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# INFLUENCE OF DEFORMATIONS FROM STATIC LOADS ON IMPACT AND FRACTURE TOUGHNESS OF CYLINDRICAL SHELLS

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The work is a study of the effect of accumulation of plastic deformation in the base metal of the pipeline from the action of inner pressure on the change of impact toughness of the Charpy specimens cut out in the longitudinal and circumferential directions. The studies in this direction are carried out on the specimen made from electrically-welded straight seam pipe of 630×8 from 17G1S steel. The obtained test results allow correcting the requirements to the specific work of impact specimens taking into account its possible reduction depending on the predicted plastic deformation of the structural element and anisotropic properties of the material. 17 Ref., 4 Tables, 10 Figures.

*Keywords: plastic deformation, ageing, impact toughness, heat-affected zone, brittle-ductile transition temperature, fracture toughness characteristics*

Various processes can develop in pipelines in operation, including strain ageing. Its development, on the one hand, leads to adverse consequences, which lower the ductility and toughness values of pipeline and pressure vessel metal, and on the other hand — ageing is used as a variant of treatment, which allows improvement of structural strength of steel products [1].

Direct evaluation of the impact of strain ageing on the change of structural material properties involves a number of difficulties, associated with absence of reliable witness-specimens. Application of the results of collateral testing, performed earlier, does not allow guaranteeing the correctness of the conclusions, because of a considerable scatter of the metal rolled stock properties, characteristic for mass production structural steels. So, works [2–4] report absence of reliable data that is one of the main causes for contradictions between the results of different studies. Further complications during such evaluations are also related to that the maximum possible changes between the metal properties during natural strain ageing after operation should be determined not so much by time, as by the magnitude of the accumulated plastic deformation.

A feature of plastic deformations in pipelines is their local nature that complicates their direct determination, and they can reach 7 and more percent [5]. Moreover, plastic deformations may accumulate in the areas of mechanical damage, corrosion defects, corrugations, etc. Plastic deformation increases the rate of corrosion processes in the areas of accumulation of plastic damage of metal.

Change of local mechanical, ductile and corrosion properties of metal of various purpose pipelines, is the main practical result of their strain ageing.

Of all the mechanical characteristics the most dangerous, as a result of strain ageing, is the change of structural steel susceptibility to brittle and ductile fracture, which are measured in terms of the values of impact toughness (*KCV*), critical brittleness temperature ($T_{cr}$) and nominal breaking stress.

Allowing for the negative impact of plastic deformation accumulation on structural strength is quite widely covered in works [6–11].

Research performed at PWI shows that in the presence of cracklike defects in the pipeline, the structural steel toughness is determined by the steel resistance to initiation and propagation of a ductile crack up to formation of a ductile zone or through thickness defect. At the initial stage the material ability to resist initiation of ductile crack extension is characterized by deformation criterion $\delta_i$ (value of critical crack tip opening displacement at the moment of ductile crack initiation). The second stage is related to stable growth of the crack, and it is characterized by the tangent of the opening angle of a stable propagating crack (COA) [12, 13].

It is known from local and foreign publications that the current requirements to the value of impact toughness of a Charpy specimen correlate quite well

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with the resistance of structural steels and their joints to possible fractures, which, in their turn, are characterized using different criteria of fracture mechanics. Thus, impact toughness values of a Charpy specimen indirectly characterize the resistance of structural materials and their joints to possible defect growth.

Approaches developed at PWI for determination of $\delta_i$ (mm), $K_{1c}^{(t)}$ (kgf/mm$^{3/2}$), and COA (tgα) characteristics by the results of impact testing of standard Charpy specimens 10 mm thick (GOST 9454–78) and of their strength allow considerably simplifying such assessment [12–17]:

$$\delta_i = 0.05\,KCV_{max}/\sigma_{0.2}; \quad (1)$$

$$K_{1c}^{(t)} = (A \cdot E \cdot KCV^{(t)} / (1-\nu^2))^{0.5}; \quad (2)$$

$$\mathrm{tg}\alpha = 0.5\frac{\sigma_t}{\sigma_{0.2}}\varepsilon_t(1+\varepsilon_t), \quad (3)$$

where $K_{1c}^{(t)}$ is the crack resistance characteristic at propagation of a through-thickness crack in a structural element of thickness $t$ for temperature $T$; $A$ is the correlation factor; $KCV^{(t)}$ is the Charpy specimen impact toughness (J/cm$^2$) at corrected temperature $T'$, taking into account the thickness; $KCV_{max}$ is the specific work of destruction of the Charpy specimen on the «upper shelf» (at completely ductile fracture): $T' = T + \Delta T$, where $\Delta T$ is temperature shift at limitation of the thickness of structural elements (5 mm < $t$ < < 10 mm); $\varepsilon_t$ is the deformation, which corresponds to tensile strength of the material $\sigma_t$; $\sigma_{0.2}$ is the yield limit (kgf/mm$^2$); $E$ is the modulus of elasticity, (kgf/mm$^2$).

