FSW-Tech

Friction Stir Welding European Qualifications

Common State of the Art Report

Project Nr: ***2017-1-SK01-KA202-035415***

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Contents

1. Introduction

Within the scope of the IO1 Common State of Art Report, of the FSW-Tech project, project partners contacted more than 116 companies from project partner's countries to apply the questionnaire developed. The aim was to understand the main qualifications that exist currently and the skills that are required to employ personnel in the area of the friction stir welding. Also, there were some questions address in order to develop the FSW Guidelines for Personnel.

Table 1-1: Summary of contacted companies

Project partner	No. of contacted companies	No. of replied companies
ASR	50	37
EWF	42	26
ISQ	30	1
IZV	16	5
VUZ	20	6

In total, 75 entities answered the questionnaire. The responses of these entities are presented and discussed within the document. The questionnaire can be find in Annex 1.

2. Answers from the Survey Questionnaire

This chapter includes all the responses gathered from partners, and the main conclusions taken from each answer.

2.1. Respondent Companies/Entities

This section presents the entities that answered the survey and their respective country (although this information was collected only in Question 2 it is presented here in order to have the linkage between the company and respective country). This was the first question of the survey and was stated as "*1 – Please identify your company name*".

Table 2-1: Survey Respondent Entities

	Company	
1	Ikon Ideea	RO
2	Universitatea din Craiova	RO
3	VARD Tulcea	RO
4	Mahle	DE
5	Duquein Composites	RO
6	Plastique Forme Romania	RO
7	Emerson	USA
8	Davai AS	DK
9	Damen Galati	RO
10	ArcelorMittal Galați	RO
11	SC Tehnoinspect SRL	RO
12	Iemants NV	BE
13	Marech & Partner OG	AT
14	MIRADRIA SRL	RO
15	SC Fritzmeier Engineering SRL	RO
16	Uni. Dunarea de Jos din Galati	RO
17	Assystem	RO
18	Inteliform	RO
19	Raduica Ovidiu	RO
20	Autoliv	SE
21	Psihoreli	RO
22	Saipem	NL
23	SC COMELF SA	RO
24	Porr Qatar Construct	AT
25	COMPA Sibiu	RO
26	CSI ROMANIA SRL	NL
27	Colegiul Tehnic Infoel Bistrița	RO
28	Uni. Politehnica Timisoara	RO
29	S.C. Kuka Systems S.R.L.	RO
30	ISIM Timisoara	RO
31	Universitatea Tehnica Cluj	RO
32	Helmholtz-Zentrum Geesthacht	DE
33	indomo construct srl	RO
34	SC Autohton Tim SRL	RO
35	ISIM Timisoara	RO
36	SFL technologies S.R.L.	RO
37	Swedish Nuclear Fuel and Waste Management Co	SE

	Company	
38	Lamef do Sul - UFRGS	BR
39	Lamef - UFRGS	BR
40	Lamef - UFRGS	BR
41	Uni. Politehnica din Bucuresti	RO
42	Dr K Asokkumar	IN
43	IK4 LORTEK	ES
44	University of Coimbra	PT
45	CRM Group	BE
46	FPT INDUSTRIE SPA	IT
47	Stirweld	FR
48	University of Ljubljana	SL
49	Cheers Interactiv	IN
50	TRA-C industrie	FR
51	Carlos Ferreira	FR
52	IEAV	BR
53	Alustir	DE
54	Promeco Oy	FI
55	Aalto University	FI
56	TU Graz	AT
57	FCT-UNL	PT
58	The Welding Institute	UK
59	Bayards Aluminium Constructies bv	NL
60	Helmholtz-Zentrum Geesthacht	DE
61	RIFTEC GmbH	DE
62	Marine Aluminium As	NO
63	Martifer Metallic Constructions	PT
64	Slovenske Železnice Vleka In Tehnika	SL
65	Adria Tehnika	SL
66	FS Maribor	SL
67	REVOZ D.D.	SL
68	LTH d.o.	SL
69	Institut za varilstvo d.o.o.	SL
70	Nemak Slovakia s.r.o.	SK
71	ŽOS vrútky a.s.	SK
72	Statika stavieb s.r.o.	SK
73	Volkswagen Slovakia a.s.	SK
74	STRABAG s.r.o.	SK
75	Energoinvest, a.s.	SK

2.2. Countries Coverage

Within Europe, the consortium was able to collect responses form 16 different countries. Also, the technology representativeness comes, mostly, from some of the respondent countries, such as Germany, France, Italy, Spain or Denmark, Finland and Norway. The partners countries were already expected to be covered, having answers from Portugal, Romania, Slovakia and Slovenia. Due to the Consortium involvement with entities not only across Europe but beyond its borders, it was also possible to get answers from two more continents, America (North and South), and Asia (India).

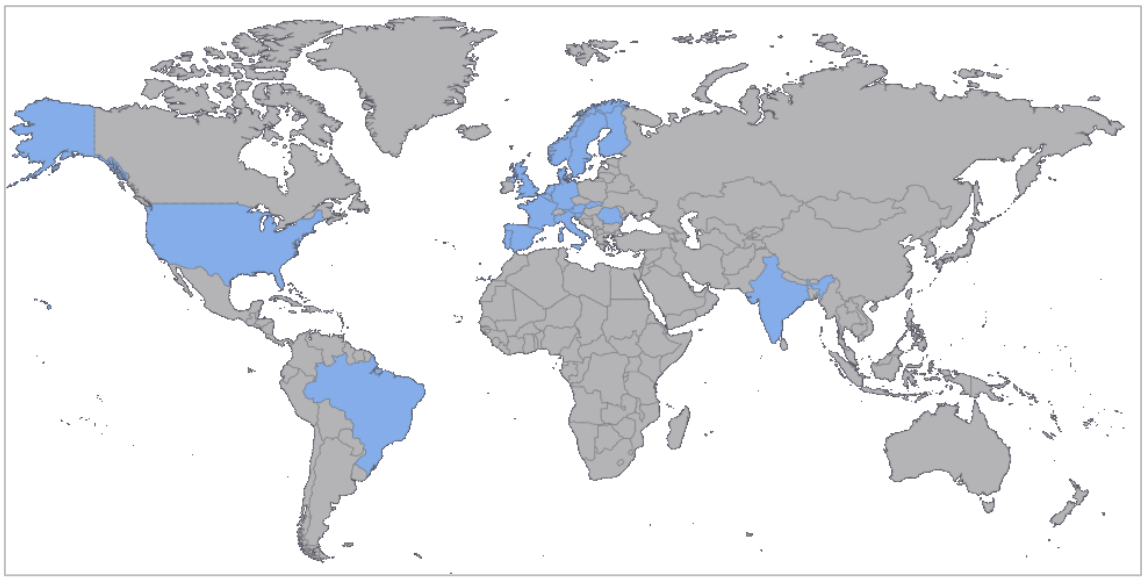

Figure 2-1: Survey Coverage around the globe

Regarding the number of answers per country the graphic below, presents the statistics from all survey responses.

