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Research paper

Design and Manufacturing of Fixture for Edge Prepration of Elbows

Nagasankar P[1*], Tamilselvi P[2], Babu T V B[3], Jasim Salahudin S[4], Aravindhan S[5], Deepak J[6].

[1,3,4,5,6] Department of Mechanical Engineering, Veltech Hightech Dr.Rangarajan Dr.Sakunthala Enginnering College,Chennai-62
[2] Department of Computer Science Engineering, JeppiaarSakunthala Enginnering College,Chennai-119
**Corresponding author E-mail: karupsshankar@yahoo.in*

Abstract

This paper is a description of an alternative fixture for the edge preparation of elbows and pipes before welding. The welding will not penetrate the cross section of the pipe if the thickness of the pipes is more than eight millimeter, so edge preparation is done before welding. Fixtures are used to hold the pipes during the process of edge preparation. This paper deals with two major issues from the design of previous fixtures.
Requirement of manual handling of the part.
Precise rotations are not possible.
The fixtures being used currently require more setting up time and they require manual handling to machine the other side. This paper describes a fixture which can reduce manual handling and be able to rotate the elbow either manually or using a motor.

Keywords: *Edge preparation; Fixtures; Manual handling, Welding, Manufacturing*

1. Introduction

Fixtures are kind of work holding devices used in lathe, milling, shaping, slotting, drilling and planning machines to hold work pieces firmly. Fixtures containing clamps, supporters and locators provide localization accuracy and foreclosure conditions. Normally, a suitable fixture is decided based upon the past design experience or from trial-and-error methods. These kind of practices will not provide themselves well to flexible manufacturing. This project talks about a fixture used for holding elbows during edge preparation.
Edge preparation is done before welding of parts. In normal welding process, to ensure the robust weld between the surfaces, the welding surfaces are prepared well. It is required for all kinds of welding and joints. Usually, little preparation is required for butt welds but some is required more for the better results. When edge preparation of pipes is done, the edges are beveled at an angle to accommodate the weld material. Edge preparation may affect the properties of the material and weld formed [18][12]. There are many ways of edge preparation such as boring, cutting and grinding [14].
There are two main features of edge preparation which influence the fatigue performance of a weld joint
a) Cleanliness of faying surface
b) Cutting of faying surface of base metal to be welded by fusion arc welding process.
Surface and edge of the plates to be welded should be cleaned to remove the oil, dust, dirt, paint, grease etc. present on the surface either by mechanical or chemical methods.

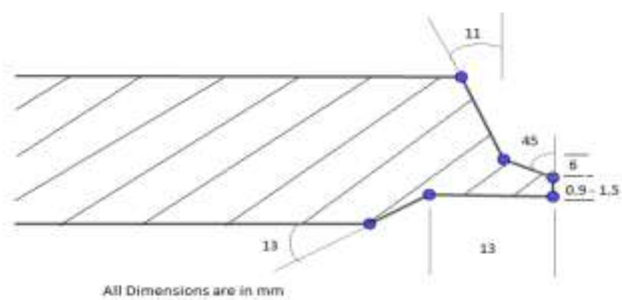

Fig1: Edge preparation of pipe to be welded

Usage of chemical approach for cleaning the surface using hydrogen containing acid (hydrochloric acid, sulphuric acid, etc.) sometimes introduce hydrogen in base metal which in long run can diffuse in weld and HAZ and facilitate crack nucleation & propagation (by HIC) besides making well-meant brittle. Further, improper cleaning sometimes causes impurities on faying surface, which, if are melted or evaporated during the welding then these impurities will induce inclusions in weld metal. The inclusions presence in weld metal makes it as stress raiser for nucleation and growth of cracks and so weakens the joint and lowers fatigue performance. Cutting of hardened steel plates by thermal cutting approaches such as gas cutting also hardens the cut edge. These hardened edges will easily cause the development of cracks in HAZ under the influence of the residual stresses caused by weld thermal cycle associated with welding.