Dependence (3) has certain physical meaning, the essence of which is in that the opening angle of a growing stable crack (tgα) will decrease with lowering of the ductile properties of the material. Consequently, it will lead to greater length of the extending crack in the case of reduction of the uniform component of metal plastic deformation $\varepsilon_t$.

Influence of plastic deformation on the change of $KCV_{max}$ characteristics of specimens cut out in the transverse direction to that of deformation, and $\sigma_{0.2}$, $\sigma_t$ was studied earlier [6], in the case of 09G2S steel. As follows from work [6], prior deformation of metal greatly lowers the value of impact toughness $KCV_{max}$ on the upper shelf and increases the brittle-ductile transition temperature ($T_{bdt}$) at a slight change of tensile strength $\sigma_t$ of the studied steels.

In order to perform a more detailed study of the possible impact of accumulated residual deformation in the pipeline on the change of impact toughness of Charpy specimens in the longitudinal and circumferential directions, a full-scale specimen was prepared from a 630×8 mm pipe under PWI laboratory conditions. By its design the specimen consisted of a pipe section and two flat covers (made in-house) of the dimensions, which allowed applying static loading by hydraulic pressure up to fracture. In order to ensure satisfactory conditions for specimen welding and to prevent fracture from appearance of a zone of irreversible deformations during testing, the cover was fitted by welded-on coils of the same diameter, as that of the pipe. For this purpose, one coil 100–120 mm wide was cut from each of the end faces (A and B) of the pipe (Figure 1).

The main objective of conducting hydraulic testing was development of deformed sections in the full-scale specimen metal in the pipe, as a result of testing, for their further study.

Characterization of the specimen components:

