THE SPRING RESEARCH ASSOCIATION

THE TORSIONAL STRESS-STRAIN BEHAVIOUR OF FIVE HEAVY SPRING STEELS AT THREE DIFFERENT HARDNESS LEVELS

by

A. P. Owen, B.Met.

Report No. 220

November 1973

THE SPRING RESEARCH ASSOCIATION

Report No. 220

THE TORSIONAL STRESS-STRAIN BEHAVIOUR OF FIVE HEAVY SPRING STEELS AT THREE DIFFERENT HARDNESS LEVELS

SUMMARY

Static torsional data have been obtained for five common heavy spring steels viz: 250A58 (En 45A), 735A50 (En 47), En 48A, 527A60 (SAE 5160) and 805A60 (SAE 8660) in the hardness range 450 HV, 500 HV and 550 HV.

These data enable comparisons, of the torsional stress-strain behaviour, to be made for material heat treated to different hardness levels. At the particular bar size under investigation, for a given hardness, there was little difference in the torsional properties of the five qualities, increasing the hardness however did produce a noticeable lift in the elastic properties of all materials.

November 1973

CONTENTS

Report No. 220

THE TORSIONAL STRESS-STRAIN BEHAVIOUR OF FIVE HEAVY SPRING STEELS AT THREE DIFFERENT HARDNESS LEVELS

by

A. P. Owen, B. Met.

1. INTRODUCTION

The vast majority of round bar spring materials above 12mm in diameter are used as torsion bars or helical compression springs where the mode of stressing is one of torsion. Unfortunately, little torsional mechanical property data is available for these heavier section sizes although tensile stress-strain data for the commonly used spring materials can be found in a variety of metals data books, reference books, and material manufacturers catalogues.

The object of this investigation was therefore to provide data on the torsional stress-strain behaviour of spring materials and to enable comparisons to be made for different levels of hardness and quality. In addition, by consulting the stress-strain curves some indication of the amount of set (in terms of strain) to be experienced when prestressing straight torsion bars can be obtained.

2. MATERIAL

Each steel was obtained in the form of as rolled bar varying in diameter from approximately 25mm to 37mm. The five steels chosen for this work covered the majority of the material used in this country for torsion bar and hot coiled heavy springs and were, in order of testing, Silicon-Manganese spring steel 250A58 (En 45A), Chromium-Vanadium spring steel 735A50 (En 47), Silicon-Chromium spring steel (En 48A) and two American specification steels now incorporated in BS 970: Part 5: 1972 as Carbon-Chromium spring steel 527A60 (SAE 5160) and Nickel-Chromium-Molybdenum spring steel 805A60 (SAE 8660).

The 'as cast' specification chemical composition and the actual chemical analysis of each steel in bar form is shown in Table I.

3. EXPERIMENTAL PROCEDURE

3.1 Specimen Preparation

Each bar was cut into approximately 450mm lengths and flats were machined at each end to facilitate gripping in the torsion testing machine. With the waste material from each bar, small samples were cut for tempering studies.

Having selected suitable heat treatments, the bars were heat treated to give triplicate specimens at each of three hardnesses (450, 500 and 550 HV) for each material, making 45 specimens in all. The heat treatments chosen are shown in Table II together with the hardness and quality of the material.

The bars were then cleaned and their diameters individually measured.

3.2 Torsion Testing

The bars were tested on an Avery torsion testing machine capable of torques up to 13.55 Nmm (120 000 lb in) and the angular strain was measured by a Torsiometer which by means of locating pins at each end, marked out a standard gauge length of 152mm.

The experimental data obtained for each specimen was converted to shear stress using the equation:

$$\text{Shear Stress} = \frac{16T}{\pi d^3}$$

where T is the torque and d the bar diameter and the angular deflection was converted to shear strain using the equation:

$$\text{Shear Strain} = \frac{\theta r}{L}$$

where θ is the angular deflection in radians, r is the radius of the bar and L is the gauge length.

From this information 15 stress/strain curves were constructed and a comparison between the results for different hardnesses and different materials was made graphically in Figures 1 - 8.

4. DISCUSSION

Figures 1 - 5 show how, for each material, the limit of proportionality is raised with corresponding increases in hardness and Figures 6, 7, and 8 present the same data in such a way as to compare the performance of each material at the same hardness level.

It will be seen that some curves terminate earlier than others but it must not be assumed that this is any indication of the maximum shear stress the materials are capable of withstanding. To economise on specimen preparation the only machining undertaken on the round bar was to provide flats at the extreme ends to facilitate gripping.

Using a torsiometer to measure strain 'end effects' were eliminated and the relationships between stress and strain, shown in the curves, completely reliable. However, due to the reduction of the cross sectional area at the ends of the bar, ultimate failure occurred at this position after varying amounts of indicated strain depending on the amount of material removed to form the flat.

The data are shown in tabular form in Table III so that comparing this with, say, Figure 3 it can be seen that the limit of proportionality of En 48A increases from 746 M/mm^2 at 450 HV to 850 N/mm^2 at 500 HV and further to 940 N/mm^2 at 550 HV. The proof stresses also increase accordingly although not always proportionally.

