

Analysis of Porosity Defects in Aluminum as Part Handle Motor Vehicle Lever Processed by High-pressure Die Casting

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Abstract. This research discusses the testing and analysis of cracking Aluminum (Al) material. Al as a handle lever was used for a braking device on a motor vehicle. Cracking of handle lever due to the part content of porosity from hydrogen gas. The existence of the H₂ can be caused by the casting process and dies design that is less perfect, especially at the gate or brisket and overflow. This research is to optimize the process of making Al part handle lever, and the construction dies by following the standard. The results of these improvements were re-evaluated through the chemical and mechanical testing properties stages, such as density test and tensile test on the workpiece as part handle lever. The loads on the tensile test are 25 kg and 35 kg, and the tensile test result has met the standard set by the motor vehicle company. The optimization result has the porosity defect can be reduced by 99 %. Therefore the best part handle lever can be produced.

Keywords. Aluminum, manufacturing, microstructure, part handle lever, and properties.

1. Introduction

Aluminum (Al) is a light metal that has properties against corrosion resistance and good electrical conductivity [1]. Future Al usage is expected to be wide open as the main material and supporting material, with the availability of the abundant Al seeds on earth. Al can be used for household appliances, aircraft materials, automotive, ships, constructions and others [2–5]. The aluminum products can be produced through the casting and forming process.

Al alloys have been used in many applications and have been widely used in industry because they have superior properties [6–12]. These properties make aluminum alloys into metals that are very suitable and economical for various applications and have made aluminum alloy as the most widely used metal after steel [13]. Al is commonly used for the manufacturing part produced in the motor vehicle companies [14–15]. Handle lever is a part that serves as braking or reduction of production rate in a motor vehicle.

Al is a common element found in the earth's crust and is the third most abundant element after oxygen (O) and silicon (Si) [16]. The excess of Al compared to other metals is that Al has a low specific gravity which makes this material light and has good corrosion resistance due to the 20



passivation phenomenon [1, 17–20]. In order to improve the mechanical properties, other elements were added into Al. On the other hand, Al also has some shortcomings, lack of Al among others, such as easy to mix with gases; hydrogen in liquid conditions that can cause porosity [21–23].

In any manufacturing or production process, various problems that can affect the quality of production are generally found. Those are because the production process is not perfect and the design needs to be an improvement. The manufacturing process of handle lever in an automotive company, especially handles lever part was found porous during the initial trial of production. Therefore, to overcome that problem, our study is to examine the cause of the occurrence of porosity made from Al as part handle lever produced by high pressure die casting.

2. Materials and methods

The purpose of simulation performed on the Al handle lever is to estimate the use of parts in the application, as an example: the part is used for braking at the speed of the motor vehicle. In the work system to clarify the problem on the Al part handle lever, can be seen in Figure 1.

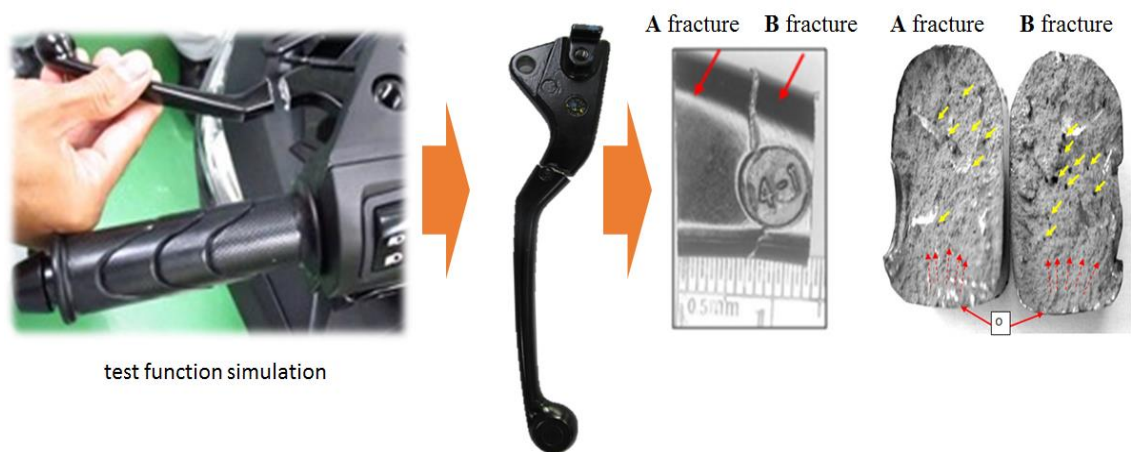


Figure 1. The braking system on a motor vehicle.

