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The differences between the strengths of quality levels of weld imperfections given in ISO 5817

M. Vural*
[a] Faculty of Mechanical Engineering, Istanbul Technical University, Gumussuyu, Istanbul, Turkey
* Corresponding author: E-mail address: vuralmu@itu.edu.tr

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ABSTRACT

Purpose: ISO 5817 "Arc-welded joints in steel-Guidence on quality levels for imperfections" is a widely used international standard for evaluating of the weld imperfections in arc welded joints. In this study, in order to see the differences between the quality levels given in ISO 5817, the welded joints of B, C and D levels are subjected to the same load and the differences of maximum stresses at the joints are analysed by FEM.
Design/methodology/approach: The welded joints with the quality levels of the weld imperfections given in ISO 5817 are modeled by a Solidworks FEM program, and they are subjected to static loading in order to determine the maximum stresses at the cross-sections of the joints.
Findings: The stress values at the welded joints generally increases from the quality level of "B" to "D". Exceptions of this behavior are the imperfections defined as "fillet welds having the throat thickness greater than nominal value", "excessive penetration" and "excessive asymmetry fillet weld". In these imperfections, the cross-sections carrying the force increases from "B" to "D". Because of static force, a greater cross-section forms a smaller stress value. Thus, it must be given in the ISO 5817 whether the welded joint is subjected to a static or dynamic load.
Research limitations/implications: Three dimensional models can be investigated and the effect of 3D weld imperfections on the behavior of a more realistic model can be calculated.
Practical implications: The results show that some imperfections like "excessive penetration" and "excessive asymmetry filet weld" have less importance compared to the others.
Originality/value: ISO 5817 is a worldwide used Standard for evaluating the weld imperfections. The quality levels of weld imperfections are compared with each other with FEM. The Standard includes 57 different quality levels and this paper compared all these levels with each other.
Keywords: Weld imperfections; Quality level; ISO 5817, Finite Element Method; Static loading

1. Introduction

Any welded joint may have any kind of weld imperfections. Their effects on the quality and performance of the welded joint are depend on the requirements of the structure in use. It is very important to decide the quality of a welded joint. The choice of quality level for any application should take account of design considerations, subsequent processing, e.g. surfacing, mode of stressing (e.g. static, dynamic), service conditions (e.g. temperature, environment), and consequences of failure. Economic factors are also important and should include not only the cost of welding but also that of inspection, test and repair. For example, if a welded structure is not critical from the point of human safety etc., some level of imperfections may not seem more important. If the imperfections are tried to remove from that kinds of welded joint, time- and money-consuming effords can be done for nothing. On the other hand, if a critical welded joint is assumed as "non-critical", so many problems can arise [1, 2, 3] .

2.ISO 5817 and its content

ISO 5817 is generally used within a total quality system for the production of satisfactory welded joints. It provides three sets of dimensional values from which a selection can be made for a particular application. The quality level necessary in each case should be defined by the application standard or the responsible designer in conjunction with the manufacturer, user and/or other parties concerned. ISO 5817 covers the limits for weld imperfections for quality levels as stringent (B), intermediate (C) and moderate (D) (Table 1) [4].

The choice of quality level for any application should take account of design considerations, subsequent processing, e.g. surfacing, mode of stressing (e.g. static, dynamic), service conditions (e.g. temperature, environment), and consequences of failure. Economic factors are also important and should include not only the cost of welding but also that of inspection, test and repair [5, 6].

The quality levels given in this international Standard are intended to provide basic reference data and are not specifically related to any particular applitacion. They refer to the types of welded joints in a fabrication and not to the complete product or component itself. It is possible, therefore, for different quality levels to be applied to individual welded joints in the same product or component. [7, 8]

Table 1.
Quality levels for weld imperfections in ISO 5817

Level symbol	Quality level
D	Moderate
C	Intermediate
B	Stringent

In ISO 5817 the weld imperfections are classified as twenty-six imperfections like cracks, porosity and cavities, solid inclusions, lack of fusion and incomplete penetration, shape imperfections and the multiple imperfections.