It must be remembered that each figure in Table III and each curve in figures 1 - 8 represents the average of three tests and the variation within each set of three tests was extremely small.

In general the higher the limit of proportionality (elastic limit), the better is the material suited for a spring application, however when proof stresses are available, as in this case, a more accurate picture is given particularly in regard to a material's suitability for a torsion bar or helical spring - since the whole shape of the curve will determine such important factors as set down on pre-stressing.

5. CONCLUSIONS

1. The variation in torsional properties of each material at one particular hardness level was not as great as the difference obtainable by varying the hardness of one particular material.

Therefore, in many instances it may be more convenient to increase the hardness of the existing material to obtain better torsional properties than to change to another material.

2. On the whole, the Si-Mn steel 250A58 (En 45) gave the best results and the Ni-Cr-Mo steel, 805A60, the poorest.

6. ACKNOWLEDGEMENTS

The author wishes to thank the West Bromwich Spring Co. Ltd., West Bromwich, The Tempered Spring Co. Ltd., Sheffield, and Geo. Turton Platts & Co. Ltd., Sheffield for their assistance with material for this programme of work.

TABLE I   CHEMICAL COMPOSITIONS OF STEELS USED

STEEL GRADE	FORMERLY KNOWN AS	C %	Si %	Mn %	S %	P %	Ni %	Cr %	Mo %	V %
250A58	En 45A	0.58 0.55-0.62	1.82 1.7-2.10	0.88 0.7-1.0	0.044 0.05 Max	0.031 0.05 Max	0.17 -	0.11 -	- -	- -
735A50	En 47	0.45 0.46-0.54	0.22 0.10-0.35	0.74 0.6-0.9	0.011 0.05 Max	0.015 0.04 Max	0.16 -	0.94 0.8-1.1	- -	0.17 0.15 Max
En 48A	En 48A	0.57 0.50-0.60	1.60 1.35-1.6[illegible]	0.74 0.6-0.9	0.033 0.05 Max	0.010 0.05 Max	- -	0.75 0.55-0.85	- -	- -
527A60	SAE 5160	0.60 0.55-0.65	0.26 0.10-0.35	0.87 0.75-1.0	0.030 0.04 Max	0.022 0.04 Max	0.22 -	0.87 0.60-0.90	0.06 -	- -
805A60	SAE 8660	0.60 0.55-0.65	0.31 0.10-0.35	0.88 0.70-1.00	0.024 0.04 Max	0.026 0.04 Max	0.59 0.04-0.70	0.53 0.40-0.60	0.19 0.15-0.25	- -

TABLE II HEAT TREATMENT DATA

STEEL GRADE	BAR DIAMETER mm	HARDNESS HV	HEAT TREATMENT
250A58	24.6	450	O.Q 900°C Temper 1 hr 460°C
	24.6	500	O.Q 900°C Temper 1 hr 430°C
	24.6	550	O.Q 900°C Temper 1 hr 405°C
735A50	33.0	450	O.Q 880°C Temper 1 hr 455°C
	33.0	500	O.Q 880°C Temper 1 hr 380°C
	33.0	550	O.Q 880°C Temper 1 hr 310°C
En 48A	36.9	450	O.Q 870°C Temper 1 hr 520°C
	36.9	500	O.Q 870°C Temper 1 hr 465°C
	36.9	550	O.Q 870°C Temper 1 hr 425°C
527A60	26.9	450	O.Q 850°C Temper 1 hr 500°C
	26.9	500	O.Q 850°C Temper 1 hr 435°C
	26.9	550	O.Q 850°C Temper 1 hr 370°C
805A60	25.6	450	O.Q 880°C Temper 1 hr 515°C
	25.6	500	O.Q 880°C Temper 1 hr 450°C
	25.6	550	O.Q 880°C Temper 1 hr 390°C

TABLE III TORSIONAL DATA

(Average of 3 tests for each condition)

STEEL GRADE	HARDNESS HV	L of P N/mm^2	0.05% PS N/mm^2	0.1% PS N/mm^2	0.2% PS N/mm^2
250A58	450	736	816	850	888
	500	840	968	1032	1096
	550	864	1040	1124	1228
735A50	450	728	840	884	920
	500	850	968	1012	1048
	550	900	1000	1028	1056
En 48A	450	736	820	856	896
	500	800	944	992	1040
	550	940	1072	1112	1164
527A60	450	760	824	872	912
	500	840	952	988	1022
	550	1020	1080	1116	1156
805A60	450	664	732	772	784
	500	856	904	916	936
	550	940	1004	1050	1076

