THE SPRING RESEARCH ASSOCIATION

THE IMPACT TRANSITION PROPERTIES OF SPRING MATERIALS

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Report No. 199

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SUMMARY

Impact tests, using the Charpy V-notch method, have been carried out on a number of spring materials. Impact transition curves have been produced from -80°C to +200°C for the different materials and a comparison between the materials has been made.

V-notch specimens machined from En 45 material had by far the lowest impact strength of the six materials investigated, while En 47 quality exhibited superior impact properties at most temperatures.

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1. INTRODUCTION

Due to insufficient impact data being available particularly at sub-zero temperatures, a project was initiated by the Association to determine the impact transition curves of several typical spring materials. In addition to this, a number of grain size and hardness measurements were made to assist in further comparisons.

2. MATERIAL

The six materials which were examined are shown in Table I together with their analyses.

In the case of En 45, En 47 and SAE 8660, the standard Charpy test pieces were machined from 9/16 in square bar and in the case of En 48A (H) (high hardness) and SAE 5160, from 5/8 in diameter bar. Each specimen was given a heat treatment typical of its group and these details are shown in Table II.

3. EXPERIMENTAL PROCEDURE

3.1 Impact Testing

For each quality, two impact tests were carried out at each of ten temperatures from -80°C to +200°C and the results listed in tabular form.

3.2 Grain Size and Hardness Tests

Confirmatory hardness tests were made on a number of broken specimens taken from the room temperature tests.

A room temperature tested specimen for each quality was mounted and polished so that grain size analysis could be carried out using a suitable etchant.

The hardness and grain size values thus obtained were noted and appear in Table II.

4. RESULTS

All the results obtained from the impact testing appear in Table III. These are represented in the form of impact transition curves in Fig. 1, where the values for a particular temperature and quality have been averaged.

Table I shows the composition of each quality of steel used and Table II gives the relevant heat treatment, hardness, and grain size data.

Table IV gives the transition temperatures calculated for each material from the curves in Fig. 1.

5. DISCUSSION

Notched-bar impact tests are used to determine the tendency of a material to behave in a brittle manner. The more brittle the material, the less energy will the material absorb on impact. Information obtained from impact testing complements data obtained from tensile and fatigue testing. The curves in Fig. 1 are typical of impact transition curves and it can be seen that the energy absorbed decreases with decreasing temperature. This decrease does not occur sharply at any particular temperature and so the transition temperature is taken as being the point midway between the two energy levels on any one curve. This corresponds approximately to a 50% brittle/50% ductile fracture.

The photograph in Fig. 2 shows a 100% brittle fracture, while that in Fig. 3 shows a 100% ductile fracture.

As can be seen from Fig. 1, En 47 is superior to the other spring materials both as regards transition temperature and impact strength. Only at temperatures greater than 80°C does another quality (En 48A) equal En 47 for impact strength. The rather low impact resistance exhibited by En 45 was confirmed by data obtained from private correspondence with B.I.S.R.A.

One interesting point is that, with the exception of En 45, there is an increase in transition temperature as the hardness of the material increases. This is not necessarily to be expected, since the materials are vastly different in composition. It may be said, however, that perhaps the hardness of the materials is influencing the transition characteristics to a greater extent than would be thought. Another point here, is that En 45 was the exception to the trend in hardness/transition temperature correlation and it was also the exception in grain size, having by far the coarsest prior austenite grain structure of the group. In fact, although En 45 had a typical grain size for steels in general the grains were, on average, seven times larger by area than the largest of the other materials. It must be emphasised, however, that the heat treatments given to the various steels were typical of common practice and that the transition curves produced will typify the characteristics of commercial spring materials. The question as to whether the impact properties of En 45 would improve significantly as the grain size is refined is worthy of further attention.