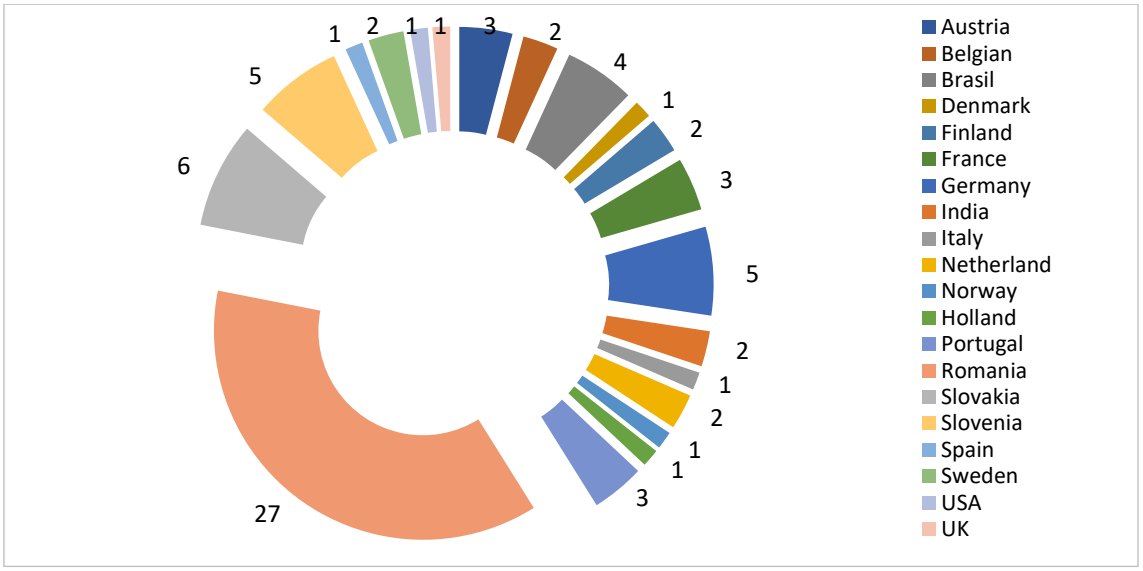

Figure 2-2: Countries that answered the Survey

2.3. Industrial Sectors

The industrial sectors that are mostly applying the Friction Stir Welding (FSW) technology were assessed in Question 3 (*Please identify your industrial domain/sector*). This information is important not only to understand for which main sectors will the Guideline be directed for, but also for the development of the educational materials, as when it comes to give examples, these ones should highlight the industry reality.

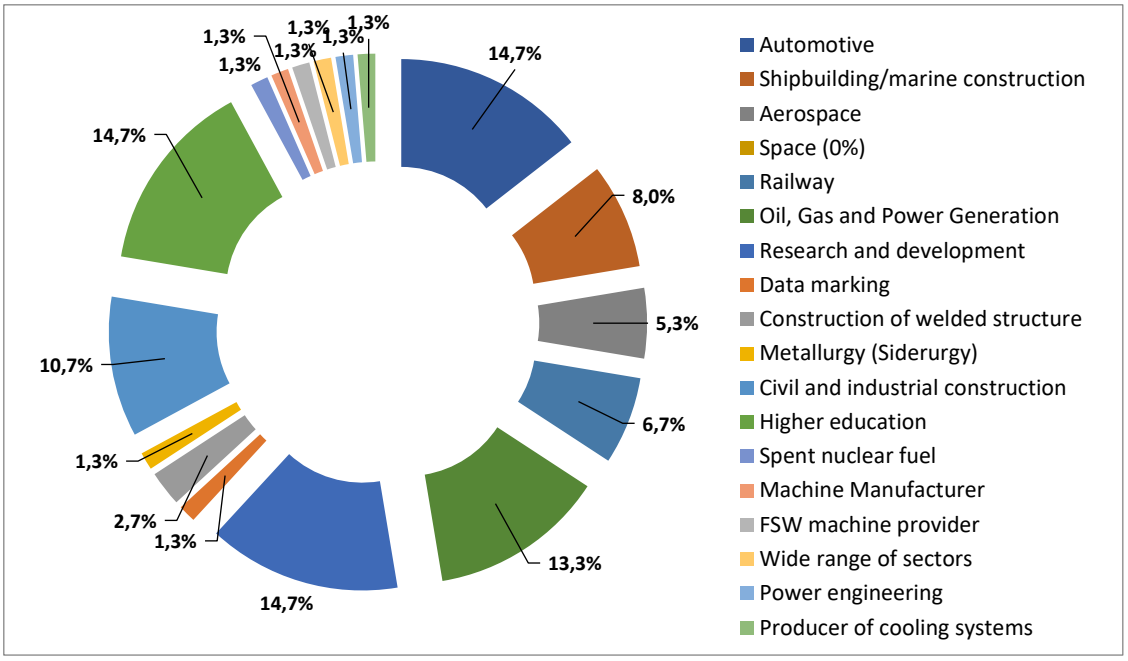

Figure 2-3: Industrial Sectors Assessed

The table below summarises the number of answers from each industrial sector, and described the responses identified in the option "*Other*".

Table 2-2: Industrial Sectors Assessed in the Surveys

Industrial Sectors	**Total**
Automotive	**11**
Oil, Gas and Power Generation	**10**
Shipbuilding/marine construction	**6**
Aerospace	**4**
Railway	**5**
Other (please specify)	**40**
– Research and development – Data marking – Construction of welded structure – Metallurgy (Siderurgy) – Spent nuclear fuel – Machine Manufacturer – FSW machine provider – Wide range of sectors – Civil and industrial construction – Higher Power engineering – Producer of cooling systems – Education	

With the responses it was possible to assess that Automotive; Oil, Gas and Power Generation; Shipbuilding and Marine construction; Aerospace and Railway are the industrial sectors representing the technology. In the "Option" section, with a considerable representativity, responses were received from FSW machine providers and manufacturers, Education and Research, Industrial Construction, among others .

2.4. Standards Awareness

In order to understand if there are already standards for the certification of the FSW personnel, Q4 was assessing if the respondents are aware of any in order to, in case of an affirmative answer, try to align the Personnel Guidelines with the standard. The Question made was as follows: *''Are you aware of any regulation/standards requirements for the training and qualification of the Friction Stir Welding personnel? If so please identify them.''* It was possible to conclude that there are ISO standards (and others) for certifying Personnel, however, most of the respondents are not aware of them – Figure 2-4.

For the development of the guideline, one of the mentioned standards was *ISO 25239-3:2011 - Friction stir welding -- Aluminium -- Part 3: Qualification of welding operators* which will be the starting point for the development of the EFSW-Operator guideline.

