
Your paper to MM Science Journal_Reviews enclosed

15 pesan

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

6 Oktober 2020 17.12

Dear Mr. Purwanto,

Recently, we received both of the reviews to your paper entitled EFFECTS OF PRESSURE IN CONTINUOUS DRIVE FRICTION WELDING ON SS 304 AND CARBON STEEL to MM Science Journal; please see enclosed.

I would like to ask you now to go through the reviews and reflect all the reviewers' comments in the contents of your paper. After this is done please send me the revised paper and it will be ready for the pre-publication final touch.

Your paper will be published in the November issue; please note that the deadline for sending your revised paper is on October 23rd (if sent later, the paper will be published in December issue)

Thank you for your cooperation

Kind regards

Mgr. Dagmar Podoláková

MM Science Journal, MM publishing, s.r.o.

Přípotoční, 151910A, 101 00 Praha 10

tel.+420 775 245 809, 222 365 170

dagmar.podolakova@mmscience.eu, <http://www.mmscience.eu/>

2 lampiran **4_MM-SJ_RevForm_NoReviewer_733_NoPaper_2020054.pdf**
2664K **4_MM-SJ_RevForm_NoReviewer_525_NoPaper_2020054.pdf**
1806K

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

12 Oktober 2020 18.53

Dear Editor,

Greetings healthy,
Here we send revisions according to the comments given by reviewers
Thank you for your help and cooperation, we hope to receive good news soon

Best Regard

Helmy Purwanto
[Kutipan teks disembunyikan]

2 lampiran



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747K

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

15 Oktober 2020 20.21

Dear Mr. Purwanto,

Thank you for sending us the final version of your paper after corrections. Since the reviewers checked the box „Acceptable with minor revisions“, there is no need to send the edited paper for final approval and, therefore, we will count on your paper to the November issue; this one comes out on the November 11th.

Thank you for your cooperation

Best regards

Dagmar Podolakova
MM Science Journal

[Kutipan teks disembunyikan]

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

16 Oktober 2020 06.07

Dear Editor
Healthy greetings
Thank you for the opportunity given to us to publish on MM Science.
What is the next step should i work on
Thank you for your cooperation

Best regards

Helmy Purwanto
[Kutipan teks disembunyikan]

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

16 Oktober 2020 16.58

Dear Mr. Purwanto,

For now, there is no action needed to take. I am gathering the final version of all papers heading to November issue and as soon as they come out, I will send you an e-mail with the issue web page confirming your paper has been published. After this, my colleague will e-mail you the invoice for the remaining 180 EUR to pay off.

Thank you

Kind regards

Dagmar Podoláková

[Kutipan teks disembunyikan]

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

5 November 2020 18.49

Dear Mr. Purwanto,

I noticed that the REFERENCES section in your paper does not follow the Paper Manuscript (enclosed).

Now we are already in the phase of the last editorial changes before the publication, therefore, I would like to politely ask you to edit the references according to the attached manuscript and send the article back to me as soon as possible. Please edit it in the enclosed version of your paper.

Thank you for your cooperation

Kind regards

Dagmar Podoláková
MM Science Journal

From: Helmy Purwanto [mailto:helmypurwanto@unwahas.ac.id]
Sent: Friday, October 16, 2020 1:07 AM

[Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

2 lampiran

 **3_Paper_Manuscript_Template_MMSJ_paper.doc**
228K

 **MMSJ_2020054.docx**
1065K

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

6 November 2020 03.38

dear Mrs. Dagmar Podolakova

Greetings Healthy,
Thanks for the correction.
here we send improvements in accordance with the template.
Thank you for your help and cooperation.

Best regards

Helmy Purwanto
[Kutipan teks disembunyikan]



MMSJ_2020054_Final.docx
1090K

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

11 November 2020 08.47

dear Mrs. Dagmar Podolakova

Greetings Healthy,
Thank you, our article was published in the November 2020 edition of MM Science.
there are slight errors in author writing on the online display for third author
it is written: "**Iman Syafaat**", which is actually: "**Imam Syafaat**". and while the pdf article is correct.
please correct and correct

Thank you for your cooperation

Best regard
Helmy Purwanto
[Kutipan teks disembunyikan]

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

11 November 2020 17.27

Dear Mr. Purwanto,

Thank you for kindly pointing this out; I have corrected it. You may check it for your convenience.

Since your paper has been successfully reviewed and published, I would like to kindly remind you that in the following days, we will issue and send you an invoice for the remaining 180 EUR.

Thank you again for publishing with us

Have a nice day

[Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

14 November 2020 02.28

dear Mrs. Dagmar Podolakova

Greetings Healthy,

We are waiting for the invoice, and sorry, to be corrected writing for the third author (attached).

Thank you for your help and cooperation.

Best regards

Helmy Purwanto

[Kutipan teks disembunyikan]



Imam Syafaat.jpg
56K

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

20 November 2020 19.04

Dear Mr. Purwanto,

I am sending you an invoice for the remaining 180 EUR.

For the correction of Mr. Syafaat's name, I have tried several times to correct it in the admin system, however, I was not successful. I have addressed the IT department to check it out and have it fixed.

I am sorry for the inconvenience, I will let you know once it is done.

[Kutipan teks disembunyikan]

 **Purwanto_Vydana faktura - SJ0582020.pdf**
190K

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

24 November 2020 16.08

Dear Ms Dagmar

We are sorry that there is a late payment due to the holiday weekend. here we send proof of payment.