2. Submerged Arc Welding

The fixture design is required for edge reparation which is done prior to common arc welding process, named submerged arc welding (SAW). In 1935, the first patent on this process was obtained and shielded an electric arc under a bed of granulated flux. It was formerly developed by Jones, Kennedy and Rothermund. A continuously fed consumable solid or tubular (metal cored) electrode is needed in this process. A blanket of granular fusible flux containing silica, lime, calcium fluoride, manganese oxide and other components protect the molten weld and the arc zone from atmospheric contamination as the molten weld and the arc zone are “submerged” under the said blanket of flux. At the molten, the flux will become conductive and provide a current path between the work and the electrode. As this thick layer of flux fully protects the molten metal, it prevents from spatter, sparks, the intense ultraviolet radiation and fumes. SAW is usually functioned in the mechanized mode, however, it is also available with semi-automatic guns with pressurized or gravity flux feed delivery.

SAW is generally limited to the flat or horizontal-fillet welding positions (horizontal groove position welds are provided with a special arrangement to support the flux). Deposition rates of 45 Kg/h were reported that compared to 5Kg/h (max) for shielded metal arc welding. Currents of up to 5000A can also be used (multiple arcs), the same ranging from 300 to 2000 A are normally employed. Variations of this welding process exist with single or multiple electrode wire. Submerged arc welding strip-cladding uses a flat strip electrode, for an example an electrode with a width of 60 mm and a thickness of 0.5 mm may be used. In single electrode system, either AC or DC power can be utilized and in multiple electrode systems, combinations of both AC and DC can be used. Though the powers supplying with a constant voltage are generally used in welding, constant current systems in combination with a voltage sensing wire-feeder may also be available. Here, the flux and filler metal are fed to the welding joint.

3. Material Used For Pipe

P91 Materials: ASTM A335 P91 are used. The united states was trying to develop a new material from 1970s to bridge the gap between austenitic steels and ferrite P22 depending on the creep rupture strength for high-temperature (from 540-600 degrees C) service. Since creep rupture strengths are generated based on long time exposure to the high service temperature, an improvement of any new material, particularly for high-temperature service, needs many years.

Grade	C	Si	Mn	P	S	Cr	Mo
P 91	0.10	0.45	0.50	0.019	0.002	9.12	0.96
E911	0.11	0.20	0.35	0.007	0.003	9.16	1.10
	Ni	Nb	V	Al	W	N	
P91	0.05	0.060	0.21	0.004	-	0.040	
E911	0.23	0.068	o.23	0.007	1.0	0.072	

Fig.2: Composition of P91 Steel

As the result of these efforts, United States introduced a new material, named P91. This material has possessed high strength. This steel material can possess low impurity levels, due to the development of processes like Electro Slag Re-melting and argon-oxygen decarburization processes, which make this steel material to perform consistently during fabrication and control the effects of aging.

4. Pre-Heating and Post-Heating of P91 Steel

Preheating means heating the base metal, either fully or the regions which is nearby the welded joint; to a particular desired temperature termed as preheat temperature preceding the welding process.

We have four main reasons to employ preheat:

- It brings down the cooling rate in the weld and base metals, creating a more ductile metallurgical structure and making more resistant to cracking
- The lower cooling rate is providing an opportunity for any hydrogen that already existed in material to diffuse out easily without propagating cracking.
- The shrinkage stresses in the weld and base metal of highly important restrained joints are greatly reduced by preheating
- It increases some steels above the temperature at which brittle fracture would happen in fabrication process. Preheating is used to ensure specific mechanical properties like high notch toughness.

In deciding whether to preheat or not, the following factors may be deliberated; they are: the section thickness, base metal chemistry, restrain, ambient temperature, cold requirements,, filler metal, hydrogen content and previous cracking problems. The two methods named are; a) Hydrogen control method and b) Heat affected zone hardness control method.

The hydrogen control method is assumed in such a way that cracking should not appear if the amount of hydrogen remaining in the joint after it was cooled down to about 50°C does not go beyond a critical value which depends on the composition of the steel and the restraint. This method is really beneficial for high strength, low alloy steels that have high harden ability. But, the calculated preheat is highly conservative for carbon steels. For an instance, small manufactured assembly products are heated effectively in a furnace, but, large structural components require banks of heating torches, induction or radiant heaters. More accuracy is not generally needed for preheating carbon steel. Although it is vital that the components be heated to the minimum temperature, it is permissible to go beyond that temperature by approximately 40^{0}C.

Post heating can be defined as the application of heat to an assembly after welding. Post heating includes post weld heat treatment (PWHT), immediate post weld heating (IPWH), normalizing, quenching and tempering.