3. Numerical Studies

In this study, the welded joints with the quality levels of the weld imperfections given in ISO 5817 are modeled by using a FEM program, and they are subjected to static loading in order to determine the maximum stresses at the cross-sections of the joints. In the study Solidworks is used as Finite Element Analysis program. [5]

3.1. Material

AISI 1020 steel is used as the material. The thickness of the material is assumed as 10 mm. The properties of the material used in the analysis is given in Table 2.

Table 2.
Physical and mechanical properties of the material used in the analysis

Properties	Value
Elastic modulus	2e+011 N/m^2
Poisson's ratio	0.29
Shear modulus	7.7e+010 N/m^2
Mass density	7900 kg/m^3
Tensile strength	4.2051e+008 N/m^2
Yield strength	3.5157e+008 N/m^2
Thermal expansion coefficient	1.5e-005 /Kelvin
Thermal conductivity	47 W/(m.K)
Specific heat	420 J/(kg.K)

3.2. Model and Analysis

The welded joints designed as in ISO 5817 which will be subjected to static loading are plotted in SolidWorks programme with the quality levels of B, C and D given in ISO 5817 for each type of weld imperfections. For obtaining a stress distribution at the cross-section, a constant force of 10.000 N is applied to each specimen having 10 mm in thickness at a appropriate direction for welded joint. CosmosWorks programme is used to obtain the analysis results as stress, elongation and deformation. The maximum stress distributions at the welded joints are shown. The cracks are excluded from the study, because no cracks are allowed in ISO 5817 as weld imperfections. Only the imperfections shown as figures in ISO 5817 are considered in the study

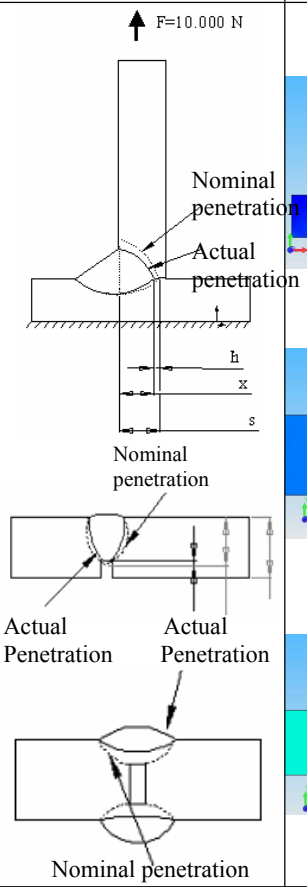
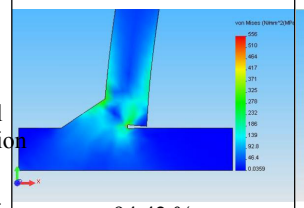
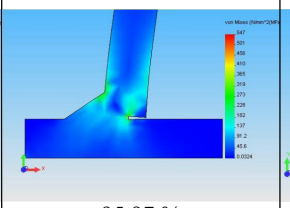
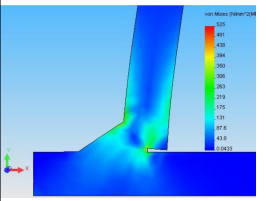
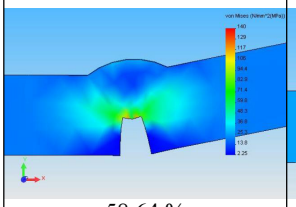
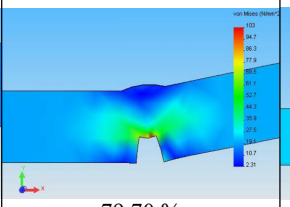
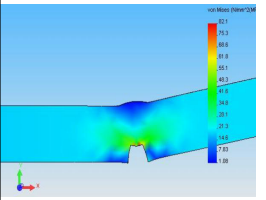
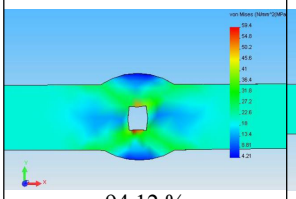
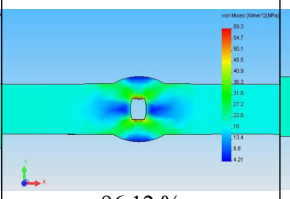
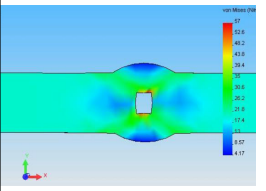
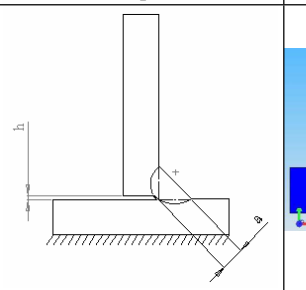
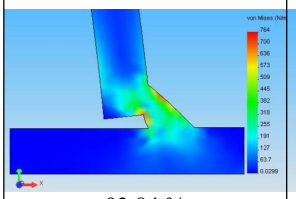
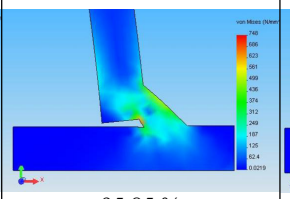
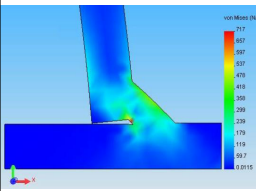
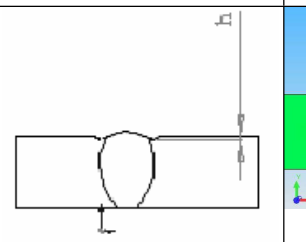
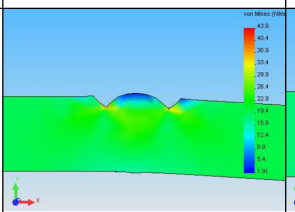
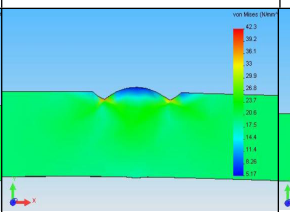
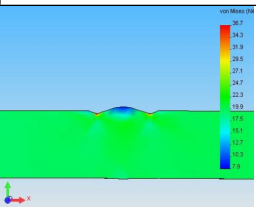
3.3. Results