Figure 2. Optical microscope image of Al part handle lever.

Analysis performed on the cracked or broken part is done based on five aspects: user, working method, materials, machine, and environment. Before the parts are manufactured, testing should be made to ensure that the parts fit into the quality standard. The first procedure of part handle lever from the casting process is done by simulation test in function. The second step is to determine the mass of the type of time on the object by density testing. The density examination resulted from the outcome of the weighing of the specimen, it is theoretically performed, namely *Archimedes* test. Discovery of crack or broken cases found in the production of Al part handle lever, part analysis problem was carried out by Scanning Electron Microscope with Energy Dispersive X-ray Spectroscopy (SEM-EDS) microstructure image analysis.

3. Results and discussion

In advance of the parts are being manufactured, the first test has been made to ensure that the parts fit into the quality standard. In this simulation test, the result of Al part handle lever is NG (No Good), that part has a crack (broken) obtained from the casting process. The density result which was performed by Archimedes test has 92.105 % density or 7.894 % porosity.

By microstructure analysis, the crack propagation was obtained from the O point. However, the initial crack was not found. Figure 2 was obtained by an optical microscope (OM). The SEM images clearly show the fracture surface of Al part handle lever in different magnifications. Figure 3 shows the crack obtained by a casting process and the morphology of H₂ inserted to the Al part. In the observations with EDS, the impurities with element contents of carbon and oxygen were found more

clearly. The SEM-EDS results show that the defects were not in the direction of fault propagation. In addition, the cause means of the fracture is not due to the impurities as shown in Figure 4.

The summary of the above analysis is: the 'cause' of the crack case in the Al part handle lever is the porosity of the casting process, gas porosity or shrinkage porosity.

From the material composition analysis results obtained by the spectrometer observation, the composition contained in the part handle lever corresponds to the composition of the material specification. Figure 5 shows the test location of material and Table 1 shows the composition results of materials by the spectrometer.

