ESTIMATION OF THE IMPACT STRENGTH OF STEELS
AT CRYOGENIC TEMPERATURES

D. V. Lebedev and G. A. Gadzhibalaev

A considerable progress has recently been made in the method of estimating the strength and ductility of metals in uniaxial static tension. This has led to the development of sufficiently reliable testing equipment and to the formulation of test specifications based on scientific considerations.

Materials used at cryogenic temperatures must satisfy a number of requirements relating not only to strength and ductility at room temperature but also to the temperature dependence of ductility under dynamic loads [1, 2]. This necessitates the development of appropriate equipment and testing methods.

In the absence of generally accepted standards for the determination of impact strength and scientifically substantiated recommendations regarding the analysis of the data obtained it is often impossible to compare the results of tests carried out at various establishment; sometimes the results of such tests are incorrectly processed and interpreted [3].

Systematic investigations of the impact strength of metals and alloys used in the cryogenic technology at temperatures ranging from 20 to -253°C have been carried out for several years at the Central Scientific-Research Institute of Ferrous Metallurgy. Impact tests at temperatures between 20 and -196°C are carried out to GOST 9454-60 and GOST 9455-60 specifications. Tests at -253°C are done with the aid of a method widely used by research workers which involves the use of paper boxes filled with a suitable coolant [4].

A specific feature of low-temperature deformation of the majority of cryogenic steels used in industrial applications is the variation in their structural state (the transformation of austenite into martensite); this must be taken into account in determining the impact strength of such materials.

In impact tests the formation of martensite in the deformed material volume adjacent to the notch takes place at appropriate temperatures. The larger is the work of deformation before the crack nucleation (\(A_3\)), the more noticeable is the deformation of the specimen tested and the larger is the quantity of martensite formed [5].

Since the formation of martensite during low-temperature deformation depends to a large extent on the stress state in the notch region (the process being activated when the severity of the stress state is increased [6]), the form and dimensions of notches in specimens tested play the decisive part in the determination of the impact strength of metastable cryogenic steels. In the case of specimens with "mild" notches (type I in GOST 9454-60) the \(\gamma \rightarrow \alpha\) transformation in the deformation zone may be inhibited; as a result, the impact strength values obtained may differ from the real impact strength of a given steel with sharp stress raisers.

To determine the influence of stress concentration, it is necessary to take into account the degree of local increase in the stress...
Fig. 2. Impact strength values determined for various steels on prismatic specimens with various notches at temperatures between 20 and \(-253^\circ C\) extrapolated to zero notch root radius.

For these reasons the current practice of determining the impact strength of a given material by tests on specimens in which only the notch root radius is varied (without taking into account the influence of the variation in the stress state due to changes in the notch depth) must be regarded as unsound, the more so that specimens catering for the influence of this factor have been specified in GOST 9454-60 (specimen type III). Moreover, as previously stated, the form of the stress state has a substantial influence on the formation of martensite in cryogenic steels dynamically deformed at low temperatures which leads to changes in their impact strength characteristics.

This is illustrated by data in Fig. 1, where the impact strength of two steels at temperatures between 20 and \(-253^\circ C\) is plotted against the notch depth for a constant notch root radius \(\rho = 1.0\) mm. It will be