DETERMINING THE CATEGORY OF WELDED JOINTS
FOR THE NON-REGULATED AREA OF MACHINE BUILDING

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Abstract: A categorization has been proposed of the welded joints depending on the type and character of loading and the needed safety requirement of the structure of which they are an integral part. Four “production requirement grades”: “PRGs”, have been introduced. They allow the objective grading of welding requirements put forward towards the preparation of each and every welded joint for which the loading and operation conditions are familiar.

Keywords: QUALITY REQUIREMENTS, LOADING, SAFETY REQUIREMENT, WELDED JOINT CATEGORIES

1. General

The proposed categorization of welded joints is designed for the non-regulated area in general machine building. The aim is, through it, to develop the requirements towards the entire welding production process that are to guarantee its quality performance.

In specialized literature, no regulatory proposals for categorization of the welded joints in the non-regulated area of industry, and for the limitation of a direct connection between a design methodology and the manner of execution of welded structures, are found. As a matter of fact, only in the standardization series BDS EN ISO 3834, in parts 2,3, and 4, the welding requirements are being specified in detail in three grades: comprehensive, standard, and elementary [2,3,4]. These requirements, however, are not referred to the specific conditions of welding product operation: their stress level, certain safety requirement, etc. For the requirements connected to welded products, in the first part of the standard BDS EN ISO 3834 [1] only general conditions are being given for the observance of:
- the welded product’s safety
- the production process complexity
- the product’s application area
- the area of the various materials used
- the magnitude of the possible metallurgical problems
- the degree to which the production irregularities (imperfections) can influence the preparation of the product.

That is why, for full value functioning of the quality assurance system in a given production firm it is expedient to dispose of a methodology by which the requirements in reference to the welding production process to be connected specifically to the structural characteristics of the welded product.

2. Methodological Prerequisites

As methodological prerequisites for categorization of the welded joints in general machine building, the following auxiliary regulatory materials can be used:

(1) According to DVS 0705 (Bulletin of the German Welding Society) [5]: in the non-regulated area of industry, in view of determining the permissible levels of imperfections it is being proposed the welded joints to be subdivided into three groups depending on the loading grade (predominant static loading). The loadings can be graded depending on the utilization of the permissible stresses, i.e. the percentage ratio of the available stresses in the welding seam \( \sigma_{av} \) towards the permissible stress \( \sigma_{perm} \), namely:
- until about 50% (\( \sigma_{av} \leq 0,5 \% \sigma_{perm} \))
- until about 75% (\( 0,5 \% \sigma_{perm} < \sigma_{av} \leq 0,75 \% \sigma_{perm} \))
- until about 100% (\( 0,75 \% \sigma_{perm} < \sigma_{av} \leq \sigma_{perm} \)).

(2) and (3) According to DAS 009:2005 (Directive of the German Committee on Steel Construction) [6], BDS EN 15085-3 [8], resp.: in the regulated area of “Construction of Steel Support Structures”, in determining the admissible thickness of the base metal (the necessary steel quality group, respectively), also a subdivision of the level of stresses \( \sigma_{ed} \) in welded joints is being introduced, in three grades:
- \( \sigma_{ed} = 0,75 \% \sigma_{av} \) (t)
- \( \sigma_{ed} = 0,50 \% \sigma_{av} \) (t)
- \( \sigma_{ed} = 0,25 \% \sigma_{av} \) (t)

where: the characteristic yield-strength limit \( \sigma_{y} \) (y), dependent on the sheet metal thickness, equals the yield-strength limit \( \sigma_{ed} \) for the respective product thickness \( t \), as taken from the steel delivery terms (the product standard).

Here too, the stress level of the welded joints is being determined with priority, from the magnitude of the static loading. The other conditions with impact on the mechanical behavior: loading dynamics, reliability level, metal strengthening as a result of cold plastic deformation, residual stresses, etc., are being accounted for indirectly by the so called referential temperature \( T_{ed} \).

(4) According to BDS EN 15085-3 [8]: in the regulated area “Railway Transportation Vehicles” the welded joints, as regards their stress level, are being subdivided into three groups depending on the used possible stress level \( S \):
- high stress level, when \( S \geq 0,9 \)
- medium stress level, when \( 0,75 \leq S < 0,9 \)
- low stress level, when \( S < 0,75 \).

3. Essence of the Categorization of Welded joints

As basic criteria for the categorization, the stress level and the nature of loading (static, dynamic) of the welded joint are being assumed. A stress level indicator is the utilized stress level \( S \). It is being assigned as a ratio between the rated (calculated) stress \( \sigma_{calc} \) and the permissible stress for the calculated connection \( \sigma_{perm} \).

\[ S = \frac{\sigma_{calc}}{\sigma_{perm}} \]

The values of the safety factor can be taken from a certain regulatory document preliminarily agreed upon with the client (the party ordering the product).

Four stress levels are being introduced: especially high (symbol high*), high, medium, and low. The especially high level is envisaged for the welded joints with predominant dynamic loading, and the other three levels for predominant static loading.

Safety requirement in the present categorization is a criterion with reduced significance, since if the product into which these connections are being input is associated with considerable risks.
Stress Level and Safety of Welded Joints

Table 1: Grades of Production Requirements Depending on the Stress Level and Safety of Welded Joints

<table>
<thead>
<tr>
<th>Stress Level</th>
<th>Utilized Stress Level, S</th>
<th>Safety Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>High*</td>
<td>S ≥ 0.9 and/or dynamic loading</td>
<td>PRG I, PRG II, PRG III</td>
</tr>
<tr>
<td>High</td>
<td>0.75 ≤ S &lt; 0.9</td>
<td>PRG II, PRG III, PRG IV</td>
</tr>
<tr>
<td>Medium</td>
<td>0.50 ≤ S &lt; 0.75</td>
<td>PRG III, PRG IV, PRG IV</td>
</tr>
<tr>
<td>Low</td>
<td>S &lt; 0.50</td>
<td>PRG IV, PRG IV, PRG IV</td>
</tr>
</tbody>
</table>

The categorization introduced gives an opportunity to objectively grade the welding technical requirements towards each and every welded product for which the loading and operation conditions are familiar.