Although there are no available data specifically related to spring materials, E. C. Bain[1] has pointed out the effect which grain size has on the impact properties of carbon steels and although the impact strength is increased with grain refinement, the smaller the grains become, the smaller is the effect on the impact strength. In quantitative terms, this means that if the grain size were decreased from 6 to 10, the corresponding increase in impact strength would be of the order of 5 joules (3.7 ft lbf). If this were the case for En 45, the improvement would not significantly alter the conclusions drawn from the impact data presented in Fig. 1. Scott[2] in his work on quenching media for the hardening of steel suggested a greater increase in impact strength on grain refinement and went on to consider the additional effect of hardness. Again this work was entirely on carbon steels and it must be emphasised that the exact nature of the relation between carbon steels and spring steels is not known. Early attempts at grain refinement of En 45 using Aluminium additions proved unsuccessful as aluminium nitride was found to precipitate at the grain boundaries causing considerable "power" cracking on rolling ingots. Since that time additions of niobium and titanium have proved more successful in reducing the grain size. En 45 has previously been chosen as a general spring material because of its relative cheapness (in small lots approximately 27% cheaper than En 47). In cases where impact and associated mechanical properties are of vital importance, the spring manufacturer has automatically changed to an En 47 (CrV) steel. This has had the effect of eliminating any great demand for a grain refined En 45. It is suggested that the impact properties of En 45 may be improved significantly by grain refinement and that a grain refining treatment such as niobium addition would not increase the cost of the material unduly.

The effect of raising the hardness of En 48A from 487 HV30 to 520 HV30 (En 48A(H)) has been to separate the transition curves above room temperature, so that En 48A remains a constant 5 joules (3.7 ft lbf) higher than En 48A(H). Although the energy absorbed has been decreased in this way by the higher hardness En 48A, the transition temperature, as seen in Table IV, has remained the same. The SAE 8660 steel, being of the nickel-chromium-molybdenum type, exhibited superior impact properties to the carbon-chromium SAE 5160 at all temperatures.

From the standpoint of the user, both impact strength and transition temperature are important. Any material which, during its life, may be subjected to impact loading, should therefore have a low transition temperature, coupled with a high impact strength.

6. CONCLUSIONS

1. Of the six steels investigated, En 47 had the highest impact strength and En 45 had the lowest.

2. En 47 also showed the best impact transition temperature of the group (i.e. lowest temperature).

3. With En 48A at temperatures less than 20°C, variation in hardness had little effect on impact properties; however, at higher test temperatures, the lower hardness En 48A exhibited better impact resistance.

4. The grain size of En 45, although typical, was far coarser than any of the other materials, and could well explain the low impact properties experienced.

7. RECOMMENDATIONS

It is suggested that research into the impact and other mechanical properties of a niobium treated En 45 may prove of great benefit to the spring manufacturer and user.

8. ACKNOWLEDGMENT

The Association acknowlege the assistance given by Dr. D. J. Stratford of Clayton Dewandre Co. Ltd. for arranging the impact testing.

9. REFERENCES

1. E. C. Bain, Functions of the Alloying Elements in Steel, American Society for Metals, Cleveland, Ohio, 1939.

2. H. Scott, The Problem of Quenching Media for the Hardening of Steel, Trans. A.S.M., 22, 1934, pp. 577-604.

TABLE I COMPOSITION OF MATERIALS

Sample	Analysis %								
	C	Mn	Si	S	P	Ni	Cr	V	Mo
En 45	0.58	0.88	1.82	0.044	0.031	0.17	0.11	-	-
En 47	0.49	0.69	0.20	0.011	0.015	0.16	0.93	0.15	-
SAE 8660	0.61	0.88	0.30	-	-	0.64	0.53	-	0.20
En 48A and En 48A(H)	0.56	0.82	1.40	-	-	-	0.75	-	-
SAE 5160	0.65	0.89	-	-	-	0.21	0.85	-	0.06

- Not determined

TABLE II HEAT TREATMENT DATA

Quality	Heat Treatment	Hardness Specification H.V. 30	Actual Hardness H.V. 30	ASTM Grain Size	Grains per sq mm
En 45	920°C, O.Q., T. 440°C - 1hr	450/480	457	6	500
En 47	860°C, O.Q., T. 440°C - 1hr	450/480	452	10	8000
SAE 8660	860°C, O.Q., T. 470°C - 1hr	450/470	460	9	4000
En 48A	870°C, O.Q., T. 480°C - 1hr	480/500	487	10	8000
En 48A(H)	900°C, O.Q., T. 405°C - 1hr	520/530	520	-	-
SAE 5160	850°C, O.Q., T. 460°C - 1hr	470/480	467	11	16000

TABLE III CHARPY V NOTCH IMPACT DATA (JOULES)