Greetings always healthy

Best regards

Helmy Purwanto

[Kutipan teks disembunyikan]

4 lampiran**MM Sceince 2.jpg**
312K**MM Sceince 1.jpg**
1310K **MM Sceince 2.pdf**
192K **MM Sceince 1.pdf**
239K

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

24 November 2020 19.02

Dear Mr. Purwanto,

Thank you for letting me know; part of the invoice is defaultly set in Czech language but the invoice is due on December 21st, so there is no need to worry that the payment will not make it to our account on time. We usually set the due for two weeks but here we were aware that the payment from a foreign country just takes a little longer that is why we allowed more than one month.

Also, I managed to fix the Mr. Imam name in the admin systém so now everything should be fine.

[Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

Helmy Purwanto <helmypurwanto@unwahas.ac.id>
Kepada: Dagmar Podoláková <dagmar.podolakova@mmscience.eu>

24 November 2020 19.12

Thank you very much, nice to cooperate with you. I hope we have more articles that can be published. healthy greetings from Indonesia.

Best regard
Helmy Purwanto
[Kutipan teks disembunyikan]

Dagmar Podoláková <dagmar.podolakova@mmscience.eu>
Kepada: Helmy Purwanto <helmypurwanto@unwahas.ac.id>

24 November 2020 19.21

We will be definitely looking forward to accept further papers from you and your team!

[Kutipan teks disembunyikan]

MM-Science Journal Paper Review Form

Please complete and return this form to MM-Science Journal by clicking the 'Submit by Email' button
by _____ at the latest

Reviewer No: _____

for the paper No: _____

Title of the paper: _____

Paper's overall score (min 0; max 1):

Kind of the intended paper

The MM-Science Journal invites high-quality submissions on substantial, original and previously unpublished research. Applied, theoretical, results-oriented and speculative papers from both academia and industry will all be considered for inclusion. Contributions are classified into and are reviewed in the following categories:

- **Research Papers** describing contributions and the latest results of scientific work.
- **Industrial Papers** should signal industrial needs for design approaches/techniques, experiences from their implementation and use, experiences from training of engineers, demands on computer support, best practice, qualitative case studies, etc.
- **Design Education Papers** should be based on a scientific approach describing substantial new experiences based on design education training, teamwork, projects or cases.
- **Philosophy or Speculations Papers** provide a category for contributions where the author has a free hand to evolve new ideas without a claim for scientific validation. However, the paper should be rigorously related to state-of-the-art literature and clearly indicate the novelty of the ideas.

For a proper evaluation and use of correct criteria we ask you to classify:

Please select:

- ☐ [A] A research paper
- ☐ [B] An industrial paper
- ☐ [C] An educational paper
- ☐ [D] A philosophy or speculation paper

I. How strong is the intended papers's content?

1. Indicate the intended paper's topicality and significance

Please select:

- ☐ [0 p.] Useless and/or not significant theme and/or subject
- ☐ [1 p.] Not topical and/or not significant theme and/or subject
- ☐ [2 p.] Up to date however less significant theme and/or subject
- ☐ [3 p.] Up to date and significant theme and/or subject
- ☐ [4 p.] New challenging and significant theme and/or subject

2. Indicate the intended paper's novelty and level of contribution to present knowledge

Please select:

- ☐ [0 p.] General and/or unarticulated material
- ☐ [1 p.] Repetition of known material
- ☐ [2 p.] New application of known material
- ☐ [3 p.] New theory contributions or additions
- ☐ [4 p.] Innovative contribution to theory, methods or models

3. Are the discourse and conclusions valid?

Please select:

- ☐ [0 p.] Not justified, no message
- ☐ [1 p.] Major omissions, weak justification
- ☐ [2 p.] Loose generalisations, weak polemic
- ☐ [3 p.] Good justification, reasonable discourse
- ☐ [4 p.] Strong justification, strong discourse

4. Is an industrial or application perspective reflected in a reasonable way by the author(s)?

Please select:

- ☐ [0 p.] No comments included
- ☐ [1 p.] Naive, invalid arguments
- ☐ [2 p.] Questionable reflection on industrial scope
- ☐ [3 p.] Reasonable reflection on industrial scope
- ☐ [4 p.] Strong, convincing reflection

for [A]: Are the scientific methods and reviews clearly described? Is a scientific contribution proved?

5. **for [B/D]:** Is the industrial reasoning from symptoms, diagnosis, and improvements to results strong?

for [C]: Does the extended abstract show good pedagogic understanding?

<input type="radio"/> [0 p.] No description included	<input type="radio"/> [0 p.] No comments included	<input type="radio"/> [0 p.] No educational aspects introduced
<input type="radio"/> [1 p.] Poor or sparse hints to methodics	<input type="radio"/> [1 p.] Jump to conclusion, no justification	<input type="radio"/> [1 p.] Poor understanding
<input type="radio"/> [2 p.] Questionable, insufficient description	<input type="radio"/> [2 p.] Major omissions, unclear reasoning	<input type="radio"/> [2 p.] Inadequate reflections
<input type="radio"/> [3 p.] Reasonable description and application of methods and reviews	<input type="radio"/> [3 p.] Reasonable thread of reasoning	<input type="radio"/> [3 p.] Reasonable educational aspects
<input type="radio"/> [4 p.] Rigour in scientific reasoning, methods and reviews	<input type="radio"/> [4 p.] Strong, convincing reasoning	<input type="radio"/> [4 p.] Good educational understanding

6. Are the references adequate and state-of-the-art?

Please select:

- ☐ [0 p.] No references
- ☐ [1 p.] Apparently only own references
- ☐ [2 p.] Less adequate references
- ☐ [3 p.] Reasonable references shown
- ☐ [4 p.] Central state-of-the-art references

Your overall score of the content strength [min 0; max 1] is: $(\sum I.) / 24 = 0.xx =$

Concerns and advice regarding the content strengths:

Your task as a reviewer is to advise the author(s) as to how to improve the intended paper and making it relevant for MM Science Journal. You must therefore explain to the author(s) about your concerns and give them advice.