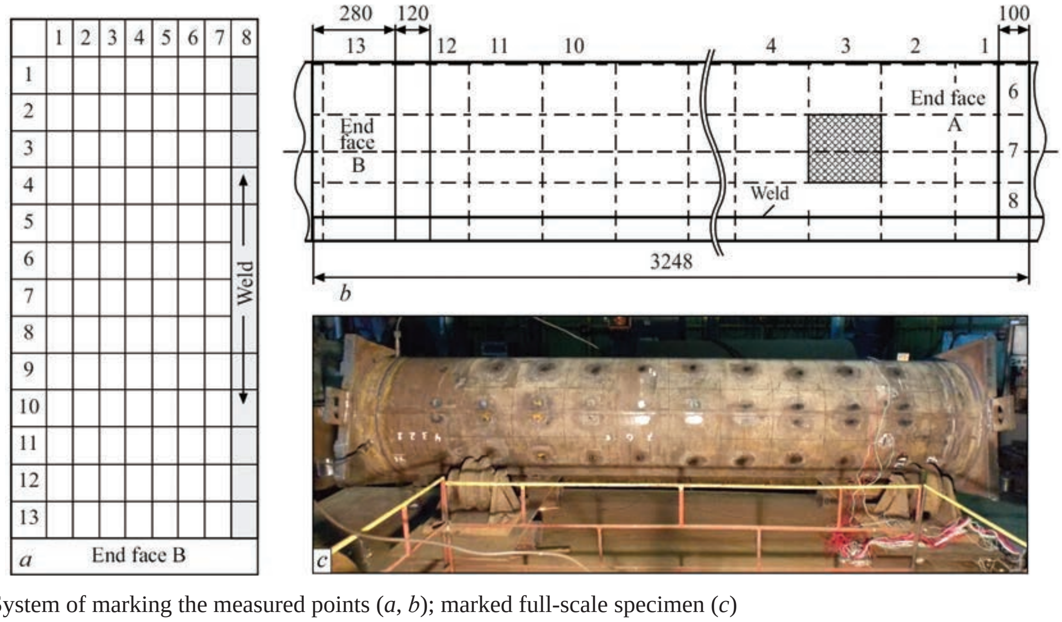


**Figure 1.** System of marking the measured points (*a*, *b*); marked full-scale specimen (*c*)

**Figure 2.** General view of the cover

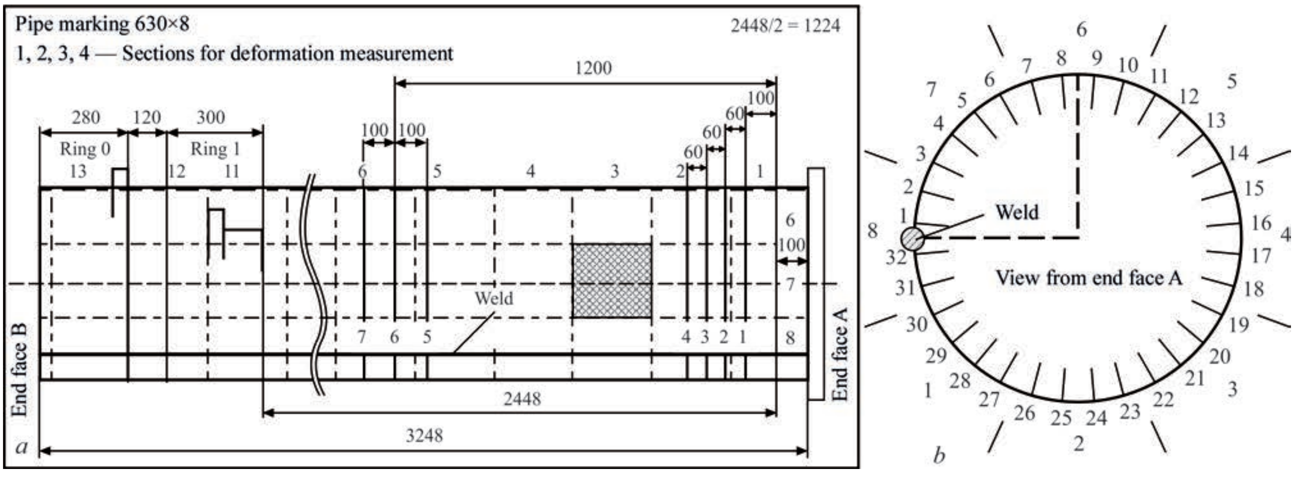


**Figure 3.** Marking for measurement of residual deformations: *a* — sections 1–7; *b* — points 1–32 for marking the measured bases

● electrically welded straight seam 630×8 pipe to GOST 10705 and GOST 10701 after service; inner and outer surfaces had corrosion damage, wall thickness measured by TUZ-3 thickness meter was 6.9–7.6 mm, length was 2970 mm, and material was 17G1S;

● flat welded cover (2 units) made in-house from sheet steel St20 50 mm thick with 30 mm thick stiffeners in the quantity of 6 pcs (Figure 2).

To study the changes of geometrical parameters (residual deformation), a system of marking the points and sections was applied on the pipe surface in the initial state, in which the measurements were taken. The end faces of the full-scale specimen were marked as A and B. The pipe surface was divided into 8 longitudinal bands and 13 rings, at the intersection of which cylindrical sectors of 247.78×247.78 mm size were formed (Figure 3). A ring («ring 0») was cut out of the pipe before specimen welding to study the pipe metal in undeformed state.

**Figure 4.** General view of the site of fracture in a pipe reference specimen after hydraulic loading by pressure 13.25 MPa

In order to reach maximum deformations, the pipe specimen was brought to destruction by hydraulic testing (Figure 4).

After completion of testing for plastic deformation, measurements of the full-scale specimen were taken by nondestructive testing methods (Table 1).

Metal from the specimen middle part, where maximum plastic deformation was observed, was used to make specimens for destructive kinds of testing (see Table 1, specimen fragment is shown by black drawing).

Investigations were conducted on specimens, made in the axial and circumferential directions. Figure 5 shows specimen layout and notch position.

Specimens were cut out of an undeformed fragment of the pipe («ring 0») and deformed fragment of the pipe, shown in Table 1.

24 Charpy specimens were made for each direction of the above-mentioned fragments. Specimens for the wrought case were subjected to natural ageing for 40 days.