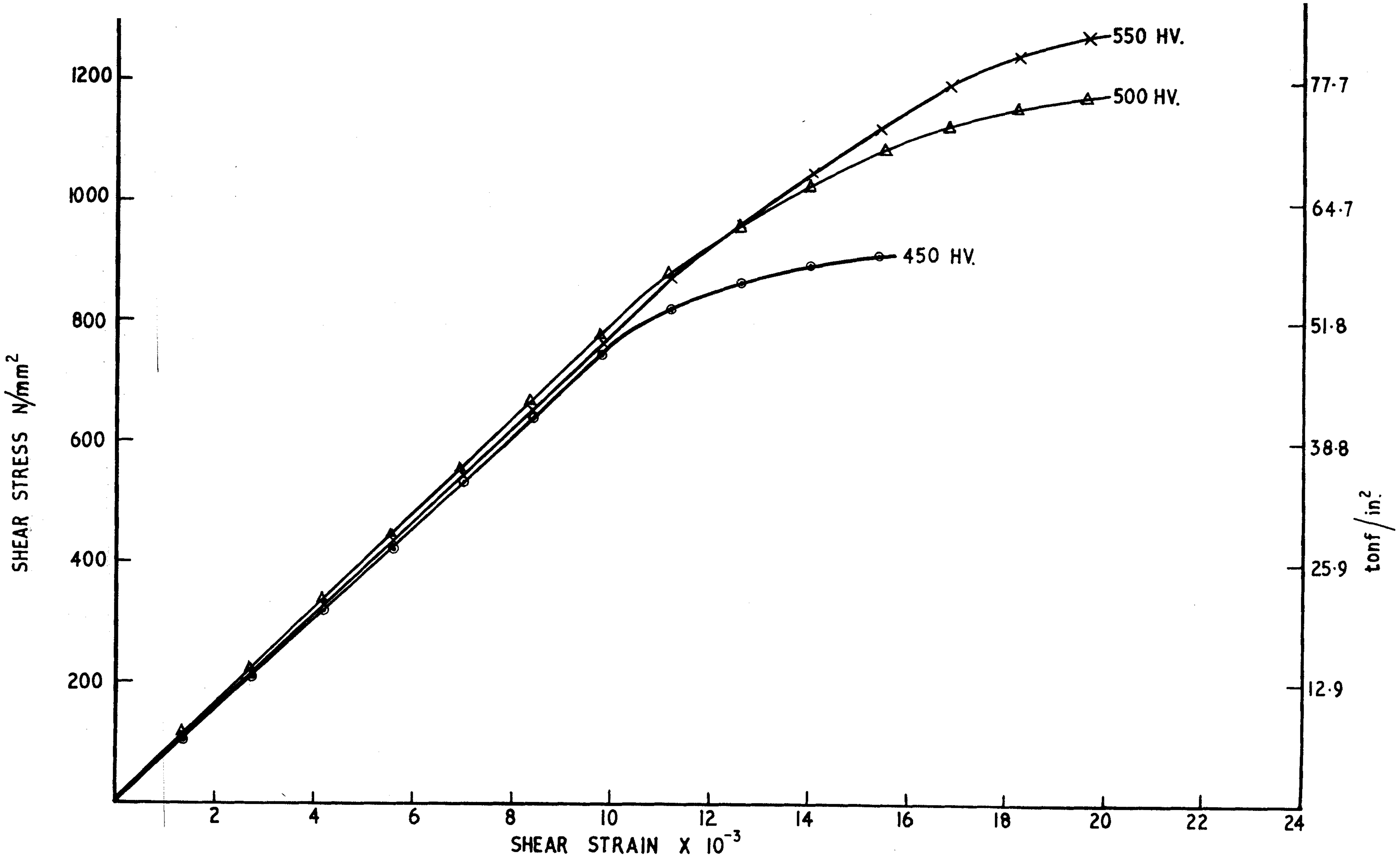

FIG. I STRESS/STRAIN DATA FOR En45A BAR

