Springer Proceedings in Materials

K. Geetha
Francisco M. Gonzalez-Longatt
Hui-Ming Wee *Editors*

Recent Trends in Materials

Select Proceedings of ICTMIM 2022

Springer

Springer Proceedings in Materials

Volume 18

Series Editors

Arindam Ghosh, Department of Physics, Indian Institute of Science, Bangalore, India

Daniel Chua, Department of Materials Science and Engineering, National University of Singapore, Singapore, Singapore

Flavio Leandro de Souza, Universidade Federal do ABC, Sao Paulo, São Paulo, Brazil

Oral Cenk Aktas, Institute of Material Science, Christian-Albrechts-Universität zu Kiel, Kiel, Schleswig-Holstein, Germany

Yafang Han, Beijing Institute of Aeronautical Materials, Beijing, Beijing, China

Jianghong Gong, School of Materials Science and Engineering, Tsinghua University, Beijing, Beijing, China

Mohammad Jawaid, Laboratory of Biocomposite Tech., INTROP, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

Springer Proceedings in Materials publishes the latest research in Materials Science and Engineering presented at high standard academic conferences and scientific meetings. It provides a platform for researchers, professionals and students to present their scientific findings and stay up-to-date with the development in Materials Science and Engineering. The scope is multidisciplinary and ranges from fundamental to applied research, including, but not limited to:

- Structural Materials
- Metallic Materials
- Magnetic, Optical and Electronic Materials
- Ceramics, Glass, Composites, Natural Materials
- Biomaterials
- Nanotechnology
- Characterization and Evaluation of Materials
- Energy Materials
- Materials Processing

To submit a proposal or request further information, please contact one of our Springer Publishing Editors according to your affiliation:

European countries: **Mayra Castro** (mayra.castro@springer.com)
India, South Asia and Middle East: **Priya Vyas** (priya.vyas@springer.com)
South Korea: **Smith Chae** (smith.chae@springer.com)
Southeast Asia, Australia and New Zealand: **Ramesh Nath Premnath** (ramesh.premnath@springer.com)
The Americas: **Michael Luby** (michael.luby@springer.com)
China and all the other countries or regions: **Mengchu Huang** (mengchu.huang@springer.com)

This book series is indexed in **SCOPUS** database.

K. Geetha · Francisco M. Gonzalez-Longatt ·
Hui-Ming Wee
Editors

Recent Trends in Materials

Select Proceedings of ICTMIM 2022

Springer

Editors
K. Geetha
JCT College of Engineering and Technology
Coimbatore, India

Hui-Ming Wee
Department of Industrial and Systems Engineering
Chung Yuan Christian University (CYCU)
Taoyuan City, Taiwan

Francisco M. Gonzalez-Longatt
Department of Electrical Power Engineering
University of South-Eastern Norway
Notodden, Norway

ISSN 2662-3161 ISSN 2662-317X (electronic)
Springer Proceedings in Materials
ISBN 978-981-19-5394-1 ISBN 978-981-19-5395-8 (eBook)
https://doi.org/10.1007/978-981-19-5395-8

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2022
This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

We are honored to dedicate the proceedings of ICTMIM 2022 to all the participants and editors of ICTMIM 2022.

Preface

With an extended gratification, we happily welcome you to the proceedings of 2022 4th International Conference on Trends in Material Science and Inventive Materials (ICTMIM 2022) at Coimbatore, India. The main objective and feature of the conference is to bring together academicians, researchers and industrialists to share and exchange their research experiences and results in different aspects of material science, computational mechanics and innovative materials.

The editorial team of 4th ICTMIM 2022 has mainly preferred the state-of-the-art discussions on the practical challenges encountered in the emerging innovative material science paradigm and solutions adopted to it. The 4th ICTMIM 2022 proceedings has been committed to remain both informative and research stimulating to cope up with the current issues present in innovative materials and general material science domain. Delegates from different countries have made the conference to be truly international in scope. Totally, 4th ICTMIM 2022 has received 197 papers, out of which 43 papers were selected for the conference. It has been strictly followed that each contributed paper has refereed by at least 2–3 international reviewers before being accepted for publication.

The 4th ICTMIM 2022 program consists of technical sessions and discussions on most of the recent material science research topics with eminent session chairs, program chairs, plenary lectures and keynote speakers by covering a wide range of topics. The conference totally had 43 oral presentations, which are delivered by the conference participants by leveraging a great opportunity for the academicians, scholars and industrialists to gain a wider knowledge on the state-of-the-art progress in material science research. Also, we are pleased to extend our gratitude to the review committee members, who have delivered their professional and technical expertise to the fullest to improve the publication quality of the research papers submitted to 4th ICTMIM 2022. Furthermore, we would like to thank the conference organizers, local organizing committee members, faculty and non-faculty members and volunteers for making this technical gathering to be a more enjoyable and informative event.

At last, we would like to extend our gratitude to the publication support delivered by Springer team in this entire journey from conference to publication and our institution JCT College of Engineering and Technology for their continual support in successfully organizing this conference event.

Dr. K. Geetha
Dean Academics and Research
JCT College of Engineering
and Technology
Coimbatore, India

Dr. Francisco M. Gonzalez-Longatt
Professor in Electrical Power
Engineering, Leader of DIgital Energy
System Lab (DIgEnSysLab)
University of South-Eastern Norway
Notodden, Norway

Dr. Hui-Ming Wee
Distinguished Professor, Department
of Industrial and Systems Engineering
Chaplain, Chung Yuan Christian
University (CYCU)
Taoyuan City, Taiwan

Contents

About the Editors

Dr. K. Geetha is currently Professor, Dean-Academics and Research in JCT college of Engineering and Technology, Tamil Nadu, India. She a rich experience of teaching and administration for the past 20 years. Her research guidance includes 14 Ph.D. scholars for their doctoral degree. Her research areas include artificial intelligence, optimization techniques, and medical image processing. She has published articles in reputed journals in her area of specialization. She is passionate about continuous teaching-learning processes and involved in research related to student-centric learning methodologies. In 2020 and 2021, she served as the conference chair of the IEEE International Conference on Artificial Intelligence and Smart Systems and the Springer International Conference on Inventive Systems and Control.

