AIP Conference Proceedings

The influence of flushing time on the bonding quality of liquid white cast iron on the solid surface of similar material

Cite as: AIP Conference Proceedings **1964**, 020027 (2018); https://doi.org/10.1063/1.5038309
Published Online: 15 May 2018

Beny Bandanadjaja, Wiwik Purwadi, Dewi Idamayanti, Noval Lilansa, Kus Hanaldi, and Friya Kurnia Nurzaenal

SJR Scimago Journal & Country Rank

Enter Journal Title, ISSN or Publisher Name

Home Journal Rankings Country Rankings Viz Tools Help About Us

AIP Conference Proceedings

Country	United States - SIR Ranking of United States
Subject Area and Category	Physics and Astronomy Physics and Astronomy (miscellaneous)
Publisher	
Publication type	Conferences and Proceedings

60

H Index

ISSN 00001984, 00002005, 00001983

Coverage 1983-1984, 2005-ongoing

Scope Today, AIP Conference Proceedings contain over 100,000 articles published in 1700+ proceedings and is growing by 100 volumes every year. This substantial body of scientific literature is testament to our 40-year history as a world-class publishing partner, recognized internationally and trusted by conference organizers worldwide. Whether you are planning a small specialist workshop or organizing the largest international conference, contact us, or read these testimonials, to find out why so many organizers publish with AIP Conference Proceedings.

AIP Conference Proceedings

Not yet assigned quartile

SJR 2018
0.18

powered by scimagojr.com

← Show this widget in your own website

Just copy the code below and paste within your html code:

<a href="https://www.scimagc

The Influence of Flushing Time on The Bonding Quality of Liquid White Cast Iron on The Solid Surface of Similar Material

Beny Bandanadjaja[1,a)], Wiwik Purwadi[1)], Dewi Idamayanti[1)], Noval Lilansa[2)], Kus Hanaldi[1)], and Friya Kurnia Nurzaenal[1)]

[1]*Foundry Engineering Department, Politeknik Manufaktur Bandung, Jalan Kanyakan No 21 - Dago, Bandung – 40135, Indonesia*
[2]*Otomation and Mechatronic Engineering Department, Politeknik Manufaktur Bandung, Indonesia*

[a)]Corresponding author: benybj@polman-bandung.ac.id or benybj@yahoo.com

Abstract. Hard metal castings are widely used in the coal mill pulverizer as construction material for coal crushers. During its operation crushers and mills experience degradation caused by abrasion load. This research dealed with the surface overlaying of similiar material on the surface of white cast iron by mean of gravity casting. The die blank casting was preheated prior to the casting process of outer layer made of Ni-Hard white cast iron to guarantee bonding processes and avoid any crack. The preheating temperature of die blankin ther range of 500C up to 850C was set up to reach the interface temperature in the range of 887°C -1198°C and the flushing time was varied between 10-20 seconds. Studies carried on the microstructure of sample material revealed a formation of metallurgical bonding at the preheating temperature above 625 °C by pouring temperature ranging from 1438 °C to 1468 °C. Metallographical and chemical composition by mean of EDS examination were performed to observed the resut. This research concludes that the casting of Ni-Hard 1 overlay by applying gravity casting method can be done by preheating the surface of casting to 625 °C, interface temperature of 1150 °C, flushing time of 7 seconds and pouring temperature of 1430 °C. Excellent metallurgical bonding at the contact area between dieblank and overlay material has been achieved in which there is no parting line at the interface area to be observed.

INTRODUCTION

Hard material such as chromium white cast iron is used as grinding element in mining industries. Abrasion process on the surface of grinding elements caused wear and need to be repaired. Surface overlaying as one of alternative solution for repairing grinding elements can be considered as manufacturing process of bimetal by using similiar material. In general, the technologyof bimetal casting consisting of working surface layer and a base part is achieved based on two systems, i.e.liquid-liquid [1,2] and liquid-solid [3,4].

The basis concept of technology applied in this research is mould cavity preparation [5,6]. Die blank was inserted in the mould and Liquid melts was subsquently poured into the mold without any preheating and preheating at various temperature. The bonding between two materials will be achieved through the formation of metallurgical bonding at the interface in kind of difussion bonding and partial melting [7].

The proper temperature of preheating, the contact interface temperature and the flushing time were the concern of this work. The interface temperature should range between 50% up to 70% of the lowest liquid temperature of both material, due to facilitate the diffusion process [8]. The preheating temperature of dieblank should avoid the initiation of crack.

