

Lightening Approach for Small Vehicles by Developing Extruded Aluminum Suspension Arm

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ABSTRACT

This paper shows the lightening approach for small vehicles by developing lower arm of the hollow extruded aluminum, which is the low cost material and has closed cross section. The manufacturing cost was reduced by developing the industrial method to form the developed lower arm of the extruded aluminum by cold press, without welding. In addition, the developed method forming of the heat-treated extruded aluminum reduces the manufacturing cost more, compared to the conventional method forming before the heat treating. The structure of the developed lower arm has the wide center part receiving the coil spring and the narrow end part connecting to the vehicle body with the bush. The center part has the same cross section as the extruded aluminum, and the end part was formed by shrinking the extruded aluminum by cold press. In addition, the original expanding clinching method was developed to joint the aluminum outer tube of the bush for the prevention action against the galvanic corrosion.

As mentioned above, the lightening approach for the suspension parts of small vehicles have been achieved by developing the lower arm made of the extruded aluminum with the elemental technologies of the material, structure and joint. The developed lower arm has already been adopted for the rear suspension of our passenger car, and achieves the weight lightening of 30% and the cost reduction of 22% compared to the conventional steel lower arm. In addition, that achieves the weight lightening of 50% compared to the lower arm made of aluminum by high vacuum die-casting. Hereafter, this developed approach by the extruded aluminum will be evolved widely to the suspension parts of not only passenger car but also the other small vehicles like ATV and EV commuter.

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INTRODUCTION

Recently, the small vehicles such as passenger car and ATV need weight lightening for lower fuel consumption by the heightened eco-consciousness. In particular, lightening suspension parts improves not only fuel consumption but also stability, controllability and driving comfort. Therefore making suspension arms and knuckles aluminum is important lightening approach for vehicles.

The lower arm is the link connecting the knuckle with the suspension frame, and the center part joint to the coil spring as shown in [figure 1](#). And, in general, the steel lower arm is ensured the rigidity for receiving the large load from the coil spring, because its central part is the crab shell structure welding two steel sheets. To make lower arm of aluminum, as same as steel, it is conceivable to have closed cross section by welding the pressed aluminum sheets. However, this method increase the manufacturing cost to a large degree, because the

cost of the pressing and welding aluminum sheets are high, compared with steel.

For the other aluminum lightening method, there is the high vacuum die-casting process [1], and it has already been mass-produced by some car makers and the mainstream method as of this writing. However, this process needs open cross section structure because cores are not available. The open cross section structure has the low section efficiency and increase the thickness of the lower arm, particularly, the joint of coil spring, therefore the lightening rate by aluminum are decreased. In addition, lower arm has long thin-walled structure and the wide projected area of the molds on the casting, so it needs the large mold clamping force and large-sized casting machine, so the casting cost is expensive.

As stated above, the conventional aluminum lightening approaches have caused the manufacturing cost rising. In addition, the hollow extruded aluminum, which is the low cost material and has closed cross section, is mostly applied to the aluminum swing arms of the motorcycles. But almost