**Table 1.** Distribution of residual deformation (%) in the circumferential direction after hydraulic loading of the pipe in the zone of cross-sections 1–4 and 5–7 ($l_0$ = 61.00 mm)

| Sector | Area | Points | (← End face A) Sections (End face B →) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 1 | 1–2 | 2.85 | 3.03 | 3.74 | 3.69 | 3.36 | 4.39 | 4.51 |
| | 2 | 2–3 | 3.13 | 3.39 | 3.70 | 3.62 | 3.61 | 4.23 | 4.02 |
| | 3 | 3–4 | 3.13 | 3.75 | 3.23 | 3.85 | T 3.56 | P 3.51 | 4.13 |
| 7 | 4 | 4–5 | 2.85 | 3.03 | 3.64 | 3.84 | 3.43 | 3.67 | 4.11 |
| | 5 | 5–6 | 2.90 | 2.77 | 2.69 | 3.07 | 3.03 | 3.36 | 3.30 |
| | 6 | 6–7 | 3.03 | 3.02 | 3.39 | 2.84 | 3.23 | 3.82 | P 3.64 |
| | 7 | 7–8 | 3.33 | 3.15 | 3.84 | 4.31 | 3.92 | 3.80 | 3.75 |
| 6 | 8 | 8–9 | 3.13 | 3.15 | 3.16 | 3.13 | 2.87 | 3.92 | 3.41 |
| | 9 | 9–10 | 2.56 | 2.49 | 2.44 | 2.33 | 3.20 | 3.20 | 2.97 |
| | 10 | 10–11 | 2.49 | 2.41 | 2.36 | 2.31 | 3.07 | 3.00 | 2.84 |
| | 11 | 11–12 | 1.93 | 2.84 | 2.80 | 3.03 | 2.54 | 2.49 | 2.90 |
| 5 | 12 | 12–13 | 1.90 | 2.08 | 2.05 | 2.28 | 2.03 | 2.59 | 2.25 |
| | 13 | 13–14 | 1.49 | 1.77 | 1.61 | 1.75 | 1.54 | 2.16 | 2.28 |
| | 14 | 14–15 | 1.92 | 1.26 | 1.72 | 1.66 | 1.64 | 2.59 | 2.77 |
| | 15 | 15–16 | 2.00 | 1.89 | 2.56 | 2.49 | 2.66 | 2.80 | 2.80 |
| 4 | 16 | 16–17 | 2.33 | 2.28 | 2.69 | 2.69 | 2.67 | 2.67 | 3.18 |
| | 17 | 17–18 | 0.97 | 1.16 | 1.77 | 1.70 | 1.57 | 2.33 | 1.46 |
| | 18 | 18–19 | 0.77 | 0.67 | 0.69 | 0.72 | 0.67 | 1.41 | 0.80 |
| | 19 | 19–20 | 1.69 | 1.90 | 2.10 | 2.26 | 1.92 | 2.67 | 2.56 |
| 3 | 20 | 20–21 | 2.11 | 2.87 | 3.36 | 3.26 | 2.49 | 2.41 | 2.72 |
| | 21 | 21–22 | 2.44 | 2.31 | 2.66 | 2.34 | 2.90 | P 3.05 | P 3.03 |
| | 22 | 22–23 | 1.92 | 2.28 | 1.87 | 1.59 | K 2.66 | K 2.87 | 2.80 |
| | 23 | 23–24 | 1.92 | 2.07 | 2.48 | 2.70 | 2.33 | H 2.05 | 2.02 |
| 2 | 24 | 24–25 | 2.44 | 3.05 | 3.46 | 4.39 | 2.54 | H 3.18 | 2.97 |
| | 25 | 25–26 | 2.74 | 3.34 | 3.69 | 3.57 | 3.79 | 3.74 | 3.64 |
| | 26 | 26–27 | 2.98 | 3.15 | 2.82 | 3.13 | H 3.43 | H 4.30 | 3.38 |
| | 27 | 27–28 | 2.54 | 2.26 | 2.89 | 3.52 | H 2.28 | H 3.43 | 3.05 |
| 1 | 28 | 28–29 | 2.92 | 3.64 | 3.21 | 3.59 | 3.33 | 4.21 | 3.90 |
| | 29 | 29–30 | 3.36 | 3.13 | 3.03 | 3.43 | 3.38 | 3.79 | 3.64 |
| | 30 | 30–31 | 2.82 | 2.74 | 2.77 | 2.80 | 2.52 | 2.70 | 2.69 |
| 8 | 31 | 31–32 | 2.80 | 3.07 | 3.69 | 3.62 | 3.46 | 3.95 | 3.67 |
| | 32 | 32–1 | 1.57 | 2.31 | 2.31 | 2.61 | 2.67 | 2.90 | 2.64 |
| Average | % | | 2.41 | 2.57 | 2.76 | 2.88 | 2.76 | 3.16 | 3.06 |