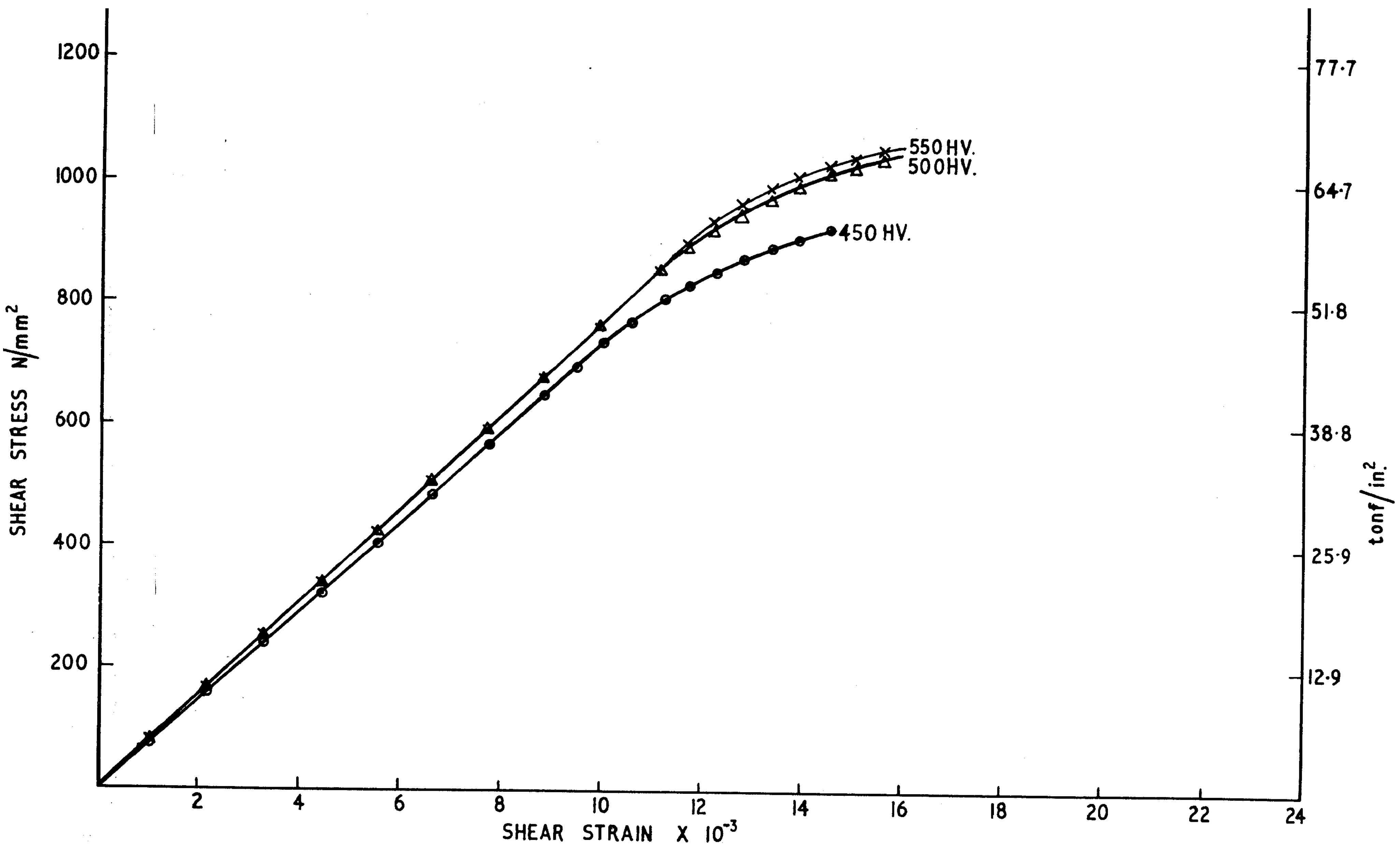

FIG. 2 STRESS/STRAIN DATA FOR En 47 BAR

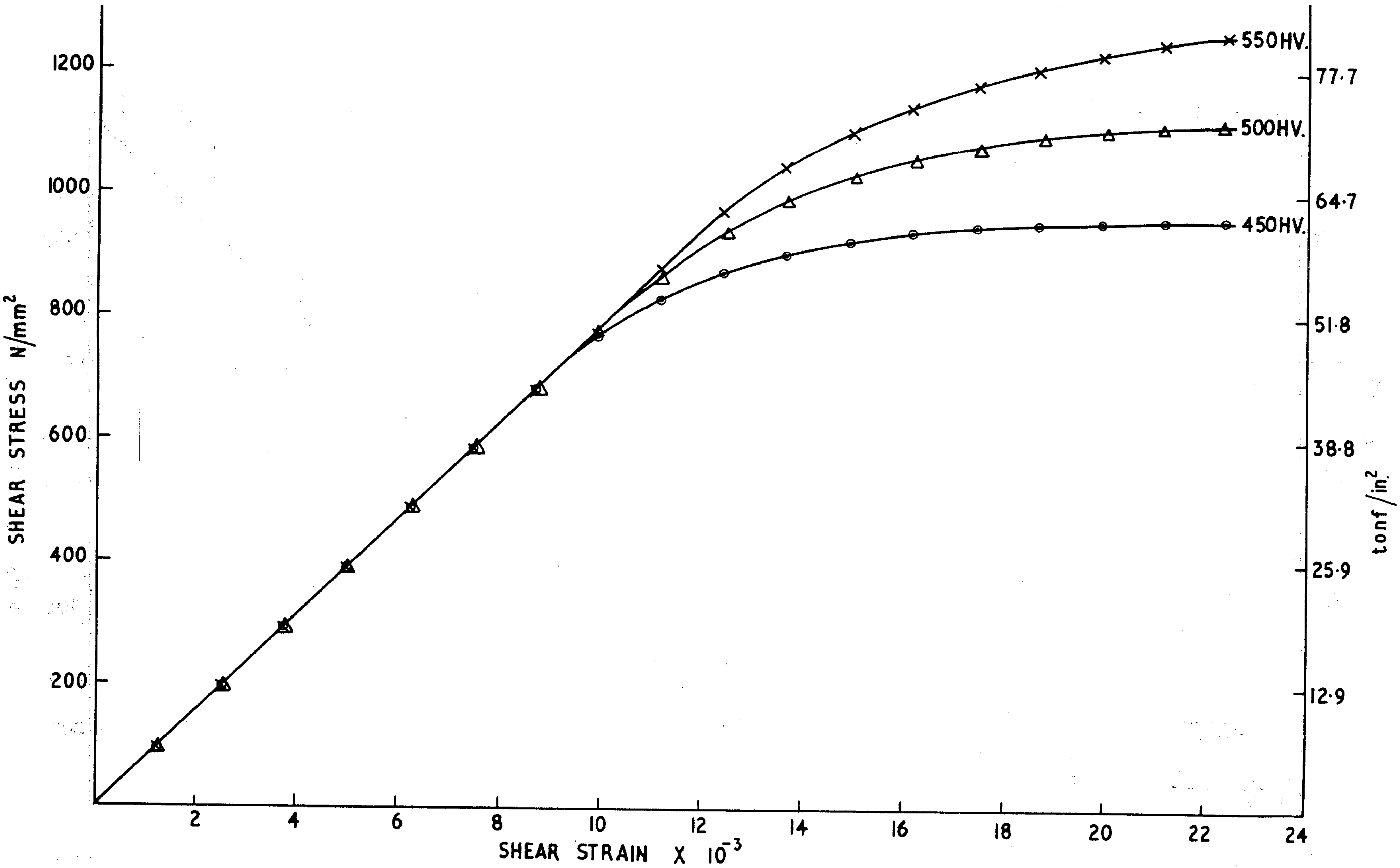