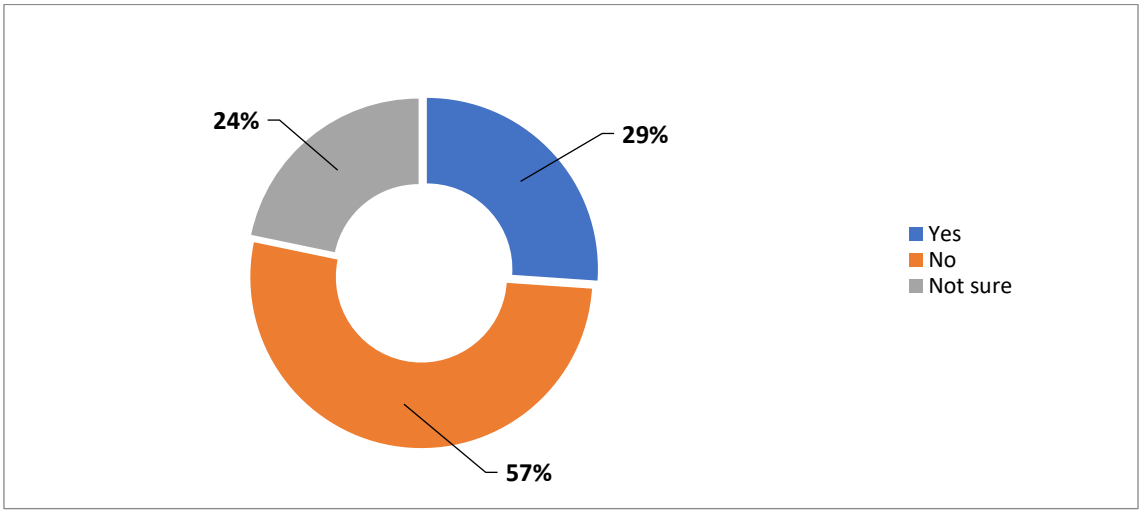

Figure 2-4: Awareness of Standards for Certifying/Qualifying personnel

If yes, please identify:

- ISO 25239-3
- EN 15085
- AWS D17.3
- HSE, QA and Fabrication certificate

2.5. Qualifications missing in FSW

Question 5, *''What levels of qualification for the Friction Stir Welding (FSW) personnel is your company looking for?''*, allowed the validation of the need of the profiles proposed to be developed under FSW-Tech project. As most of the respondents identified Operator and Engineer as the most urging need within their companies. Although the specialist was less indicated as a need, when compared to the Engineer or the Operator, there are still companies missing someone for this specific job, validating also the need for the development of a guideline for this professional profile.

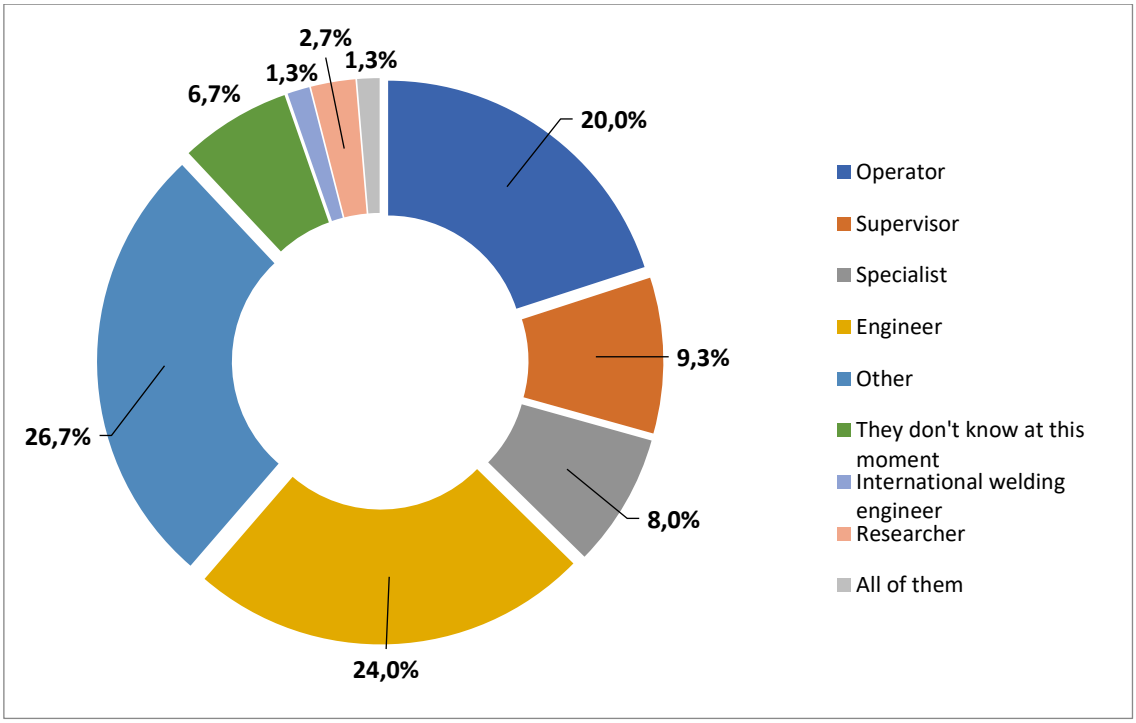

Figure 2-5: Levels of Qualification missing in industry

Table 2-3: Levels of Qualification missing in industry

Professional Profiles	**Total**
Operator	**15**
Supervisor	**7**
Specialist	**6**
Engineer	**18**
Other (please specify)	**20**
– They don't know at this moment – International welding engineer – Researcher – All of them	

2.6. Access Conditions for Operator

In order to define the access conditions for someone to entry the Operator Training Qualification, question 6 was put in place, "*What are or what should be the access conditions of the FSW personnel to access training at the operator level?*". This information is one of the topics to be defined within the Operator's Guideline. Most of the respondents identified secondary diploma as the most suitable degree of education, which in most of European countries corresponds to mandatory education.

