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# STATISTICAL ANALYSIS OF TOTAL IMPACT ENERGY OF LARGE THICK WALLED PRESSURE VESSEL

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## ABSTRACT
*The testing of impact energy thick-walled pressure vessel material showed a vast range of different results. Pressure vessels were made by hot plastic deformation treatment. Three sets of specimens were isolated from the vessel, each having a different orientation of fatigue cracks in relation to the vessel axis. Impact tests were performed on the Charpy specimens in accordance with ASTM E23. The results showed a large range of different results, even within each sets of specimens. The results of impact energy were processed by means of Weibull statistical analysis. Based on these results of a direction distribution coefficient m was obtained and results reliability interval of impact energy was defined*
**Keywords:** impact energy, statistical analysis, thick pressure vessels.

## 1. INTRODUCTION
Determination of total impact energy of large structures, especially structures were made by hot plastic deformation treatment (forging) can result in a large wastage of the test results. Research presented in this paper are focused on getting a more complete picture of the impact energy and hardness of material thick-walled pressure vessels. Taking samples for testing of such structures means very often destruction of structures or parts of structures that is not always possible. If it is already possible to take samples then the question is where to take, and whether the results of the tests on these samples relevant to the assessment of complete pressure vessels.
Impact the force on notched specimens can provide an explanation of the behavior of materials in disturbed distortion, ie. in the spatial stress state.

This test procedure can be established tendency to brittle fracture, or the tendency to increase stiffness during operation (aging).
Impact tests of samples were carried out at room temperature + 20°C. The test temperature was selected on the basis of the technological process where water as hydraulic medium are used. Test procedure was performed according to ASTM E 23. The notch was prepared by milling.

## 2. SPECIMENS AND TEST

Tested pressure vessel were produced by plastic deformation of a single piece of the steel quality 40Mn6. The vessels are large dimensions: diameter $d_o$=998/$d_i$=800 mm, wall thickness of cilindrical part was t = 99 mm, and wall thickness of bottom vessel head was about 200 mm. Tested specimens series have been taken out from the central part of the vessel (M samples), in the area of the bottom vessel head (samples B) and the top vessel head (samples T). Same sizes Charpy specimens (10x10x55) are used for testing. The test results are presented in Table 1. Samples are taken from axial (A) and tangential (C) direction in relation to the vessel axis. Notches were in radial (R), tangential (C) and axial (A) direction. Results of measurement of HV1 hardness in the 5 points are shown in Table 2.

*Table 1. Samples data and results of total impact energy*

| Specimen index and direction | Notch direction | Total impact energy $A_{tot}$, J | | | Average value of three samples |
|---|---|---|---|---|---|
| M-A | C | 44,25 | 36,42 | 53,80 | 44,82 |
| M-A | R | 35,58 | 45,82 | 41,82 | 41,07 |
| M-C | R | 35,21 | 34,66 | 34,38 | 34,75 |
| B-C | R | 35,39 | 30,6 | 25,61 | 30,50 |
| B-A | C | 48,57 | 47,31 | 34,37 | 43,41 |
| B-A | R | 49,84 | 53,27 | 50,1 | 51,07 |
| T-C | A | 54,7 | 52,3 | 47,8 | 51,6 |
| T-C | R | 26,1 | 26,9 | 27,5 | 26,8 |

** M-middle, B-bottom vessel head, T-top vessel head, A-axial, C-tangential, R-radial,*

*Table 2. Hardness HV1*

| Measurement | Specimen T | Specimen M | Specimen B |
|---|---|---|---|
| 1 | 171 | 178 | 165 |
| 2 | 171 | 178 | 171 |
| 3 | 175 | 182 | 165 |
| 4 | 175 | 175 | 171 |
| 5 | 178 | 175 | 162 |
| **Average value** | **174** | **177,6** | **166,8** |

## 3. STATISTICAL ANALYSIS USING WEIBULL PROBABILITY DISTRIBUTION

Testing probability distribution shows that the distribution does not follow the Gauss's normal distribution, than an asymmetric curve, for example, Weibull's probability function, indicate references Vukojevic et al. (2015). Weibull distribution function is partly leaning on empirical approach.
Determining the probability of the existence $P_s$ was made with the assumption that all the specimens were subjected to a same test conditions. For each test obtained the corresponding probability of existence which is determined from equation:

$$P_s = 1 - \frac{1-0,3}{[illegible]} \quad ... (1)$$

Probability of failure of the sample volume V at the critical value of the stress intensity factor is defined as:

$$P_s(V) = exp\left[-V\left(\frac{K_{Ic}-K_u}{[illegible]}\right)^{[illegible]}\right] \quad ... (2)$$

Results of statistical analysis using the Weibull's distribution function are shown in Figures 2, 3 and 4.

