimens for a further theoretical compilation.

2. Test procedures.

The test procedures for specimens 1 to 5 are already given in report /1/.
For specimens 6, 7 and 8 the following data can be mentioned.
Specimen 6 was tested under a nominal fatigue stress of +1760/-880 kg/cm^2 at a temperature of -37°C. The testing was stopped when very large cracks

had developed. During the fatigue test, impact loading was generated after regular intervals of about 1000 load cycles. The impact loading was carried out with a dropweight of 45 kg at heights of 1,5 meter in such a way that the specimen was hit at the top of the bulkhead plate, just when in fatigue loading the amplitude reached a value of about 95% of maximum tensile load. In this way any critical point in view of brittle crack initiation due to sensitiveness to impact at low temperatures should be discovered.

The specimens 7 and 8 were tested at room temperature under a nominal fatigue stress of +810/-405 kg/cm^2 respectively +1260/-630 kg/cm^2. Specimen 7 was tested until the point that very large fatigue cracks had developed, while fatiguing of specimen 8 was finished when cracks had developed with estimated values of crack surfaces between 100 and 500 mm^2. After the fatigue test specimen 8 was loaded under axial tensile load of 600 ton (about 3500 kg/cm^2); no complete fracture occurred.

3. Test results.

The test results are given in the form of diagrams with Wöhler curves. In figure 1 and 2 the points of 0, 100 and 500 mm^2 crack area are presented for bottomplate and brackets. Looking for these points with their location as determined after a thorough analysis of crack surface and development of crack area it is clear that the differences in result between the specimen tested at low temperature and the specimen tested at room temperature have to be considered as significant. So two lines can be drawn for the different phases of the development of the crack area; one line for room temperature and one line for a temperature of about -37°C.
In figures 3 up to 8 the lines of 0, 100 and 500 mm^2 are compared for the earlier results of St. 42 at room temperature and the new-found lines for St. 52 at room temperature and at -37°C.

Comparing these lines of St. 52 for room temperature and temperatures of -37°C, we see that they are in good agreement with the results of earlier investigations as mentioned by Munse /3/. Extrapolating the data mentioned by Munse the decrease of the temperature from +20°C up to -37°C may effect an increase of the fatigue limit of 20-30%.

Comparing St. 42 and St. 52 under fatigue at the same temperature (room temperature) it can be stated that the results confirm the expectation that steels with higher yield point and ultimate strength would not behave much better under fatigue loading. In this way the results are in entire agreement with the conclusions of Committee 11 of the 5th International Ship Structures Congress /4/. These conclusions are based largely upon the investigation of Fisher and others /5/, who have conducted nearly 400 bending tests of welded beams with 3 grades of steel resulting in the conclusion that "structural steels with yield points between 250 and 700 N/mm² did not exhibit any significant difference in fatigue strength."

At first sight it may appear that there is some difference between the results of St. 52 and St. 42 for 0 mm² crack area.
It should be kept in mind that especially crack initiation is not easily definable and the determination of the initiation point is somewhat more arbitrary. Even with extrapolation of the curves of crack growth the initiation almost never can be determined with the same accuracy as can be done in the case of the propagation through the points of 100 and 500 mm².
Besides, differences in crack initiation between specimens of different steel will be caused by difference in welding details and imperfections of the weldment. In the same way there will exist more scatter in crack initiation for the same kind of specimen. However the lines of zero crack surface are in fact of no practicle value out of a viewpoint of strength.
But although the initiation in St. 52 seems to happen somewhat earlier, the behaviour during crack propagation seems to be somewhat better when looking for the lines of 100 and 500 mm². However the differences in behaviour are rather of practical interest.

With regard to the investigation in Belgium, France, Germany and Italy we must state, that a good comparation of the results could not be made up to now, partly due to the fact that not all the tests are finished and not all the results are available, partly due to a lack of time and to the fact that many results of the investigations of the other countries have to be adapted to another form of presentation before a comparison and total analysis will be possible. However, as far as a comparison could be made already the results are in very good agreement with each other. As well the results of France as reported in /6/ as the results of Germany reported in /7/ give the same conclusion; there is no significant difference between St. 52 and St. 42 in behaviour under fatigue loading.

References.

/1/ First interim-report of Dutch part in the - EGKS program 6210-55/2/162 - of the Committee "Fatigue et Construction Type".
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"Low cycle fatigue investigations with ship structural components made of higher strength steel".
Report no. 175, S.S.L. Delft, April 1973.

/2/ J.J.W. Nibbering:
"A program for low-cycle fatigue investigations with ship structural components made of higher strength steel".
Report no. 142a, S.S.L. Delft, March 1970.

/3/ "Fatigue of welded steel structures".
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Welding Research Council, New York, 1964.