The susceptibility of steel to cold cracking [9] can be expressed as equation (1 and 2) below:

Proceedings of the International Seminar on Metallurgy and Materials (ISMM2017)
AIP Conf. Proc. 1964, 020027-1–020027-8; https://doi.org/10.1063/1.5038309
Published by AIP Publishing. 978-0-7354-1669-7/$30.00

$$CE = C + A(C)\frac{Si}{24} + \frac{Mn}{6} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Cr+Mo+Nb+V}{5} + 5B \quad \text{.....(1)}$$

Whereas
$$A(C) = 0.75 + 0.25 \tanh\{20(C - 0.12)\} \quad \text{.....(2)}$$

As a parameter for describing the probability of the occurrence of cold cracking, a cracking index (Cl) was proposed. CI is expressed as equation (3):

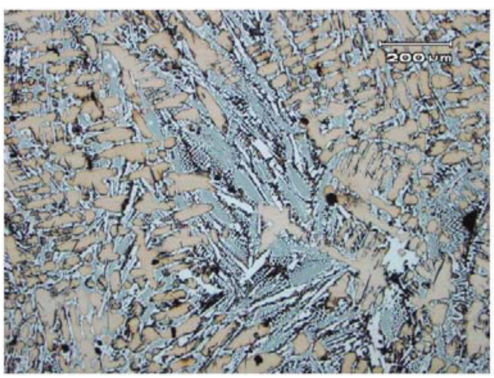
$$CI = CE + 0.15 \log H_{hs} + 0.3 \log(0.017 k_{t\sigma w}) \quad \text{.....(3)}$$

The necessary preheating temperatures to avoid cold cracking are determined by satisfying the following criterion $t_{100} \geq (t_{100})_{cr}$ where t_{100} is the cooling time to 100 °C (212 °F). Critical time $(t_{100})_{cr}$ is given as equation (4):

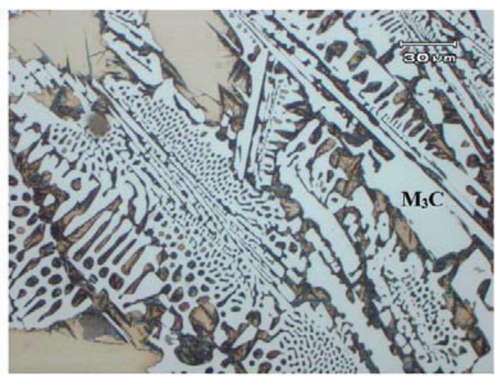
$$(t_{100})_{cr} = \exp(67.6CI^3 - 182CI^2 + 163.8\,GI - 41) \quad \text{.....(4)}$$

The aim of this paper is to describe a technology of surface overlaying by applying castings method for a white cast iron – ductile cast iron bimetallic grinding roll which applied for coal mill crusher. In the presented technology, preheating die blank was done by passing liquid melts in direct contact. This technology can be a significant contribution for commonly used technologies of surface overlaying,becauseit does not initiate cracks in the interface area (joint area) and heat affected zone.

The microstructure of Ni-Hard 1 consists of eutectic carbide M_3C and austenite-martensite matrix. This can be achieved with a chemical composition of Ni-Hard 1 containing 4% Ni and 2% Cr.



(a)



(b)

FIGURE 1.(a) Microstructure of Ni-Hard 1 Contained Primary Dendrite, Eutectic Carbide and (b) Microstructure of M_3C

MATERIALS AND METHODS

The aim of this study is to make surface overlaying on the top of solid surface of solid Ni-Hard material. The overlaying technique is using liquid Ni-Hard which is pouring to flow or flush the on to the surface of solid Ni-Hard. To be bond, it need a time for increasing the temperature of solid surface then the diffusion mechanism can take a part of bonding at suitable temperature. Further, this study also aimed to find the appropriate flushing time in order to make the best bonding between liquid material into solid surface.

To give an approach of the required flushing time, simulation was conducted by using solid cast software. Casting simulation with *software solidcast 8.2* was applied to calculate the interface temperature, which will will be increased due the the pouring of liquid melts and the following. The data was used to determine reference value of pouring temperature and flushing time. Figure 2 describe the interdependence of interface temperature on the flushing time by pouring temperature of 1490 °C.