II. How well is the intended paper written?

1. Is the intended paper well structured and organised?

Please select:

- ☐ [0 p.] Inadequate structure
- ☐ [1 p.] Irrelevant material included
- ☐ [2 p.] Inadequate content/length relation
- ☐ [3 p.] Reasonable structure
- ☐ [4 p.] Good structure

2. Is the use of English satisfactory?

Please select:

- ☐ [0 p.] Unacceptable language, obscure terminology
- ☐ [1 p.] Extensive revision necessary
- ☐ [2 p.] Needs some revisions as indicated
- ☐ [3 p.] Acceptable
- ☐ [4 p.] Good grammar and vocabulary

3. Are the illustrations and tables clear, effective and understandable?

Please select:

- ☐ [0 p.] Unacceptable
- ☐ [1 p.] Major flaws, missing illustrations
- ☐ [2 p.] Partly inadequate
- ☐ [3 p.] Reasonable clear concept
- ☐ [4 p.] Complete, precise

Your overall score of the formal qualities [min 0; max 1] is: $(\Sigma \text{II.}) / 12 = 0,yy =$

Instructions and advice regarding the formal qualities:

As a reviewer you should also advise the author(s) concerning the formal aspects of the intended paper. Please give your instructions and advice here.

Review summary and recommendation

Based upon your scoring of the paper manuscript:

the content strength [min 0; max 1] is: 0,xx =

the formal qualities [min 0; max 1] is: 0,yy =

i.e. overall score [min 0; max 1] is: $(24 \times 0,xx + 12 \times 0,yy)/36 = 0,zz =$

From it follows, that your final evaluation of the intended paper is:

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
not acceptable		acceptable with major revisions		acceptable with minor revisions		acceptable as it is				
<div></div>		<div></div>		<div></div>		<div></div>				

In case your overall score is over 0.85 it is a must to comment and reason so high rating (paper must be really exceptionally quality to be rated by so high rating). Please, write down a few 5 sentences explaining such a high evaluation into section Comments to the MM Science Journal redaction (next page).

Reflection

What is your competence as a referee in relation to the actual paper and topic?

Please select:

- ☐ I am an expert in the subject area of the paper
- ☐ I am knowledgeable in the area but not an expert
- ☐ I am not an expert; my evaluation is that of an informed outsider

Do you have comments to the MM Science Journal redaction (not to be forward to the author(s)) concerning your evaluation, the paper, your comments etc ?

Please check when ready:

- ☐ **This is my final version of the review**

Reference: McAloone T. and Andreasen M.M., DESIGN 2008 Conference Paper Review Form, Dubrovnik. Technical University of Denmark, Lyngby, Denmark, 2008

Your personal data are handled in accordance with the principles of new EU Regulations on the protection of personal data (GDPR).

In case of any questions regarding our principles connected with the protection of personal data or data contained in our filing system, please contact us: dagmar.podolakova@mmscience.eu

MM-Science Journal Paper Review Form

Please complete and return this form to MM-Science Journal by clicking the 'Submit by Email' button
by _____ at the latest

Reviewer No: _____

for the paper No: _____

Title of the paper: _____

Paper's overall score (min 0; max 1):

Kind of the intended paper

The MM-Science Journal invites high-quality submissions on substantial, original and previously unpublished research. Applied, theoretical, results-oriented and speculative papers from both academia and industry will all be considered for inclusion. Contributions are classified into and are reviewed in the following categories:

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For a proper evaluation and use of correct criteria we ask you to classify:

Please select:

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- ☐ [D] A philosophy or speculation paper

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1. Indicate the intended paper's topicality and significance

Please select:

- ☐ [0 p.] Useless and/or not significant theme and/or subject
- ☐ [1 p.] Not topical and/or not significant theme and/or subject
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- ☐ [3 p.] Up to date and significant theme and/or subject
- ☐ [4 p.] New challenging and significant theme and/or subject

2. Indicate the intended paper's novelty and level of contribution to present knowledge

Please select:

- ☐ [0 p.] General and/or unarticulated material
- ☐ [1 p.] Repetition of known material
- ☐ [2 p.] New application of known material
- ☐ [3 p.] New theory contributions or additions
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3. Are the discourse and conclusions valid?

Please select:

- ☐ [0 p.] Not justified, no message
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Please select:

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for [A]: Are the scientific methods and reviews clearly described? Is a scientific contribution proved?

5. **for [B/D]:** Is the industrial reasoning from symptoms, diagnosis, and improvements to results strong?