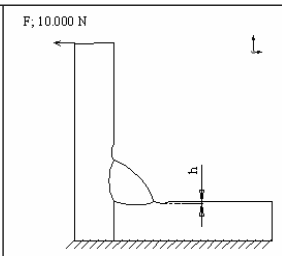
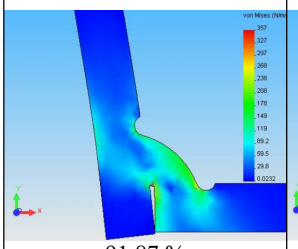
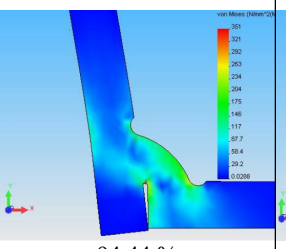
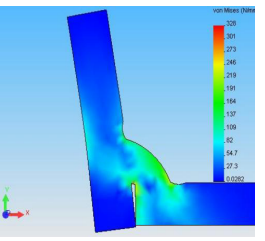
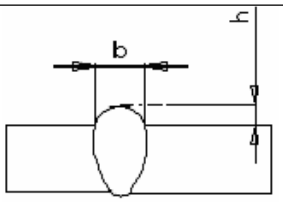
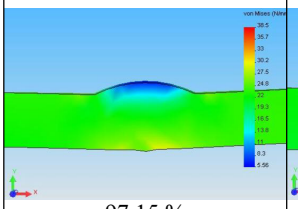
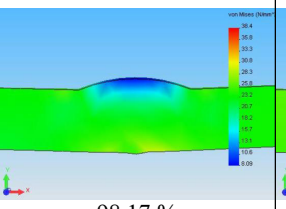
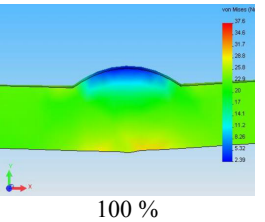
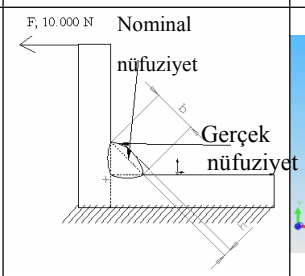
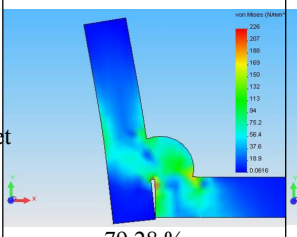
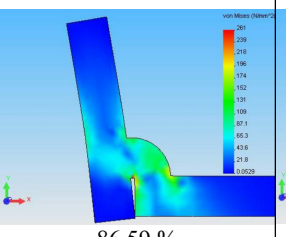
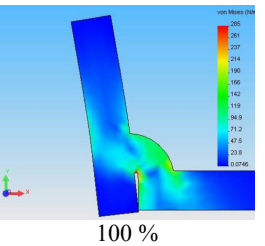
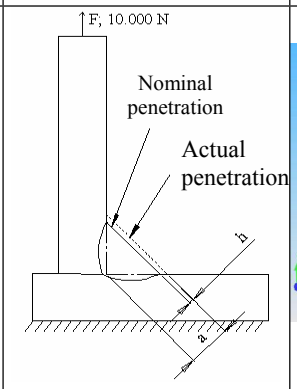
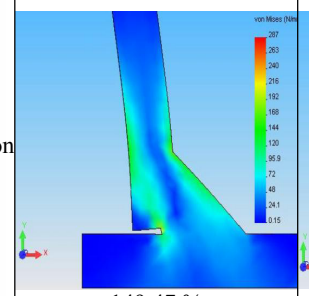
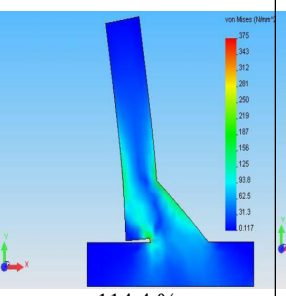
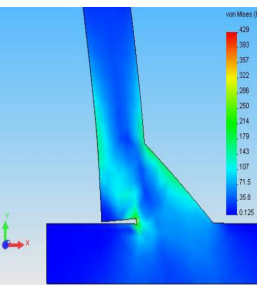
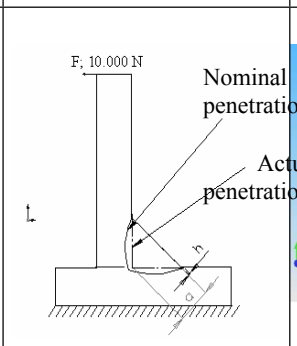
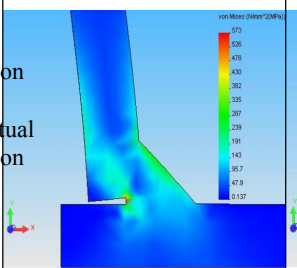
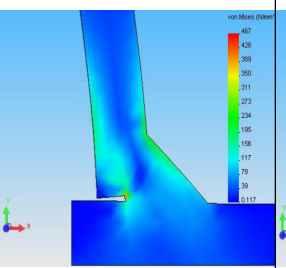
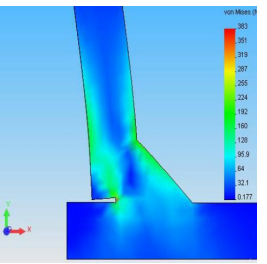
The results are given as in the original body of ISO 5817 Standard in Table 3.. The performances of the quality levels are compared with those of the level B's as percentages. The dimensions of the imperfections given as "not permitted" are assumed as having its nominal value.