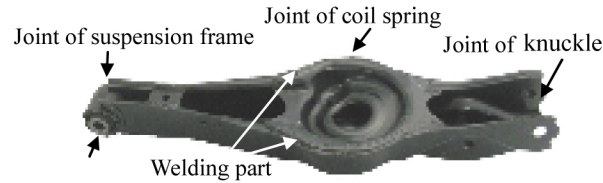


Figure 1. Steel lower arm of passenger car

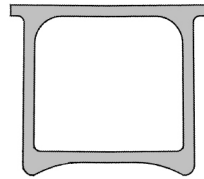


Figure 2. Cross section of hollowed extruded aluminum

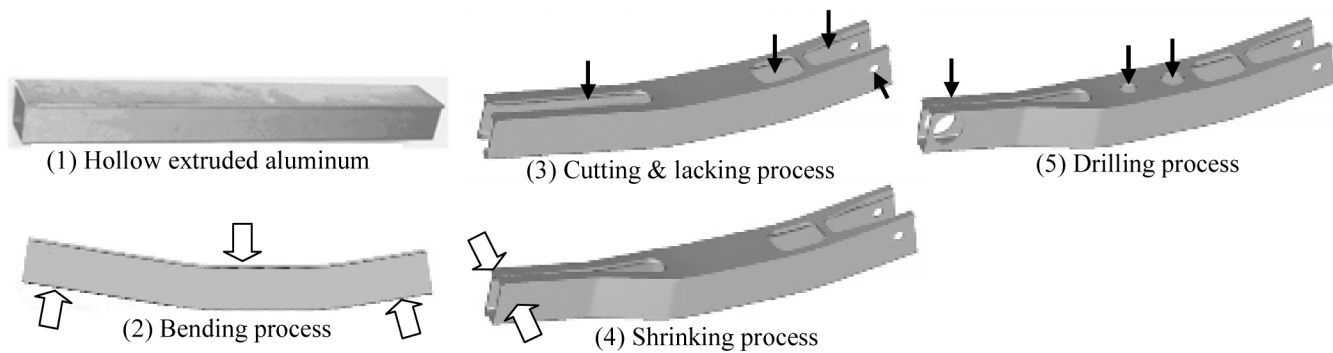


Figure 3. Developed cold press process diagram

all of those swing arms have the structure welding to the other casting parts, so the manufacturing cost has been expensive by welding and casting.

Therefore, for reducing the manufacturing cost, the structure of the hollow extruded aluminum without welding and casting is expected for the new aluminum lightening of lower arm and that has been approached by developing elemental technologies of the material, the structure and the joint in this paper.

DEVELOPMENT OF EXTRUDED ALUMINUM LOWER ARM

1. Brief of New Structure and Manufacturing Process

The following structure and manufacturing process were developed to form the lower arm of the extruded aluminum by cold press, without welding. [Figure 2](#) shows the cross section of the hollowed extruded aluminum used for the developed lower arm, and it became the cross section of the wide center part receiving the coil spring. Next, [figure 3\(1-5\)](#) shows the cold press process of the lower arm. After the bend process (2), the narrow end part of the lower arm was formed

by cut and lack with the upper ceiling and bottom (3), and shrinking the end part by cold press (4).

All of above-mentioned processes were executed by cold pressed, because the manufacturing cost was aimed to reduce greatly. Moreover, there was no heat treat process after press, by pressing the heat-treated aluminum.

2. Development of New Clinch Joint Method

2-1. Galvanic corrosion by steel outer tube

The lower arm with the developed structure and manufacturing process (shown in [figure 3\(5\)](#)) could not assure the required twisting rigidity, if nothing was done, since the end part by shrinking was divided to two lateral parts. So, the structure had the robust closed cross section by uniting the lateral parts as shown in [figure 4](#), by which the bush inserted to the penetrated hole on the lower arm after drilling as shown in [figure 3\(5\)](#). However, as the result of the cyclic corrosion test to the lower arm using the steel outer tube of the bush, the galvanic corrossions were occurred on the lower arm around the outer tube, as shown in [figure 5](#). Since these galvanic corrossions could have made the jointing

force between the bush and the lower arm decreased, the prevention action against the galvanic corrosion by the substitution of aluminum outer tube was decided. The outer tube of bush was applied of 6061-T6 extruded aluminum (outer diameter $\phi 42\text{mm}$, length 40mm, thickness 2mm) and was squeezed $\phi 1\text{mm}$ after the adhesion to the rubber in the manufacturing process of the bush.