Dr. Francisco M. Gonzalez-Longatt is currently a full professor in electrical power engineering and Founder and leader of the DIgEnSys-Lab (Digital Energy Systems Laboratory) at the Department of Electrical Engineering, Information Technology and Cybernetics, University of South-Eastern Norway, Norway. He is a former Lecturer in Electrical Power System at Electrical Power System in School of Electronic, Electrical and Systems Engineering at Loughborough University (2013–2019). He is Vice-President of Venezuelan Wind Energy Association, Fellow of the Higher Education Academy (UK), Senior Member of the IEEE, member of The Institution of Engineering and Technology—The IET (UK) and member of International Council on Large Electric Systems —CIGRE. His research interest includes innovative (operation/control) schemes to optimise the performance of future energy systems.

Dr. Hui-Ming Wee is the Associate Dean, Chaplain and Distinguished Professor in Chung Yuan Christian University. He has received an excellent research award from the Taiwan Ministry of Science and Technology, an excellent life researcher award from CYCU and the Medal for Distinguished Industrial Engineer Award. He has published more than 400 papers in refereed journals, international conferences and book chapters. His papers were cited over 3275 times (Scopus) with h-index: 32. He has co-edited six books and holds two patents; was keynote speaker to a number of international conferences, Senior Member for Asian Council of Science Editors (ACSE), Board of Directors for International Engineering and Technology Institute (IETI) and Editor/editorial board member for a number of international journals.

Computation of Properties for a Friction Stir Welded 6082 Aluminum Alloy Using Artificial Neural Network Model

Saumil K. Joshi, Dhairya Vyas, and Sheshang Degadwala

Abstract This paper identifies the effect of two different non-consumable tools with different shoulder geometries (Raised and Recced) on aluminum alloy undergoing Friction Stir Welding (FSW) processes. Properties like Ultimate Tensile Strength (UTS) and microhardness of 4-mm-thick 6082 aluminum alloy butt weld joints have been investigated at three different rotation speeds and traverse rates. Tensile and microhardness tests have been carried out on 36 welding joints to find the best combination of tool traverse rate and tool rotation speed for obtaining higher UTS and lower Hardness as compared to the base metal. ANN model has been developed based on BP Neural Network to predict the UTS and hardness of aluminum alloy in FSW. Results show that raised tool geometry gives 6% better desirable properties than the recced tool geometry.

Keywords Friction stir welding · Aluminum alloy · Microhardness · Tensile strength · Artificial Neural Network

1 Introduction

Auto motive industries, railway, the heavy structure of shipbuilding, marine, aerospace, etc., widely consume aluminum material and its alloy. Various series of aluminum from 1 to 9XXX are available on market. Out of which, highly alloyed 2XXX, 6XXX, and 7XXX series aluminum fall in the category of non-weld able materials due to porosity, poor solidification, and mechanical properties as compared to the base metal of weld zone during welding by fusion technology [1, 2]. To counter this problem, friction Stir welding innovation (a solid-state joining technology) was

S. K. Joshi (✉)
Mechanical Engineering Department, Sigma Institute of Engineering, Vadodara, Gujarat, India
e-mail: 14meams03@gmail.com

D. Vyas
Shree Drashti Infotech LLP, Vadodara, Gujarat, India

S. Degadwala
Computer Engineering Department, Sigma Institute of Engineering, Vadodara, Gujarat, India

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2022
K. Geetha et al. (eds.), *Recent Trends in Materials*, Springer Proceedings in Materials 18, https://doi.org/10.1007/978-981-19-5395-8_1

designed at The Welding Institute (TWI) of the UK in 1991 as a solid-state joining innovation. This joining technology was at first connected to aluminum composites [2].

In friction stir welding, the non-consumable tool rotates and travels along the mating surface of the two plates [3]. This non-consumable tool consists of (1) Shoulder and (2) Pin. These both have specially designed geometry, which generates required friction for welding. The geometry plays a vital role in material movement during the welding operation. At the starting of the welding process, the tool probe charged into the adjoining edge of plates up to the shoulder surface. Thus, out of the total generated heat, 80% heat generates by the shoulder geometry, and the rest is by pin geometry [4]. During the welding process, the flow of material and flow of workpiece heat are the two primary functions of the FSW tool. Because of localized heating, plastic deformation of work piece occurs, and the material becomes softened around the pin, which leads to the flow of metal from retarding side to the advancing side of the probe. Because of this, solid-state joint is formed [5]. FSW is also significantly considered as a green technology because of its special characteristics like energy efficiency, environment friendly, and versatility. FSW does not require any special type of filler metal and shielding gas or flux to cover the welding. Hence, FSW is a rapidly developing green welding technology. This paper explores FSW in more depth and identifies the influence of two different shoulder geometries on UTS and the hardness of the weld zone of the aluminum 6082 alloy plates.

There have been many types of research on the different aluminum alloy series such as 2XXX, 6XXX, and 7XXX. The aeronautics, automotive, maritime industries have a wide variety of aluminum alloy applications. In addition to that, aluminum replaces steel in the heavy structures of industries due to its higher lightweight to strength ratio. The short survey of literature found that 6xxx aluminum alloys were mainly used in various applications. The Al 6082 has reasonable strength and is the best in the 6-series alloys, taking into consideration its different uses and characteristics. Al 6082, precipitation hardening Alloy, excellently characteristic for corrosion resistance, found its diverse mechanical properties.