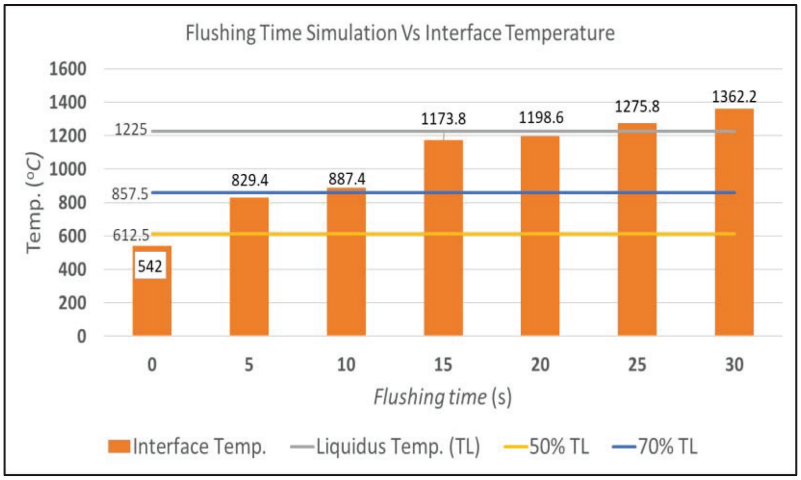


FIGURE 2. The Simulation Flushing Time on Result of Interface Temperature

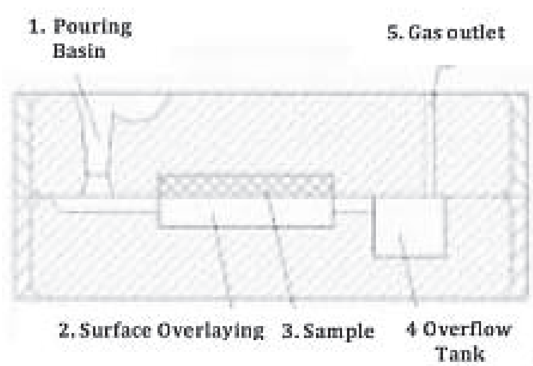
Without any flushing time the minimum target of 50% of Liquidus Temperature at the interface as pre requisite for diffusion bonding was not achieved. The interface temperature was 542 °C and it was considerably below the minimum temperature of 612.5 °C. Flushing time of 5 seconds resulted an increase of temperature upto 829.2 °C (67.7% of T_L) and therefore 5 seconds was setup as the baseline. Flushing time of 25 seconds resulted an increase of temperature upto 1275 °C (T_L = 1225 °C) and therefore 25 seconds was setup as the maximum value.

Table 1 and 2 describe the chemical composition of material. The die blank and overlay composed from the same material that were Ni-Hard 1 white cast iron.

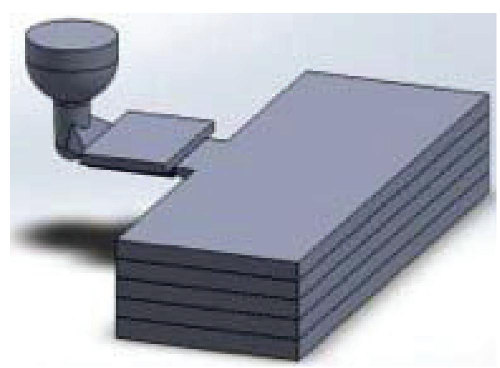
TABLE1. Chemical Composition of The Ni-Hard 1 (White Cast Iron)

Elements Content (%wt.)						
C	Si	Mn	P	S	Ni	Cr
3.36	0.38	0.27	0.007	0.009	3.9	2.07

The processes then follow by implementation with an experiment of surface overlaying of Ni-Hard Material. The processes is using parameter of flushing time that is given by the simulation. Figure 3 show the design of surface overlaying processes. Die blank was cleaned by mean of shot blasting and inserted into the mould. Liquid melts was poured into the mold at pre determined pouring temperature, reservoir basin or overflow tank was built as a cavity in the mould to produce the exact flushing time. During the process two thermocouples were placed at the bottom of the casting to measure the temperature of liquid and at the top of cavity to measure the temperature of the die blank**.**



(a)



(b)

FIGURE 3.(a) Casting Design and (b) Technical Drawing

To facilitate the formation of metallurgical bonding at the interface, following parameters and value were set up: flushing time 5 to 25 seconds with an interval of 5s and pouring temperature of 1430 °C– 1470 °C , aspects were done: the performance the quality of the joint were evaluated focused on the interface area. The macroscopic examinations were carried out by using stereo microscopy, which is then followed by microscopic examinations. Sampels were taken from the casting at the cross section area to provide the surface of both material and its interface area.