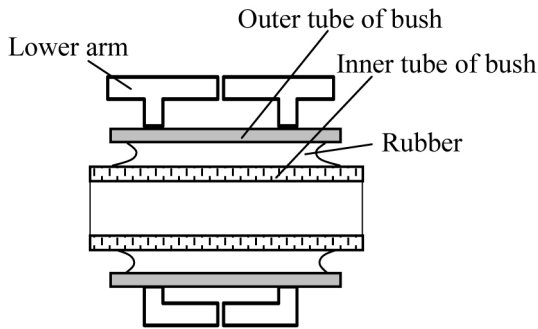


Figure 4. Cross section structure of uniting parts with bush

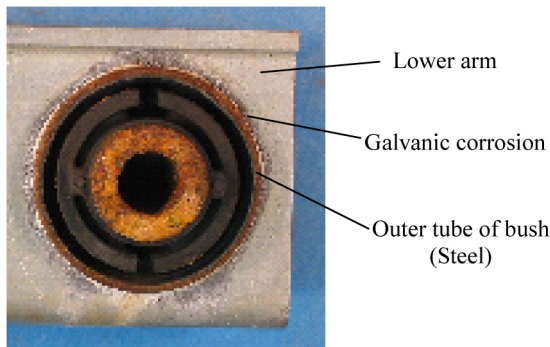


Figure 5. Galvanic corrosion around steel outer tube by cyclic corrosion testing (JASO M 609, 50cycle)

2-2. Clinch joint of aluminum outer tube

Next, the outer tube of the bush was aimed to joint to the lower arm by the press fitting between the proper sized hole of the lower arm and the external diameter of the outer tube. As the result of the bush omission test after outer tube inserting to the hole, as shown in [figure 6](#), the bush omission load (assumed to the jointing force) increased with the lap of the press fitting ([the internal diameter of the hole] - [the external diameter of the outer tube]). However, the bush omission load decreased above the 0.2mm lap. As the result of investigating, as shown in [figure 7](#), the decrease of the omission load was become clear by decreasing the external diameter with the outer tube galled by the lower arm. In addition, the lap of the press fitting could make loose by the manufacturing dispersion. Therefore, the required jointing force was considered to be not assured by only press fitting.

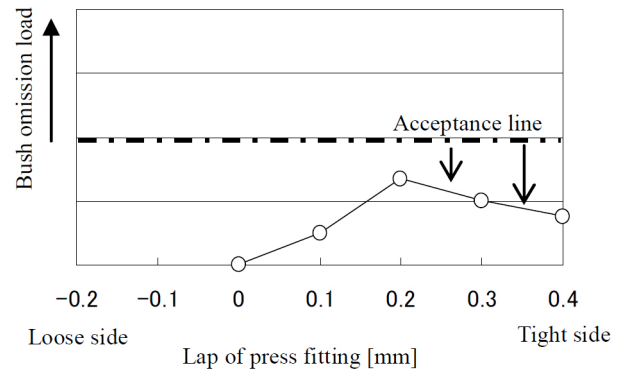


Figure 6. Bush omission load by only press fitting

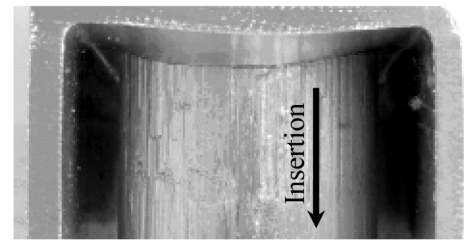


Figure 7. Galling of aluminum outer tube with press fitting

Since the press fitting of aluminum to aluminum has the problem as mentioned above, the development of the new mechanical clinch method regardless of the lap (or gap) had been approached. The new clinch method assured the jointing force between the bush and the lower arm by expanding the ends of the outer tube after the insertion of the bush to the lower arm.

[Figure 8](#) shows the first test with the new clinch method. The ends of the outer tube were expanded by the compressive load (clinch load) from the plain ring-shaped stamps after the bush inserting and fitting the stamps on the both sides. However, as the result, the diameter of the outer tube was expanded only $\phi 0.5\text{mm}$, as shown in [figure 9](#). The reason was considered that the outer tube has high hardness 102HB as 6061-T6 aluminum by the work hardening of the squeezed process and has large deformation resistance because the expanding clinch was the second deformation, so the central of the outer tube was widely buckled by the clinch load before expanding the ends of the outer bush enough, as shown in [figure 10](#), since expanding clinch with plain stamps needs larger clinch load.