Several aspects govern heat generation and metal mixing during the operation, determining the weld's final quality and attributes [6, 7]. The two main variables are tool RPM and welding feed; even so, tool shape and dimensions (i.e., pin diameter, pin length, shoulder diameter, shoulder concavity angle), tool tilt angle, plunge depth, applied load, the thickness of welded plates, weld setup, alloy composition, and preliminary temper all play a key role [8–10]. As a result, many efforts have investigated the FSW process parameters and their impact on weld microstructures and mechanical characteristics. The effect of tool RPM [11–14], welding feed [12–17], welded alloy setup [18, 19], and pin shapes[20–23] on the welding of dissimilar aluminum alloys have been widely researched to date. Very little research is found based on the effect of the FSW tool shoulder profile. So, two different combinations of tool pin profiles and shoulder geometries were analyzed during the research.

In addition to that computer-aided ANN, design is also incorporated in this study due to the increased use of AI (Artificial Intelligence) in the areas of science and engineering [24–26]. ANN is among the most critical aspects of exploration in the fields of genetics, telecommunications, information systems, engineering, and mathematics. ANN is a "Knowledge-Based Information System." It is a mathematical technique to simulate the biological neural system. So, it is like a human system of thought [27]. The neural network is initially programmed with experience or facts and then used to assess the effects of all problems like that of the nervous system. ANN creates and patterns the complex relationship between inputs and outputs. These relationships tend to solve humanly or statistically complex challenges.

In this study, two FSW tools with two different shoulder geometries (raised and recessed) with round pin profiles are used to friction weld the 6082 aluminum alloy plates. Welding is performed at predefine tool rotation speed and tool travel speed. After welding different quality tests are performed on welded aluminum alloy plate. By using these experimental outputs, ANN creates the relationship between three input variables, namely FSW shoulder geometry, spindle rotation speed (RPM), Spindle Traverse Rate (Feed—mm/min), and two responses or output variables, namely Ultimate Tensile Strength (UTS) and hardness. This relationship helps to predict the responses or outcomes.

2 Experimental Process

The base metal 6082 aluminum alloy plate of 4 mm thickness has been used in experiments. 6082 aluminum alloy consists of magnesium and silicon. Its composition is 0.78% Mg, 0.95% Si, 0.08% Cu, 0.39% Fe, 0.48% Mn, 0.05% Ti, 0.04% Zn, and 0.03% Cr, with the remainder Al [28]. It is highly ductile and tough due to the presence of magnesium. Nowadays, 6082 aluminum has replaced other 6XXX series aluminum alloys. FSW process conducted on 300 × 150 × 4 mm 6082 aluminum alloy plate. Hence, the total weld length available for welding was 300 mm.

During the process, a non-consumable tool made of H-13 dies steel material rotates at three different tool rotation speeds (2300, 2500, and 2700 RPM) and tool travel speed (20, 30, and 40 mm/min). This non-consumable tool is made from H-13 die steel material. During the fabrication of the FSW tool, the ratio of tool shoulder diameter to pin diameter is maintained at 3 as per the observation of many research work [29–31]. Also, the pin length is kept 2 mm less than the thickness of the workpiece plate to avoid direct contact between the rotating tool and base plate [3, 8, 32]. Figure 1 shows the tool dimensions and actual tool geometry.

Planning of experiment is most important for experimentation and analysis. In this study, the Taguchi method has been used as a statistical technique that optimizes and designs the experiments. Tool rotation speed and tool traverse speed have three levels, and shoulder geometry has two levels; therefore, mixed level Taguchi design has been adopted for the design of experiments. The mixed level Taguchi method is performed on Minitab 18 software which gives a total of 36 experiment combinations for both, tool raised and recessed geometry together as given in Table 1.

FSW welding of 6082 aluminum alloy plates of dimension 300 × 75 × 4 mm has been carried out on a CNC milling machine (HASS USA). It has been observed

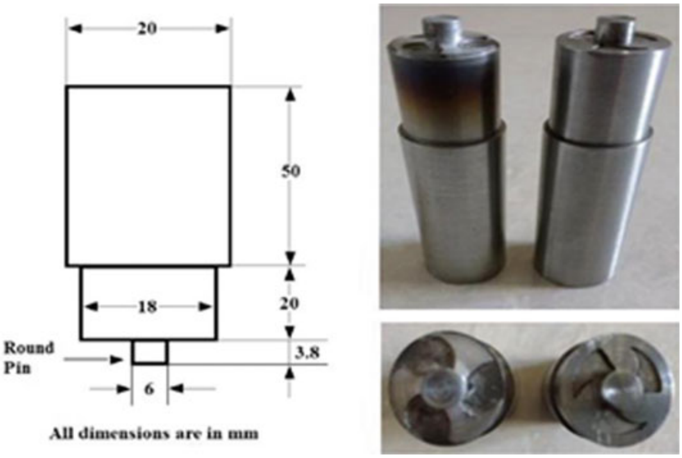

Fig. 1 FSW tool dimension and geometry

Table 1 Design of experiment

No.	Shoulder geometry	Spindle rotation speed (RPM)	Spindle traverse speed (mm/min)	No.	Shoulder geometry	Spindle rotation speed (RPM)	Spindle traverse speed (mm/min)
1	Raised	2300	20	19	Recessed	2300	30
2	Raised	2500	30	20	Recessed	2500	40
3	Raised	2700	40	21	Recessed	2700	20
4	Raised	2300	20	22	Recessed	2300	30
5	Raised	2500	30	23	Recessed	2500	40
6	Raised	2700	40	24	Recessed	2700	20
7	Raised	2300	20	25	Recessed	2300	40
8	Raised	2500	30	26	Recessed	2500	20
9	Raised	2700	40	27	Recessed	2700	30
10	Raised	2300	20	28	Recessed	2300	40
11	Raised	2500	30	29	Recessed	2500	20
12	Raised	2700	40	30	Recessed	2700	30
13	Raised	2300	30	31	Recessed	2300	40
14	Raised	2500	40	32	Recessed	2500	20
15	Raised	2700	20	33	Recessed	2700	30
16	Raised	2300	30	34	Recessed	2300	40
17	Raised	2500	40	35	Recessed	2500	20
18	Raised	2700	20	36	Recessed	2700	30

Fig. 2 FSW experimental setup

that during the FSW process, the tremendous force is developed on plates, leading to, abutting of plates during the process, damage of worktable and workpiece plate. Hence, it is important to fix the plates with special fixtures as shown in Fig. 2. The tool has been positioned in an orthogonal direction to the welding surface during the welding process, as shown in Fig. 2.