FIG.3 STRESS/STRAIN DATA FOR En 48A BAR

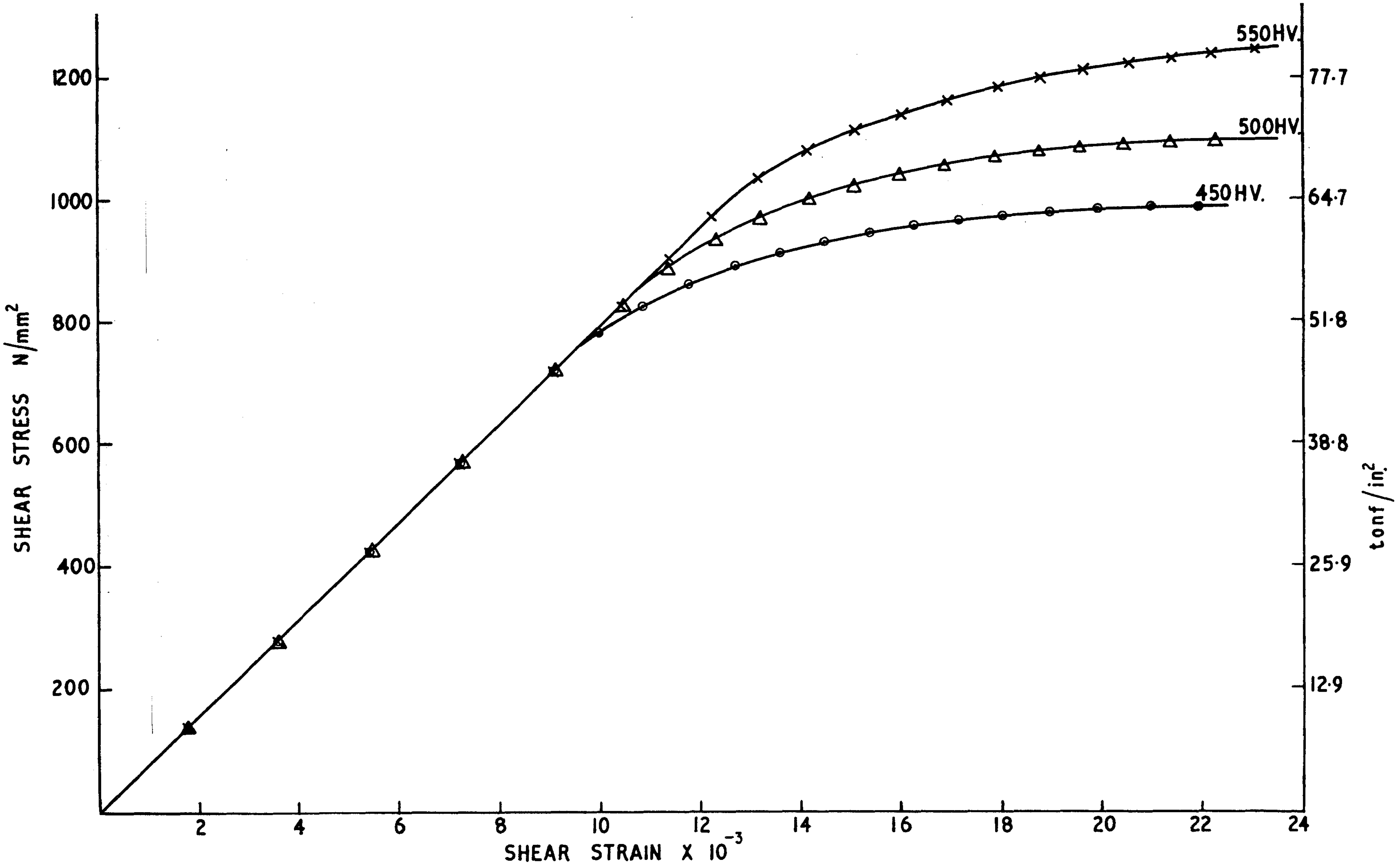

