Final report 73p7

TECHNICAL UNIVERSITY OF LIBEREC
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TU Graz

i. General Information

1. Project overview
Project duration: 1.7. 2015 – 30.6. 2016

2. Project participants

a. Technical University of Liberec, Faculty of Mechanical Engineering
Department of Engineering Technology
Researchers:
Ing. Jaromir Moravec, Ph.D., EWE
Ing. Jiri Sobotka, Ph.D
Students:
Ing. Lukás Zuzánek
Ing. Ondrej Ridky

b. Graz University of Technology, Faculty of Mechanical Engineering and Economic Sciences
Institute of Materials Science and Welding
Researchers:
Dr. Martina Dikovits
Dr. Coline Beal
Prof. Norbert Enzinger
Students:
Rebecca Chandezon
Michael Aigner, BSc
Dipl.-Ing. Bernhard Krenmayr

3. Project meetings

The 1st project meeting was held in Graz at the Institute of Materials Science and Welding. Firstly, both institutes introduced themselves and showed a presentation related to the own institute and their facilities. Afterwards TUG organised a laboratory tour through their labs. Furthermore, first results were presented of each group and intensive discussions took place. A further, more detailed working plan was defined based on the before shown results. Dr Moravec and Dr Sobotka gave an expert lecture on contact-less deformation measurement X-Ray diffraction analysis. On the next day Gleeble® experiments were performed together. Lastly, discussions about the both institutes teaching systems took place.
In December Dr. Moravec visited the institute for a 2nd time for short discussions about the status of the project and results obtained so far. The 3rd project meeting was held in Liberec at the Department of Engineering Technology. We discussed the last results, and organised the final steps for the last months concerning writing the final report and we planned a publication. We did a laboratory tour through many labs of the department. Finally, an expert lecture based on electron beam welding was given by Dr. Beal.

ii. Results and discussion of the project

At the start of the project intense literature research was carried out by the project members especially to receive first information of process parameters for the diffusion bonding process itself. Based on this literature review, a first test matrix including three different parameters (temperature, force, holding duration) was defined and first diffusion bonding experiments were performed in a Gleeble® 3800 device. Different possibilities were taken into account, for example on which material the controlling thermocouple should be fixed. One thermocouple was welded on the boarder of the titanium side, which was also the controlling thermocouple and a second thermocouple was welded on the border of the steel sample. For these temperature investigations a type K thermocouple was used. After some first trials the tool Minitab was used for generating a final test matrix. Temperatures between 825 and 925 °C, times of 40 and 90 minutes and forces between -0.5 and 0.7 kN were used for the tests. Furthermore, the tests were performed using vacuum and later on performed under Argon atmosphere as well. Additionally, the change of length was measured using a L-Gauge to validate plastic deformation. These Gleeble® tests were performed at both institutions. The temperature along the sample axis was investigated during the tests. The temperature on the steel side is decreasing much faster than on the titanium side. The samples after diffusion bonding showed different shape. There were samples which showed intense plastic deformation, samples with no bonding at all and some samples which showed a bonding and no plastic deformation. Some of the diffusion bonded samples were used for tensile tests, performed at TUL as well as for microstructural analysis, performed at TUG. In the following part two samples are explained in detail. First the results of sample number 5 are shown, which was diffusion bonded using parameters of 900 °C, 40 minutes and a force of -0.5 kN. Then the results of sample number 7 with parameters of 950 °C, 40 minutes and a force of -0.5 kN are shown. Figure 1 shows the macro image of the sample after the diffusion process. No plastic deformation is visible. In Figure 3 the microstructure is present, on the left hand side the steel and on the right hand side the titanium is shown. To further investigate the boundary between them, an EDX line scan was performed and is presented in Figure 5. It is visible that there is a higher diffusion of iron in the titanium and not the other way around. Furthermore hardness measurements were performed. Figure 7 shows the obtained results. The difference to sample 5 is that in sample 7 an easy visible plastic deformation occurred and can be seen in Figure 2. The only difference in the process parameters was the temperature; this sample was deformed at 950 °C whereas sample 5 was deformed at 900 °C. Figure 4 shows the obtained microstructure, again on the left side the steel and on the right side titanium. Additionally, a hardness measurement was performed and is shown in Figure 6.