Friction Stir Welding experiments were carried out on a 4-mm-thick 6082 aluminum alloy plate. Experiments are conducted using two different FSW tools with circular pin profiles having raised and recessed shoulder geometries as shown in Fig. 1. Tool parameters were kept constant throughout the welding process.

The front and back surfaces of thirty-six welding samples prepared from the CNC milling machine have been noticed. The surface appearance of one of the samples of friction stir weld of 6082 aluminum alloy at 2700 rpm spindle rotation speed and 40 mm/min feed rate by raised shoulder feature tool have been shown in Fig. 3.

Further, as per the ASTM E8M-11 standards, tensile test and Vickers hardness specimens as shown in Fig. 4 were produced perpendicular to weld zone by Abrasive Water Jet Cutting (AWJM) which is displayed in Fig. 4. UTS and Microhardness of each sample were identified through Universal Testing machine and Vickers hardness tester machine, respectively, and encapsulated in Table 2.

Fig. 3 Surface appearance

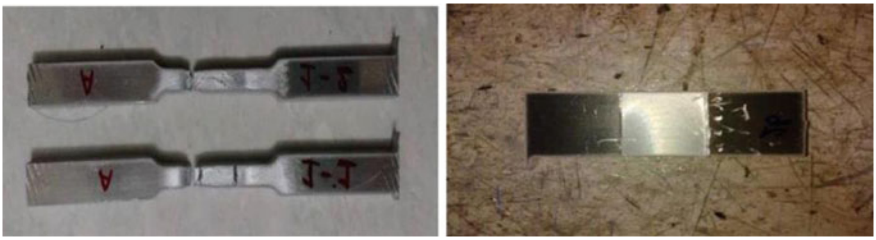

Fig. 4 Tensile and hardness test specimen

Table 2 Experimental result

Sr. No.	RPM	FEED	UTS	Microhardness	Sr. No.	RPM	FEED	UTS	Microhardness
1	2300	20	168	57	19	2300	30	162	57
2	2500	30	168	56	20	2500	40	164	61
3	2700	40	172	61	21	2700	20	115	51
4	2300	20	168	54	22	2300	30	159	58
5	2500	30	171	55	23	2500	40	151	59
6	2700	40	168	60	24	2700	20	116	50
7	2300	20	159	56	25	2300	40	135	49
8	2500	30	171	57	26	2500	20	147	50
9	2700	40	176	58	27	2700	30	145	42
10	2300	20	159	57	28	2300	40	138	50
11	2500	30	165	59	29	2500	20	144	51
12	2700	40	171	61	30	2700	30	146	41
13	2300	30	168	47	31	2300	40	137	49
14	2500	40	164	49	32	2500	20	144	48
15	2700	20	159	44	33	2700	30	147	41
16	2300	30	165	45	34	2300	40	133	50
17	2500	40	171	50	35	2500	20	142	47
18	2700	20	159	48	36	2700	30	144	40

3 ANN Modeling

3.1 Introduction

Artificial Neural Network is a numerical framework in light of the human sensory system, also known as a "Learning-Based Information System." Implies, first, we instruct the network, and then, this network gives the proper answers of any issue simply like a human by utilizing that information. The basic flow diagram of this system is represented in Fig. 5.

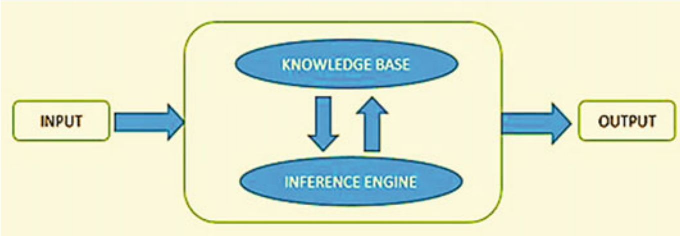

Fig. 5 Knowledge-based information system

It can discover the association between the information and yield values with the goal that it is utilized to foresee the result for further independent info might be non-linear and unpredictable, after preparing of network regardless of the possibility that it is non-clear. ANN has various fields of use like assembling, signal processing, bio-electric signal characterization, pattern recognition, speech recognition, picture handling, correspondences, independent vehicle, and route control of gantry crane to give some examples.

Indeed, even in production, Artificial Neural Network utilized cold forging for anticipating the flow stress in hot deformity, for the forecast of production conduct, for apparatus wear observing and for streamlining of assembling procedures among numerous others, is very much archived and just a couple of examples are recorded here [34–37].

Neurons are non-linear functions. The variable of this function is called as input of the system and the value of this function is called the output of the system. Figure 6 shows the basic structure of the ANN.

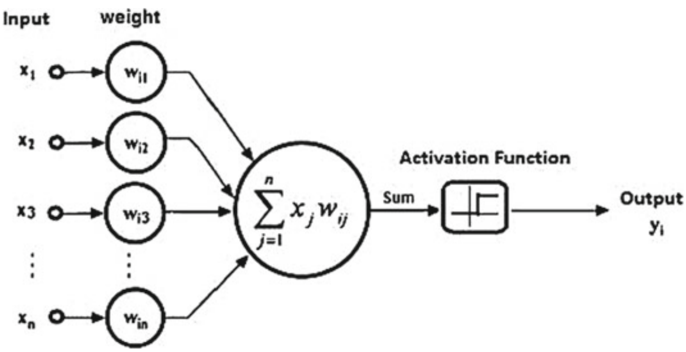

Fig. 6 Basic artificial neurons [33]

3.2 Backpropagation Neural Network

Backpropagation Neural Network is a training and learning model incorporating a feedback-based system. The model measures the gradient of the loss function and passes it to the optimization method to update the weights to decrease the loss functions. Figure 7 indicates the basic architecture of the Backpropagation Neural Network.