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<input type="radio"/> [1 p.] Poor or sparse hints to methodics	<input type="radio"/> [1 p.] Jump to conclusion, no justification	<input type="radio"/> [1 p.] Poor understanding
<input type="radio"/> [2 p.] Questionable, insufficient description	<input type="radio"/> [2 p.] Major omissions, unclear reasoning	<input type="radio"/> [2 p.] Inadequate reflections
<input type="radio"/> [3 p.] Reasonable description and application of methods and reviews	<input type="radio"/> [3 p.] Reasonable thread of reasoning	<input type="radio"/> [3 p.] Reasonable educational aspects
<input type="radio"/> [4 p.] Rigour in scientific reasoning, methods and reviews	<input type="radio"/> [4 p.] Strong, convincing reasoning	<input type="radio"/> [4 p.] Good educational understanding

6. Are the references adequate and state-of-the-art?

Please select:

- ☐ [0 p.] No references
- ☐ [1 p.] Apparently only own references
- ☐ [2 p.] Less adequate references
- ☐ [3 p.] Reasonable references shown
- ☐ [4 p.] Central state-of-the-art references

Your overall score of the content strength [min 0; max 1] is: $(\sum I.) / 24 = 0.xx =$

Concerns and advice regarding the content strengths:

Your task as a reviewer is to advise the author(s) as to how to improve the intended paper and making it relevant for MM Science Journal. You must therefore explain to the author(s) about your concerns and give them advice.

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1. Is the intended paper well structured and organised?

Please select:

- ☐ [0 p.] Inadequate structure
- ☐ [1 p.] Irrelevant material included
- ☐ [2 p.] Inadequate content/length relation
- ☐ [3 p.] Reasonable structure
- ☐ [4 p.] Good structure

2. Is the use of English satisfactory?

Please select:

- ☐ [0 p.] Unacceptable language, obscure terminology
- ☐ [1 p.] Extensive revision necessary
- ☐ [2 p.] Needs some revisions as indicated
- ☐ [3 p.] Acceptable
- ☐ [4 p.] Good grammar and vocabulary

3. Are the illustrations and tables clear, effective and understandable?

Please select:

- ☐ [0 p.] Unacceptable
- ☐ [1 p.] Major flaws, missing illustrations
- ☐ [2 p.] Partly inadequate
- ☐ [3 p.] Reasonable clear concept
- ☐ [4 p.] Complete, precise

Your overall score of the formal qualities [min 0; max 1] is: $(\Sigma \text{II.}) / 12 = 0,yy =$

Instructions and advice regarding the formal qualities:

As a reviewer you should also advise the author(s) concerning the formal aspects of the intended paper. Please give your instructions and advice here.

Review summary and recommendation

Based upon your scoring of the paper manuscript:

the content strength [min 0; max 1] is: 0,xx =

the formal qualities [min 0; max 1] is: 0,yy =

i.e. overall score [min 0; max 1] is: $(24 \times 0,xx + 12 \times 0,yy)/36 = 0,zz =$

From it follows, that your final evaluation of the intended paper is:

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
not acceptable		acceptable with major revisions		acceptable with minor revisions		acceptable as it is				
<div></div>		<div></div>		<div></div>		<div></div>				

In case your overall score is over 0.85 it is a must to comment and reason so high rating (paper must be really exceptionally quality to be rated by so high rating). Please, write down a few 5 sentences explaining such a high evaluation into section Comments to the MM Science Journal redaction (next page).

Reflection

What is your competence as a referee in relation to the actual paper and topic?

Please select:

- ☐ I am an expert in the subject area of the paper
- ☐ I am knowledgeable in the area but not an expert
- ☐ I am not an expert; my evaluation is that of an informed outsider

Do you have comments to the MM Science Journal redaction (not to be forward to the author(s)) concerning your evaluation, the paper, your comments etc ?

Please check when ready:

- ☐ **This is my final version of the review**

Reference: McAloone T. and Andreasen M.M., DESIGN 2008 Conference Paper Review Form, Dubrovnik. Technical University of Denmark, Lyngby, Denmark, 2008

Your personal data are handled in accordance with the principles of new EU Regulations on the protection of personal data (GDPR).

In case of any questions regarding our principles connected with the protection of personal data or data contained in our filing system, please contact us: dagmar.podolakova@mmscience.eu

EFFECTS OF PRESSURE IN CONTINUOUS DRIVE FRICTION WELDING ON AISI 304 AND A36

HELMY PURWANTO, MUHAMMAD DZULFIKAR,
IMAM SYAFAAT, SOHABAT IMANU, NUR KHOLIS

Department of Mechanical Engineering, Faculty of Engineering,
Universitas Wahid Hasyim

DOI : will be added by publisher

e-mail : helmypurwanto@unwahas.ac.id

Friction welding is a connection by frictional heating due to the rotation of one metal against another metal under the influence of axial compression. This study aims to determine and analyse the effect of pressure on the shape of the welded connection, microstructure, tensile strength and hardness in Continuous Drive Friction Welding (CFDW). The materials used were AISI 304 and A 36 carbon structural steel with a diameter of 10 mm. The Forging pressure was given 3 MPa, 4 MPa, and 5 MPa, at a constant rotating speed of 2000 rpm. The results of friction welding at a pressure of 5 MPa formed a perfect, straight and neat welded connection and the particle structure solidified and shrunk resulting in the highest tensile strength value of 510.26 MPa and an average hardness of 83.67 HRB. Frictional welding at 3 MPa pressure showed a tensile strength value of 476.20 MPa and a compacted and elongated particle structure resulting in a straight but wavy welded connection with a hardness value of 81.00 HRB. Meanwhile, frictional welding at 4 MPa pressure showed a low tensile strength value of 459.32 MPa, the solid particle structure following the direction of rotation produced a broken connection forming two welding lines with a hardness value of 81.67 HRB.

