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Assessment of Toughness Behaviour of Low Alloy Steels by Subsize Impact Specimens

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ABSTRACT

Notched bar impact testing is used for assessing the toughness behaviour of low alloy steels. For determination by means of a complete impact energy vs. temperature curve about 18 ISO-V specimens are needed. The amount of material necessary for this purpose not always is at disposal. Various standards therefore provide smaller specimens. With dimension 3 x 4 x 27 mm^3 the so-called KLST specimen of DIN 50 115 provides a high material economy as compared to the ISO-V specimen with 10 x 10 x 55 mm^3.

Based on the experience gained in this field during more than 10 years the use of subsize specimens for special applications is recommended.

1. Introduction

Notched-bar impact testing has been used for decades for assessing the toughness behaviour of low alloy steels. The dependence of the material properties on specimen shape and size has to be regarded as a disadvantage. To-date, there exist no generally accepted correlations among the various specimen types.

In nuclear technology the ISO-V specimen is used preferably, to which the most important parameters (41 J- and 68 J- and 0,9 mm lateral expansion) are referred. To determine all index temperatures by means of one complete transition curve 12 to 18 ISO-V specimens are necessary. The amount of material required is not always at disposal, specifically in quality- and failure-analysis. There are other reasons as well that narrow the range of applicability of the ISO-V specimen, e.g. too small dimensions of the semi-finished product or local gradients of material properties. Consequently there are various standards providing smaller specimens.

Notched-bar impact testing yields the material parameters impact energy, lateral expansion and percentage of shear fracture as functions of test temperature, which by tendency all give the same informations. In this paper predominantly the impact energy will be considered.

2. Sensitivity of different specimen types

In principle the most divergent specimen types might be used. Therefore it is clear that national standards show differences among each other. Fig. 1, in selection, shows the specimen types provided by DIN 50115 together with the modified subsize specimen. All specimen types deliver the transition curves characterizing notched-bar impact testing. As shown in Fig. 2 schematically, with the specimen size becoming smaller the transition region is shifted to lower temperatures. The impact energy itself depends, among other variables, on net test section, notch root radius, and impact velocity. Differences in material condition, respectively, are detected clearly with any specimen type. Fig. 3, by means of some examples, elucidates this fact for ISO-V and KLST specimen types.

3. Correlations between index temperatures

The toughness behaviour of a material is characterized by stating certain index temperatures. With ISO-V specimens the temperatures for impact energy of 41 and 68 J (T_{41} and T_{68}) as well as for 0,9 mm lateral expansion ($T_{0,9}$) are used. The corresponding index temperatures for subsize specimens are to be determined. The data base consists of 24 complete transition curves with ISO-V and KLST specimens for low alloy steels in different conditions.

From the ratio of the impact energies of the KLST specimen and the ISO-V specimen in the upper shelf region the index values have been determined by the following relation:

$$T_{KLST} = T_{ISO-V} \cdot \frac{\text{Impact energy in upper shelf, KLST}}{\text{Impact energy in upper shelf, ISO-V}}$$

Statistical analysis of all results yielded the following values:

ISO-V	T 41	T 68	T 0,9
KLST	T 1,9	T 3,1	T 0,3

Fig. 4 shows that the correlations between the index temperatures are located within a relatively narrow scatter band, although the material conditions cover the very broad range of transition temperatures of 300 K. For conversion the following simple relation is obtained: T ISO-V = T KLST + 70 K.

4. Special features with manufacturing and testing of subsize specimens

Since the notch root-radius will affect the test results, special care has to be taken during specimen fabrication. Milling cutters after Schnadt, showing particular durability, have been found useful. Checks are carried out simply by means of a profile projector. If only a small amount of material is at disposal or if property profiles have to be determined, electro-erosive machining of small notched profile blocks offers advantages. Width of cutting of 0,2 mm can be achieved with no final preparation of the eroded surfaces being necessary.

For testing subsize specimens a small impact apparatus has to be used. An automatic specimen loading device is suitable, thus minimizing errors in test temperature. Notched-bar impact testing can also be carried out with instrumentation. Fig. 5 shows load vs.time records of ISO-V and KLST specimens.

Experimental data scatter with KLST specimens is not larger as with ISO-V specimens, provided there are no local material property gradients. Fig. 6 proves this statement by means of statistical tests.