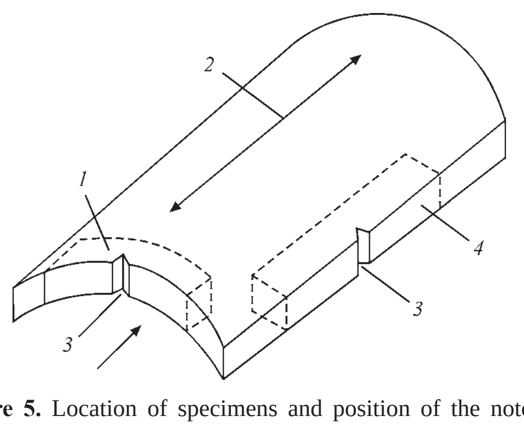


**Figure 5.** Location of specimens and position of the notch in Charpy impact specimen (*KCV*) in the pipe: *1* — general view of welded specimens cut out in the circumferential direction; *2* — direction of pipe longitudinal axis; *3* — orientation of V-shaped notch; *4* — general view of impact specimens, cut out in the axial direction. Size of axial specimens 10.0×6.9 ± 0.1 mm — treated; for transverse specimens — 10.0×7.1 mm — untreated

Figure 6 shows the general view of the specimens made in the axial and circumferential directions.

Impact out-of-plane bending tests were conducted in the temperature range from –60 to 40 °C.

Results of testing specimens, made from an undeformed pipe fragment («ring 0»), are shown in Table 2 and in Figure 7.

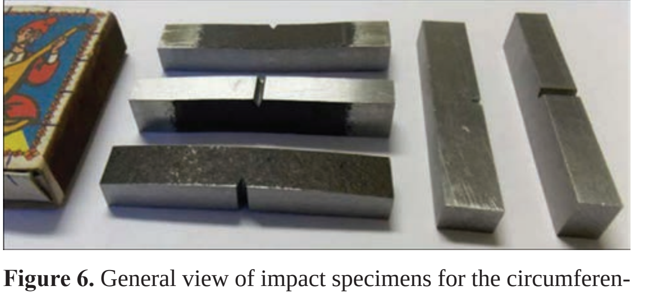

**Figure 6.** General view of impact specimens for the circumferential and axial directions

**Table 2.** Results of testing Charpy impact specimens, made from an undeformed pipe fragment

| Number | Circumferential direction | | | | | Axial direction | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *B*, mm | $H_1$, mm | *F*, mm² | *t*, °C | *KCV*, J/cm² | *B*, mm | $H_1$, mm | *F*, mm² | *t*, °C | *KCV*, J/cm² |
| 1 | 7.46 | 8.25 | 61.55 | –40 | 38.18 | 6.94 | 8.12 | 56.35 | –40 | 47.03 |
| 2 | 7.46 | 8.25 | 61.55 | –40 | 28.76 | 6.94 | 8.23 | 57.12 | –40 | 66.88 |
| 3 | 7.38 | 8.28 | 61.11 | –40 | 24.87 | 6.94 | 8.20 | 56.91 | –40 | 41.29 |
| 4 | 7.44 | 8.14 | 60.56 | –20 | 28.90 | 6.94 | 8.22 | 57.05 | –20 | 72.22 |
| 5 | 7.42 | 8.35 | 61.96 | –20 | 27.76 | 6.94 | 8.22 | 57.05 | –20 | 67.84 |
| 6 | 7.43 | 8.30 | 61.67 | –20 | 30.16 | 6.94 | 8.20 | 56.91 | –20 | 70.64 |
| 7 | 7.38 | 8.35 | 61.62 | 0 | 55.66 | 6.94 | 8.24 | 57.19 | 0 | 111.38 |
| 8 | 7.40 | 8.35 | 61.79 | 0 | 44.51 | 6.94 | 8.20 | 56.91 | 0 | 119.84 |
| 9 | 7.42 | 8.32 | 61.73 | 0 | 40.01 | 6.94 | 8.28 | 57.46 | 0 | 126.35 |
| 10 | 7.45 | 8.16 | 60.79 | +20 | 66.13 | 6.94 | 8.18 | 56.77 | +20 | 150.26 |
| 11 | 7.44 | 8.29 | 61.68 | +20 | 67.93 | 6.94 | 8.16 | 56.63 | +20 | 138.27 |
| 12 | 7.45 | 8.27 | 61.61 | +20 | 65.25 | 6.94 | 8.24 | 57.19 | +20 | 130.09 |
| 13 | 7.49 | 8.23 | 61.64 | +40 | 66.52 | 6.94 | 8.20 | 56.91 | +40 | 140.92 |
| 14 | 7.42 | 8.15 | 60.47 | +40 | 66.81 | 6.94 | 8.28 | 57.46 | +40 | 129.66 |
| 15 | 7.47 | 8.36 | 62.45 | +40 | 67.09 | 6.94 | 8.30 | 57.60 | +40 | 126.91 |
| 16 | 7.40 | 8.32 | 61.57 | –60 | 14.34 | 6.94 | 8.18 | 56.77 | –60 | 45.80 |
| 17 | 7.48 | 8.24 | 61.64 | –60 | 18.30 | 6.94 | 8.18 | 56.77 | –60 | 13.48 |
| 18 | 7.46 | 8.30 | 61.92 | –60 | 9.50 | 6.94 | 8.12 | 56.35 | –60 | 29.94 |