RESULTS AND DISCUSSION

The observation has conducted by measuring pouring time, pouring temperature and chemical composition of Nihard1 white cast iron, as shown at Table 2.

TABLE 2. Pouring Time, Pouring Temperature and Chemical Composition

	1	2	3	4	5		
Pouring time (s)	7	17	17	24	25		
Pouring Temperature (°C)	1468	1439	1438	1448	1459		
Flushing time (s)	5	10	15	20	25		
Chemical Composition (%)	C	Si	Mn	P	S	Ni	Cr
	3.36	0.38	0.27	0.007	0.009	3.9	2.07

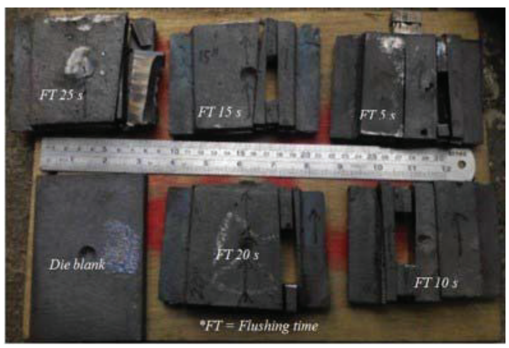


FIGURE 4. Sample Preparation for Visual and Microscopic Observation

Figure 4 show the sample preparation for visual and microscopic observation. Sample was cut at cross sectional area on interface to observe the microstructure and the quality of bonding by optical microscope and SEM.

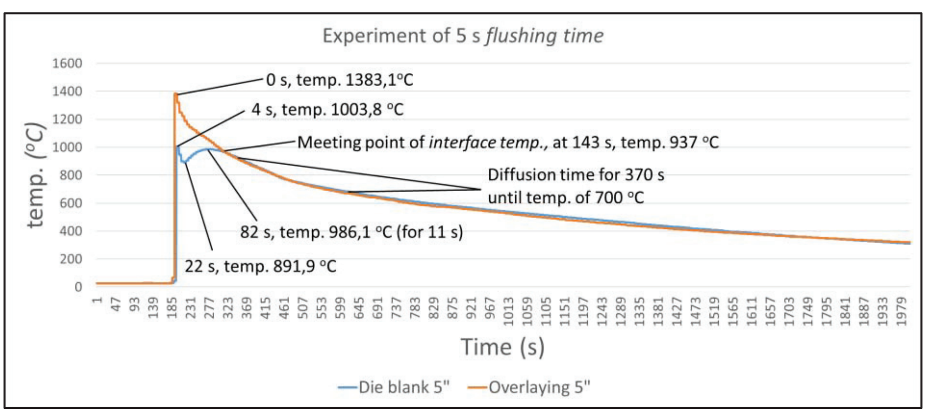


FIGURE 5. Temperature Change on Flushing Time of 5 Seconds

Figure 5 show the experiment of 5 s flushing time. The temperature of liquid melts as it entered into the mold was 1383.1ºC(it contributed a temperature difference between pouring temperature and temperature at *cavity* of84.9˚C). It required subsequently 4 seconds to obtain equal temperature of those dieblank and overlay material at temperature of 1003.8ºC. Due to the absorption of heat by the sand, the temperature dropped rapidly. The temperature increased up to 937ºC (76.57 % of T_L) in 143 seconds. Total available difusion time (>700ºC) was 370s.