5. Examples of application

Figs. 7, 8 and 9 give some examples of application. Positive experience could also be achieved by testing irradiated specimens in the hot cell. Fig. 9 indicates that the use of electron-beam welded compound specimens is also possible. Minimization of specimen dimensions to 1 x 4 x 27 mm^3 (see Fig. 1) has also been tested successfully. For stating statistically proved correlations sufficient test results, however, are lacking. With decreasing specimen dimensions reproducable tempering becomes specifically important, last not least because the transition temperatures are very low. This fact, finally, constitutes a natural boundary for the minimization of notched-bar impact specimens.

6. Conclusions

Extensive comparative notched-bar impact testing with ISO-V and KLST specimens has shown that material property differences are detected in both cases with the same sensitivity. Furthermore, it was found that experimentally ascertained correlations exist between both specimen types. Thus, notched-bar impact testing with subsize specimens offers a valuable extension of the means of destructive materials testing.

In the technical literature the evidence of the KLST specimen is assessed ambiguously. Besides appraisal by LUCAS / 1 /, also rejection because of poor accuracy and lacking resolution of the KLST specimen is reported by WEIGEL / 2 /. The results of the present investigation, however, prove the usefulness of the KLST specimen.

7. References

/ 1 / G.E.Lucas, J.W. Sheckherd, G.R.Odette:
Developments in small-scale strength and impact testing. Department of Chemical and Nuclear Engineering, University of California, Santa Barbara, 1982.

/ 2 / K.Weigel:
Sind Klein-Kerbschlagbiegeproben zur Zähigkeitsbeurteilung von Schweißgütern geeignet? OERLIKON-Schweißmitteilung Nr. 102 (1983), S. 12 - 19.

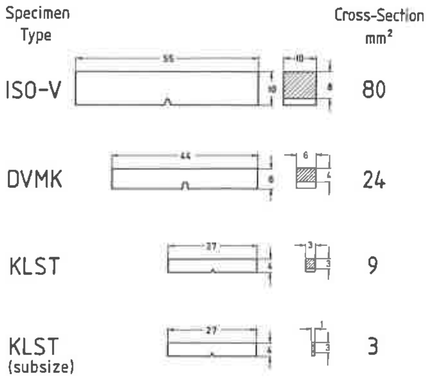

Fig. 1
Standard and subsize impact specimens.

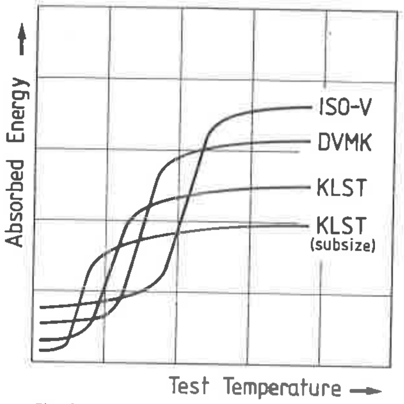

Fig. 2
Correlation between impact specimens (schematic).

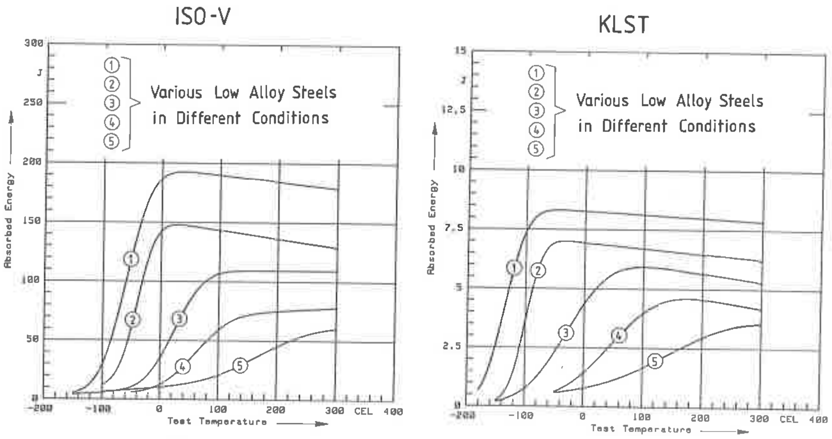

Fig. 3
Sensitivity of different impact specimens against toughness differences of low alloy steels.