FIG. 4 STRESS/STRAIN DATA FOR SAE 5160 BAR

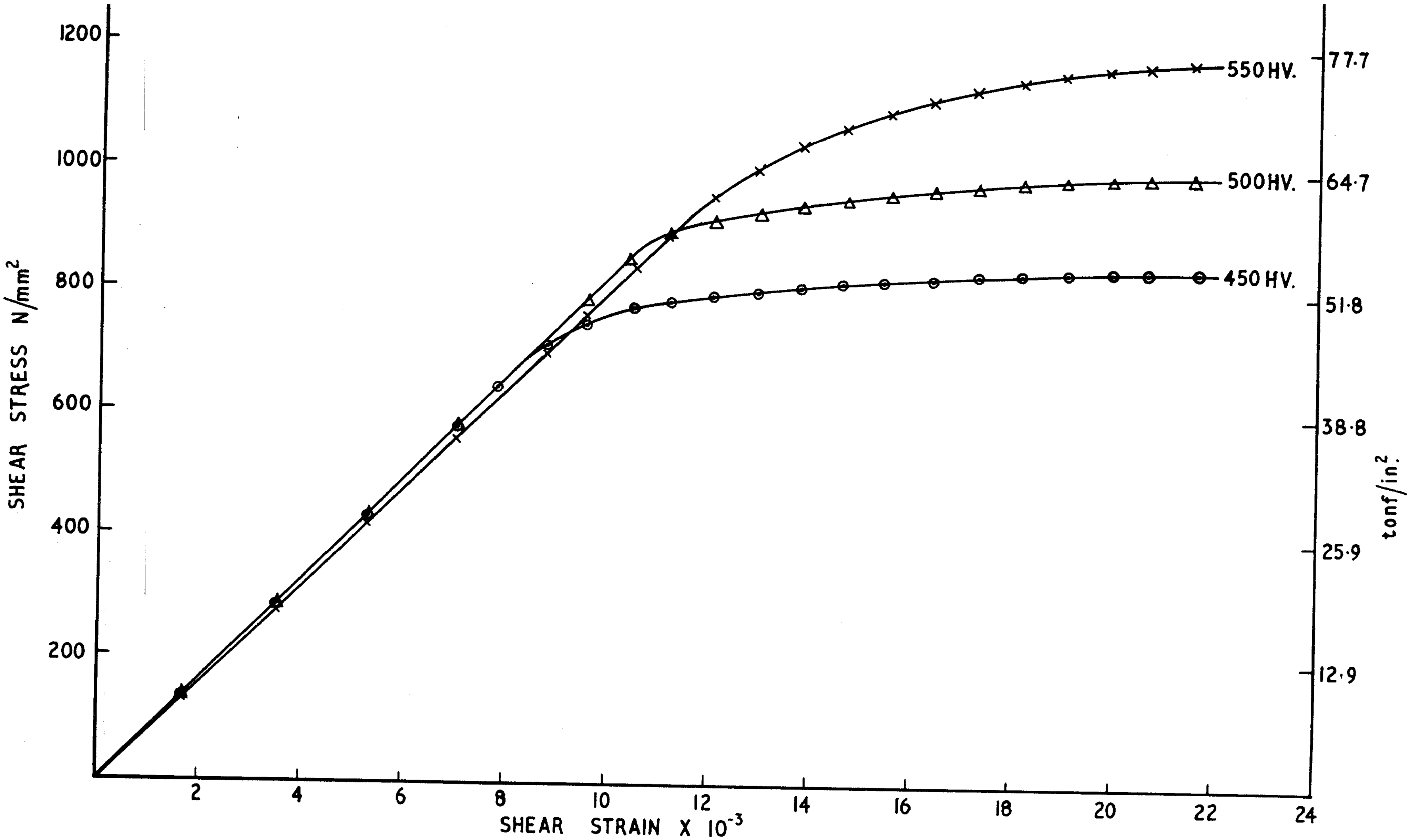

FIG. 5 STRESS/STRAIN DATA