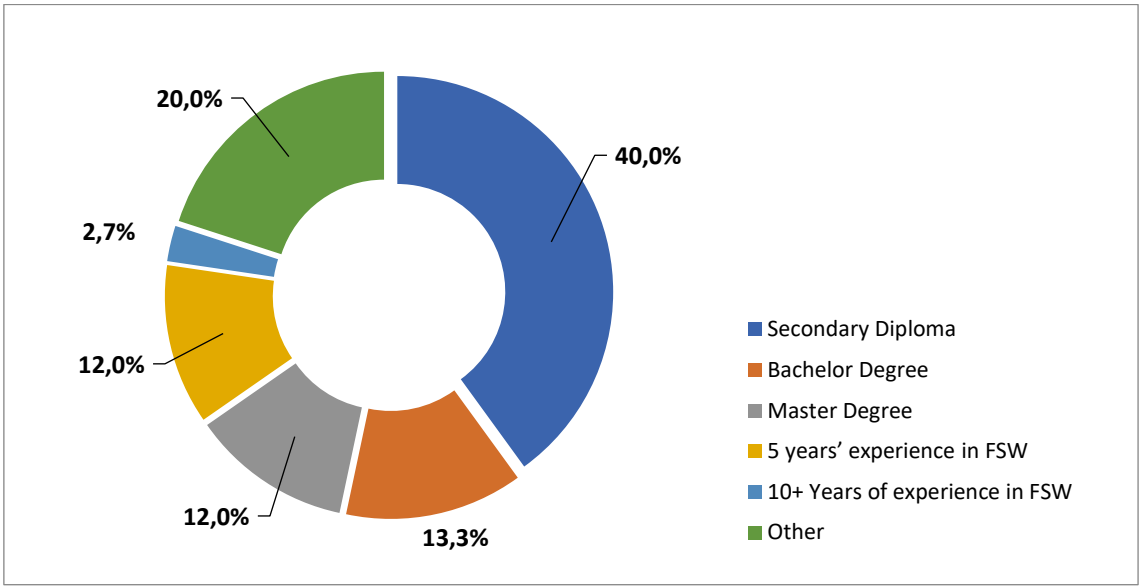

Figure 2-6: Operator Access Conditions

Table 2-4: Operator Access Conditions

Degree of Education/Experience	Total
Secondary Diploma	**30**
Bachelor Degree	**10**
Master Degree	**9**
5 years' experience in FSW	**9**
10+ Years of experience in FSW	**2**
Other (please specify)	**15**

- Formation in manufacturing technology should be demonstrated (maybe Secondary Diploma meets this requirement)
- Preferably technical education but most could be learned on the job since welding procedures should be edited and range of variables fixed and thus little to be touched by the operator
- No pre-qualification necessary for machine operators
- Technical education; depending on skills
- Technical school
- Secondary diploma with experience/training in CNC controlled machines
- Operator should be qualified by a training course only. This training could be an internal one as well. Any educational degree should not be mandatory for an operator

2.7. Access Conditions for Specialist

As for the Operator, the Specialist will also need to have access conditions to training defined within its guideline. The same question done for the operator, with the very same objective, was done for the Specialist as well, *''What are or what should be the access conditions of the FSW personnel to access training at the supervisor/coordinator level (specialist)?''*. The conclusion from the answers received was that the education level for Specialist should be Bachelor's Degree. The answers from all surveys were compiled and are shown in Figure 2-7.

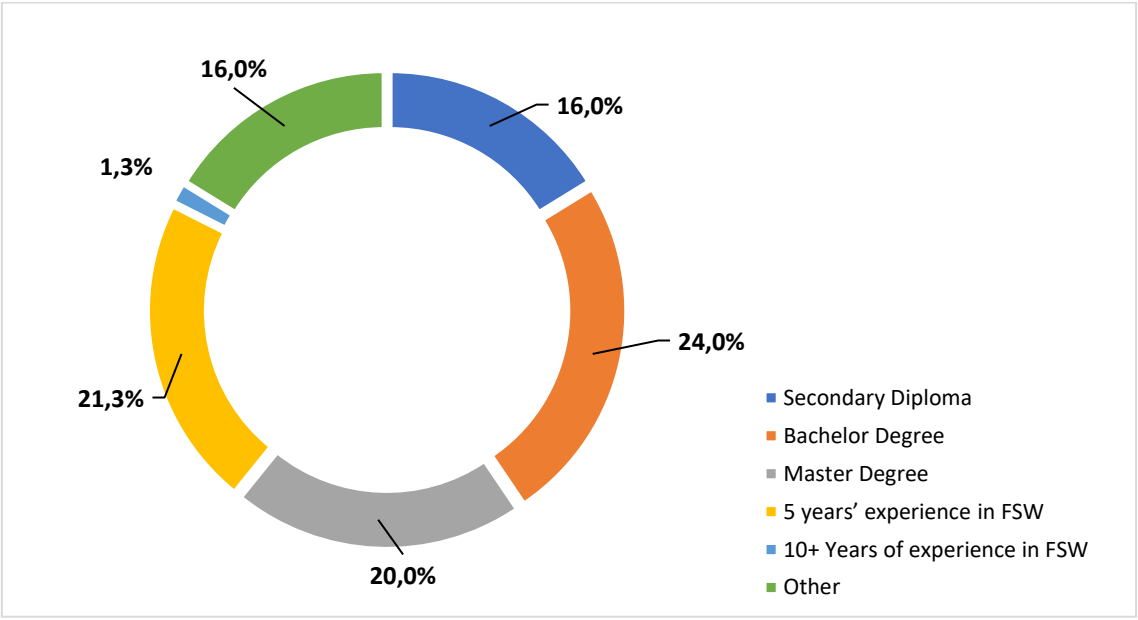

Figure 2-7: Specialist Access Conditions

Table 2-5: Specialist Access Conditions

Degree of Education/Experience	Total
Secondary Diploma	**12**
Bachelor Degree	**19**
Master Degree	**15**
5 years' experience in FSW	**16**
10+ Years of experience in FSW	**1**
Other (please specify)*)	**12**

- ECVET level 6
- Formation (Bachelor degree) in manufacturing technology and materials science (priority in metallic materials)
- Higher technical degree or x years' relevant experience
- Sufficient training and examination by an Authorised National Body or a suitable Certification Body
- Secondary vocational education
- Secondary diploma plus 5 years experience

2.8. Access Conditions for Engineer

The conclusion from the answers received for the Engineer's access conditions were that the person attending training should have either Bachelor's or Master's degree. During the development of the guideline, both levels will be taken in consideration and a decision amongst both will be taken.

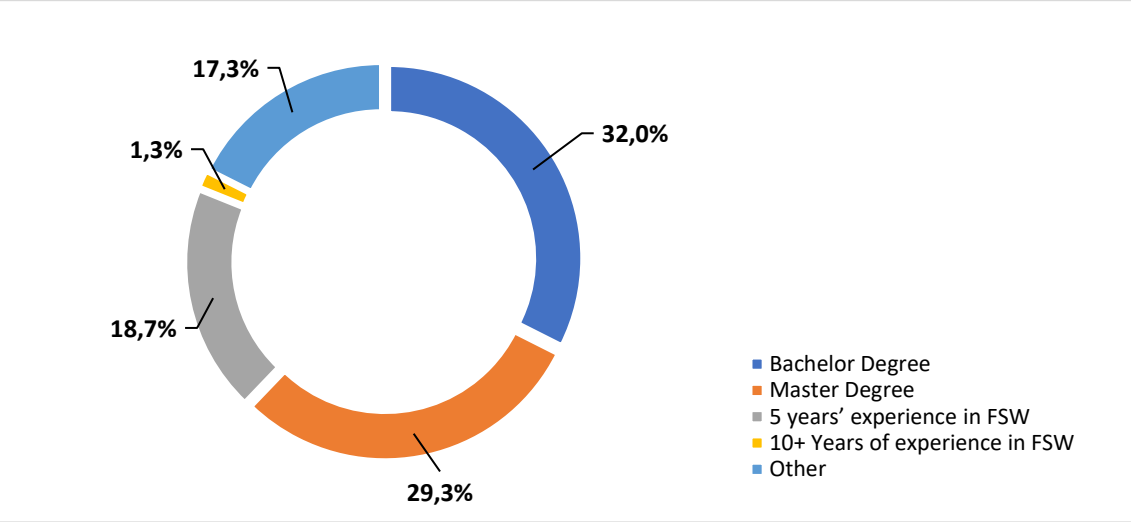

Figure 2-8: Engineer Access Conditions

Table 2-6: Engineer Access Conditions

Degree of Education/Experience	Total
Bachelor Degree	**24**
Master Degree	**22**
5 years' experience in FSW	**14**
10+ Years of experience in FSW	**1**
Other (please specify)	**13**
– ECVET level 6 – Technical engineer – Formation (Bachelor degree) in manufacturing technology and materials science (priority in metallic materials) – Bachelor plus 5 years experience	

2.9. Theoretical vs. Practical Training

Regarding question 9, not addressed at any specific professional profile, it was possible to conclude that both theoretical and practical training are important for the respondents.