Backpropagation is a preparation strategy utilized for a multi-layer neural system. It is additionally called the generalized delta rule. It is an angle plummet technique that limits the aggregate squared mistake of the yield figured by the net.

Any neural system is relied upon to react effectively to the info designs that are utilized for preparing which is named as a remembrance and it ought to react sensibly to include that is like however not the same as the examples utilized for preparing which is called speculation. Figure 8 represents the algorithm of the Backpropagation neural network. Table 3 shows the input data which we use to train the ANN system. During the training, 3 input neurons, 10 hidden neurons, and 2 output neurons (3-10-2) are utilized. Here, we predict the probability as an outcome and probability lies between 0 and 1. Thus, we use the log (Sigmoid) transfer function.

The preparation of a neural system by back spread happens in three phases:

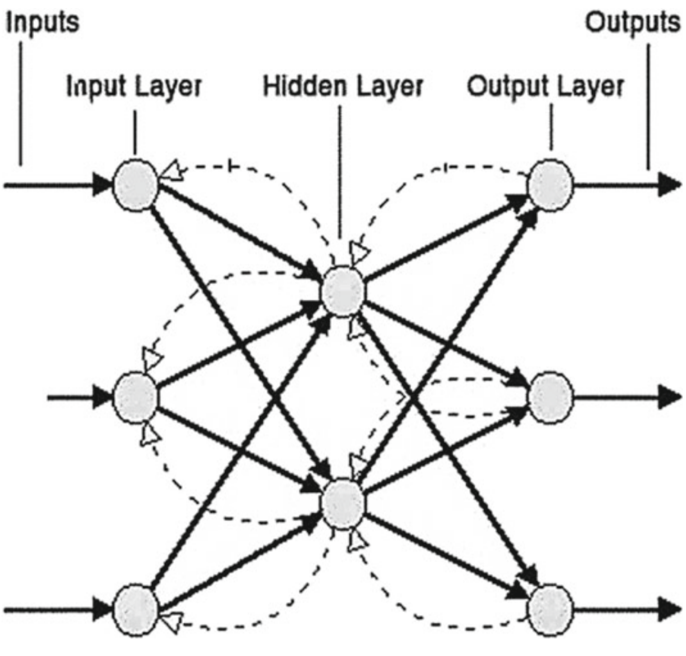

Fig. 7 Back propagation model [33]

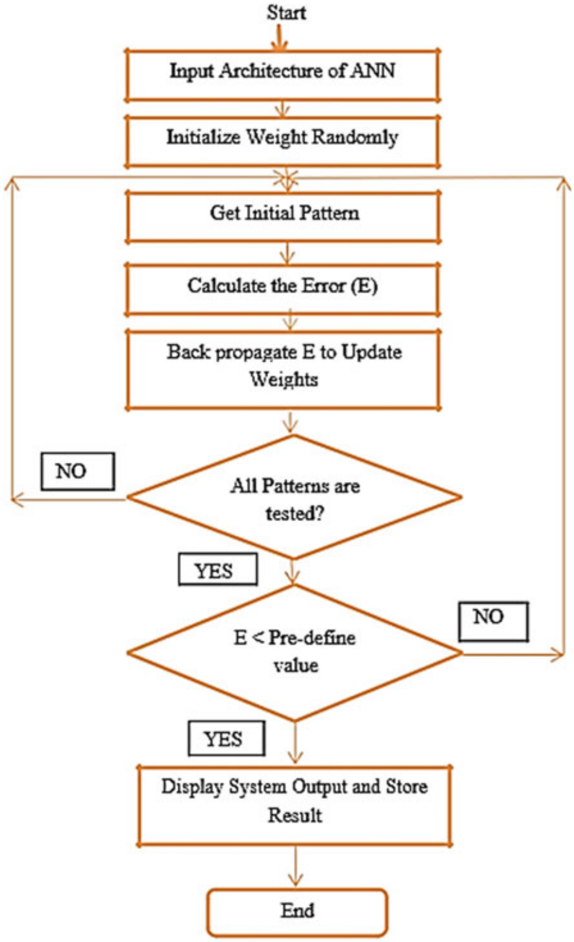

Fig. 8 Backpropagation ANN algorithm

Table 3 ANN training data

1	Network outline	3-10-2
2	No. of hidden layer	1
3	Transfer function utilized	Log (Sigmoid)
4	No. of epochs	1000
5	No. of hidden neuron	10
6	No. of pattern utilized for exercise	100%
7	Max. validation check	1000

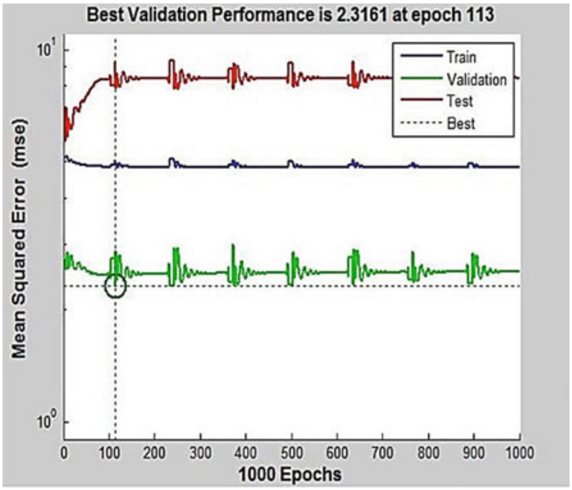

Fig. 9 Mean square error graph

1. Feedforward of the input design
2. Count and Back proliferation of the related fault
3. Alterations of the weights.

Algorithm of Backpropagation Neural Network:

The last MSE is little as appeared in Fig. 9. Both the approval set and the test set error have comparative qualities. No critical overfitting has happened by epoch 113 (The finest endorsement execution). The direct relapse among the system yields and the relating goals appear in Fig. 10. For our situation, the yield tracks the objective extremely well to training, testing, and approval, and the r-esteem is somewhat more than 0.99 for the aggregate reaction.