/4/ 5th International Ship Structures Congress, September 1973 - Hamburg.
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/5/ J.W. Fisher, K.H. Frank, M.A. Hirt and B.M. McNamee:
"Effect of weldments on the fatigue strength of steel beams".
NCHRP Report no. 102, Highway Research Board, 1970.

/6/ "Compte-rendu d'essais de fatigue en traction ondulée et traction-compression d'éléments soudés en acier ordinaire et acier a

haute resistance".
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/7/ "Vergleichende Untersuchungen an gekerbten Proben aus Schiffbaustahl Gütegrad A und höherfestem Schiffbaustahl DH 36",
von H. Paetzold.
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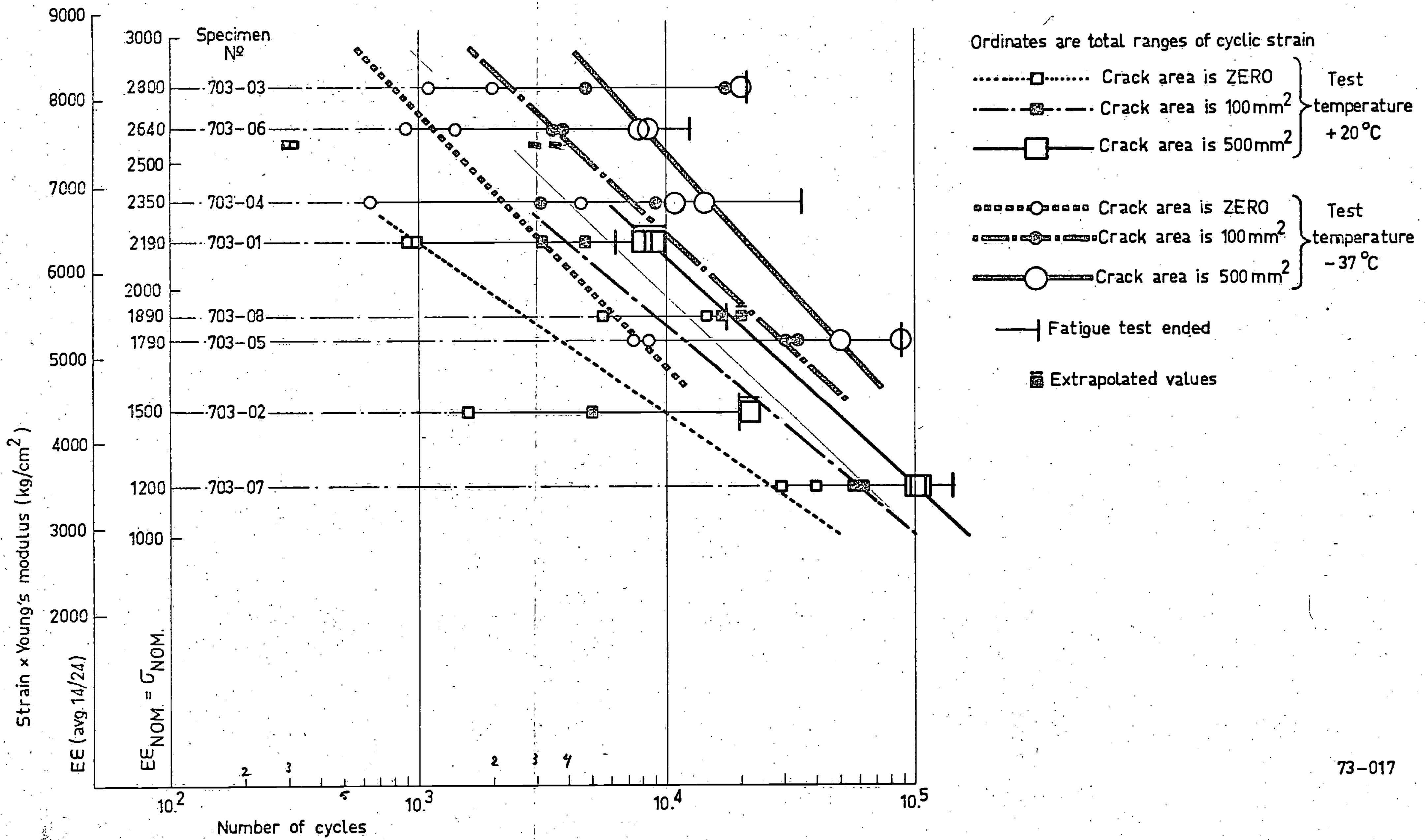

Fig. 1. Fatigue lines for brackets of H.S. steel.