KEYWORDS

Friction welding, forging pressure, friction characteristics, strength of friction welding joint

INTRODUCTION

Welding technology has been applied broadly in the field of engineering. In the petrochemical and power generation industries, especially on the motor shaft and generator, a connection between stainless steel and carbon structural steel is needed. Various welding methods have been developed to meet construction needs. One of which that can be applied to two different types of material with a cylindrical solid shaft-shaped rod is friction welding. It is a welding of solid state due to frictional heating and pressure. Former is produced from the relative motion of material by rotating or alternating motion [Meshram et al. 2007][Li et al. 2016], while latter has technical advantages and high efficiency and better process stability compared to fusion welding. In the weld area diffusion occurs between the metal which is joined [James and Sudhish 2016]. The amount of frictional heating determines the formation of intermetallic compounds which further affects the mechanical properties of the connection [Mehta 2019]. Friction welding is a forging technique since there is no melting and welding done by applying pressure [Akhil and Charles 2017]. The presence of pressure and friction causes an increase in temperature at the

welding interface to form an intermetallic layer on copper and AISI 430 ferritic stainless-steel material [Shanjeevi et al. 2017].

At the connection of 1045 and 316L, the addition of welding pressure results in increased interface hardness, while the tensile strength and connection fail in the thermo-mechanical affected zone on the 316L stainless steel austenite side [Khidhir and Baban 2019]. In stainless steel duplex friction welding, the welding area has a higher hardness and tensile strength than base metal. This is due to grain repairs which cause failure away from the connection during tensile testing [Ajith et al. 2015]. The highest hardness in friction welding occurs at the interface area due to forging by friction pressure [Muralimohan et al. 2014].

Frictional pressure is one of the factors that influences welding results. Axial pressure is an important welding parameter [Handa and Chawla 2014]. Friction pressure affects the microstructure in the interface area and tensile strength. The connections on AISI 304 ZE and AISI 1060 are perfect and the tensile strength increases with the addition of frictional pressure [Ates and Kaya 2014], as well as on AISI 304 with AISI 1021, but the impact toughness decreases [Handa and Chawla 2014]. In addition, frictional pressure affects the hardness of the welding area. The higher the pressure, the harder the welding area [Handa and Chawla 2014]. Hardness of the welding occurs because of the oxidation process during friction welding [Ates et al. 2007]. Pressure, rotational speed and friction time affect the interface overflow interface [Kirik and Özdemir 2015], occurs because the material in the friction area becomes semi-solid. Friction time affects the quality of the welding joint. Long friction time causes a decrease in strength in the formation of eutectoid and insoluble systems and increased strength in soluble systems [Meshram et al. 2007]. The greater the pressure, the greater the tensile strength of the weld joint [Muralimohan et al. 2014].

There have been many studies on friction welding in similar and dissimilar materials. Study of the influence of rotational speed, friction pressure, friction time, forging pressure has been widely reviewed. Large friction and forging pressures are required to obtain a good weld joint, and the average pressure applied is above 25 MPa. However, in this study, by using a simple welding equipment design and welding was performed with relatively small forging pressures of 3 MPa, 4 MPa and 5 MPa, respectively. This study aims to determine and analyze the effect of pressure on the friction welding process on welding results, microstructure, hardness and tensile strength on stainless steel AISI 304 with ASTM A36 carbon structural steel.

METHOD

The materials used were stainless steel AISI 304 and ASTM A36 carbon structural steel with a length of 100 mm each and a diameter of 10 mm. The chemical composition of the material by using a spectrometer is shown in Table 1. Continuous Drive Friction Welding (CFDW) used a friction welding tool with a rotation of 2000 rpm on stainless steel materials, while carbon structural steel provided pressure. Friction welding using equipment as shown in Fig. 1. The friction pressure of 1 MPa for 15 seconds, while the forging time was 5 seconds. The forging pressure was varied at 3 MPa, 4 MPa and 5 MPa. Micro observation used a metallurgical microscope, testing the average hardness used the Rockwell method and tensile testing used a universal testing machine with a draw speed of 10 mm/s. Hardness testing is carried out on the weld area (interface joining) and base metal. Tensile test specimens were made according to ASTM E8 standard.

Material	Chemical compositions % wt																		
	S	Al	C	Ni	Nb	Si	Cr	V	Mn	Mo	W	P	Cu	N	B	Sb	Mg	Co	Fe
AISI 304	0.024	0.004	0.027	8.457	0.017	0.413	18.574	0.075	1.153	0.321	0.018	0.036	0.542	0.078	0.001	0.011	0.002	0.148	Bal.
A36	0.024	0.001	0.057	0.008	0.000	0.147	0.336	0.002	0.309	0.000	0.000	0.019	0.012	0.003	0.000	0.001	0.002	0.002	Bal.