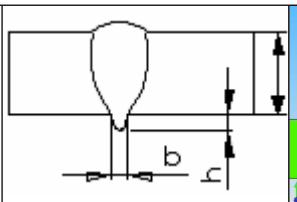
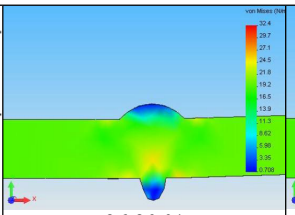
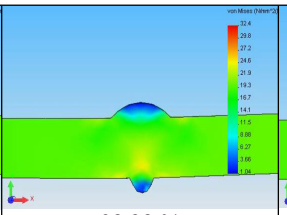
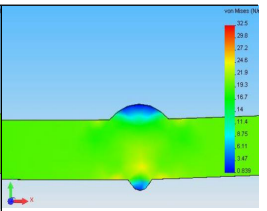
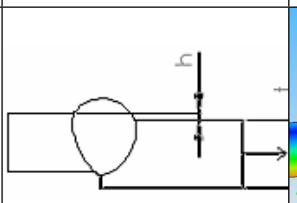
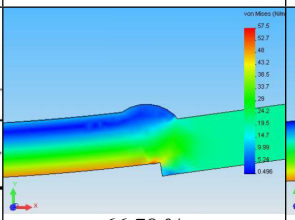
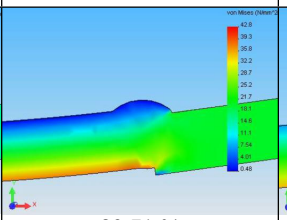
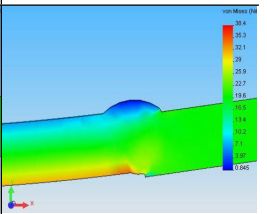
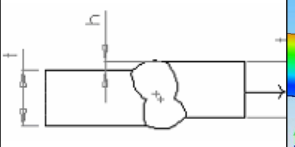
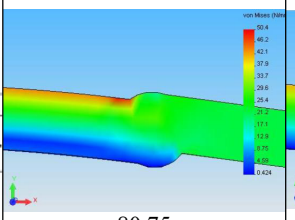
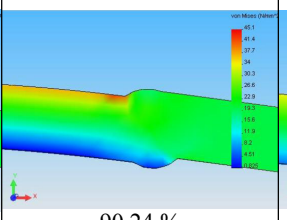
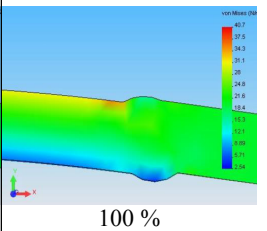
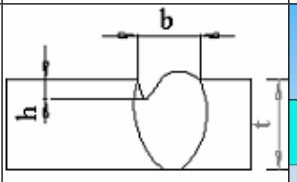
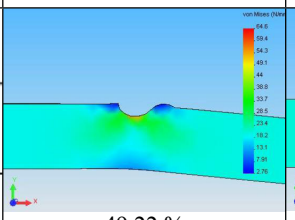
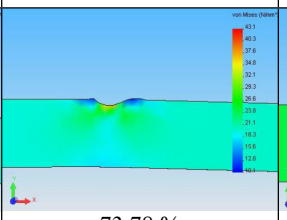
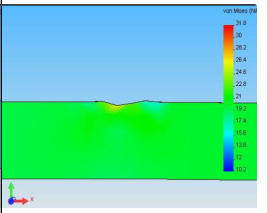
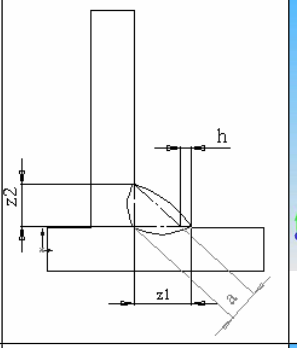
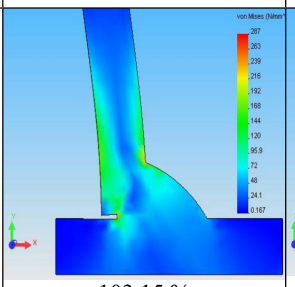
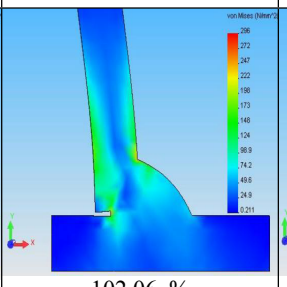
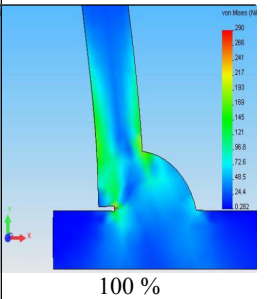
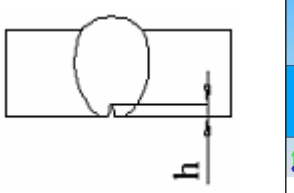
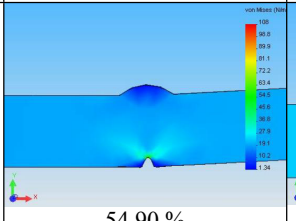
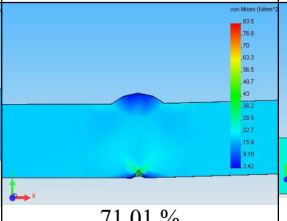
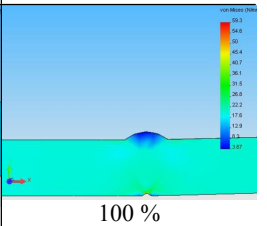
4. Conclusional Remarks