Sample 5) 900 °C, 40 minutes, - 0.5 kN

Figure 1. Macro image of the sample after the diffusion bonding; performed at 950 °C, 40 minutes and – 0.5 kN.

Sample 7) 950 °C, 40 minutes, - 0.5 kN

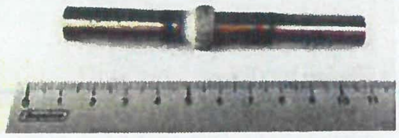

Figure 2. Macro image of the sample performed at 950 °C, 40 minutes and – 0.5 kN.

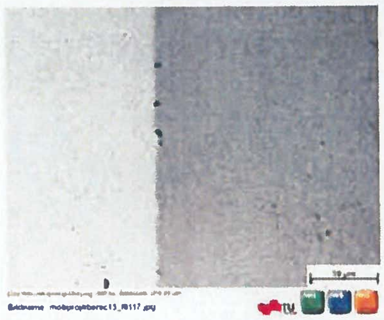

Figure 3. Microstructure of the sample, left side steel, right side titanium, of the sample performed at 950 °C, 40 minutes and – 0.5 kN.

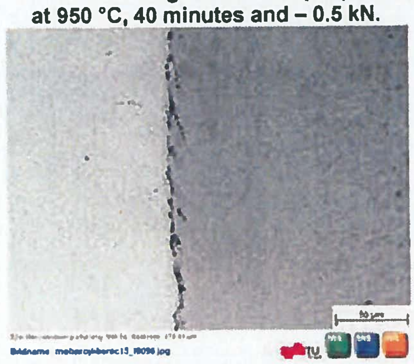

Figure 4. Microstructure of the sample performed at 950 °C, 40 minutes and – 0.5 kN.

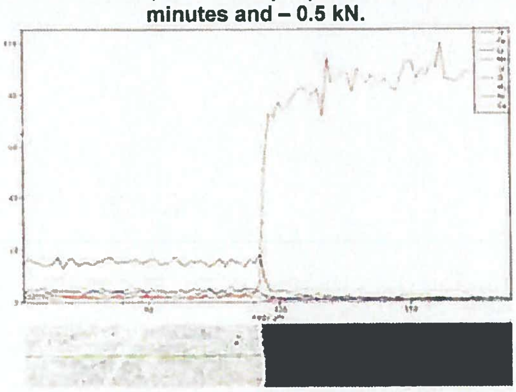

Figure 5. EDX Linescan along the boundary of the sample performed at 950 °C, 40 minutes and – 0.5 kN.

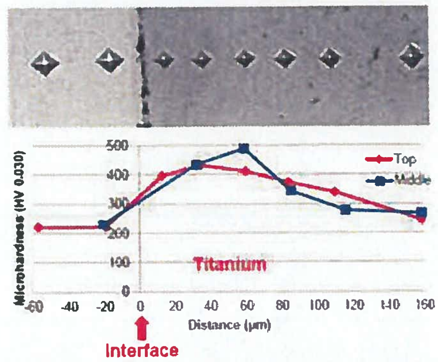

Figure 6. Hardness measurement of the sample performed at 950 °C, 40 minutes and – 0.5 kN.

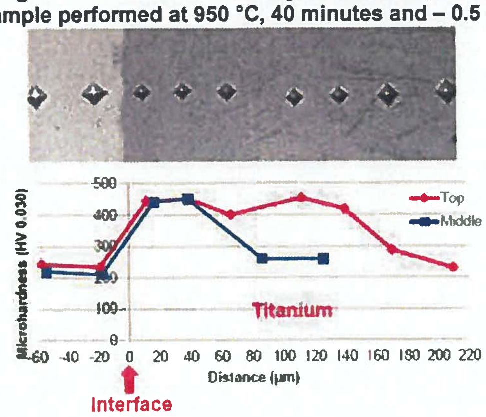

Figure 7. Hardness investigations of the sample performed at 950 °C, 40 minutes and – 0.5 kN.