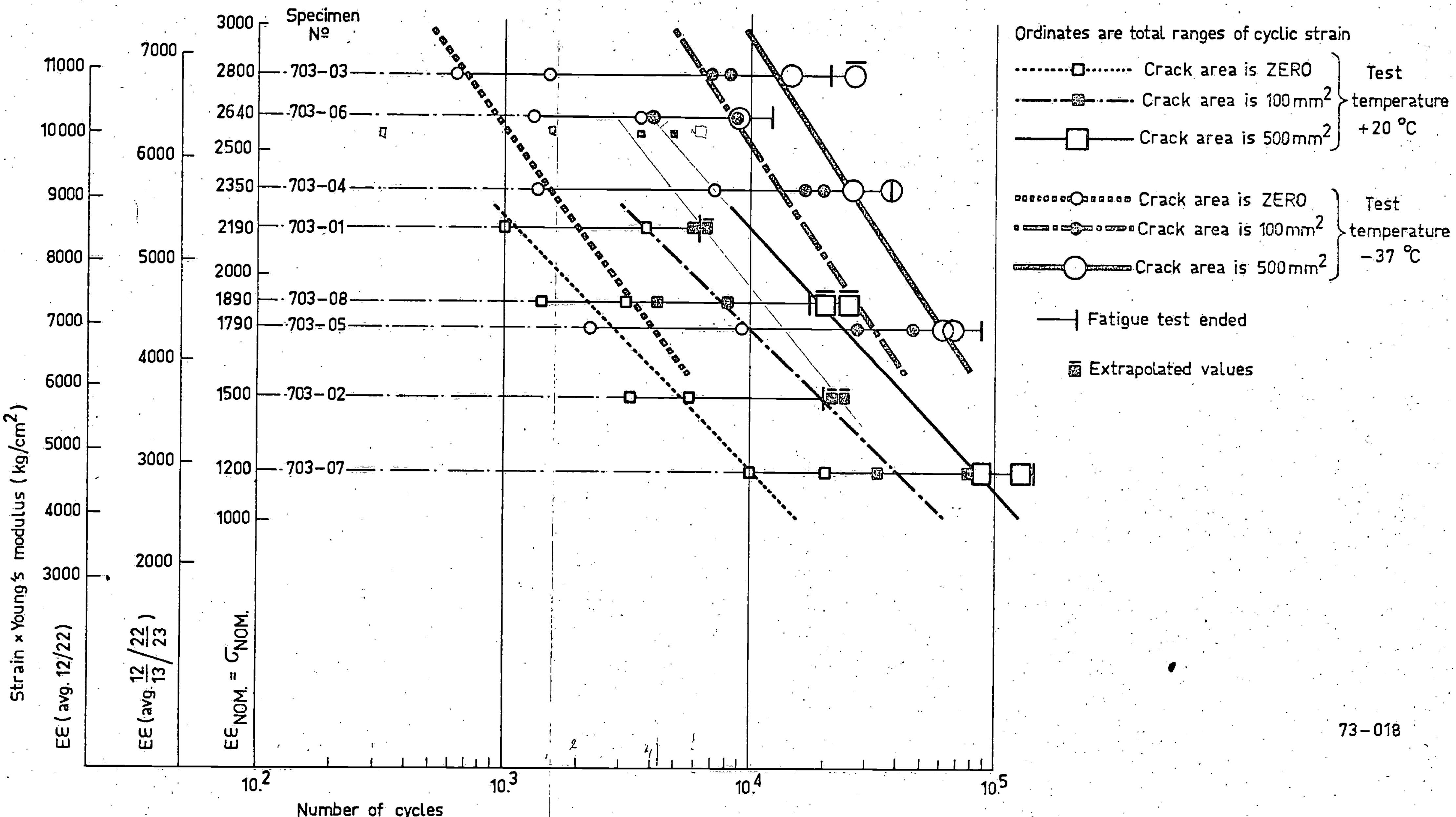

Fig. 2. Fatigue lines for bottom of H.S. steel.