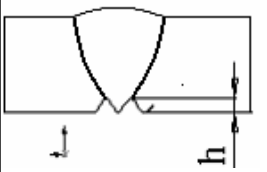
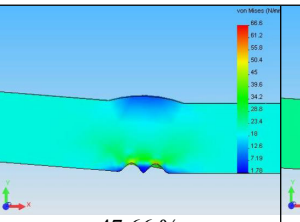
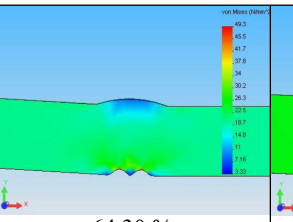
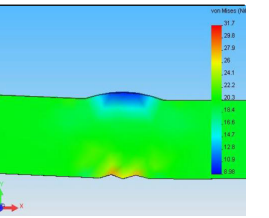
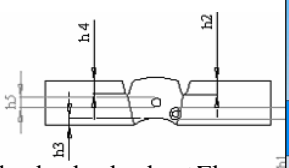
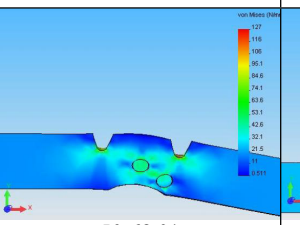
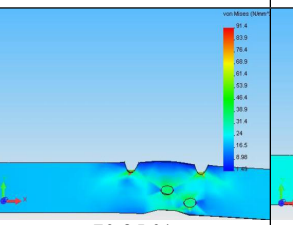
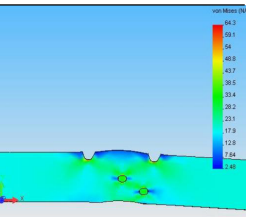
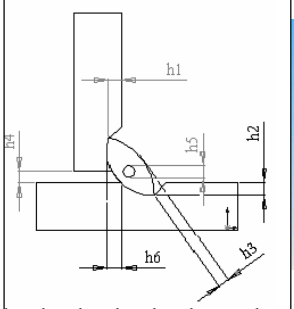
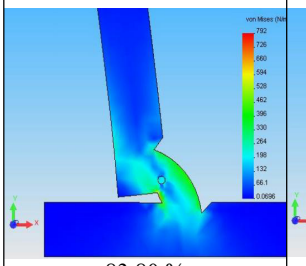
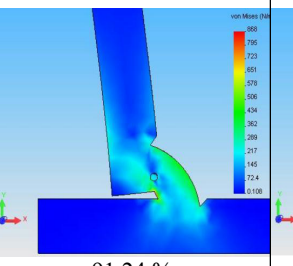
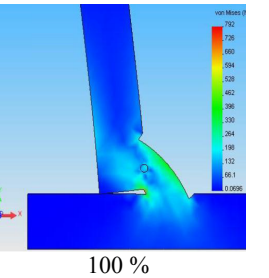
The aim of this study is to determine the behavior of the quality levels of weld imperfections given in ISO 5817 as figures under a certain static stress. As seen from the graphes, the stress values at the welded joints generally increases from the quality level of "B" to "D". Exceptions of this behavior are the imperfections defined as "fillet welds having the throat thickness greater than nominal value", "excessive penetration" and "excessive asymmetry fillet weld". In these imperfections, the cross-sections carrying the force increases from "B" to "D". Because of acting the force as statically, a greater cross-section forms a smaller stress value. For this reason, it must be given in the ISO 5817 whether the welded joint is subjected to a static or dynamic loading.