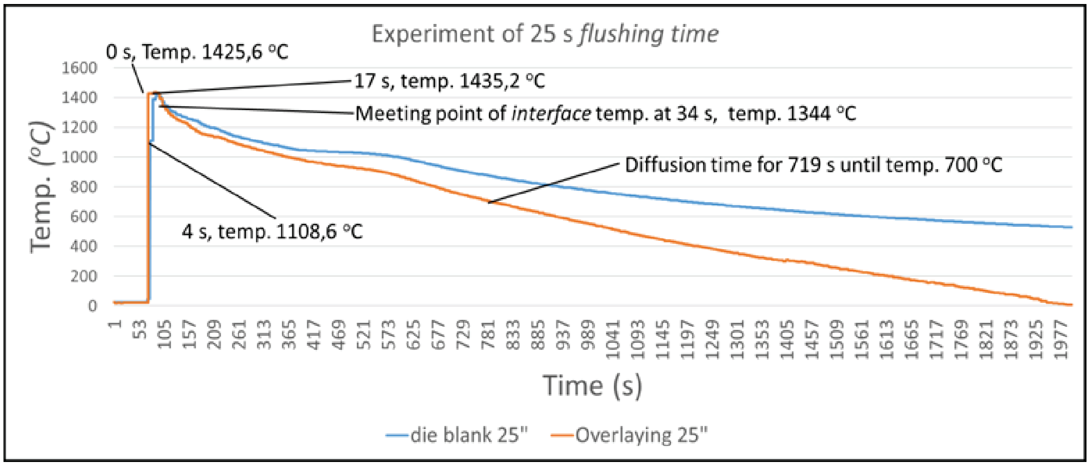


FIGURE 6. Temperature Change on Flushing Time of 25 Seconds

Figure 6 show the experiment of 25 s flushing time. The temperature of liquid melts in the mold was 1425.6ºC (temperature difference between pouring temperature and temperature at *cavity* was 33.4 °C). 4 seconds after pouring the temperature of dieblank was equal to the temperature of overlay material (1108.6 °C). The flushing time of 24s caused a remarkable increase of temperature at dieblank upto 1435.2 °C after 17s. The interface temperature after 34 s was 1344 °C (>T_L) which indicates that the interface was melted. Total available difusion time (>700 °C) was 719s.

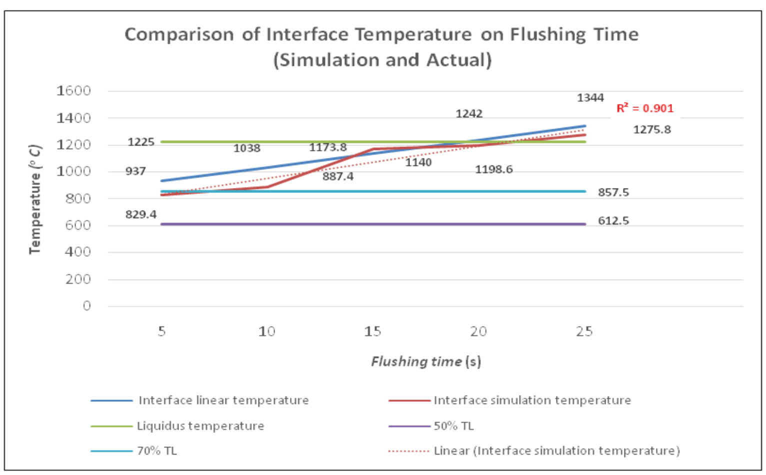


FIGURE 7. Comparation of Interface Temperature on Flushing Time (Simulation and Actual)

Figure 7 show the comparison of actual flushing time vs simulation. It can be seen that the gap difference between simulation and actual is about 107 to 68 °C. The difference then be corrected on the simulation, then the prediction will be more accurate.

The Formation of Microstructure at The Interface

By flushing time of 5s a line at the interface was clearly identified. By further SEM and EDS examination, the layer formed at the interface area could be identified as oxide layer. Die blank and overlay material did not form a metallurgical bonding, as seen on Figure 8.