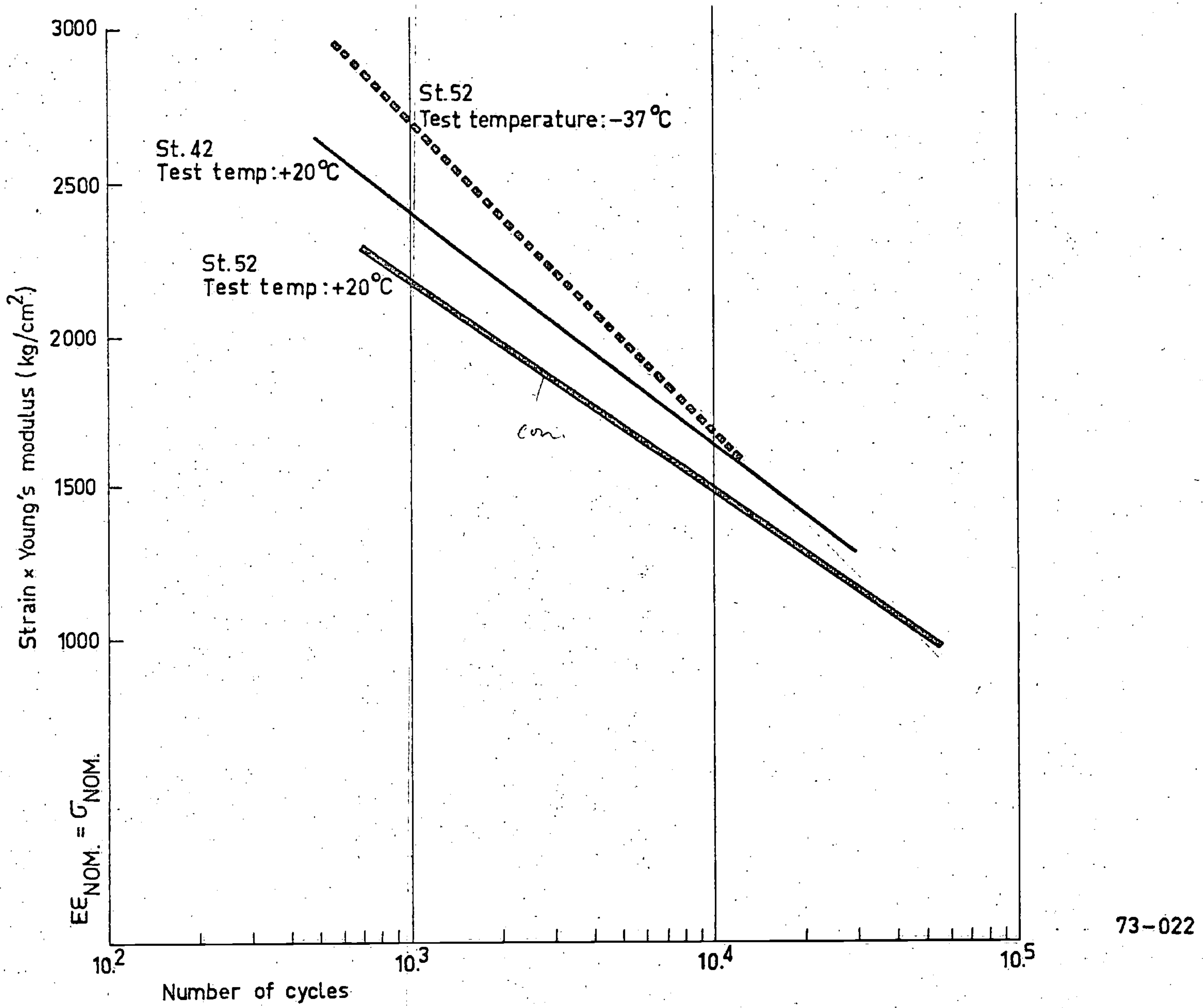

Fig. 3. Fatigue lines for bracket: crack area is 0 mm^2. Comparison of H.S. steel with mild steel.