Table 1. Chemical composition of AISI 304 and ASTM A36 carbon structural steel

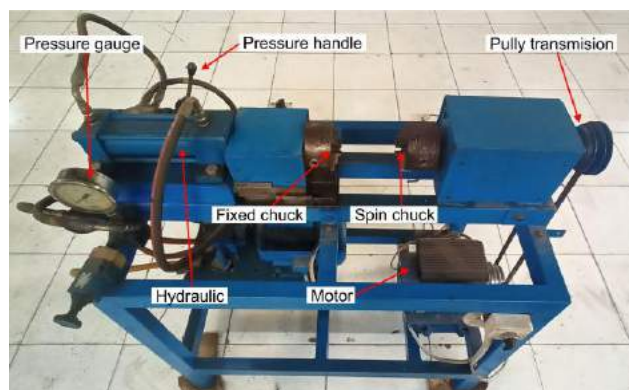


Figure 1. Friction welding equipment

RESULTS AND DISCUSSION

The results of the welding joint using Continuous Drive Friction Welding (CFDW) are shown in Fig. 2. From each pressure variable, samples of carbon structural steel and stainless steel can be perfectly connected.

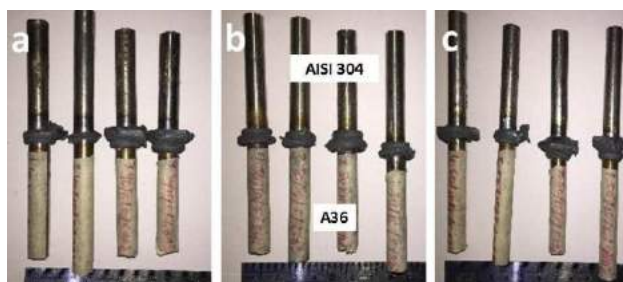


Figure 2. Results of friction welding a). pressure of 3 MPa, b). pressure of 4 MPa, and c). pressure of 5 MPa.

Macroscopically, all pressure variables can be connected properly. Stainless steel and carbon structural steel and generally have similar properties, especially the melting point. This causes the connection can be formed and overflow occurs on the side of stainless steel or carbon structural steel. At the connection, overflow was found because the tip of the sample experienced semi-solid and the influence of forging pressure. The presence of pressure and friction at the interface causes heat, and this heat can melt the interface into a semi-solid state. Macro photo and cross section of the weld joint are shown in Fig. 3.

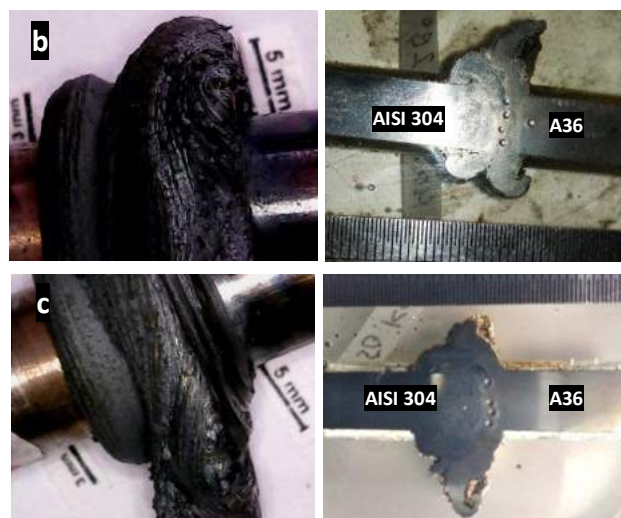


Figure 3. Macrostructures of the result of friction welding and its cross section a). pressure of 3 MPa, b). pressure of 4 MPa, and c). pressure of 5 MPa.

Fig. 3 shows the weld joint worked well since there was no visible porosity or failed to swell at each connection macroscopically. In each variable, the cross section showed the side of the carbon structural steel pressed by stainless steel. Overflow also appeared higher in carbon structural steel compared to stainless steel. This was due to the higher hardness of stainless steel compared to carbon structural steel. Therefore, the deformation of carbon structural steel was greater than stainless steel. The results of measurements of overflow height at each pressure variable are shown in Fig. 4.

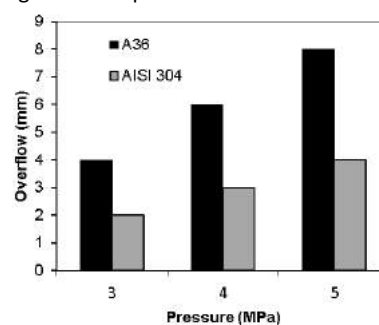


Figure 4. Relationship of welding pressure with the formed overflow

The greater the pressure, the greater the average overflow formed. This overflow was formed because the interface experienced friction into heat. The heat reached its melting point so that it became semisolid. Due to pressure, the semi-solid material formed an overflow. The higher the pressure, the greater the compressive force of the interface surface. Thus, the deformation that occurred was greater.

The microstructure at the interface or weld zone is shown in Fig. 5. The boundary between stainless steel and carbon structural steel is clearly visible. Microscopically it is visible gap in the interface.