4 Result

The initial stage to portray the joint is a pictorial assessment of roots and tops. Other than agreeing on this, additionally the leave opening hole was analyzed. A hover of metal plasticized by the tool shoulder continuously exists in the nearby areas. The presence of this material implicates the weld quality. With a decent joint, the hover nearer to the leave opening hole is fully finished. Both tools delivered a total hover in the gap.

A subjective examination of tops and roots has been conveyed out. Every one of the roots has demonstrated no deformities. Figure 11 appears the tops of the weld.

The average properties obtained from the weld UTS tests are condensed in Table 2. Not surprisingly, the weld qualities acquired were lesser than those of ordinary aluminum 6082. Experiment no. 3 displayed the best quality by raised tool shoulder feature, and experiment no. 20 showed the best quality by recessed tool shoulder

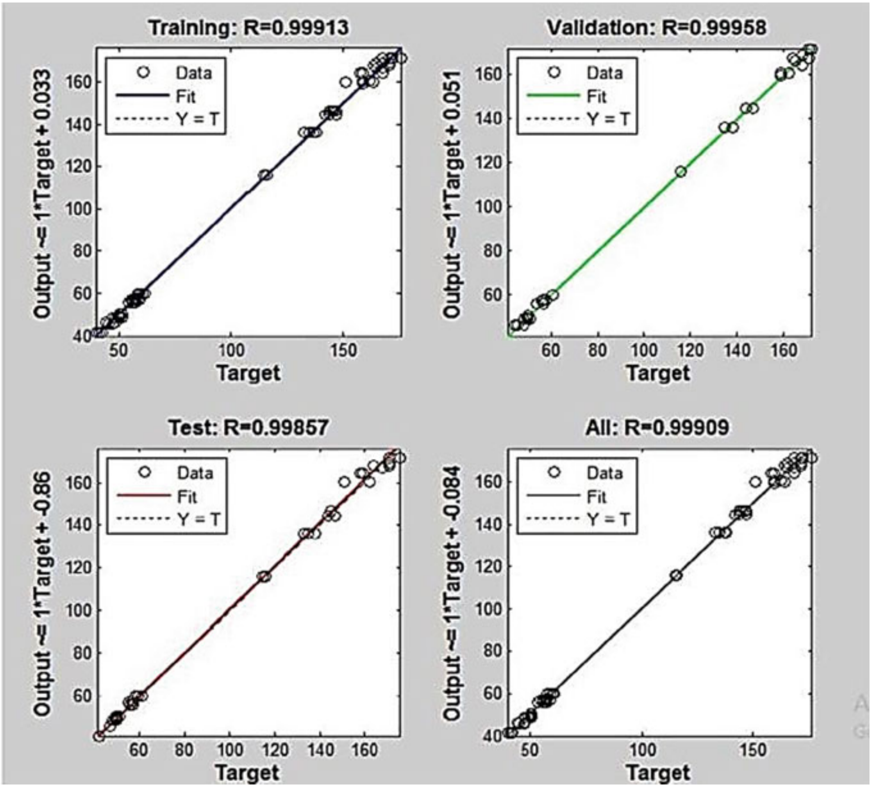

Fig. 10 Regression plot for performance analysis

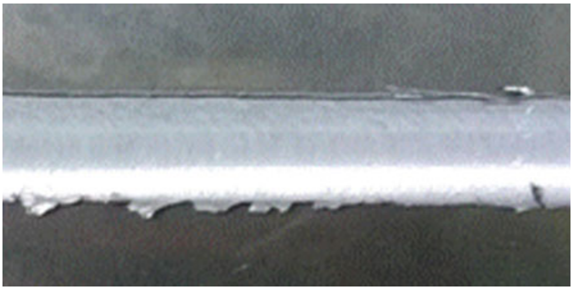

Fig. 11 Crown obtained by tool 1

feature. Figure 12 shows the 3D graph of variation of UTS at different feed and RPM.

Micro Vikers hardness acquired for all the welds are listed in Table 2. Vickers microhardness (HV) was measured along the weld zone on the cleaned cross-segment utilizing 100 gm of the connected load. The outcomes demonstrate that the hardness of the weld zone gained was lower than the standard aluminum 6082 compound.

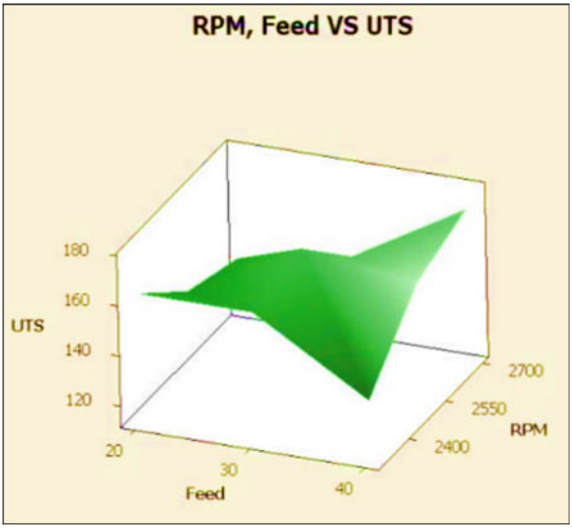

Fig. 12 UTS graph

Figure 13 demonstrates the 3D chart of a variety of micro Vickers hardness at various feed and RPM.