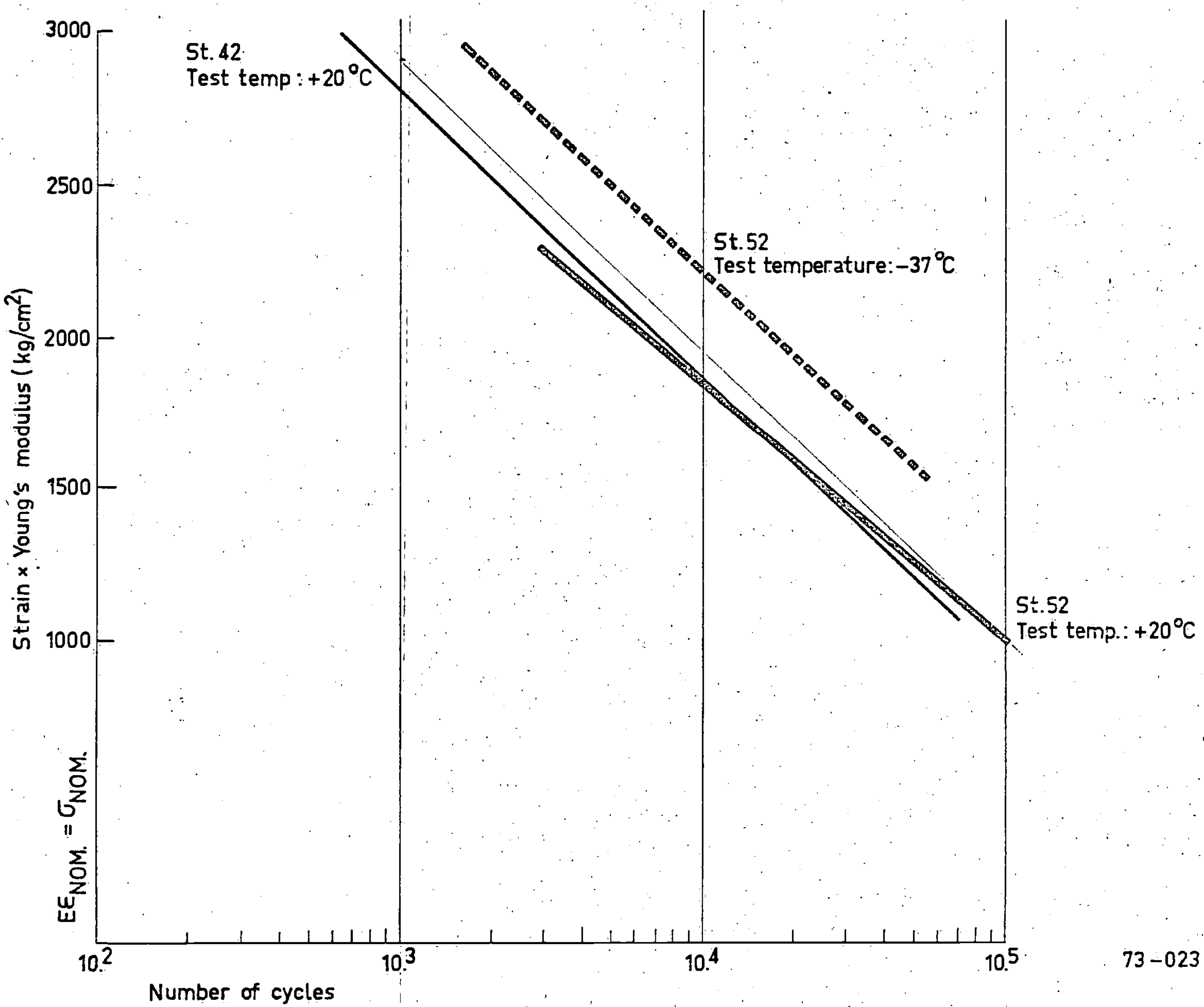

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Fig. 4. Fatigue lines for bracket: crack area is 100 mm². Comparison of H.S. steel with mild steel.