FOR SAE 8660 BAR

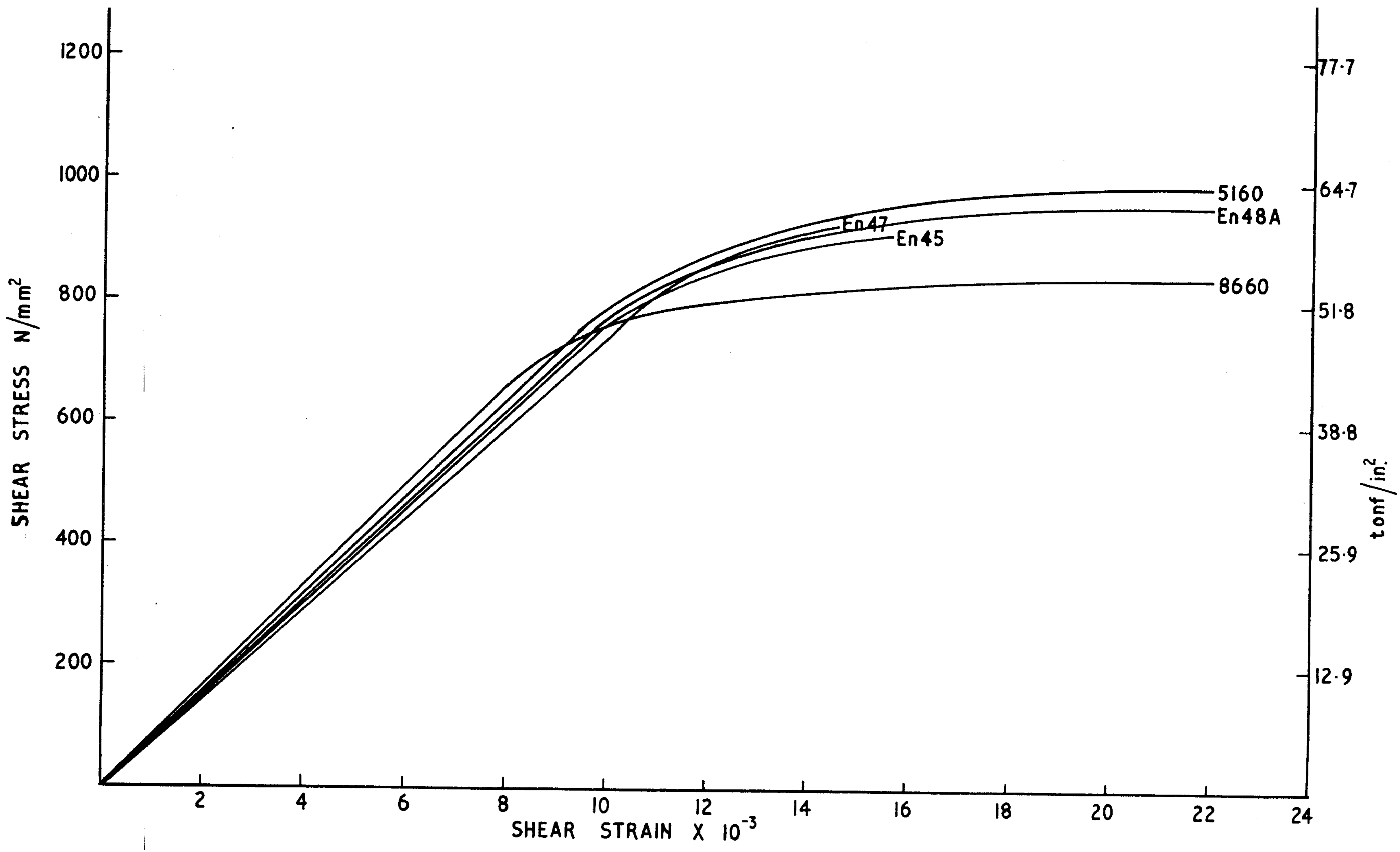

FIG. 6 STRESS/STRAIN CURVES FOR 450 HV.