Untreated steel has great affinity towards Hydrogen, which can cause cracks.

Pre welding heating has to be done to remove moisture and post welding heating has to be done as soon as welding is over.

5. Related Work

There is substantial literature work about fixtures and fixturing principles, but not specifically for the purpose of edge preparation.

[1.] Here analyzing quality of welded connection using submerged arc welding process parameters like welding speed, welding voltage and welding current are considered as the design variables.

[2.] In this paper, the effect of clamping sequence on workpiece location error is modeled analytically for a work piece - fixture system. Part location error is calculated by the movement of a response point on the surface.

[3.] In this paper contact condition modeling based on frequency response is explained. Considering possible contributing factors to contact condition such as material properties, surface finish, and hardness and contact area between the workpiece and fixture device.

[4.] This paper describes different edge preparation calculate the depth of the filler material penetrated into the weld joint. Then tensile stress of each weld is obtained.

[5.] In this paper there is a brief explanation about the submerged arc welding which includes the methods and mechanism used.

Submerged arc welding is high protective method of welding. The arcs are struck and burn under a layer of flux, the molten flux will become conductive and offer a current path between the work piece and the electrode.

[6.] In this paper, the spiral submerged arc welded joints and the longitudinal submerged arc welded joints were explored at different location of the APIX80 pipeline steel base metal and compare fracture toughness.

[7.] Here, a 3 wire submerged arc welding process is used to understand the molten pool behaviour and the temperature distribution. Then developing model is based on 3D numerical heat transfer and fluid flow. Here, the volume of fluid can be utilized to find the shape of the free surface.

[8.] A high-speed video camera is used to film the movement of molten metal at the wire end in submerged arc welding through a preset tunnel; the welding electric signal was used at the same time. For simulating the metal transfer in submerged arc welding, a physical modeling experiment was performed.

[9.] This paper offers a methodology of fixture layout optimization considering the factors such as immobility, repeatability and stability of fixture.

Here the locator layout has been well optimized based on the location accuracy and the work piece repeatability. The clamp layout optimization helps to minimize the amount of clamping force.

[10.] FSW (friction stir welding) of titanium alloys can be considered as the most challenging welding process. It mentions about welding process used to developing new fixture.

An FSW process in the key application of titanium alloys in the aeronautic and aerospace industries may be mainly intended to enhance the performances of the welded parts in the recent times.

[11.] This work mainly deals with design, fabrication and testing of intelligent fixture with an intention to decrease work piece deformation and shear while doing various machine tool operation in which force–controlled clamping element can be used.

[12.] This paper describes different types of edge preparation, to calculate the depth of the filler material penetrated into the weld joint. Then tensile stress of each weld is obtained.

[13.] This paper explains about micro milling process and its performance. The different cutting edge preparation process showed that different effects were observe with respect to process forces, tool wear and surface quantity.

[14.] The preparation of cutting edges intented to increase the quality of machined surface and the stability of cutting tools. The manufacturing of rounded cutting edges by putting elastic bonded super abrasive grinding wheels based on accuracy and repeatability is done.

It is a new approach of analysing several methods and applying in industries with different properties.

6. Fixture Model

The fixture that we have designed consists of the following parts.

- Bed.
- Worm Gear.
- Worm.
- Table with slots.

Working:

The bed carries the entire fixture and it is bolted and has no movement. The bed also has a slot in which ball bearings run between the worm gear and the bed.

The worm gear is connected to the table by bolts. The worm gear can be rotated by rotating the worm. This can be done manually or by using a motor.

The table consists of T – slots spaced in a regular interval. The elbow can be held without movement by using clamps in the T- slot.

After machining of one side of the elbow, the other side can be machined by rotating the table for 180°. This will reduce the setup time or the need for any equipment to turn it.

The components of the fixture are made up of the following materials.

1. BED & TABLE: The bed will be made of cast iron, because of its load bearing capacity, machinability and ability to absorb vibrations.
2. WORM: Steel is selected for the worm since, it is the standard worm material used.
3. WORM GEAR: Phosphor Bronze is selected for the worm gear because of its wear resistance property.