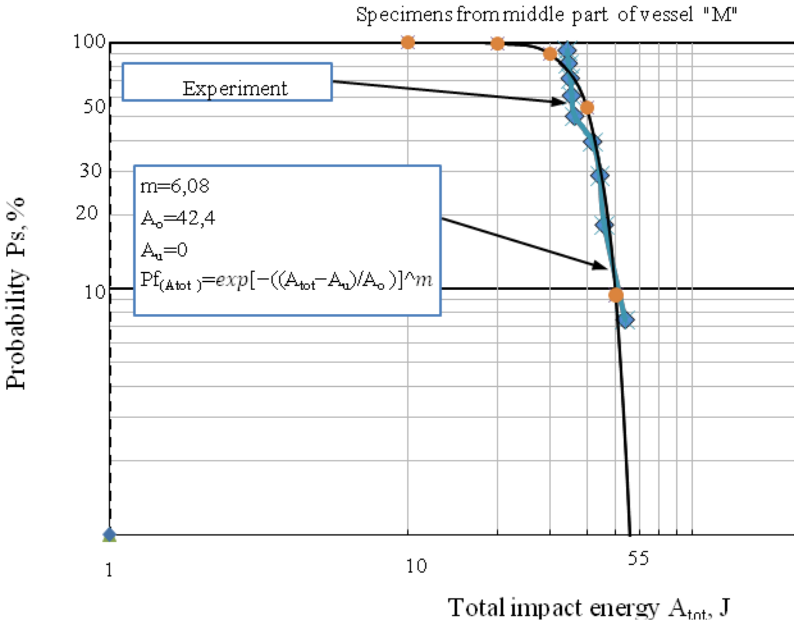


*Fig. 2. Weibull diagram for specimens from vessel middle-specimens M*

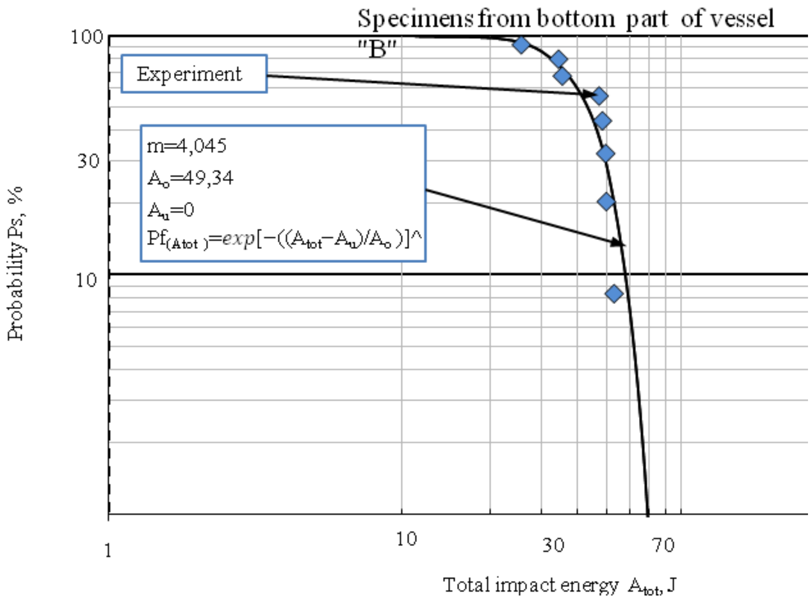


*Fig. 3. Weibull diagram for specimens from bottom vessel head-specimens B*

Statistical analysis shows the reliability of the obtained results of impact energy. The higher value of the Weibull's coefficient *m* means higher reliability and less wastage of value, while the value $A_o$ represents mean value of the distribution. Reliability curve obtained by Weibull's distribution shows the interval 99% probability of the measured total impact energy appear in the distribution interval. Thus, from the curve presented in Fig.2, Fig. 3 and Fig. 4, its obvious the widest interval for the measured values of energy have specimens taken out from top vessel head "T" ($A_{tot}$ = 25÷55 J) in Fig. 4. Reliability interval is narrowest for the tested specimens taken out from the middle part of the vessel "M" ($K_{Ic}$ = 35÷55 J), Figure 2. For the bottom vessel head, specimens marked with "B", the reliability interval of $A_{tot}$ is within 25÷50 J, as shown in Figure 3.

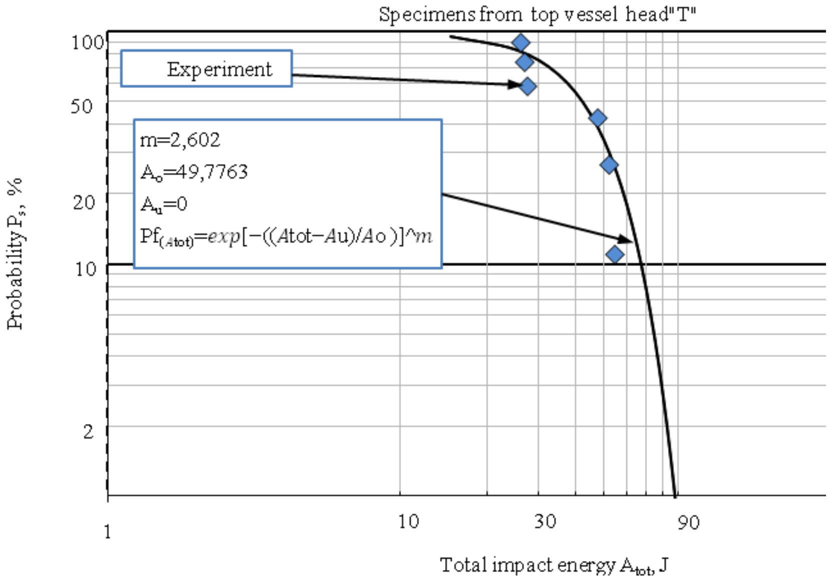


*Fig. 4. Weibull diagram for specimens from top vessel head-specimens T*

Based on statistical analysis could be considered to be the most critical part is top vessel head ("T" specimen).
The measured hardness values show no significant difference in the measured values. This fact has no influence on the results of the total impact energy.

## 4. CONCLUSION

The analysis of the results according to the location of specimens sampling, it is clear that the results of impact energy are worst for specimens taken out form top vessel head (plate of the top vessel head marked with "T"). This part of the vessel has suffered the least plastic deformation which results in the lowest impact energy out to date.

Top vessel head of the structure was only possible to take the test samples, without destruction of structure. This research was clearly demonstrated that large structures, where are not possible to take samples without totally destruction or damage, determining the total impact energy, get a result that could lead to the adoption of wrong conclusion.

## 5. REFERENCES

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