**Table 3.** Results on mechanical properties of an undeformed pipe fragment

| Characteristics | Undeformed fragment («ring 0») | |
|---|---|---|
| | In the axial direction | In the circumferential direction |
| Yield limit $\sigma_{0.2}$, MPa | 410–410 | 490–494 |
| Tensile strength $\sigma_t$, MPa | 568–581 | 591–593 |
| Relative elongation $\delta_5$, % | 24.9–26.9 | 21.3–22.3 |

Table 3 gives the results of tensile mechanical testing of specimens made from an undeformed pipe fragment.

As is easily seen from Figure 7, the pipe wall metal has a considerable anisotropy of impact toughness properties in the circumferential and axial directions, that is indicative of low resistance of this material to crack growth in the axial direction.

In addition, a considerable difference of brittle-ductile transition temperatures is observed for the axial and circumferential directions determined by 30 J/cm² criterion.

So, for the axial direction this temperature is approximately –48 °C, while for the circumferential direction it is –15 °C.

Considering that the temperature of brittle-ductile transition ($T_{bdt}$) at plastic deformation of metal shows a tendency to grow, with accumulation of plastic deformations of metal it may lead to $T_{bdt}$ shifting to the plus temperature region in individual pipe areas. Consequently, it may lead to considerable decrease of service properties of pipe metal.

In order to solve this problem, Table 4 and Figure 8 give the results of testing Charpy impact specimens, made from a fragment of a pipe ring, which was exposed to plastic deformation of approximately 3.5 % (see Table 1).

Figures 9, 10 give comparative graphs of the results of testing Charpy impact specimens, made from undeformed and deformed (3.5 %) pipe fragments.

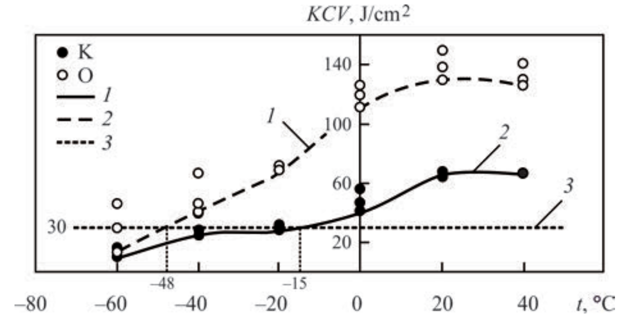


**Figure 7.** Temperature dependence of impact toughness of Charpy specimens oriented in the circumferential (K) and axial (O) directions for undeformed pipe metal: *1* — curve by minimum values for circumferential specimens; *2* — curve by minimum values for axial specimens; *3* — 30 J/cm² level

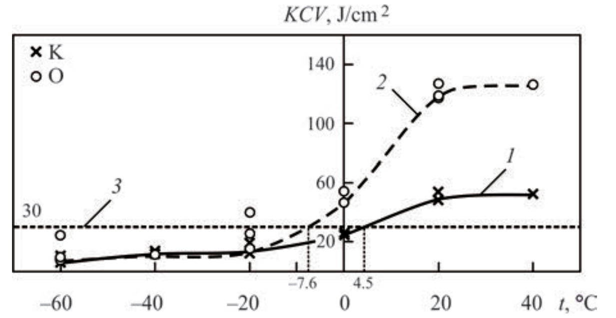


**Figure 8.** Temperature dependence of impact toughness of Charpy specimens oriented in the circumferential (K) and axial (O) directions for deformed pipe metal: *1* — curve by minimum values for circumferential specimens; *2* — curve by minimum values for axial specimens; *3* — 30 J/cm² level