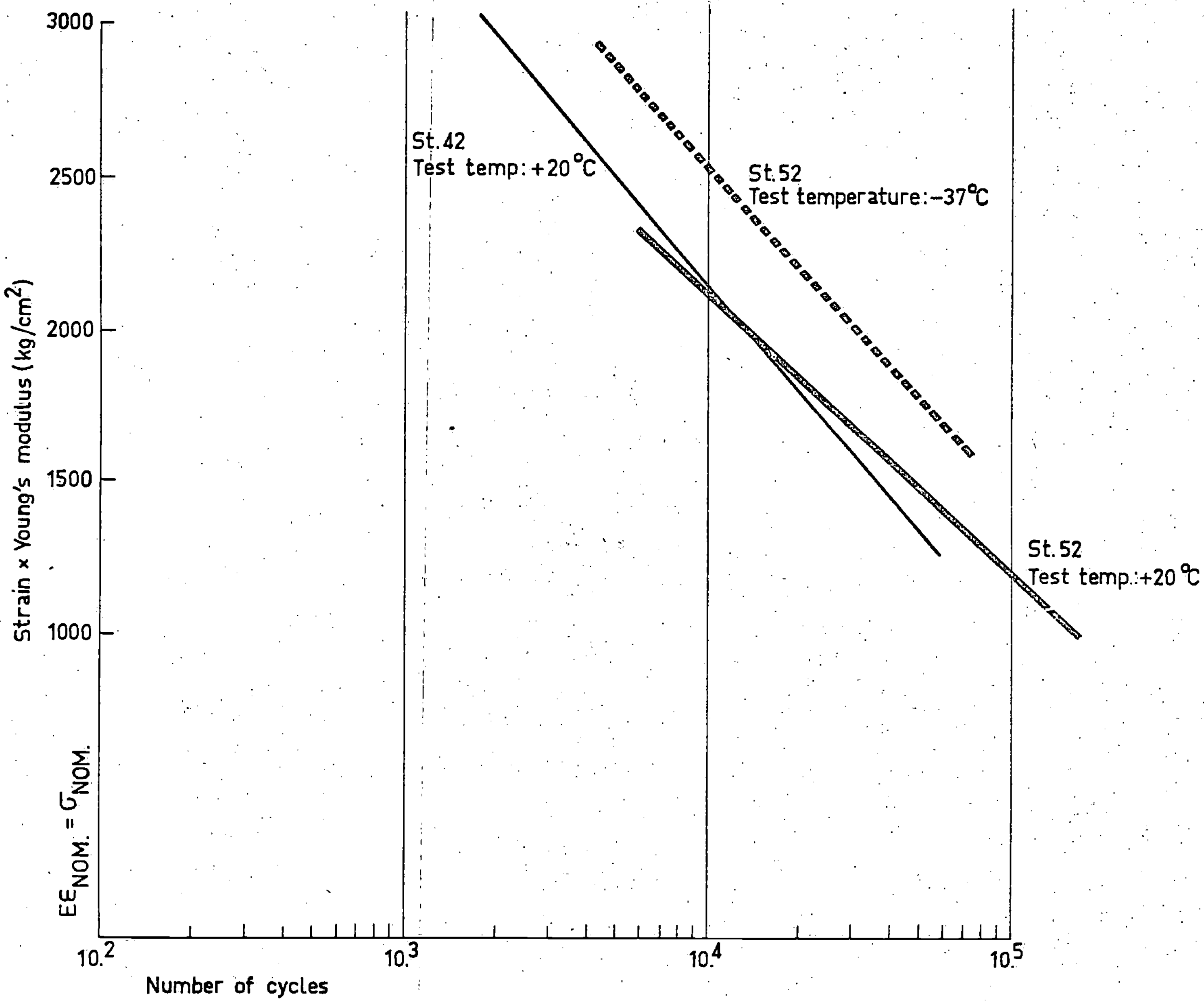

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Fig. 5. Fatigue lines for bracket: crack area is 500 mm^2.
Comparison of H.S. steel with mild steel.