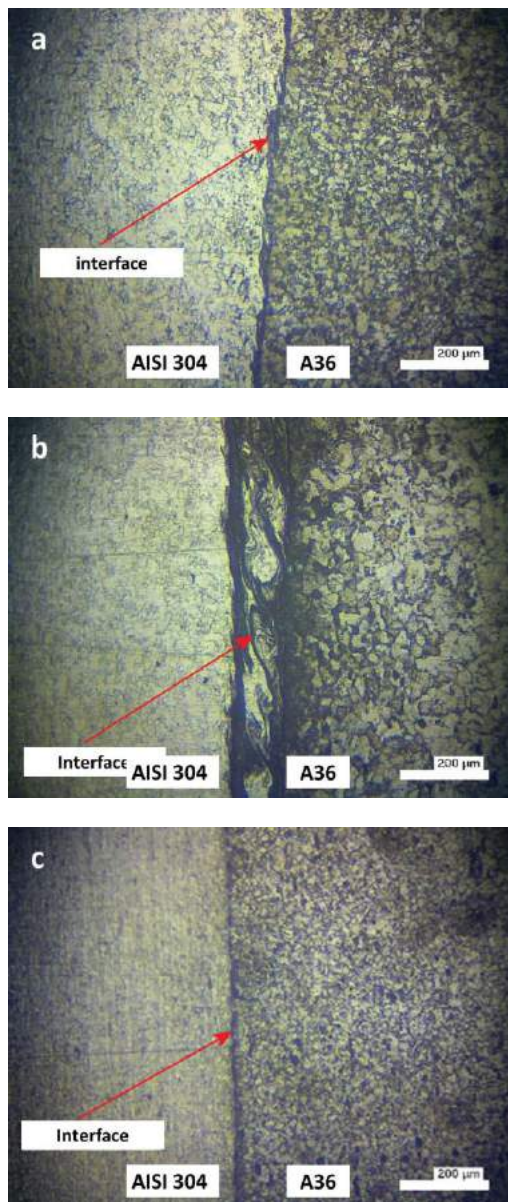


Figure 5. Welding area (interface) SS 304 and A 36 carbon structural steel, a). pressure of 3 MPa, b). pressure of 4 MPa, and c). pressure of 5 MPa.

Microscopically, the process of Continuous Drive Friction Welding material AISI 304 and A 36 carbon structural steel did not include stirring or mixing dissimilar material. Welding ties merely occurred at the interface. In this welding, unbounded religion, especially at the pressure of 4 MPa, was found (Fig.5b). Unlike the friction stir welding process, there was a stirring process for welded parts called nugget zones or weld nuggets [Mehta 2019] [Setiawan et al. 2018]. In the weld area, there were interface defects in the pressure of 3 MPa (fig. 5a) and 4 MPa (fig. 5b). There were also cavities at the interface between stainless steel and carbon structural steel. It was possible that the given friction pressure was still lacking. However, connection with pressure of 5 MPa (Fig. 5c) formed a perfect welding connection, straight and neat, and compact particle structure with minimal interface to the connection defects. With a pressure of 5 MPa, it looks microscopically enough to provide a good connection

Rockwell hardness test results in the base metal and the weld zone (interface) is shown in Fig. 6.

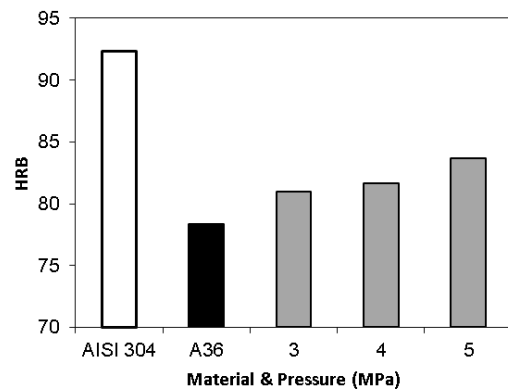
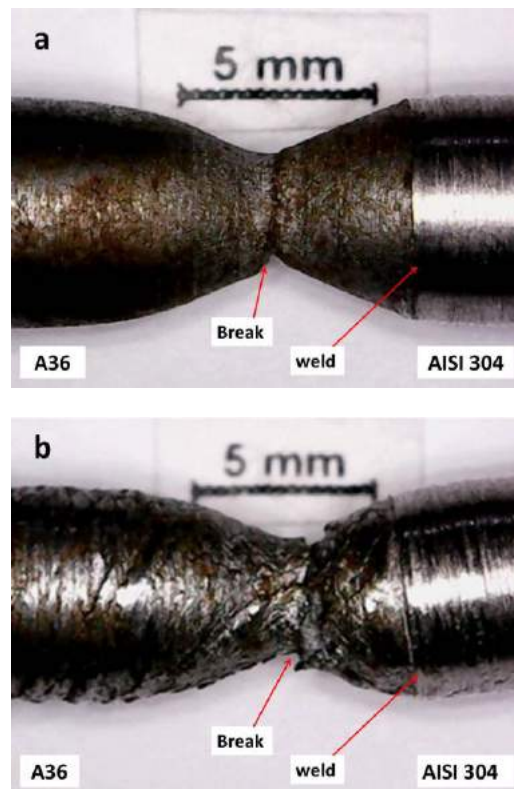


Figure 6. Rockwell Hardness AISI 304, A 36 carbon structural steel dan hardness in the weld zone in each pressure variables

The average hardness base metal of AISI 304 is 92.33 HRB and base metal A 36 carbon structural steel hardness was 78.33 HRB. The average weld zones in the variable of weld 3, 4 and 5 MPa were 81.00, 81.67 and 83.67 HRB, respectively. The average hardness of AISI 304 was higher than that of A 36 carbon structural steel; this made A 36 carbon structural steel more easily deformed compared to AISI 304 as shown in Fig. 3 and Fig. 4 (formed overflow). The average hardness in the weld zone was higher than A 36 carbon structural steel and lower than AISI 304. This proves that in the weld zone area there is a mixed phase between AISI 304 and A 36 carbon structural steel. The higher the friction pressure that was given during the friction welding process, the average hardness in the weld zone area was also greater. This also proves that pressure affects the forging of a semi-solid area due to heat friction.

The shape and location of the tensile test break are shown in Fig. 7, while the results of tensile testing are shown in the graph Fig. 8.