**Table 4.** Results of testing impact specimens made from pipe specimen fragment deformed by 3.5 %

| Number | Circumferential direction | | | | | Axial direction | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *B*, mm | $H_1$, mm | *F*, mm² | *t*, °C | *KCV*, J/cm² | *B*, mm | $H_1$, mm | *F*, mm² | *t*, °C | *KCV*, J/cm² |
| 1 | 7.1 | 8.0 | 56.80 | –60 | 7.75 | 6.88 | 8.06 | 55.45 | –60 | 24.71 |
| 2 | 7.1 | 8.06 | 57.23 | –60 | 7.71 | 6.86 | 8.0 | 54.88 | –60 | 10.71 |
| 3 | 7.1 | 8.0 | 56.80 | –60 | 5.35 | 6.87 | 8.03 | 55.17 | –60 | 6.58 |
| 4 | 7.0 | 7.92 | 55.44 | –40 | 12.03 | 6.85 | 7.95 | 54.46 | –40 | 11.70 |
| 5 | 7.15 | 8.03 | 57.41 | –40 | 13.83 | 6.86 | 8.07 | 55.36 | –40 | 10.46 |
| 6 | 7.1 | 8.15 | 57.87 | –40 | 12.37 | 6.86 | 8.07 | 55.36 | –40 | 11.51 |
| 7 | 7.0 | 7.9 | 55.30 | –20 | 13.29 | 6.86 | 8.05 | 55.22 | –20 | 40.02 |
| 8 | 7.1 | 7.9 | 56.09 | –20 | 24.43 | 6.86 | 8.12 | 55.70 | –20 | 13.20 |
| 9 | 7.0 | 8.06 | 56.42 | –20 | 19.14 | 6.86 | 8.06 | 55.29 | –20 | 25.14 |
| 10 | 7.05 | 7.93 | 55.91 | 0 | 25.04 | 6.86 | 8.13 | 55.77 | 0 | 54.15 |
| 11 | 7.1 | 7.95 | 56.45 | 0 | 26.40 | 6.86 | 8.08 | 55.43 | 0 | 46.91 |
| 12 | 7.0 | 8.02 | 56.14 | 0 | 26.18 | 6.87 | 8.0 | 54.96 | 0 | 47.31 |
| 13 | 7.1 | 8.2 | 58.22 | +20 | 48.78 | 6.88 | 8.1 | 55.73 | +20 | 117.89 |
| 14 | 7.1 | 8.06 | 57.23 | +20 | 54.69 | 6.88 | 7.91 | 54.42 | +20 | 119.44 |
| 15 | 7.1 | 8.1 | 57.51 | +20 | 49.21 | 6.85 | 8.05 | 55.14 | +20 | 127.49 |
| 16 | 7.1 | 8.06 | 57.23 | +40 | 52.25 | 6.86 | 8.03 | 55.09 | +40 | 127.25 |
| 17 | 7.1 | 8.0 | 56.80 | +40 | 52.64 | 6.86 | 8.07 | 55.36 | +40 | 125.72 |
| 18 | 7.0 | 8.04 | 56.28 | +40 | 53.13 | 6.88 | 8.16 | 56.14 | +40 | 127.18 |

As one can see from Figures 9 and 10, after deformation of pipe metal by 3.5 % in the circumferential direction a considerable shift of brittle-ductile transition temperatures determined by 30 J/cm² criterion, is observed for the axial and circumferential directions. In this case, the shift of brittle-ductile transition temperatures for the axial and circumferential directions was assessed by minimum values of impact toughness of Charpy specimens. It should be also noted that specimens cut out in the axial direction are more sensitive to the effect of pipe metal plastic deformation in the circumferential direction (3.5 % of plastic deformation) on the general change of brittle-ductile transition temperature, than those cut out in the circumferential direction. So, the given graphs of the dependence of impact toughness of Charpy specimens on testing temperature show that the total shift of brittle-ductile transition temperatures is equal to 40 °C for the axial direction and about 20 °C for the circumferential direction. At the same time, the brittle-ductile transition temperature, which was determined on the specimens in the circumferential direction, is much higher than that for specimens in the axial direction. Moreover, in the ductile condition a drop of impact toughness of the Charpy specimens is observed for the circumferential direction at pipe deformation by 3.5 % during hydraulic loading, that is absent in specimens in the axial direction (see Figures 9, 10).

The latter case completely confirms the validity of the proposed approach to lowering of the characteristics of brittle and tough fracture resistance of pipeline metal under the impact of strain ageing.