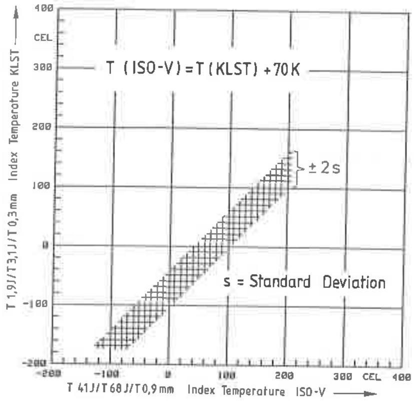

Fig. 4
Correlation between ISO-V and KLST specimens, based on a wide range of index temperatures, (data from 24 transition curves each).

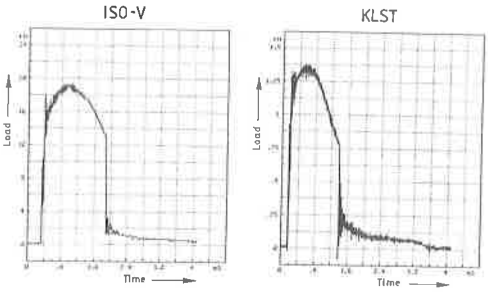

Fig. 5
Load vs. time records from instrumented impact tests with ISO-V and KLST specimens.

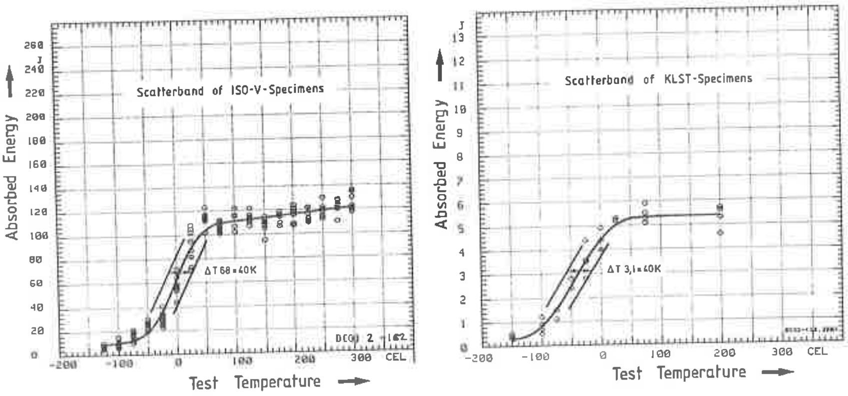

Fig. 6
Comparison of scatterbands from ISO-V and KLST specimens.

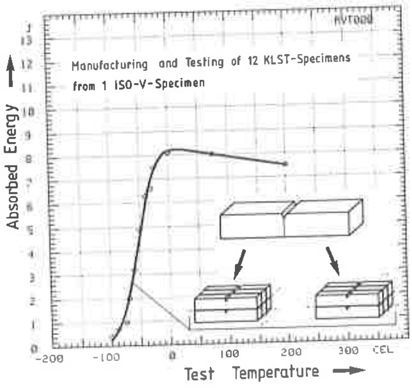

Fig. 7
Determination of the transition curve with 12 KLST specimens, taken from one broken ISO-V specimen.

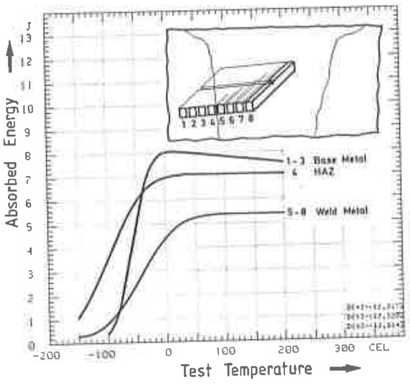

Fig. 8
Characterization of toughness behaviour for a butt weld by KLST specimens.

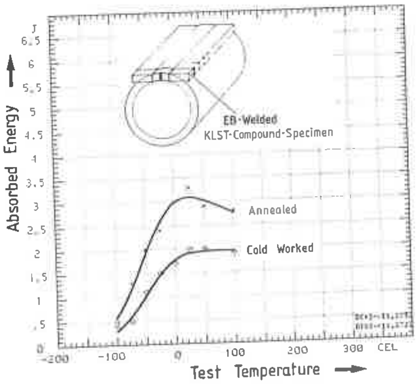

Fig. 9
Influence of annealing on the transition curve of a thinwalled tube material determined with EB-welded KLST Compound-Specimens.