Table 3.
The performances of the quality levels as compared with those of the level B's as percentages

Imperfection designation	ISO 6520 ref.	Explanation	Limits for imperfections for quality levels		
			Moderate D	İntermediate C	Stringent B
Lack of penetration (Incomplete imperfection)	402		Short imperfections		
			 94.42 %	 95.97 %	 100 %
			 58.64 %	 79.70 %	 100 %
			 94.12 %	 96.12 %	 100 %
Bad fit-up, Filet welds			 93.84 %	 95.85 %	 100 %
Undercut	5011 5012		 83.59 %	 86.76 %	 100 %

			 91.87 %	 94.44 %	 100 %
Excess weld metal	502		 97.15 %	 98.17 %	 100 %
Excessive convexity	503		 79.28 %	 86.59 %	 100 %
Filet weld having a throat thickness greater than the nominal value	-		 149.47 %	 114.4 %	 100 %
Filet weld having a throat thickness smaller than the nominal value	-		 66,84 %	 82,01 %	 100 %

Excessive penetration	504		 96.30 %	 98.28 %	 100 %
Linear mis-alignment	507		 66.78 %	 89.71 %	 100 %
			 80.75	 90.24 %	 100 %
Incompletely fillet groove	508		 49.22 %	 73.78 %	 100 %
Excessive symmetry fillet weld	512		 103.15 %	 102.06 %	 100 %
Root concavity	515		 54.90 %	 71.01 %	 100 %

Shrinkage groove	5013		 47.66 %	 64.30 %	 100 %
Multiple imperfections in any cross-section	-	 $h_1+h_2+h_3+h_4+h_5 \leq \Sigma h$	 50.62 %	 70.35 %	 100 %
		 $h_1+h_2+h_3+h_4+h_5+h_6 \leq \Sigma h$	 83.80 %	 91.24 %	 100 %

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[1] ISO 5817: 2003, "Arc-welded joints in steel, nickel and nickel alloys, titanium and titanium alloys (except electron beam welds) – Guidance on quality levels for imperfections,

[2] ISO 6520, 1982, "Classification of imperfections in metallic fusion welds, with explanations".

[3] Carosena Meola, Antonino Squillace, Fabrizio Memola Capece Minutolo and Renata Erica Morace, Analysis of stainless steel welded joints: a comparison between destructive and non-destructive techniques , Journal of Materials Processing Technology, Volumes 155-156, 2004, Pages 1893-1899

[4] Jerzy Nowacki and Paweł Rybicki , The influence of welding heat input on submerged arc welded duplex steel joints imperfections, Journal of Materials Processing Technology, Volumes 164-165, 15,2005, Pages 1082-1088

[5] P.K. Palani and N. Murugan Selection of parameters of pulsed current gas metal arc welding, Journal of Materials Processing Technology, Volume 172, Issue 1, 2006, Pages 1-10,

[6] ISO 4063: 1990, "Welding, brazing, soldering and braze welding of metals-Nomenclature of processes and reference numbers for symbolic representation on drawings".

[7] ISO 2553: 1984, "Weld-Symbolic representation on drawings"

[8] Cosmosworks program manual.