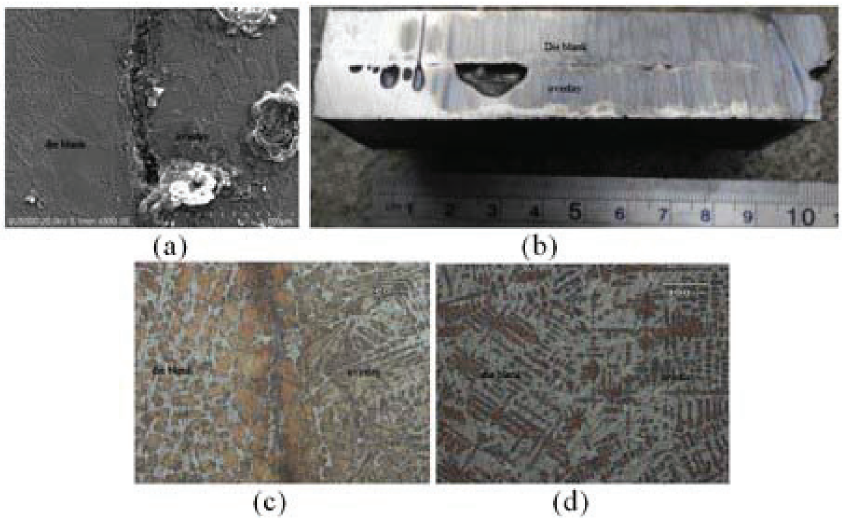


FIGURE 8.(a) 5 Seconds Flushing Time, Interface Line Under SEM, (b) 2 Materials, {c,d) Interface Area Die Blank and Overlay Under Optical Microscope

Flushing time of 10s–20s resulted a good metallurgical bonding and caused the absence of interface oxide layer. There was no markable interface line can be observed. The orientation of microstructure of both die blank material and overlay material indicated good bonding. The growth of eutectic colony in kind of edgewise growth and cooperative growth was unified. The interface was not to be observed, since the microstructure was uniform, as seen on Figure 9.

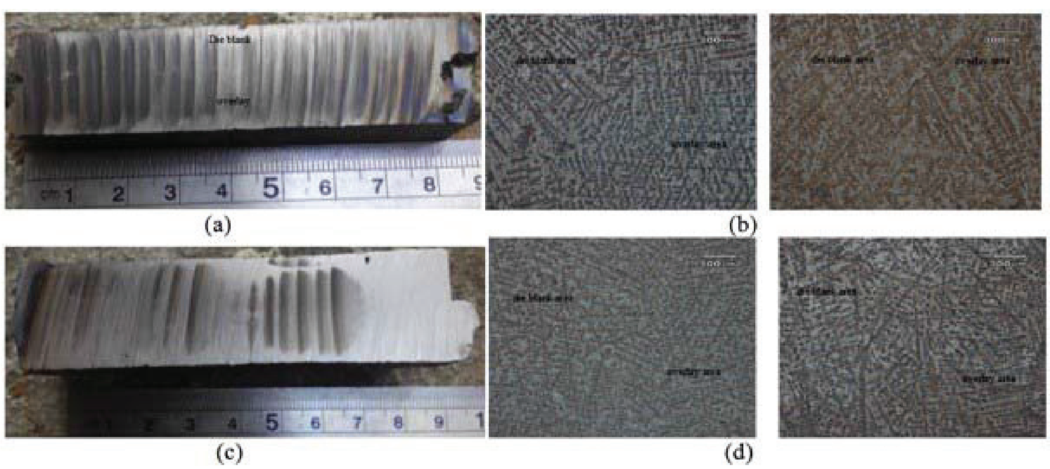


FIGURE 9.(a)10-20 Seconds Flushing Time 2 Materials at 10 s, (b) Interface Area at 10 s, (c) 2 Materials at 20 s, (d) Interface Area at 20 s

By longer flushing time (25 s) the interface temperature exceeded the liquidus temperature significantly and caused partial melting of dieblank. As shown at Figure 10 (b) it was partial melting of dieblank and drifting to overflow tank.

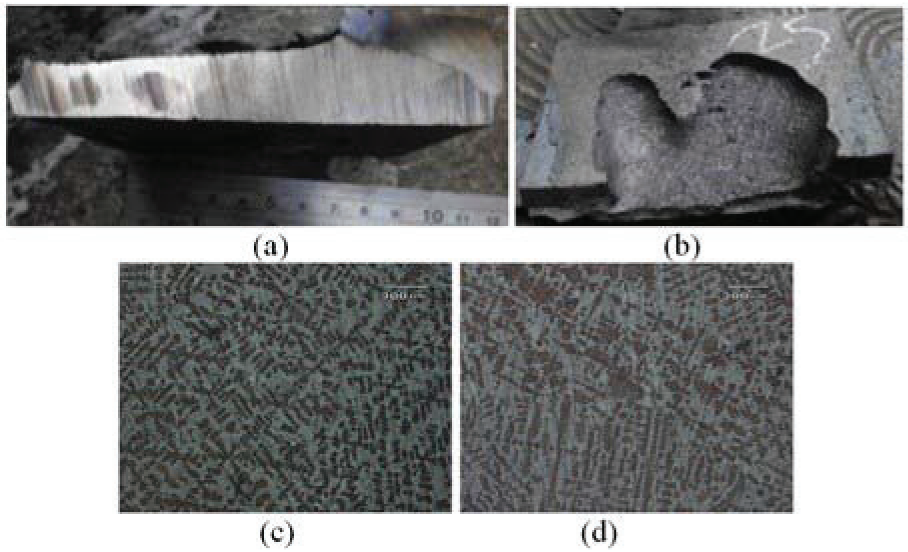


FIGURE 10.(a) 10-20 Seconds Flushing Time 2 Materials at 25 s, (b) Partial Melting at 25 s, (c,d) Interface Area at 25 s