Table 1: Composition by weight of Phosphor Bronze

Component	Weight %
Copper	90.5 - 92.8
Iron	0.1(max)
Phosphorus	0.03 - 0.35
Lead	0.05(max)
Tin	7-9
Zinc	0.2(max)

Table2: Mechanical Properties

Physical properties	Metric	English	Comment
Density	8.8 g/cc	0.318 lb/in^3	At 20^{0}C
Mechanical properties			
Hardness	85	85	
Tensile strength (ultimate)	550 MPa	79800 psi	
Tensile strength(yield)	450 MPa	65300 psi	
Elongation at break	33%	33%	In 50 mm
Modulus of elasticity	110 GPa	16000 psi	
Poisson's Ratio	0.341	0.341	
Machinability	20%	20%	

7. Design Calculation

Calculating the number of teeth on worm gear:

Assumptions:

q=11, number of starts (Z_1) =3, Torque=175 Nm.

[According to "Effects of wheel designs on the torque applied to large hand wheel" by Mark.L.Mulkin Maximum Torque = 175 Nm]

Table.3: Working condition of worm & wheel

Condition	Worm	Worm wheel
Medium service condition (or) Low speed condition	Cast iron (or) steel	Phosphor bronze

7.1 Calculation of z_1&z_2:

Take Z_1=3, Diameter factor q=d/m

Lead angle $= \gamma = \tan^{-1}(Z_1/q)$

γ =Tan-1(3/11) = 15.25^o

7.2 Calculation of Power:

Assuming max rpm to be N=200
Torque generated (T)=175Nm
Power=2πNT/60= (2×3.14×200×175)/(60)
P=3695W

7.3 Design Twisting Moment:

$[M_t]=M_tK_d$ K(K_d K=1)
=60P/2πN = (60×3695) / (2× 3.14× 200)=175 Nm

7.4 Calculation of Compressive Stress:

From PSGDB table 32 (page 8.45)
$[\sigma_c]$=159 N/mm^2
(for sliding velocity of up to 3)

7.5 Bending Stress:

For phosphor bronze: $[\sigma_b]$ =50 N/mm^2

7.6 Calculating Centre Distance:

$a= (z/q + 1)\sqrt[3]{(\frac{540}{z/q(\sigma c)})^2[M_t]}$
Here M_t= (M_t/10) in Nmm
(Z= iZ_1= 3×24=72)
(Taking i=3, Z_1 =24)
(q=d/m)
$a = (72/11 +1)\sqrt[3]{(\frac{540}{72/11(159)})^2[17500]}$
= (7.545) (16.763)
a =126.486 mm (centre distance)

7.7 Calculating Module:

M_x=2a/ (q+Z+2x)
(x=0, addendum module)
=2×126.486/ (11+72)
=3.047mm
Standard module m_x=6mm
Revision of centre distance
a=0.5m_x (q+z)
a=249 approximately 250
a=250mm

7.8 Calculating Virtual Number Ofteeth :(Zv)

tanγ=z/q
=15.25^0
$Z_v=z/\cos^3\gamma$
=80.11
From PSGDB 8.18
Form factor [y_r] =0.499

7.9 Checking for Bending Stress:

σ_b=1.9[M_t]/ (m_x^3 ×q×z×y_r)
=1.9 ×17500/ (6 ×6× 6× 11× 72× 0.499)
= 3.895 N/mm^2

$\sigma_b < [\sigma_b]$ [Design safe]

7.10 Checking For Crushing:

$\sigma_c= \frac{540}{(\frac{z}{q})}\sqrt[3]{(\frac{\frac{z}{q}+1}{a})^3[M_t]/10}$
=82.5(0.6936) =57.22N/mm^2
$\sigma_c < [\sigma_c]$
Design found to be safe.

7.11 Bearing Design:

Assumptions:

- $F_a<F_r$ (Axial force < Radial force)
- N ≤ 200 rpm
- Radial Load ≈ 1.5 tones (1.5 tones = 1500 * 9.81 N = 14.715 KN)

Using value of N, we get f_n= 0.4 (f_n is Bearing Speed Factor)
P = x F_r+ y F_a (F_a/F_r≤ e, so x = 1, y = 0)
So, P = 1* 14.715 KN = 14.715 KN
Dynamic Load (C) = $f_h * P / f_n$ (f_h is Fatigue life factor, f_h = 4.5)
= 165.543 KN
Life in hours (L) = (C/P)^3
= 1424 Hrs
≈ 1500 Hrs.
From DATA BOOK for Dynamic Load 165.54 kN, Series designation 6415 is suitable.
Dimensions of bearings are:
D = 190 mm
d = 75 mm
B = 45 mm
No of balls (z) ≈ 10

8. Result and Analysis

8.1 Final Design:

Dimensions of the components of the fixture were finalized and the 2-D and 3-D designs of the fixture were developed.