Temperature	Quality					
	En 45	En 47	SAE 8660	En 48A	SAE 5160	En 48A(H)
-80°C	0	20.3	10.8	10.8	2.7	9.5
-80°C	0	19.0	13.6	10.8	2.7	10.8
-40°C	2.7	24.4	13.6	13.6	2.7	14.9
-40°C	1.4	20.3	10.8	10.8	4.1	10.8
-20°C	1.4	27.1	16.3	13.6	4.1	13.6
-20°C	2.7	27.1	13.6	10.8	5.4	13.6
0°C	2.7	25.8	13.6	13.6	6.8	13.6
0°C	2.7	27.1	17.6	13.6	6.8	14.9
R.T (19°C)	5.4	19.0	21.7	19.0	19.0	16.3
19°C	5.4	19.0	21.7	21.7	19.0	17.6
40°C	10.8	27.1	19.0	21.7	13.6	20.3
40°C	8.1	27.1	23.0	23.0	13.6	23.0
60°C	8.1	23.0	16.3	20.3	19.0	23.0
60°C	6.8	29.8	21.7	23.0	20.3	19.0
80°C	12.2	29.8	21.7	32.5	19.0	19.0
80°C	9.5	29.8	19.0	29.8	19.0	24.4
100°C	10.8	29.8	16.3	29.8	13.6	27.1
100°C	10.8	29.8	16.3	27.1	13.6	24.4
200°C	8.1	27.1	19.0	27.1	16.3	24.4
200°C	9.5	29.8	21.7	29.8	19.0	24.4

TABLE IV IMPACT TRANSITION TEMPERATURES

QUALITY	En 45	En 47	SAE 8660	En 48A	SAE 5160	En 48A(H)
TRANSITION TEMPERATURE	$+25^{o}C$	$-35^{o}C$	$-8^{o}C$	$+20^{o}C$	$+20^{o}C$	$+20^{o}C$