Tables 4 and 5 represent the variation in exploratory outcome and ANN-anticipated after effect of Friction Stir Welding properties. The variety in the exploratory outcome and ANN anticipated outcome is near each other, closer around 2.45% in UTS and 3.66% in Microhardness, which falls in the acceptable range. So prepared system 3-10-2 can be utilized to foresee mechanical properties of the FSW process.

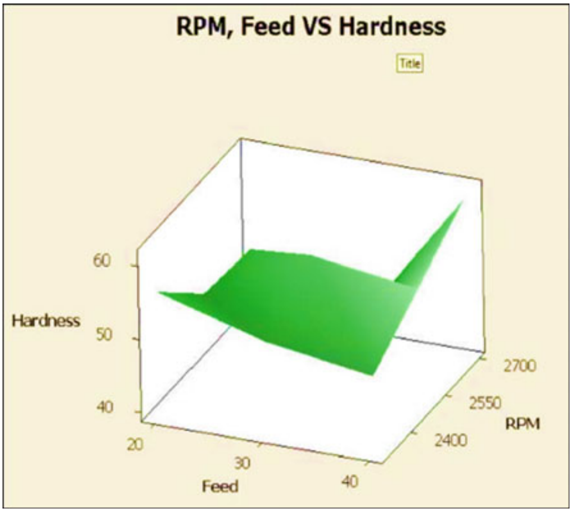

Fig. 13 Micro hardness graph

Table 4 Comparison of experimental result and ANN result for UTS

Sr. No.	Tool	RPM	FEED	UTS	UTS ANN	% Error
1	1	2300	40	174.66	170.37	2.45
2	2	2500	30	148.66	145.91	1.85
3	2	2700	40	145.33	146.03	0.48

Table 5 Comparison of experimental result and ANN result for hardness

Sr. No.	Tool	RPM	FEED	Hardness	Hardness ANN	% Error
1	1	2300	40	51	52.24	2.43
2	2	2500	30	50	51.83	3.66
3	2	2700	40	50	51.84	3.68

5 Conclusion

In the present work, 36 trials of FSW have been completed according to the pre-characterized set of info parameters blend for tensile strength and hardness of FSW weld on 6082 aluminum combination. The accompanying imperative conclusions are as follows:

- The test result demonstrates that tensile strength is increasing with increment in axle revolution speed. Greatest elasticity, 176 N/mm^2 accomplished at 2700 rpm axle revolution speed and 40 mm/min traverse speed of shaft with the utilization of raised device shoulder geometry.
- Almost the same tensile strength was obtained by utilizing both raised and recessed shoulder geometry, raised geometry to give a 6% preferable outcome over recessed apparatus geometry. The hardness of the weld nugget zone is lower at higher spindle rotation speed compared to standard hardness by using raised geometry.
- The created ANN system can be utilized to foresee the UTS and hardness of 6082 aluminum plates welded at the given FSW condition. Comes about shows that the system outcome is exceptionally shut to the experiment result. The examination demonstrates that the most extreme 2.45 and 3.68% variety in UTS and hardness individually.

References

1. Singh G et al (2017) Experimental comparison of friction stir welding process and TIG welding process for 6082-T6 Aluminium alloy. Mater Today: Proc 4(2):3590–3600
2. Terry K (2005) An outsider looks at friction stir welding. Report: ANM-112N-05-06
3. Mishra RS, Ma Z (2005) Friction stir welding and processing. Mater Sci Eng R Rep 50(1–2):1–78

4. Schmidt H, Hattel J, Wert J (2003) An analytical model for the heat generation in friction stir welding. Modell Simul Mater Sci Eng 12(1):143
5. Thomas W et al (2002) Friction based welding technology for aluminum. In: Materials science forum. Trans Tech Publications Ltd
6. DebRoy T, Bhadeshia H (2010) Friction stir welding of dissimilar alloys–a perspective. Sci Technol Weld Joining 15(4):266–270
7. Murr L (2010) A review of FSW research on dissimilar aluminum alloys. J Mater Eng Perform 19:1071–1089
8. Mishra RS et al (2011) Friction stir welding and processing VI. John Wiley & Sons
9. Babu AS, Devanathan C (2013) An overview of friction stir welding. Int J Res Mech Eng Technol 3(2):259–265
10. Pandya S, Menghani J (2013) Friction stir welding of dissimilar 5xxx to 6xxx Al alloys: a review. Appl Mech Mater. Trans Tech Publications Ltd
11. Palanivel R et al (2012) Effect of tool rotational speed and pin profile on microstructure and tensile strength of dissimilar friction stir welded AA5083-H111 and AA6351-T6 aluminum alloys. Mater Des 40:7–16
12. Kasman Ş, Yenier Z (2014) Analyzing dissimilar friction stir welding of AA5754/AA7075. Int J Adv Manuf Technol 70(1–4):145–156
13. Sivachidambaram S, Rajamurugan G, Amirtharaj D (2015) Optimizing the parameters for friction stir welding of dissimilar aluminum alloys AA5383/AA7075. ARPN J Eng Appl Sci 10:5434–5437
14. Mastanaiah P, Sharma A, Reddy GM (2016) Dissimilar friction stir welds in AA2219-AA5083 aluminum alloys: effect of process parameters on material inter-mixing, defect formation, and mechanical properties. Trans Indian Inst Met 69(7):1397–1415
15. Ghosh M et al (2013) Friction stir-welded dissimilar aluminum alloys: microstructure, mechanical properties, and physical state. J Mater Eng Perform 22(12):3890–3901
16. Saravanan V, Rajakumar S, Muruganandam A (2016) Effect of friction stir welding process parameters on microstructure and mechanical properties of dissimilar AA6061-T6 and AA7075-T6 aluminum alloy joints. Metallography, Microstructure, Anal 5(6):476–485
17. Rao S, Naik Y (2018) Understanding the effect of multiple traverse feed during friction stir welding processes. Arch Metall Mater
18. Scialpi A, De Filippis L, Cavaliere P (2007) Influence of shoulder geometry on microstructure and mechanical properties of friction stir welded 6082 aluminum alloy. Mater Des 28(4):1124–1129
19. Guo J et al (2014) Microstructural and mechanical properties of dissimilar friction stir welds between AA6082-T6 and AA7075-T651. Mater Des 56:185–192
20. Kasman Ş (2019) Identification of the pin offset effect on the friction stir welding (FSW) via Taguchi-Grey relational analysis: a case study for AA 7075–AA 6013 alloys. Materialwiss Werkstofftech 50(11):1364–1381
21. Sharma N et al (2018) Material stirring during FSW of Al–Cu: effect of pin profile. Mater Manuf Processes 33(7):786–794
22. Sahlot P et al (2018) Wear-induced changes in FSW tool pin profile: effect of process parameters. Metall and Mater Trans A 49(6):2139–2150
23. Tamadon A, Baghestani A, Bajgholi ME (2020) Influence of WC-based pin tool profile on microstructure and mechanical properties of AA1100 FSW welds. Technologies 8(2):34
24. Eren B, Guvenc MA, Mistikoglu S (2021) Artificial intelligence applications for friction stir welding: a review. Met Mater Int 27(2):193–219
25. Maleki E (2015) Artificial neural networks application for modeling of friction stir welding effects on mechanical properties of 7075-T6 aluminum alloy. In: IOP Conference Series: Materials Science and Engineering. IOP Publishing
26. Yousif Y, Daws K, Kazem B (2008) Prediction of friction stir welding characteristic using neural network. Jordan J Mech Indus Eng 2(3)
27. Graupe D (2013) Principles of artificial neural networks, vol 7. World Scientific