8.3. D Design:

This is the 2D diagram of the proposed fixture done in AutoCAD Software. It contains the dimensions of the fixture.

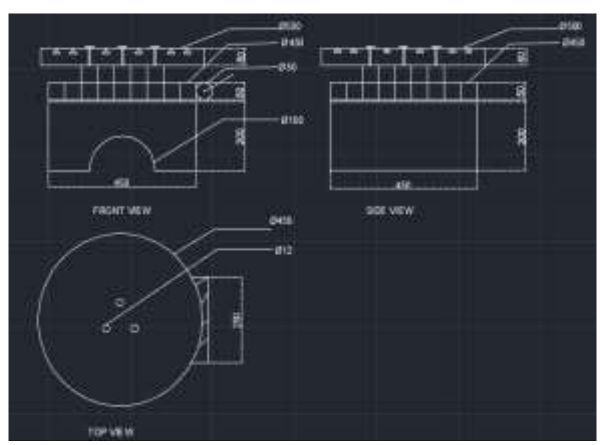

Fig.2.2: D Design of Fixture

This the 3D diagram of the fixture drawn using Creo.

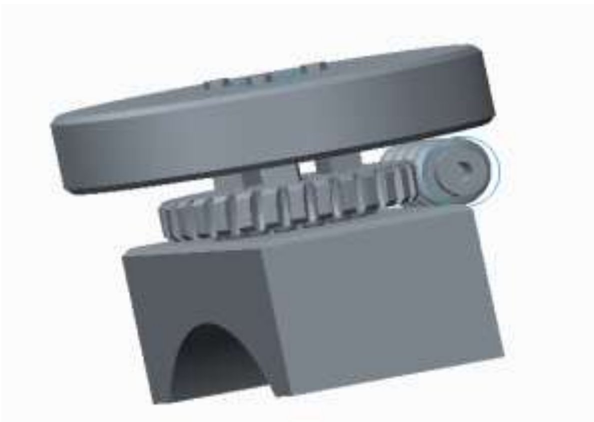

Fig 3: D Design of Fixture

8.3 Analysis of Clamping Force:

Analysis was done in ANSYS WORK BENCH 14.5. The forces involved during machining were resolved and applied on the clamp to find the deformation and principle stress subjected on the elbow.
The figure shown below gives the details of the analysis and was found to be satisfactory.

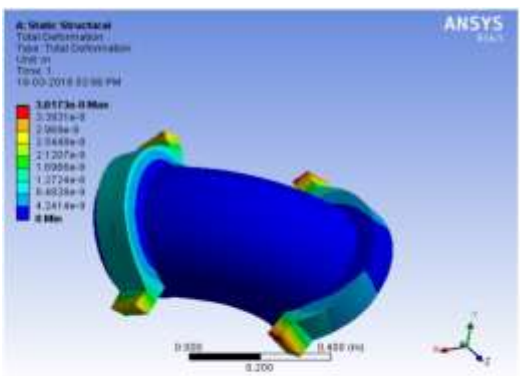

Fig. 4: Total Deformation

The Deformation analysis was done at a force of 600N (Assuming force exerted during boring operation as approximately =540N) and maximum deformation was found to be $3.8173*10^{-8}$ mm, which is safe. The clamp will be able to hold the elbow without any considerable amount of deformation.

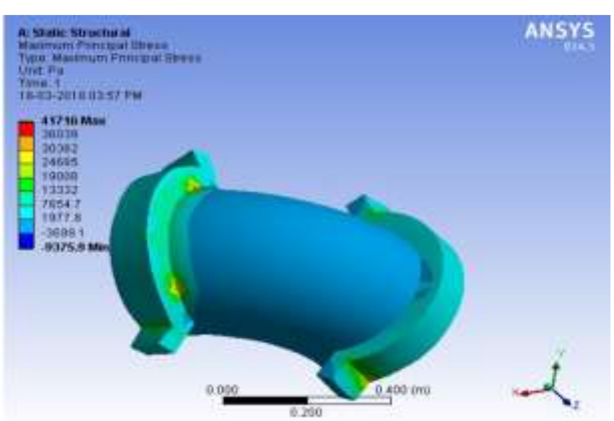

Fig 5: Maximum Principle Stress

Maximum and Minimum Principle Stresses were found to be 41716 and 13279(in Pascal) respectively. This value is less than the Tensile Strength of P91 Steel (560MPa), so the analysis shows that the design is safe.