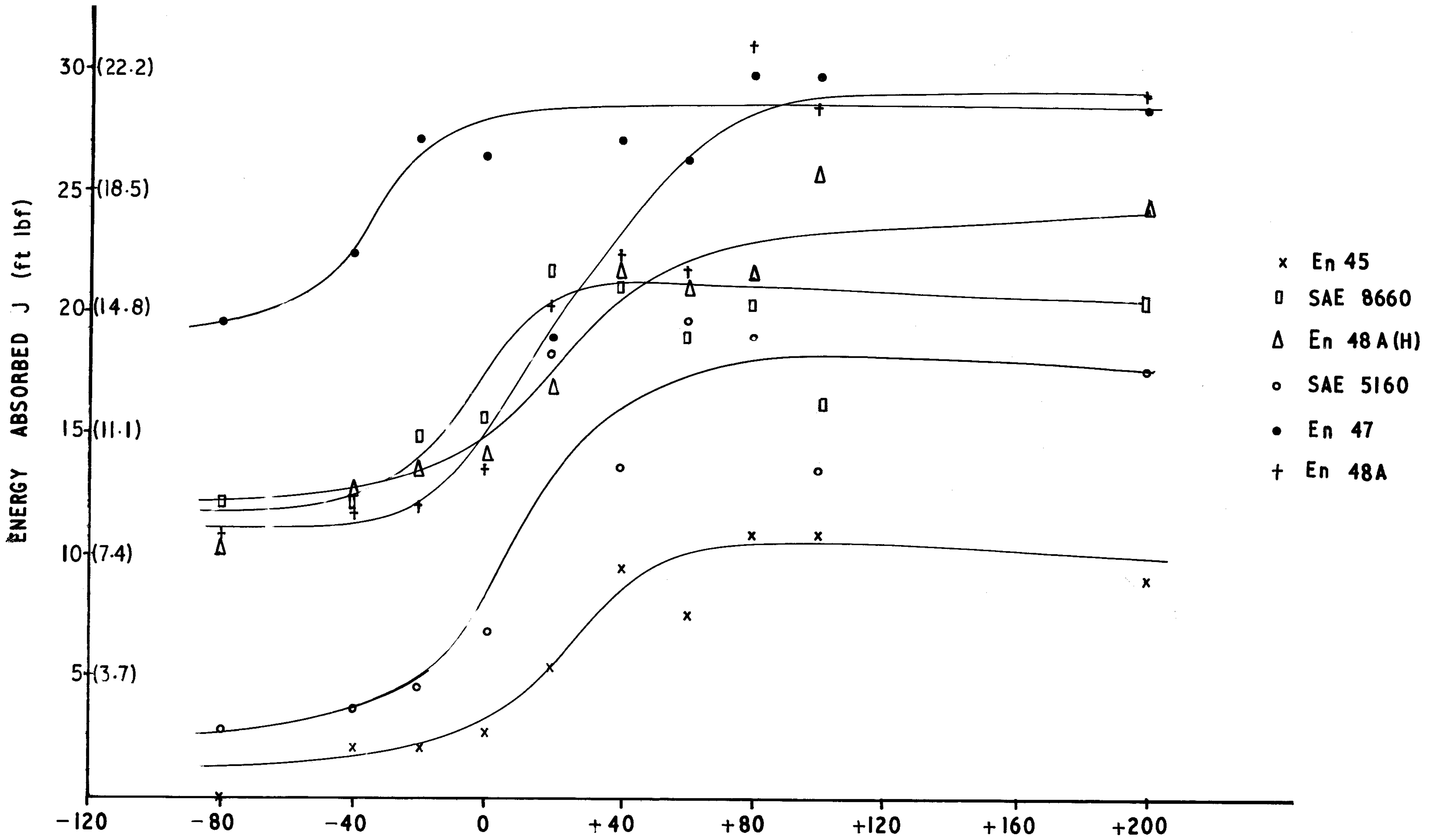

FIG.I. IMPACT TRANSITION CURVES FOR CHARPY 'V' NOTCH SPECIMENS.

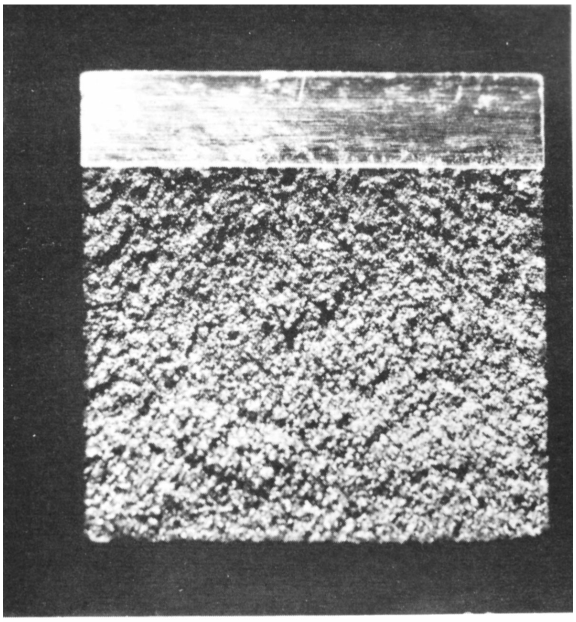

FIG. 2 X 6

FRACTURE SURFACE OF ROOM TEMPERATURE En 45 SPECIMEN

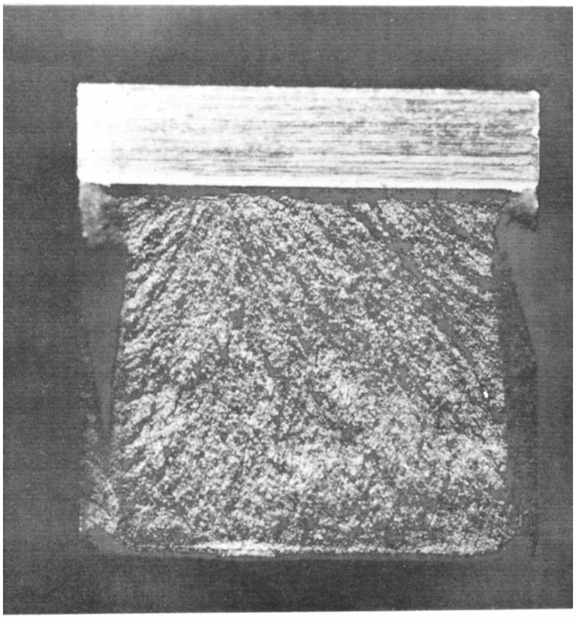

FIG. 3 X 6

FRACTURE SURFACE OF ROOM TEMPERATURE En 47 SPECIMEN