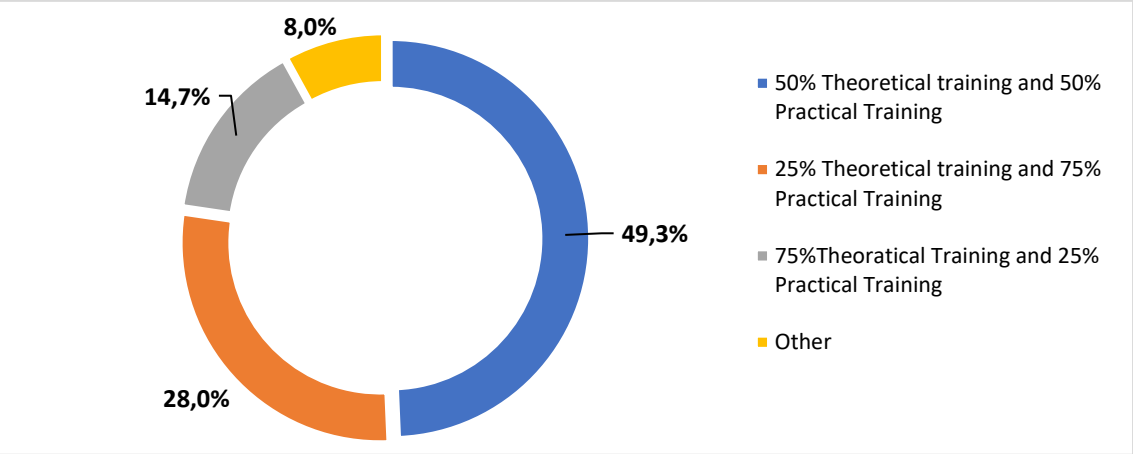

Figure 2-9: Theoretical and Practical Training

Table 2-7: Theoretical vs. Practical Training

Theoretical vs. Practical Training	Total
50% Theoretical training and 50% Practical Training	**37**
25% Theoretical training and 75% Practical Training	**21**
75%Theoratical Training and 25% Practical Training	**11**
Other (please specify)	**6**
– I thought this would depend on the role of the FSW personnel – Depends for which level, operator 25/75, supervisor 50/50, engineer 75/25 – Please check ISO25239 - This reads for me that the practical training should be the major part – More to practical ones	

2.10. FSW Variants

In order to understand which are the variables of the process mostly used in industry, the following question was included: *''What variants of the process are mostly used at your company?* Answers allowed to conclude that Friction Stir Spot Welding and Stationary Shoulder should be included in the training guideline with more relevance than other variants. However, it will be important to mention all variants assessed in the survey.

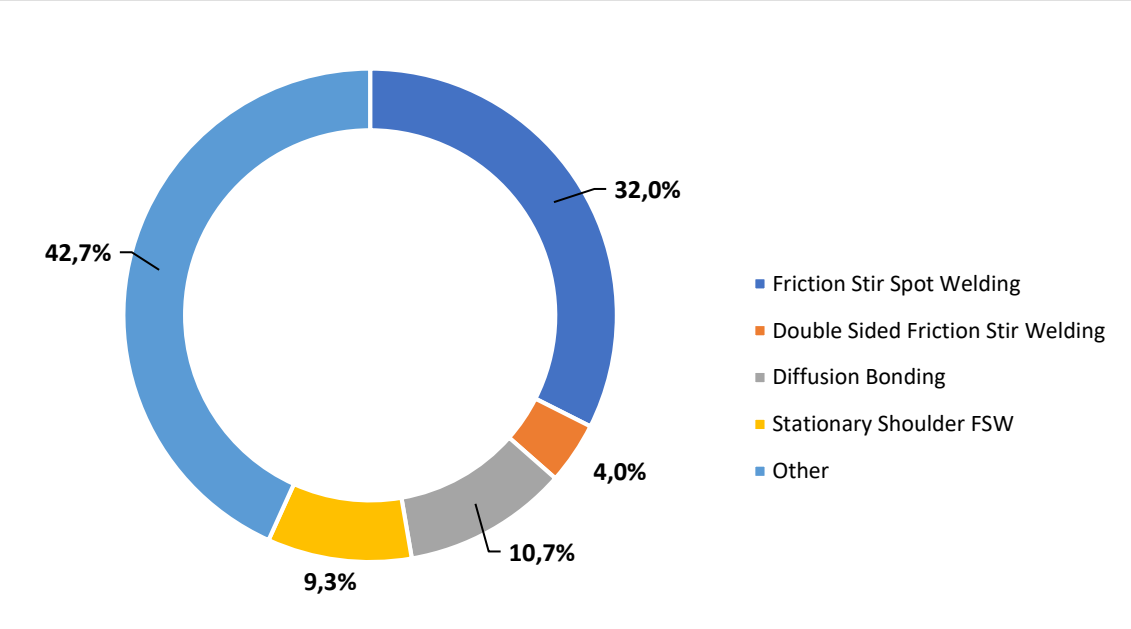

Figure 2-10: FSW Variants

Table 2-8: FSW Variants

FSW Variants	Total
Friction Stir Spot Welding	**24**
Double Sided Friction Stir Welding	**3**
Diffusion Bonding	**8**
Stationary Shoulder FSW	**7**
Other (please specify)	**32**
– Friction Hydro-Pillar processing – T joint – Friction Stir Processing – all but SSFSW are available but not often used – We use spot, double, stationary but most of the time basic FSW – Not used at this moment	

2.11. Applicable Industries for FSW

Question 11, "*Which is the main industry this process is directed for?''*, was included with the same aim as question 10. Respondents identified the following industries:: Automotive, Aerospace, Shipbuilding or Marina and Railways.

