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Redesign of automotive brake pedal based on castability analysis

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ABSTRACT – Change of automotive component material for any particular purposed (i.e. weight reduction, cost reduction) may affect the manufacturing process which will influence the final geometry of product. For this reason, an original automotive brake pedal that was initially made of steel was substituted with aluminum alloy and aim to be manufactured by casting process. In this research, the design review and modification on the brake pedal was carried out based on the casting rules. Initial castability evaluation on the original and modified brake pedal design was carried out using Ansys FLUENT simulation software. The results of the study show that changes on the design features of an original brake pedal were necessary as to improve its castability.

1. INTRODUCTION

Brake pedal is an important automotive component to stop or reduce the speed of a motor vehicle. At present, many cars have brake pedal that is made of steel. A brake pedal may consist of three major components namely brake pedal, rubber foot and switch pad contact [1]. Each brake pedal component has to undergo a series of sheet forming processes before assembled together by welding process. Changing the material of a brake pedal to a lighter material such as aluminum may affect the final geometries and the manufacturing process. Thus, automotive design engineers have to modify the original design of a brake pedal as to fulfill the new manufacturing process requirement.

In aluminum alloy brake pedal production, casting has an advantage of producing in single process and suitable to substitute the original manufacturing processes (combination of press forming and welding process) [2]. However, castability of brake pedal should be investigate and analyze early in design in order to form the component without formation of effects such as cracks, segregations, pores or misruns [3]. According to Ravi [4] there are three major approaches for castability analysis: process simulation, parametric cost estimation and features-based castability checks. Geometric features such as undercuts, holes, sharp corners and hot spots were recognized from a solid model of the casting and analyzed by a number of dimensionless criteria functions. These criteria were developed through a detailed study of design heuristics used by practicing engineers and were written as functions of geometric attributes of component and tool features.

This paper intends to improve the original brake pedal design based on castability. An original brake pedal design was evaluated and the geometries that were critical modified and redesign to a new brake pedal design. The comparison between these two designs was carried out to prove that the modified brake pedal design is better in terms of castability.

2. METHODOLOGY

The research was carried out in three stages of process as following:

Stage 1: Brake pedal design review
Stage 2: Modification of brake pedal
Stage 3: Castability analysis

The original brake pedal design was reviewed based on the casting rules. This is where the steel design of brake pedal shows a potential problem at the joining region between pedal pad and brake pedal arm due to sharp corner. The critical area was found at the bottom of this joint. The other locations that have critical area are the sharp corner and edges in the middle of the brake pedal arm.

At the joint between brake pad and brake pedal assembly the ribs were added according to castability rules such in Figure 1. The added dimension of ribs was 20.2 mm on both sides which is approximately 80% from the total length of the joint. The ribs were also added in the front and behind of the joint with the dimension of 7.5 mm. According to the castability rules, the fillet was required to avoid stress concentration. On the other location of brake pedal arm the fillets were added with the dimension ranging from 1-3.75 mm depending on the part thickness.

Afterwards, the castability analysis of brake pedal designs was performed by using Ansys FLUENT simulation software. Pressure distribution and temperature changes were used to differentiate the castability of these two designs. The modified area of pedal pad was chosen as the point for comparison between the original and modified brake pedal design.

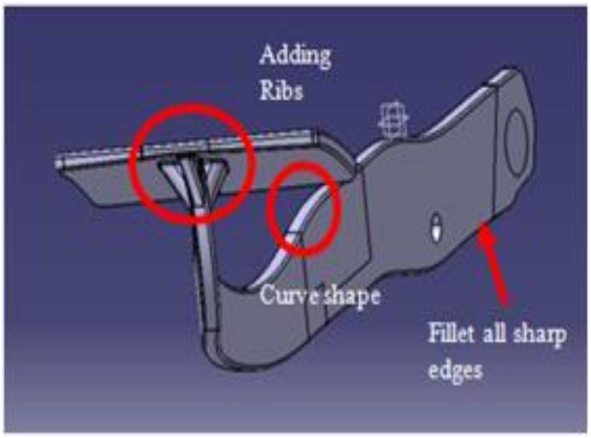

Figure 1 Modification Design

3. RESULTS AND DISCUSSION

The result of the comparison between new modification brake pedal and the old brake pedal design are summarized in Table 1.

Table 1 Brake Pedal Comparison Based on Castability

Castability Characteristics	Old Design	New Design
Max Pressure (kPa)	187	151
Temperature (K)	827	855
Air Entrapment	Yes	No

Comparing the old designed brake pedal and the new designed brake pedal, the maximum pressure value was less than the original brake pedal after the addition of the ribs at the joining sections. High pressure at the surface of the casting may lead to hot tearing which caused by the non-uniform cooling rate of the material that lead to quicker solidification. Uneven cooling rate may also cause a misrun when the temperature of the material drops. This happened when the temperature decreased and solidified earlier before filled up sufficiently into the cavity. The porosity may occur due to shrinkage of the solidified aluminum. Hot tear, misrun and porosity may occur at the joining location of the sharp angles at the corners.

The effect of high pressure may lead to the porosity due to entrapment of air that happened at the pedal pad surface where the concentration stresses are high. This may happened due to the incorrect shape dimension of the joint from thin to thick area and formed a separation direction of metal flow that was inadequate. The separation of metal flow may cause cold shut due to the evolution of the gas that had happened. The gas evolved or expanded when it accumulated at the region area of porosity.

The temperature of molten metal is important as it represents the fluidity of material. High temperature of molten metal may cause causalities of the material to flow smoothly before it solidified. Low temperature of the casting may lead to solidification of the material become quicker. This will influenced the flow distribution that could not reached the location to fill the mold sufficiently due to quick solidification of the material and may lead to defection such as porosity due to shrinkage of the material. Shrinkage happened due to the material thermal expansion at the time molten metal when it began to solidify. Significantly the temperature of the original brake pedal showed that the molten metal was not reachable enough by the end location of the casting

Unlike the new brake pedal, the temperature of the molten metal was as even as the liquids condition. This showed that the temperature maintained at the melting point condition. When the temperature was high, the flow of the molten metal increase in time, and the molten metal was able to fill sufficiently into the mold cavity before solidification. This potentially happened when the molten metal started to solidify before filling up the cavity. For the new designed, the potential of the defect was probably less due to the temperature of the molten metal was maintained and helped the flow of the material to fill up sufficiently in the mold cavity.

4. CONCLUSIONS

Based on the result, the ribs and fillet of the design influenced the castability of brake pedal design. The pressure and temperature elements affected the castability of the brake pedals where they influenced the fluidity and the flow of the material. New design of brake pedal proved that the casting defect can be reduced and it will be easier to cast based on the simulation result obtained.

5. ACKNOWLEDGEMENT

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