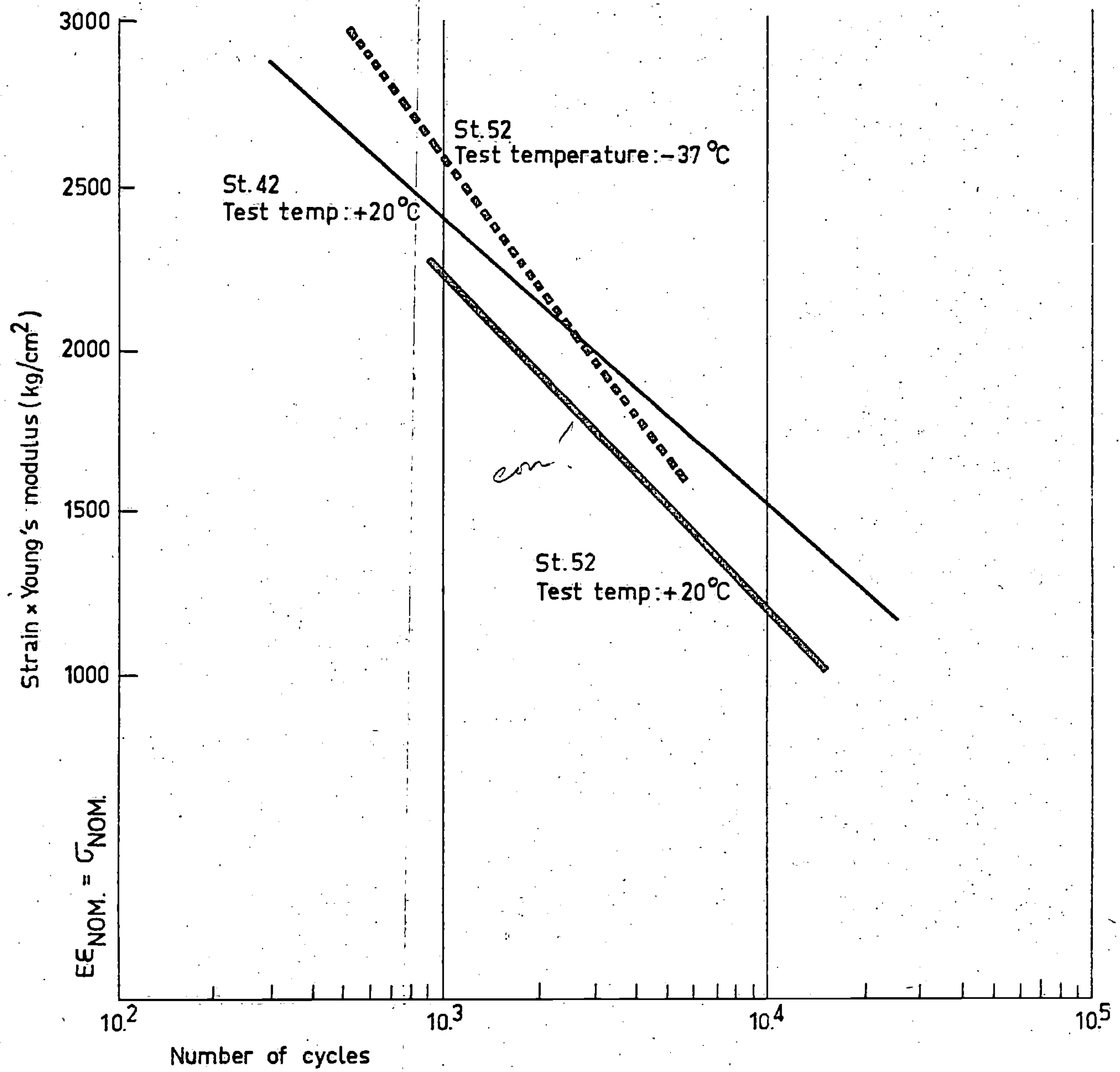

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Fig. 6. Fatigue lines for bottom: crack area is 0 mm².
Comparison of H.S. steel with mild steel.

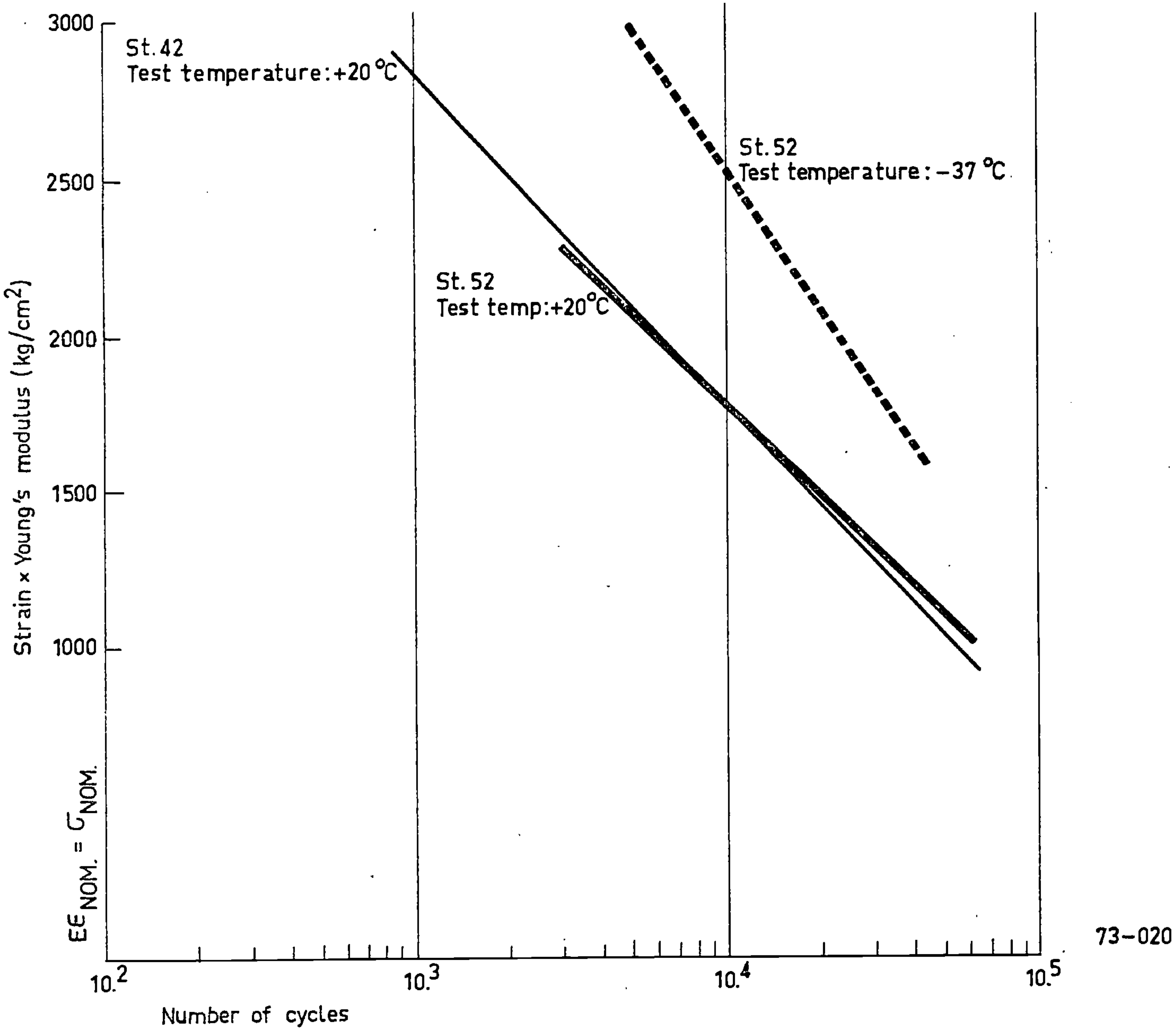

Fig. 7. Fatigue lines for bottom: crack area is 100 mm^2. Comparison of H.S. steel with mild steel.