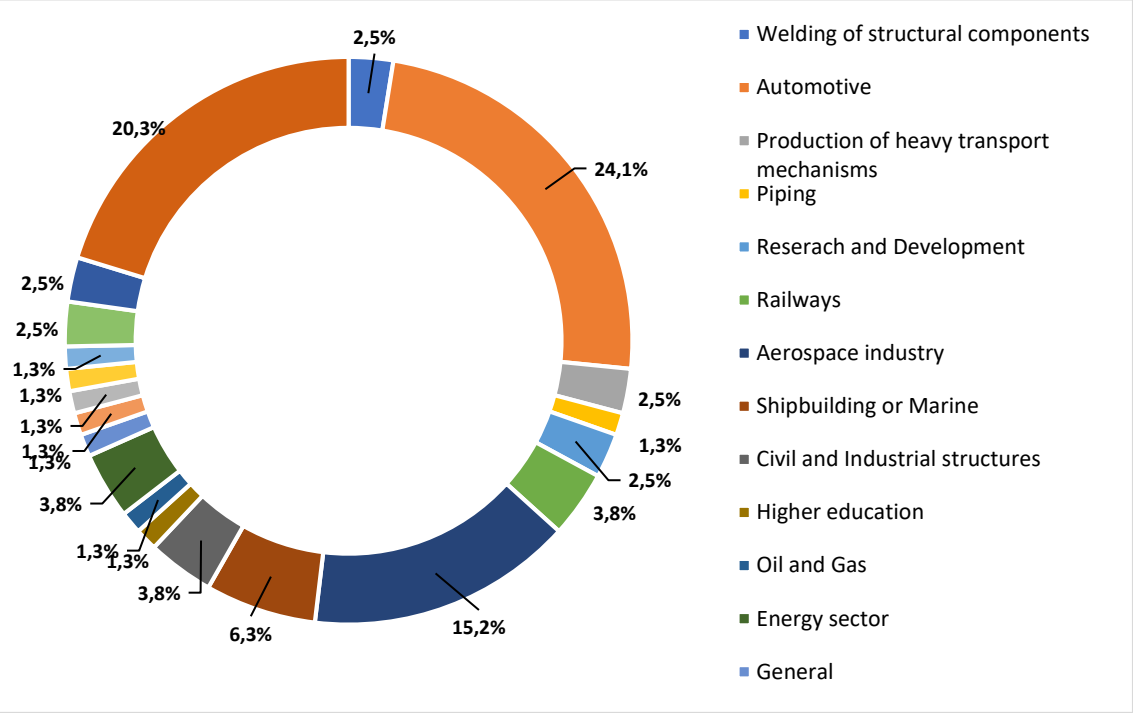

Figure 2-11: Applicable Industries for FSW

Table 2-9: Applicable Industries for FSW

Applicable Industries for FSW	Total
Automotive	**19**
Aerospace industry	**12**
Shipbuilding or Marine	**5**
Railways	**3**
Civil and Industrial structures	**3**
Energy sector	**3**
Production of heavy transport mechanisms	**2**
Offshore	**2**
Transportation Industry	**2**
Welding of structural components	**2**
Higher education	**1**
Oil and Gas	**1**
General	**1**
Defence industry	**1**
Heat Exchangers	**1**
Aluminium alloys	**1**
Piping	**1**
R&D	**1**
Other	**16**

2.12. Main applications of FSW

The main applications identified by the respondents are presented in Figure 2-12.

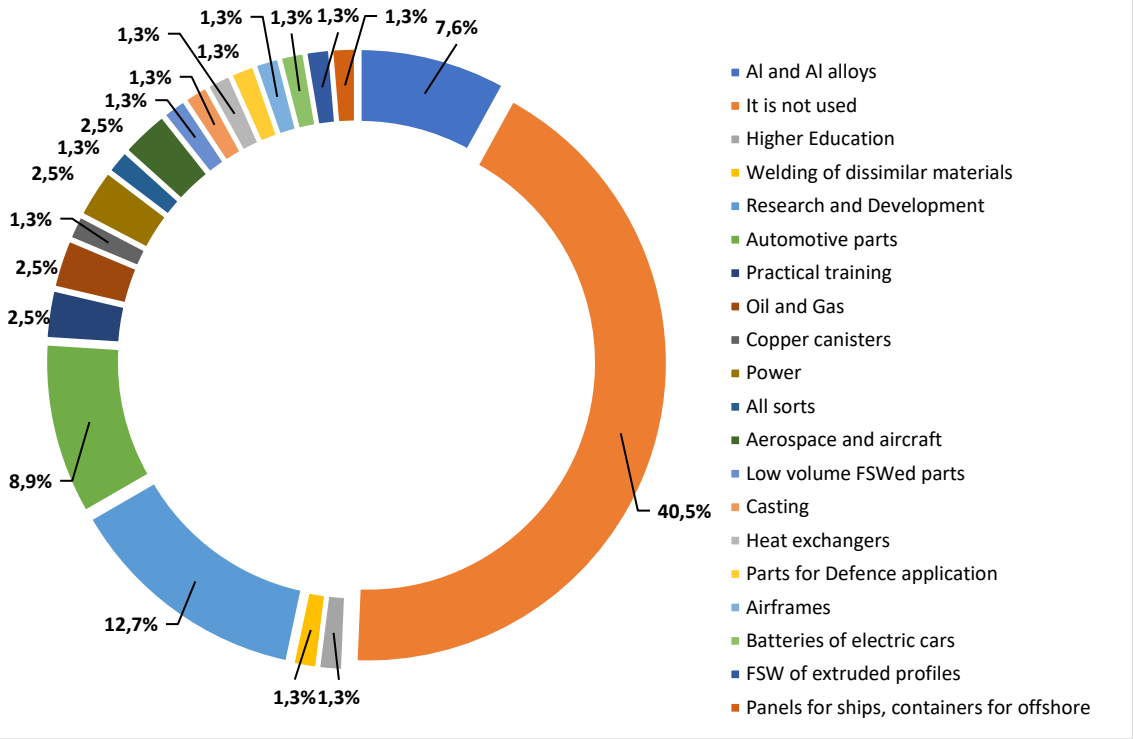

Figure 2-12: Main applications of FSW

Table 2-10: Main applications of FSW

Applications	Total
Al and Al alloys	**6**
It is not used	**32**
Higher Education	**1**
Welding of dissimilar materials	**1**
Research and Development	**10**
Automotive parts	**7**
Practical training	**2**
Oil and Gas	**2**
Copper canisters	**1**
Power	**2**
All sorts	**1**
Aerospace and aircraft	**2**
Low volume of FSW parts	**1**
Casting	**1**
Heat exchangers	**1**
Parts for Defence application	**1**
Airframes	**1**
Batteries of electric cars	**1**
FSW of extruded profiles	**1**
Panels for ships, containers for offshore	**1**

2.13. Materials mostly used in FSW

The materials identified as mostly used within FSW were Aluminium and Steel, being these the two main materials to be the focus during training.