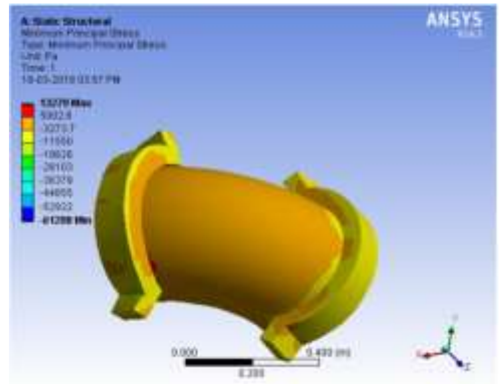

Fig: 6: Minimum Principle Stress

9. Conclusion

The objectives associated with edge preparation and the fixture designs were studied. We have designed the fixture to be simple but efficient than the previous design. This fixture will also reduce the required production time. Force analysis was done using ANSYS Workbench 14.5 and the design was found to be safe.

The design was relatively better than the previous fixtures in terms of handling.

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References

[1] Serdar Karaoglu and Abdullah SecginSensitivity Analysis of Submerged Arc Welding Process Parameters' Journal of Material Processing Technology 202, (2008).500-507.
[2] Anand Ragu and ShreyesAnalysis of The effects Of Fixture Clamping Sequence on Part Location Errors' International Journal of Machine Tools And Manufacturing 44 (2003) 373-382.
[3] J.H.Yeh and F.W.Liou 'Contact Condition Modelling For Machining Fixture Setup Processes' International Journal Of Machine Tools and Manufacture 39, (1998) 787–803.
[4] V.Vara Prasad and D.Lingaraju 'Effect Of Different Edge PreparationOn The Tensile And Hardness Properties Of Gtaw Welded 6082 Aluminum Alloy ' Materials Today: Proceedings 4, (2016) 157-165.
[5] L.Fratini ,Micari and G.Buffa 'New Fixture For Fsw processes of titanium Alloys' Cirp Annals - Manufacturing Technology. 59(2010) 271-274 .
[6] XuchenHongsheng 'A Comparison Between Fracture Toughness at Different Locations of Longitudinal Submerged Arc Welded and Spiral Submerged Arc Welded Joints of API X80 Pipeline Steels – Engineering Fracture Machine'. 148(2015) 110-121.
[7] D.V. Kiran, D.W. Choa, W.H. Songb, S.J. Naa 'Arc Behaviour In Two Wire Tandem Submerged Arc Welding' Journal of Materials Processing Technology. 214 (2014) 1546–1556.

[8] DegalaVerkathKiran 'Arc Interaction and Molten Pool Behaviour in The Three Wire Submerged Arc Welding Process' International Journal of Heat and Mass Transfer 87 (2015) 327-340.

[9] Ke Li, Zhisheng Wu, Yanjun Zhu, CuirongLiu 'Analysis of Metal Transfer in Submerged Welding Arc'Journal of Materials Processing Technology. (2017)

[10] L. Fratini ,F. Micari , G. Buffa, V.F. Ruisi 'New fixture for FSW processes of titanium alloys CIRP Annals' - Manufacturing Technology 59 (2010) 271–274.

[11] M.A. Mannan,J. P. Sollie 'A force –controlled clamping element for intelligent fixturing' International journal of machine tools and manufacturing. (1997)

[12] E. Uhlmann, D. Oberschmidt Y. Kuch A. Löwenstein I. Winker 'Effects of different cutting edge preparation methods on micro milling performance'. (2016)

[13] Jan C. Aurich , Christian Effgen, Benjamin Kirsch et.al Cutting edge preparation with elastic bonded super abrasive grinding wheels, (2016)

[14] Alimkina a , Yu. P. Astakhov a , A. V. Baraev a , Yu. M. Dolzhanskii a & S. A. Kochergin. 'Effect of the method of edge preparation on the mechanical properties of laser welded joints in thin wall titanium shells.