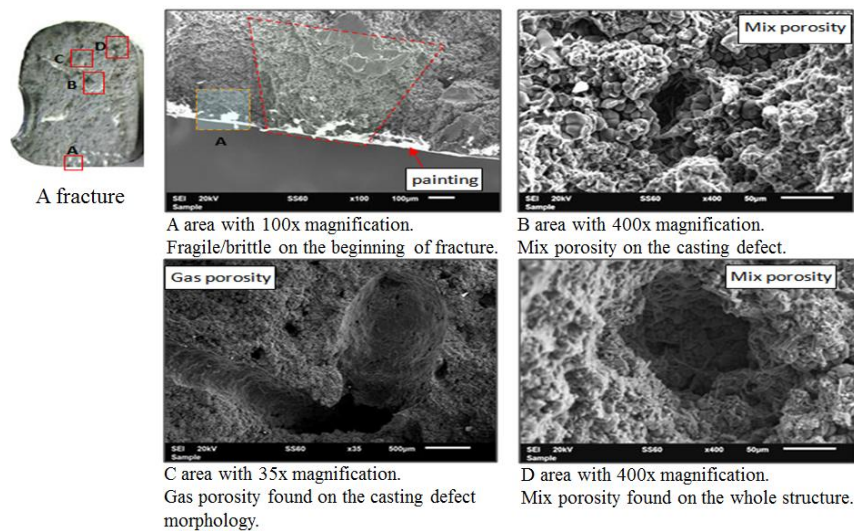
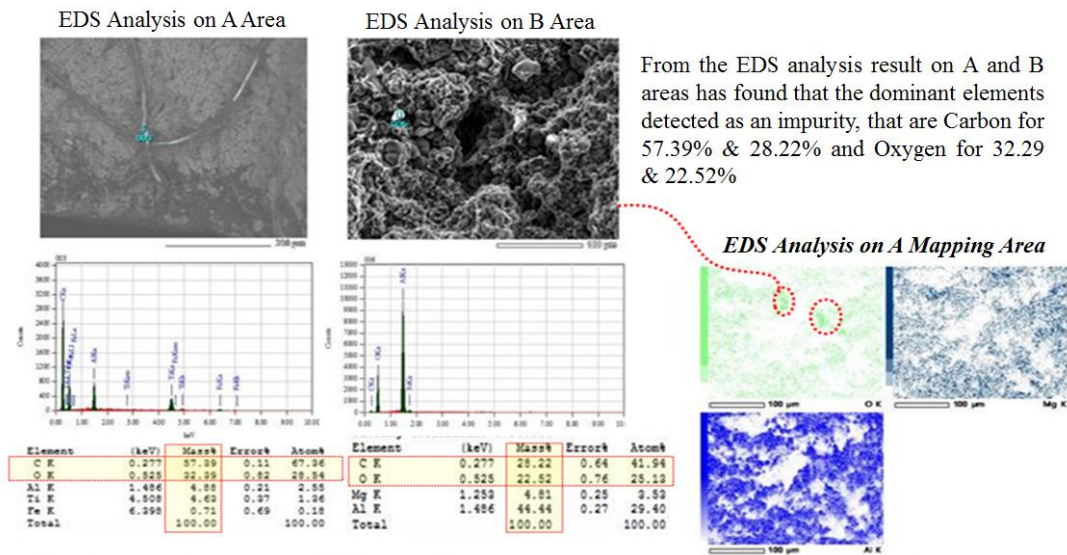


Figure 3. SEM fracture images of Al part handle lever with different area and various magnification.



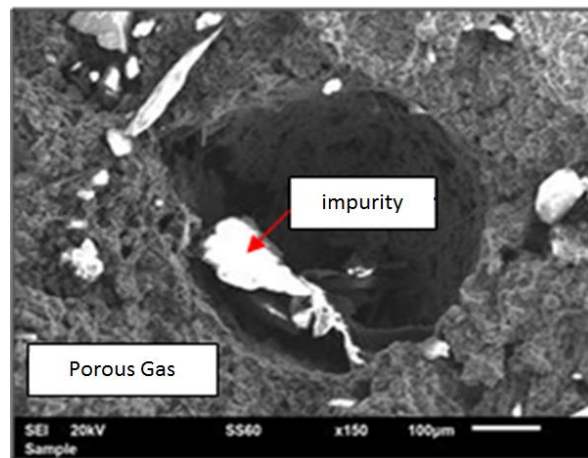


Figure 4. EDS analysis results of Al part handle lever and fractography with impurity.

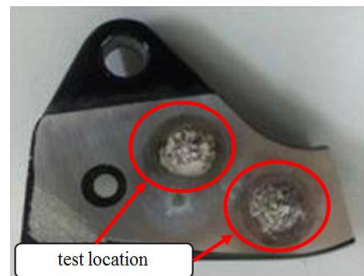


Figure 5. Material test location.

Table 1. The composition result of materials by the spectrometer

Items	Composition of Elements (%)							Result
	Si	Fe	Cu	Mn	Mg	Zn	Ni	
Standard								
HD4	0.50 –	0.50 –	0.10	0.50 –	4.00 –	0.10 –	0.10 –	
HES C-101-03	1.10	0.80	Max	0.80	5.50	Max	Max	OK
Spark 1	0.89	0.72	0.05	0.60	4.63	0.03	0.01	
Spark 2	0.87	0.70	0.04	0.59	4.61	0.03	0.01	

The following tensile test simulation results on the Al part handle lever based on updated parameters. The illustrations and results of the tensile test can be seen as following Figure 6 to10, respectively.