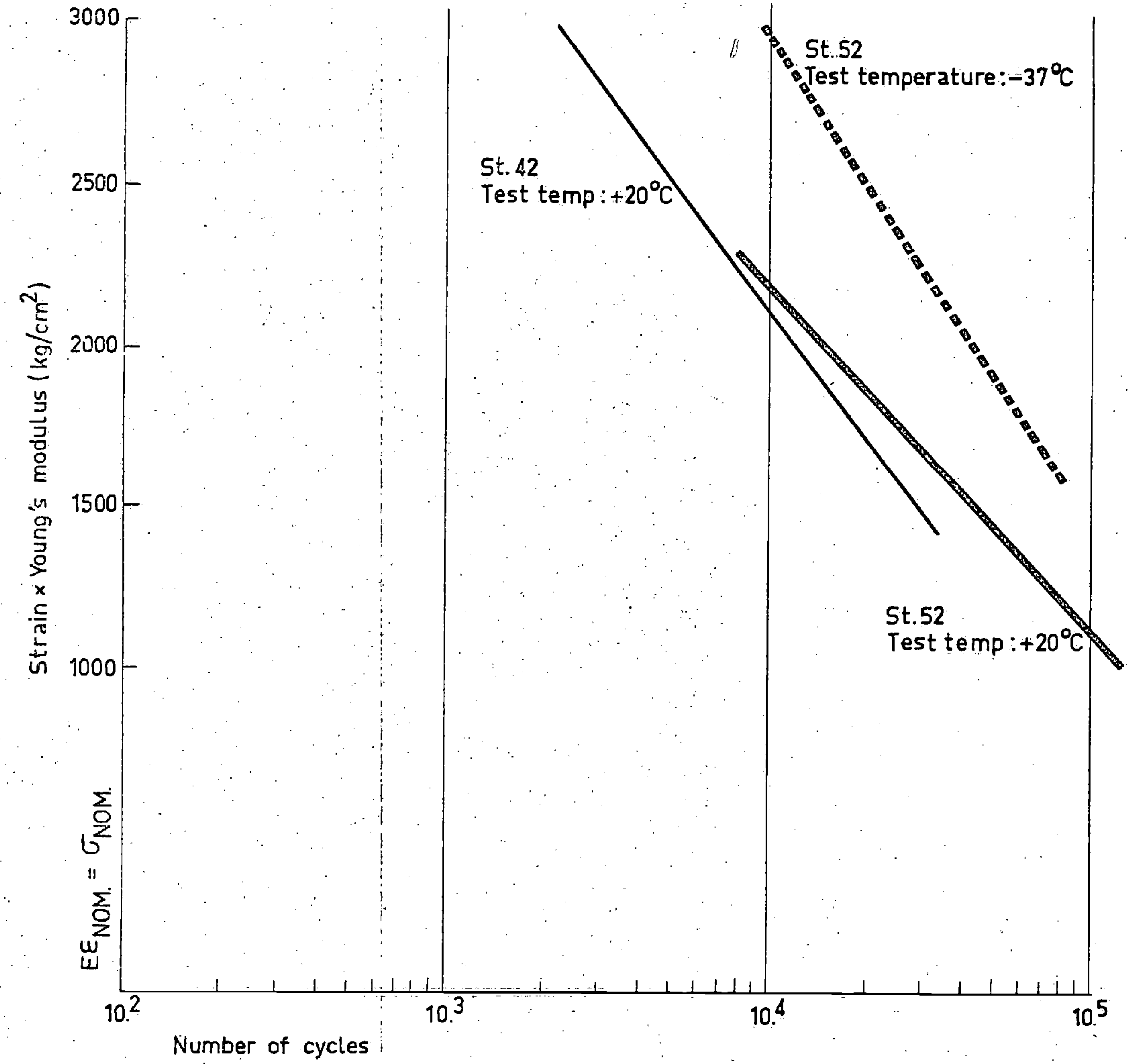

Fig. 8. Fatigue lines for bottom: crack area is 500 mm^2.
Comparison of H.S. steel with mild steel.

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