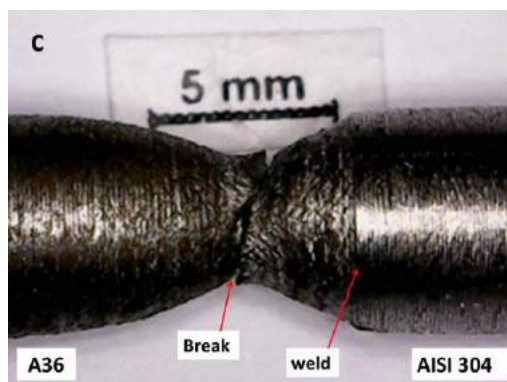


Figure 7. The shape and the tensile test break [a]. pressure of 3 MPa, b). pressure of 4 MPa, and c). pressure of 5 MPa.

All samples in the tensile test break use A 36 carbon structural steel material. This proves that the weld joint between AISI 304 and A 36 carbon structural steel by friction welding was successfully carried out. The connection strength was greater than the tensile strength of A 36 carbon structural steel.

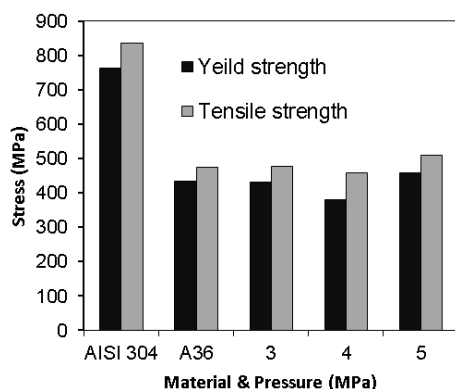


Figure 8. Yield stress and maximal stress AISI 304, A 36 carbon structural steel and pressure variable

The average results of yield strength and maximum tensile strength of AISI 304 were 763.39 MPa and 836.67 MPa, while A 36 carbon structural steel was 433.71 MPa and 474.19 MPa. In the tensile strength using friction welding with a pressure of 3 MPa, the average yield strength was 431.68 MPa and maximum tensile strength was 476.20 MPa. With pressure of 4 MPa, yield tensile strength was 381.38 MPa and the maximum tensile strength was 459.32 MPa. With pressure of 5 MPa, yield strength was 457.55 MPa and maximum tensile strength was 510.26 MPa. The pressure variables of friction welding did not seem to have a significant effect on tensile strength. This further proves the area of tensile test drop off occurs in the parent metal, i.e. A 36 carbon structural steel metal. This proves that the weld joint between AISI 304 and A36 using the Continuous Drive Friction Welding method has been successful with forging pressures of 3, 4 and 5 MPa. As has been reported by [Ajith et al. 2015] that the tensile strength of the welded joint is better than that of duplex stainless steel base metal. This is due to the improvement of grain in the area due to heat of friction, and confirmed by an increase in hardness compared to carbon structural steel.

CONCLUSION

Based on observations and data obtained from experiments on friction welding dissimilar materials AISI 304 and A 36 carbon structural steel at low pressure, it can be concluded:

1. Stainless steel 304 could be connected using the Continuous Drive Friction Welding (CFDW) method at low pressure.
2. Microstructure in the weld zone did not appear to be stirring between stainless steel and carbon structural steel. It was apparent there was an interface area between stainless steel and carbon structural steel. At a pressure variable of 5 MPa a perfect, straight and neat welding connection was produced and the particle structure solidified and shrunk with minimal visible defect in the connection.
3. Frictional pressure affected the average hardness of the weld area or interface; the greater the pressure, the greater the hardness of the weld area.

The bonding of the welded connection was stronger than the strength of the parent metal, i.e. carbon structural steel. Thus, this method can be applied to construction.

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CONTACTS:

Dr. Helmy Purwanto, ST., MT

Scopus ID : 57194497351

Orchid : <http://orcid.org/0000-0002-2280-9236>

Department of Mechanical Engineering, Faculty of Engineering, Universitas Wahid Hasyim

Jl. Menoreh Tengah X/22 Sampangan Semarang 50236, Indonesia

+62 81390089207, helmypurwanto@unwahas.ac.id

Muhammad Dzulfikar, ST., MT

Scopus ID: 57200214175

Orchid : <http://orcid.org/0000-0001-5140-9701>

Department of Mechanical Engineering, Faculty of Engineering, Universitas Wahid Hasyim

Jl. Menoreh Tengah X/22 Sampangan Semarang 50236, Indonesia

+62 85226622609, dzulfikar@unwahas.ac.id

Imam Syafaat, ST., MT

Scopus ID: 57203430586

Orchid : <https://orcid.org/0000-0003-3395-9173>

Department of Mechanical Engineering, Faculty of Engineering, Universitas Wahid Hasyim

Jl. Menoreh Tengah X/22 Sampangan Semarang 50236, Indonesia

+62 82133164470, imamsyafaat@unwahas.ac.id

Sohabat Imanu, ST.

Scopus ID : -

Orchid : -

Department of Mechanical Engineering, Faculty of Engineering, Universitas Wahid Hasyim

Jl. Menoreh Tengah X/22 Sampangan Semarang 50236, Indonesia

Nur Kholis, ST.

Scopus ID : -

Orchid : -

Department of Mechanical Engineering, Faculty of Engineering, Universitas Wahid Hasyim

Jl. Menoreh Tengah X/22 Sampangan Semarang 50236, Indonesia