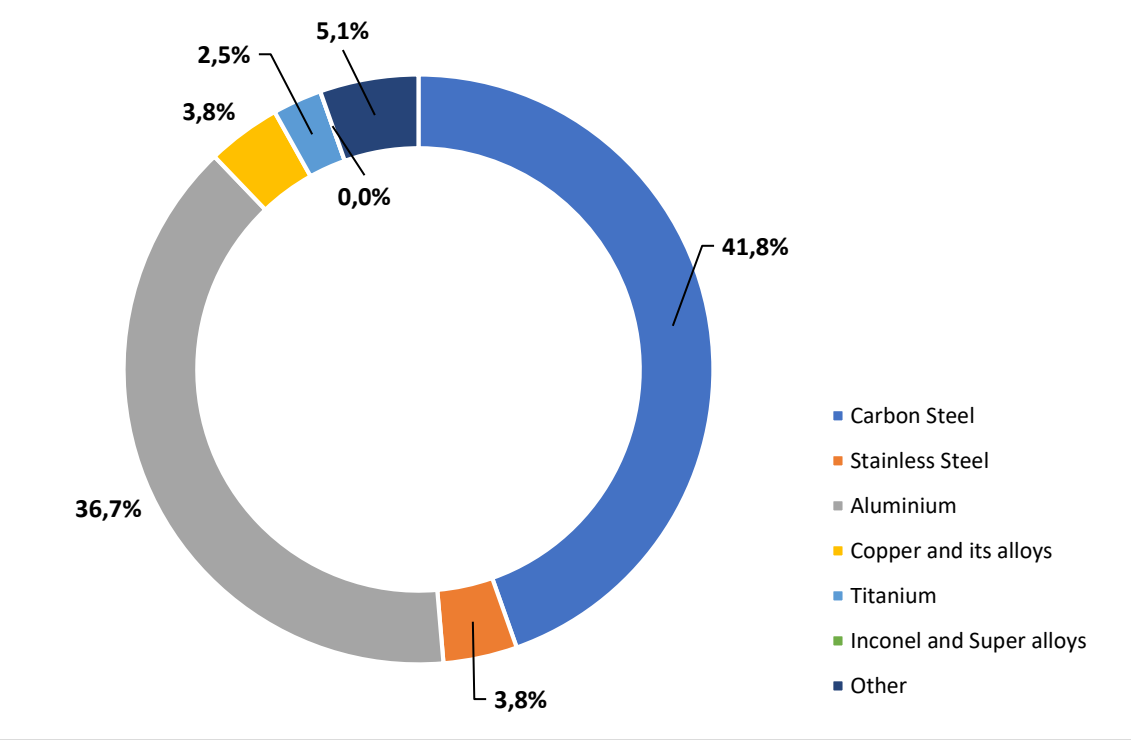

Figure 2-13: Materials mostly used in FSW

Table 2-11: Materials mostly used in FSW

Materials for FSW	Total
Carbon Steel	**33**
Aluminium	**29**
Stainless Steel	**3**
Copper and its alloys	**2**
Titanium	**2**
Inconel and Super alloys	**0**
Other (please specify)	**5**
– All type – Arm steel	

2.14. Quality Assessment

Regarding the awareness of regulation/standards/Client Technical Specifications to assess the quality of the friction stir welds and process, most of the respondents answered yes, however without detailing the ones they are aware.

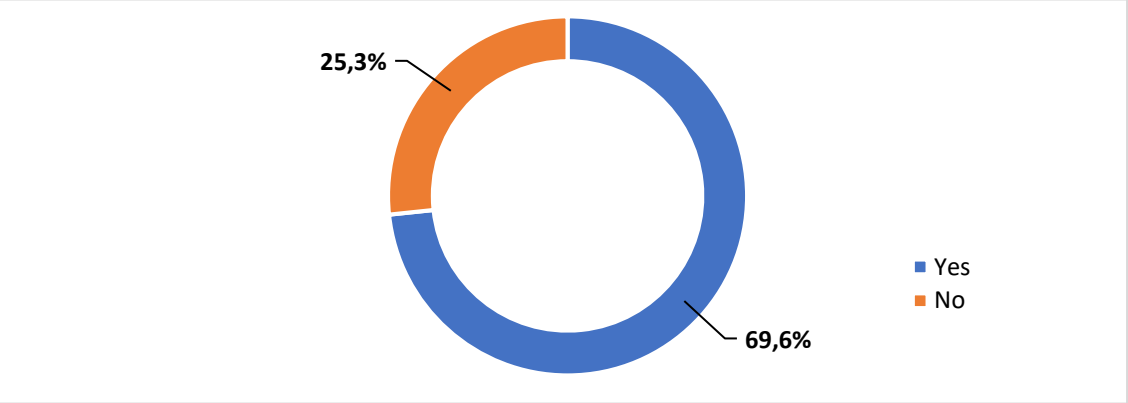

Figure 2-14: Quality Assessment

2.15. Personnel Gaps & Needs at Companies

The most urging needs and challenges relating to FSW in the inquired entities are at the Engineer level.

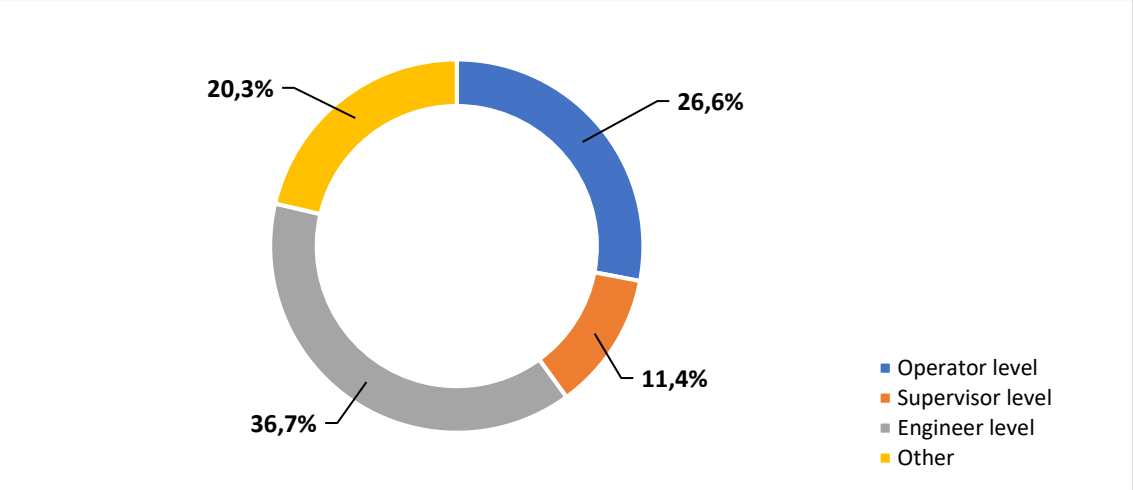

Figure 2-15: Personnel Gaps & Needs at Companies

Table 2-12: Personnel Gaps & Needs at Companies

Most Urging Needs	Total
Operator level	**21**
Supervisor level	**9**
Engineer level	**29**
Other (please specify)	**16**
– Market Awareness of its potential – Adoption of FSW in design codes for aluminium structures – The most urgent challenges are not related to the training of personnel	

2.16. FSW Skills Gaps

In order to understand the specific gaps regarding skills that companies feel that needs to be met, an open answer was included to close the questionnaire. The question was: "*What are the most important gaps regarding qualification and skills of the FSW professionals*?". The answers received, after being analysed individually, were grouped in themes and summarized in Table 2-13. From this grouping it was possible to understand the topics that should be addressed in training and included in the educational materials.