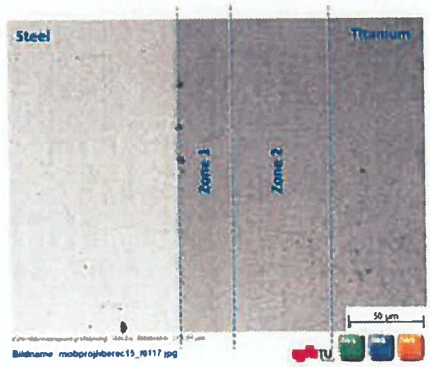

Figure 8. Identification of the different appearing zones in the titanium.

Lastly the width of the different zones was investigated. The different appearing zones are shown in Figure 8. By using equations the theoretical width of the zones could be calculated as well, and the obtained results are in good agreement with the measured values (see Table 1).

Table 1. Results of the obtained zones in the titanium.

Temperature in °C	Time in min	Force in kN	Zone 1 in µm	Zone 2 in µm	Theor. Zone 1 in µm
825	40	-0.7	28+/-2	-	30
825	40	-0.5	29	-	30
900	40	-0.5	35+/-3	70+/-10	48
925	40	-0.5	44	88	54
950	40	-0.5	63	222	64
1000	40	-0.7	73	-	83

To perform tensile tests, tensile test samples were necessary. Due to machining of the diffusion bonded samples, the right geometry was received. A typical sample is presented in Figure 9. Afterwards the samples could be tested in a machine shown in Figure 10.

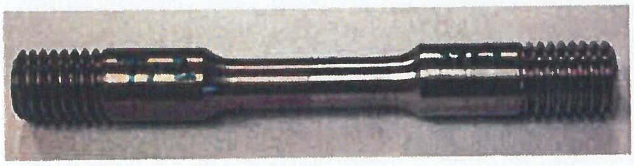

Figure 9. Tensile test sample.

Figure 10. Tensile test machine.

The following results in Table 2 were received out of the tensile tests. Further parameters are also shown in the table which were not in the originally planned matrix.

Table 2. Overview of the first tensile test results.

Temperature in °C	Force in kN	Time in min	Ultimate tensile strength in MPa
830	1.1	40	233
845	1.1	20	217
860	0.6	40	254
860	0.8	40	207
860	0.6	90	222
860	0.8	90	230

Since the received ultimate tensile strength was not that high, further investigations on the diffusion process in the Gleeble® were made. On the one hand a better polished sample surface and on the other hand Argon atmosphere was used during the process. The received results are shown in Table 3. Much higher values are received due to these modifications in the diffusion bonding process.

Table 3. Results of the tensile test of modified process parameters.

Temperature in °C	Force in kN	Time in min	Ultimate tensile strength in MPa	Atmosphere
860	0.5	180	315	Vacuum
860	0.5	40	280	Vacuum
860	0.5	40	328	Argon

iii. <u>Conclusion of the project</u>

In June 2015 the project entitled "Interdisciplinary cooperation in the field of research focused on the influence of process parameters on the mechanical properties of diffusion heterogeneous welds" was accepted by Aktion Austria – Czech. For our two institutes, the Department of Engineering Technology (TUL) and the Institute of Materials Science and Welding (TUG), it was a good opportunity for a first common project. The project mainly consists of two goals: on the one hand we wanted to do a research project of diffusion bonding and on the other hand we wanted to get to know how other teaching systems at the other university works and if there are possibilities for students or lecturer exchange for the future. For the first point, intensive contact and sharing of knowledge took place during the last year. We performed many experiments and received some good results with further ideas for further improvements. Some first trials based on further ideas were already performed and showed promising results (see Table 3). Therefore, we shifted our proposed publication to December 2016, since we are still performing some experiments, and want to show our best results in a journal paper. For the second goal, we performed lectures at the institute during our meetings. However, to find a possibility for students to do a lecture at the other university with deduction at the home university was not that easy, due to student fees and curriculum.

Signatures:

(Dr. Jaromir Moravec) (Dr. Martina Dikovits) (Dr. Coline Beal)