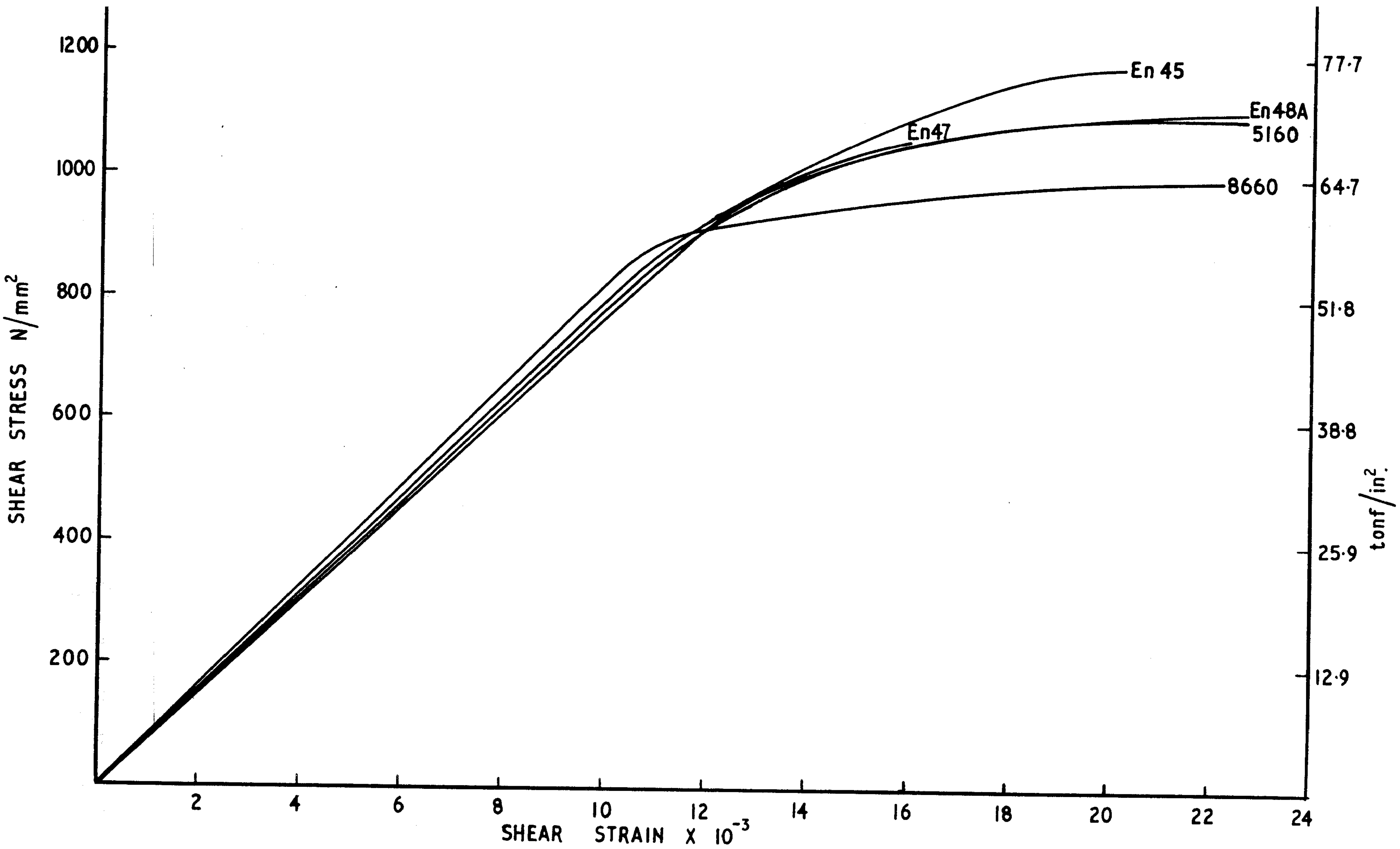

FIG. 7 STRESS/STRAIN CURVES FOR 500 HV.

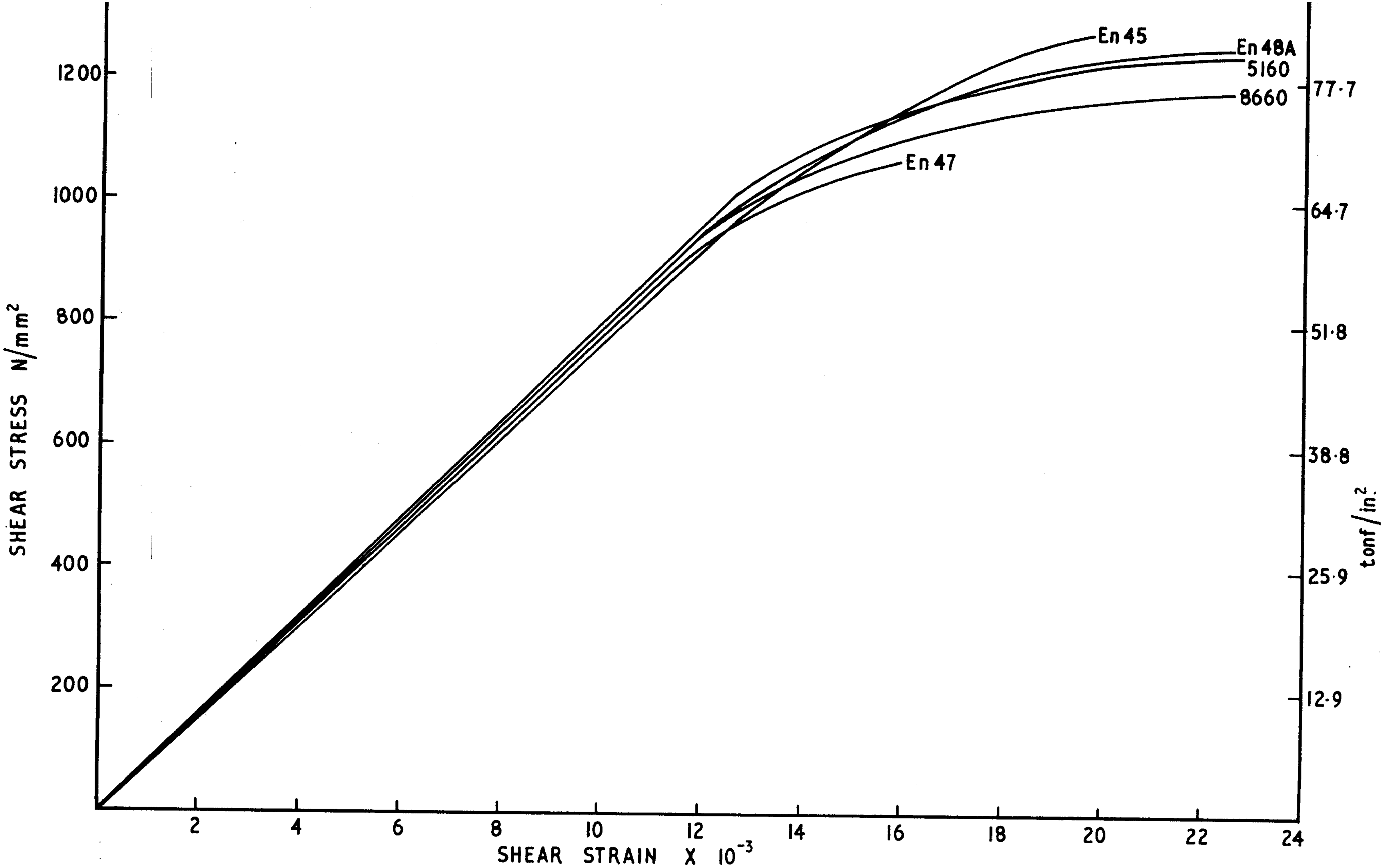

FIG. 8 STRESS/STRAIN CURVES FOR 550 HV.