28. Patel UA (2015) Optimization of process parameter in MIG welding process on dissimilar material by using artificial neural network. Ganpat University
29. Rajakumar S, Muralidharan C, Balasubramanian V (2011) Influence of friction stir welding process and tool parameters on strength properties of AA7075-T6 aluminum alloy joints. Mater Des 32(2):535–549
30. Elangovan K, Balasubramanian V (2008) Influences of tool pin profile and tool shoulder diameter on the formation of friction stir processing zone in AA6061 aluminum alloy. Mater Des 29(2):362–373
31. Malarvizhi S, Balasubramanian V (2012) Influences of tool shoulder diameter to plate thickness ratio (D/T) on stir zone formation and tensile properties of friction stir welded dissimilar joints of AA6061 aluminum–AZ31B magnesium alloys. Mater Des 40:453–460
32. Mehta KP, Badheka VJ (2016) A review on dissimilar friction stir welding of copper to aluminum: process, properties, and variants. Mater Manuf Processes 31(3):233–254
33. Yegnanarayana B (2009) Artificial neural networks. PHI Learning Pvt. Ltd
34. Kanti KM, Rao PS (2008) Prediction of bead geometry in pulsed GMA welding using back propagation neural network. J Mater Process Technol 200(1–3):300–305
35. Najafi B, Ardabili SF (2018) Application of ANFIS, ANN, and logistic methods in estimating biogas production from spent mushroom compost (SMC). Resour Conserv Recycl 133:169–178
36. Ghosh S et al (2016) Development of the location suitability index for wave energy production by ANN and MCDM techniques. Renew Sustain Energy Rev 59:1017–1028
37. Renno C, Petito F, Gatto A (2016) ANN model for predicting the direct normal irradiance and the global radiation for a solar application to a residential building. J Clean Prod 135:1298–1316

Study of Frictional Force and Volumetric Wear Rate of T6 Heat Treated Hypereutectic Al–18Si–3.6Cu–0.36Ce Alloy

Krishnaraddi Gangal and K. Devendra

Abstract Current research work is to study the effect of applied loads and the sliding speeds on the tribological behaviors of As-cast and T6 heat treated (cast aged at 1, 3, 5 and 7 h) conditions of the hyper eutectic Al–Si alloy with cerium alloying element. Experiments are conducted for different loads and sliding speeds on pin-on-disk tribometer setup, friction force, weight loss of the test specimen and surface roughness are frequently noted during test for applied loads (9.81–39.24 N) and sliding speeds (1–4 m/s). Experimental results of Al–18Si–3.6Cu–0.36Ce alloy concludes that the volumetric wear rate and the friction force F_n are dominated by applied loads and transition point of wear mechanism than the sliding speeds. Wear rate and F_n are increasing with load and decreased sliding velocity. COF varied in the range of 0.214–0.353; the wear rates are ranging from 0.88 to 6.8 $mm^3/m \times 10^3$. Rare-earth element Ce to Al–Si and T6 treatment noticeably enhances the mechanical and tribological properties of the hypereutectic alloy.

Keywords T6 heat treatment · Tribometer · COF · Wear rate · Transition point · As-cast · Hypereutectic alloy

1 Introduction

Hypereutectic aluminium alloys are abundantly used among the metal matrix alloys in wider range of automobile industrial applications because of their inherent physical properties such as high strength to weight ratio and are the most promising material with the effective tribological performance over the other alloys with fuel-efficient engine components [1–3]. Torabian et al. study reported that Al–Si alloys exhibit lower wear rates for increasing sliding speed up to certain speed and beyond that

K. Gangal (✉)
Department of Mechanical Engineering, Rural Engineering College Hulkoti, Hulkoti 582205, India
e-mail: krishnargangal@gmail.com

K. Devendra
Department of Mechanical Engineering, SKSVMACET, Laxmeshwar, India

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2022

K. Geetha et al. (eds.), *Recent Trends in Materials*, Springer Proceedings in Materials 18, https://doi.org/10.1007/978-981-19-5395-8_2