Hardness

Hardness measurement was conducted to all speciments. Table 3 shows the hardness of dieblank as well as the overlay material. Since the overlay material had similar microstructure to the dieblank, the hardness of those material did not show significant difference. The similar fraction of carbide and the similar microstructure of matrix has contributed to the simillar hardness. As shown on Table 3 the hardness ranges between 56 HRC to 60.4 HRC.

TABLE 3.Hardness of Dieblankand Overlay Material

Rockwell C Hardness testing (load 150 Kg)								
Sample	Die blank area, HRC				Overlay area, HRC			
flushing time(seconds)	1	2	3	average	1	2	3	average
5	54.2	57.3	57.5	56.33	55	56.6	60.5	57.37
10	59.6	57.9	57.9	58.47	56.1	56.7	57.3	56.70
15	55.8	56.3	56	56.03	57.4	56.4	56.3	56.70
20	56	56.4	55.6	56.00	57.4	56.6	55.5	56.50
25	57.4	58.7	60.5	58.87	60.7	60.7	59.8	60.40

CONCLUSION

Based on the obtained results it can be concluded that influental parameters for creation of a metallurgical bonding at the interface of bimetallic casting without the presence of crack are interface temperature and the flushing time. The decissive influence of preheating temperature on the preventing of crack results from its ability to decrease the cooling rate of overlay material after solidification and the subsequent cooling. At higher temperature of interface near to the solidus temperature (1003.8°C) and 10 seconds of flushing time, muzzy condition of interface and fusion process may take place. Metallurgical bonding occured most favourably at preheating temperature of 625 °C, maximum interface temperature of dieblank of 1080 °C and cooling rate of 44 °C.min^{-1}.

ACKNOWLEDGMENT

This work is part of the research program *Riset Andalan Perguruan Tinggi dan Industri* (RAPID) which is financed by *Kementerian Riset, Teknologi dan Pendidikan Tinggi*.

REFERENCES

1. S. Žic, I. Džambas, M. Konić, Possibilities of implementing bi- metallic hammer castings in crushing industries, Metalurgija **48**, 51-54 (2009).
2. X.Xiao,S.Ye,W.Yin,X.Zhou,Q.Xue,HighCrwhitecastiron/ carbon steel bimetal liner by lost foam casting withliquid-liquid composite process, China Foundry **9**, 136-142 (2012).
3. T. Heijkoop, I. Sare, Cast-bonding – a new process for manufac- turing composite wear products, Cast Metals **2**, 160-168 (1989).
4. W. Wołczyński, Z. Pogoda, G. Garzeł, B. Kucharska, A. Sypień, T.Okane,PartI.Thermodynamic and kinetic aspects of the hotdip (Zn) – coating formation, Archives of Metallurgy and Materials **59**, 1223-1233 (2014).
5. Y. Aftandilyants. Manufacturing technology of bimetallic castings by high durability**,** *Presentation of Innovations Market for R&D*, Hannover (April 2007).
6. S. Jura, J. Suchoń, Layered castings sort steel cast iron, Solidification of Metals and Alloys **24**, 67-70 (1995).
7. T.Wróbel,Characterization of bimetallic castings with anaustenitic working surface layer and an unalloyed cast steel base, Journal of Materials Engineering and Performance **23,**1711-1717 (2014).
8. G. Mahendiran, V Balasubramanian, T. Sethilvelan, Mechanical and metallurgical properties of diffusion bonded AA2024 aluminium alloy and commercial grade copper, Elixir Mechanical Engineering. **38**, 4283-4289 (2011).
9. By N. Yurioka, H. Suzuki, S. Ohshita And S. Saito, Determination of Necessary Preheating Temperature in Steel Welding, welding research , supplement to the welding journal (June 1983).