Table 2-13: FSW Skills Gaps

Qualifications
There is no qualification and training Operator skills
Quality/Standards – Certification/Qualification
Research Lack of documentation in Romania International recognition Quality standards and components tests Insufficient guidelines for machine operators and machine setters Formal qualifications for FSW personnel other than operator e.g. Inspector, Engineer and Supervisor Acceptance criteria for visual inspections and extent of NDT
Practical Training
Experience Best practice knowledge transfers Formal training at all levels Practical Training Not enough practical experience A lot can be learned on the job, product development is often a bottleneck
Process Knowledge
Influence of process variables and machine knowledge Metallurgy of weld Lack of knowledge of basic metallurgy aspects Optimisation of parameters, tool selection, evaluation to suit application General lack of knowledge of the technology (potential for applications, critical process characteristics, economics, etc) Lack of systematized information on process parameters for different materials/applications To know the importance of the fixtures. To have open mind on the value of the stirring tool design FSW part design Technical skills Know-how on influence of tool features and clamping Understanding of the needed tools for the process

3. Conclusions

The project partners approached around 75 companies involved in the education, production and research of steel and aluminium components. Most of these companies are established in Europe.

The most represented manufacturing sector is the automotive industry, which is the mainstay of the European economy, the segment of education, Oil, Gas and Power Generation and Research and Development are also representative of the us of FSW.

Only 29% of the respondents are at least partially aware of the standards and documents that in place for friction welding.

The main required qualification that the respondent's companies need is operators and engineers. 26.7% of respondents are currently unable to comment or do not seek this type of staff.

For the Operator qualification, companies indicated that it would be best to complete a secondary diploma. As another requirement, some companies mentioned also practice in the field. For the Specialist qualification

For access conditions of the specialist the respondents choose bachelor's degree and 5 years of experience, and bachelor and engineering education for the access conditions of the engineer. Most of the respondents agreed that the scope of course should consist of 50% of the theoretical part and 50% of the practical part.

From question 10, regarding the process variants, it is suggested that Friction Stir Spot Welding, Diffusion Bonding, Stationary Shoulder FSW and Double-Sided Friction Stir Welding are the most widely used variants of the technology. Some of the companies also use Friction Hydro-Pillar processing. The industries where the technology is mostly addressing, according to the respondents, are automotive, aerospace and shipbuilding. The most widely used materials in FSW manufacturing companies are steel and aluminium.

The majority of the respondents(70%), are aware of regulations, standards or Client Technical Specifications to assess the quality of the friction stir welds and of the process. However, when answering the questionnaire, the respondents didn't identify them.

The most demanding qualifications that industry currently needs, in the area of friction stir welding, are Operator and Engineer.

The lack of education, the quality of education, the lack of documentation and the lack of practice are among the most important gaps in qualifications and skills for FSW professionals.

From the above findings it was possible to validate the need of the three proposed professional profiles: Operator, Specialist and Engineer.

4. Annex – Survey Questionnaire

FSW-Tech – Development of a Guideline for FSW Personnel

The European Federation for Welding, Joining and Cutting (EWF) is a representative of the manufacturing community in Europe - along with its 31 European members, the National Welding Institutes – working in training and education in the field of welding technologies. This survey, in the framework of the FSW-Tech Erasmus+ project, is targeted at industrial companies, associations of companies and public bodies that work in the Friction Stir Welding field. Its objective is to understand what are the qualifications in place at the moment, and what are the skills required to employ personnel in this area (from Engineer to Operator). The project main aims are to develop a guideline for three professional profiles in Friction Stir Welding, Operator, Specialist and Engineer, educational material and a guideline for implementation of the curricula at European level.

Attending to the growth in FSW use and the evident need for metal qualified personnel in Europe, VET Providers will have to carry on fostering lifelong learning through FSW continuous training. Hence, Welding education and training for technicians, practitioners and welders must include FSW learning modules in their basic programmes.

This survey takes about 3 minutes to fill and the main aim is to identify personnel skills needs. If you want to know more about the FSW-TECH project, please contact ***Organisation Person*** (***e-mail address***).

1. Please identify your company name

2. Please identify your company's country

3. Please identify your industrial domain/sector

- ○ Automotive
- ○ Shipbuilding/marine construction
- ○ Aerospace
- ○ Space
- ○ Railway
- ○ Oil, Gas and Power Generation
- ○ Other (please specify)

4. Are you aware of any regulation/standards requirements for the training and qualification of the Friction Stir Welding personnel? If so please identify them.

- ○ Yes
- ○ No
- ○ Not sure
- ○ If yes, please identify: _____

5. What levels of qualification for the Friction Stir Welding (FSW) personnel is your company looking for?

- ○ Operator
- ○ Supervisor
- ○ Specialist
- ○ Engineer
- ○ Other. Please specify: _____

6. What are or what should be the access conditions of the FSW personnel to access training at the operator level?

- ○ Secondary Diploma
- ○ Bachelor Degree
- ○ Master Degree
- ○ 5 years' experience in FSW
- ○ 10+ Years of experience in FSW
- ○ Other (please specify)

7. What are or what should be the access conditions of the FSW personnel to access training at the supervisor/coordinator level (specialist)?

- ○ Secondary Diploma
- ○ Bachelor Degree
- ○ Master Degree
- ○ 5 years experience in FSW
- ○ 10+ Years of experience in FSW
- ○ Other (please specify)

8. What are or what should be the access conditions of the FSW personnel to access training at the Engineer level?

- ○ Bachelor Degree
- ○ Master Degree
- ○ 5 years experience in FSW
- ○ 10+ Years of experience in FSW
- ○ Other (please specify)

9. What time is or should be dedicated to the theoretical training and to the practical training for the qualification of FSW personnel?

- ○ 50% Theoretical training and 50% Practical Training
- ○ 25% Theoretical training and 75% Practical Training
- ○ 75%Theoratical Training and 25% Practical Training
- ○ Other (please specify)

10. What variants of the process are mostly used at your company?

- ○ Friction Stir Spot Welding
- ○ Bobbin Friction Stir Welding
- ○ Double Sided Friction Stir Welding
- ○ Diffusion Bonding
- ○ Stationary Shoulder FSW
- ○ Other (please specify)

11. Which is the main industry this process is directed for?

12. What are the main applications of FSW at your company?

13. Which are the materials mostly used in your company?

- ○ Carbon Steel
- ○ Stainless Steel
- ○ Aluminium
- ○ Copper and its alloys
- ○ Titanium
- ○ Inconel and Super alloys
- ○ Other (Please specify)

14. Are you aware of any regulation/standards/Client Technical Specifications to assess the quality of the friction stir welds and of the process that are currently being used in your company?

- ○ Yes
- ○ No

If you answered YES please identify which are the standards/regulation being used:

15. What are the most urging needs and challenges relating to FSW in your industry/company?

- ○ Operator level
- ○ Supervisor level
- ○ Engineer level
- ○ Other (please specify)

16. What are the most important gaps regarding qualification and skills of the FSW professionals?