From the above results it should be noted that testing of Charpy specimens cut out in the direction of pipeline axis, leads to considerable error in assessment of pipeline material resistance to brittle and quasibrittle fracture. So, at assessment of transition temperature by specimens of 30 J/cm² impact toughness

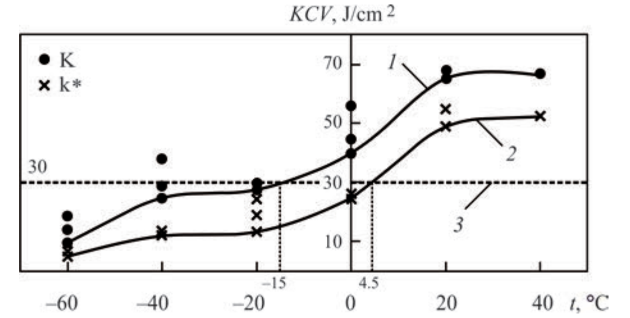


**Figure 9.** Temperature dependence of impact toughness of Charpy specimens oriented in the circumferential direction for undeformed (K) and deformed (K*) pipe metal: *1* — curve by minimum values for specimens for undeformed metal; *2* — for deformed metal; *3* — 30 J/cm²

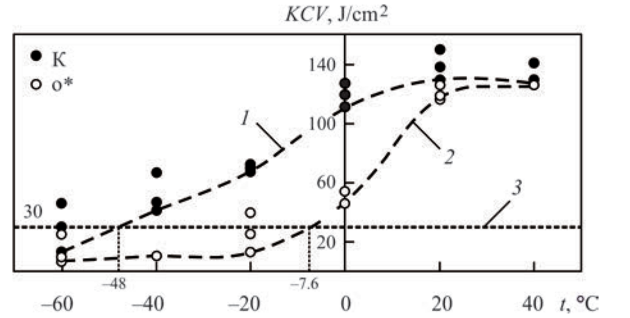


**Figure 10.** Temperature dependence of impact toughness of Charpy specimens oriented in the axial direction for undeformed (O) and deformed (o*) pipe metal: *1* — curve by minimum values for specimens for undeformed metal; *2* — for deformed metal; *3* —30 J/cm² level

for an undeformed pipe, the error is more than 40 °C. More over, the ductile fracture resistance ($KCV_{max}$) of the material in the axial and circumferential directions differs by almost two times that only worsens the assessment (see Figures 7, 8).

The same tendency is also in place for pipe deformation by 3.5 % in the circumferential direction, where at assessment of the transition temperature by impact toughness specimens at 30 J/cm$^2$, the error is more than 12 °C at more than two times decrease of material ductile fracture resistance ($KCV_{max}$). In this case, increase of $\sigma_{0.2}$ yield limit is not even taken into account.

Obtained conclusions can be useful for assessment of the welded joint HAZ resistance to brittle and quasibrittle fracture in pipelines.

## Conclusions

1. Plastic deformation of pipeline wall can significantly lower the ductile fracture resistance characteristics ($\delta_i$, tg$\alpha$, $KCV$, $\varepsilon_t$, $T_{bdt}$) even at relatively low values of plastic deformation in its local regions. So, for instance, for 17G1S steel 7.0 mm thick the error is more than 12 °C, at assessment of transition temperature by impact toughness specimens at 30 J/cm$^2$ for a pipe with 3.5 % deformation.

2. Determination of the temperature of brittle-ductile transition by minimum values of impact toughness of Charpy specimens for axial direction does not correspond to the real state and is seriously underestimated, compared to specimens made in the circumferential direction. So, for instance, for 17G1S steel 7.0 mm thick, at assessment of transition temperature by impact toughness specimens at 30 J/cm$^2$ for an undeformed pipe, the error is more than 30 °C.

3. Obtained conclusions can be useful for assessment of welded joint resistance to brittle and quasibrittle fracture of pipelines.


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**SEPTEMBER 9, 2013** Las Vegas High Roller amusement ride of 168 m was opened in the USA. The observation wheel is the fantastic fulfillment of achievements of machine-building and design as well as world record-holder in height. New amusement ride is equipped with 28 cabins of 6 meters diameter, each of which can include up to 40 people. External rim of «High Roller» wheel was welded from two tubular steel beam of inch thickness, then they were joined in groups of four on four beams forming rim section. Each of these elements then were joined and as a result an external wheel rim was obtained. Supporting structures were designed and constructed in the same way in order to carry tremendous load of the wheel.

**SEPTEMBER 10, 1957** Plasma cutter was patented. Plasma cutting was invented in 1954 in a laboratory of Linde department of Union Carbide Company. Young scientist Robert Gage found that TIG arc passed through small diameter nozzle significantly rises its intensity and temperature. Passing through this focused arc sufficiently large gas flow, he discovered that such arc can be used for metal cutting. Arc temperature, reaching more than 24000 K, melts metal and intensive air flow blows out molten metal for cutting. Since gas in arc was in overheated state, called plasma, this process was named plasma cutting.