The requirements to the execution of welded products of the non-regulated area can be formed by two requirement arrays: base requirements (of the BDS EN ISO 3834) and reference requirements (developed for the purpose). The reference requirements constitute an expansion and specification of the base requirements and for the most part draws on the experience and those components of the applied standards in the regulated area that are best suited for the products of the non-regulated area.

The structuring of the reference requirements has been done analogically in the manner used in the harmonized European applied/product standards, for instance for the “Structural Components” [10], the “Unfired Pressure Vessels” [11], “Railway Vehicles and Components” [12], etc.

The producer must be in a position to fulfill the basic components of the PRGs that are given on tables 2 and 3. Based thereon the details can be developed for all quality components, numbering 22 in total, as found in part 1 of the BDS EN ISO 3834.

The production requirement grades PRG I, II, III and IV must be entered in the structural and in the welding process documentation. If in the structural documentation the production requirement grade is not entered, it is considered that the welded joints must be prepared according to the requirements of PRG III at least.

Before starting production, the producer of the welded product must receive, contract, and finally specify with the client the entire necessary information and requirements to every part of the welded product.

4. Conclusions

1) A categorization of the welded joints has been proposed depending on the type and character of loading, and the necessary safety requirement of the structure of which they (the welded joints) are an integral part.

2) Four “production requirement grades”: “PRGs” have been introduced. They allow the objective grading of welding technical requirements put forward towards each and every welded product for which the loading and operation conditions are familiar.

3) The results obtained can be used for full value functioning of the quality assurance systems in welding production.

5. References

### Table 2: Basic Welding Technical Requirements to the Producer Depending on the PRG production grades

<table>
<thead>
<tr>
<th>Production Requirement Grades</th>
<th>PRG I</th>
<th>PRG II</th>
<th>PRG III</th>
<th>PRG IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality and Execution Documentation</strong></td>
<td>required</td>
<td>required</td>
<td>required</td>
<td>not required</td>
</tr>
<tr>
<td><strong>Base Quality Requirements</strong></td>
<td>comprehensive as per BDS EN ISO 3834-2</td>
<td>comprehensive as per BDS EN ISO 3834-2</td>
<td>standard as per BDS EN ISO 3834-3</td>
<td>elementary as per BDS EN ISO 3834-4</td>
</tr>
<tr>
<td><strong>Producer Certification under the BDS EN ISO3834-2,3,4</strong></td>
<td>according to part 2</td>
<td>according to part 2</td>
<td>according to part 3</td>
<td>according to part 4</td>
</tr>
<tr>
<td><strong>Assessment Level of Imperfections under the BDS EN ISO 5817 (B,C or D)</strong></td>
<td>A (=B + additional requirements)</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td><strong>Responsible Coordinator for Welding (RSPW)</strong></td>
<td>grade A*</td>
<td>grade A or B**</td>
<td>C***</td>
<td>not necessary</td>
</tr>
<tr>
<td><strong>RSPW Deputy</strong></td>
<td>deputy: grade A&lt;sup&gt;a&lt;/sup&gt; next deputy: grade B or C&lt;sup&gt;b&lt;/sup&gt;</td>
<td>deputy: grade C</td>
<td>not necessary</td>
<td>not necessary</td>
</tr>
<tr>
<td><strong>Welders and Operators</strong></td>
<td>For every welding process and material group, welders are needed who has passes an examination under the BDS EN 287-1, and operators, under the BDS EN ISO 14732</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Examiner Personnel</strong></td>
<td>- examiner personnel for welding quality testing - supervision of welding quality testing: responsible SPW (coordinator) - non-destructive testing personnel: grade 1 as per the BDS EN 473 - non-destructive testing supervision: grade 2 as per the BDS EN 473</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Welding Procedure Specifications (WPS)</strong></td>
<td>WPSs as per: the BDS EN ISO 15609 or BDS EN ISO 14555</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Welding Procedure Qualification Record (WPQR)</strong></td>
<td>WPQR as per the BDS EN ISO 15610, BDS EN ISO 15611, BDS EN ISO 15612, BDS EN ISO 15613, BDS EN ISO 15614 or BDS EN ISO 14555</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* “International/European Welding Engineer” qualification
** “International/European Welding Technologist/Technician” qualification
***“International/European Welding Specialist” qualification
<sup>a</sup> No deputy equal in rights (grade A) required in small welding enterprises with only one welding production sector
<sup>b</sup> In welding enterprises with more welding production sectors, an additional grade C deputy is required for every sector

### Table 3: Type and Volume of Trials and Imperfection Assessment Level Depending on the Production Requirement Grade

<table>
<thead>
<tr>
<th>Production Requirement Grade</th>
<th>Imperfection Assessment Level under the BDS EN ISO 5817</th>
<th>Volumetric Tests RT or UT</th>
<th>Surface Tests MT or PT</th>
<th>Visual Test VT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRG I</td>
<td>A = B + additional requirements</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>PRG II</td>
<td>B</td>
<td>10%</td>
<td>10%</td>
<td>100%</td>
</tr>
<tr>
<td>PRG III</td>
<td>C</td>
<td>not necessary</td>
<td>10%</td>
<td>100%</td>
</tr>
<tr>
<td>PRG IV</td>
<td>D</td>
<td>not necessary</td>
<td>not necessary</td>
<td>100%</td>
</tr>
</tbody>
</table>