Based on the standard that has been set by the company on the strength of the part handle lever, it can be concluded that the production of Handle Lever parts is fine and safe for the use of mass production. Compared with the production of other parts with the similar material Al alloy, and the similar process die-casting shows increasing mechanical properties, which has been proofed by Avelle *et al.* described the influence of casting defects on static and fatigue strength is investigated for a high pressure die cast aluminum alloy. In this case, defects count for their size and location, while quality control often takes no account of component working conditions [24]. Besides, other researchers Nakata et al. have proven improvement in the mechanical properties was accomplished due to the microstructural modification of an aluminum die casting alloy by multi-pass friction stir processing (MP-FSP), which is a solid-state microstructural modification technique using a frictional heat and stirring action. The hardness of the MP-FSP sample is about 20 Hv higher than that of the base metal.

The tensile strengths of the MP-FSPed specimens were significantly increased to about 1.7 times if compare of the base metal [25]. Thus, the application of the high pressure die-casting is a very effective method for the mechanical improvement of aluminum alloys.

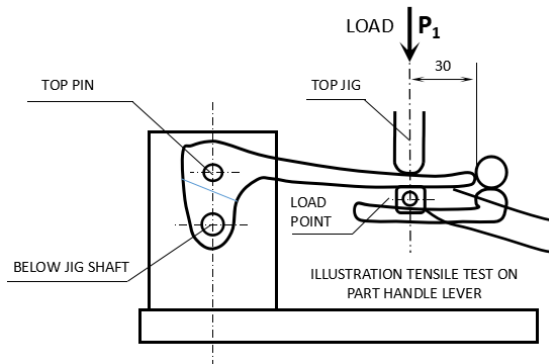


Figure 6. Illustration of tensile test workpiece

Compressive extention at preset point (load 20 kgf) mm	Compressive extention at preset point (load 35 kgf) mm	Maximum load (kgf)
2,80856	3,82955	122,44880

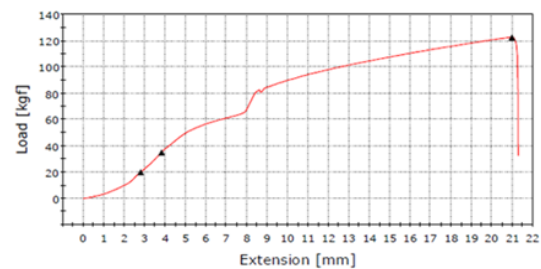


Figure 7. The values of compressive extension test 1 at preset point is 2.80856 mm

Test Load	Standard		Actual		Judgement
			Sample No.	Result	
20 Kg	Max Displacement	Max 5 mm	1	2,81 mm	OK
			2	3,66 mm	OK
35 kgf	Max Displacement	Max 5 mm	1	3,83 mm	OK
			2	4,91 mm	OK
Max Load	Min Load	60 kgf	1	122,45 kgf	OK
			2	114,23 kgf	OK

Figure 8. Results of compression testing

Compressive extention at preset point (load 20 kgf) mm	Compressive extention at preset point (load 35 kgf) mm	Maximum load (kgf)
3,66180	4,91224	114,23241

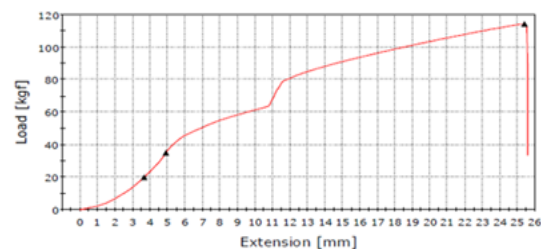


Figure 9. The values of compressive extension test 2 at preset point is 3.66180 mm

4. Conclusions

Analysis of porosity defects in Al as the part handle motor vehicle lever has been processed by high pressure die casting, by a standard operational procedure such as the fluxing process frequency standard and the optimization of special particle lever parameter on the casting process has been well determined. The optimum dies design with the addition of two runners is accompanied by the change of gate and overflow. From the results clearly, show the improvements in the process have been successfully made, and the mechanical properties and safety have met the standards. Therefore, the application of the high pressure die-casting is proven as a very effective method for the mechanical improvement of aluminum alloys.

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