

Cast Body Nodes for 2016 Acura NSX

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ABSTRACT

Ablation casting is an emerging technology which combines traditional sand molding techniques with rapid cooling due to the use of a water soluble binder. High cooling rates and control of solidification direction allows for exceptional mechanical properties and complex shapes. Through the use of ablation, six different body node castings have been manufactured for the 2016 NSX aluminum space frame. The high mechanical properties allowed these castings to be integrated into the crash structure for energy absorption. Using the traditional casting alloy A356, target mechanical properties were 190 Mpa Yield Strength, 280 Mpa Tensile Strength and 12% min elongation. The high elongation was achieved due to the refined eutectic microstructure produced by high cooling rates. The eutectic microstructure produced by ablation was found to be Level 5 or 6 on the AFS scale. Light weighting could also be achieved when compared to traditional GDC castings. By using sand molds instead of steel dies, the nominal wall thickness was set to 4 mm instead of 5-6 mm when using traditional gravity die casting. Further light weighting was achieved by using sand cores to create complex hollow internal sections. The combination of high properties and hollow shapes made ablation cast nodes ideal for a lightweight space frame structure.

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INTRODUCTION

To achieve the target Power-to-Weight ratio for the 2016 NSX, it was crucial to have a light weight body construction. Through body construction design studies it was determined an all aluminum space frame was best suited for this application. For maximum efficiency the construction would consist of aluminum extrusions which were joined to aluminum cast nodes.

During initial prototype builds, the aluminum nodes consisted of traditional sand castings. The nodes performed favorably; however, to increase light weighting and reduce MIG length the body construction needed improvement. Specifically, certain aluminum nodes were targeted to be increased in size for part integration and reduction of weld length. This would further reduce overall body weight and increase body accuracy due to reduced heat input from MIG welding.

By increasing size, the aluminum nodes in the space frame became part of the energy absorption zone. This required the nodes to have higher elongation requirements which were beyond the capability of traditional sand castings. Therefore, new casting methods were investigated to create large / hollow high performance aluminum nodes.

Current casting methods were investigated first to determine feasibility of achieving the targeted node shape, wall thickness and performance. These traditional methods included: Gravity Die Casting, Sand Casting + Chills and HIP, Ultra High Vacuum High Pressure Die Casting, and Low Pressure Die Casting - VRC/ PRC. Each casting process was evaluated against the following preferred performance requirements:

- **Mechanical Properties:** Must be similar to extrusions in strength with a 12% min elongation.
- **Weld-ability:** Low porosity in welding areas to ensure good joining.
- **Hollow capability:** In order to maximize efficiency, parts must be made hollow with an internal core.
- **Wall Thickness:** To meet weight targets wall thickness must be 4.00 mm nominal.
- **Size:** Must be able to produce a hollow part 600 mm in length.
- **Volume:** Cost Effective for low volume production.

Each of the above casting processes were compared against the targeted performance values at a high level. Table 1 shows the results of that comparison. In Table 1 a circle indicates meets targets, triangle indicates close to or at minimum and X indicates does not meet target.

Table 1. High Level Process Comparison Chart

General Criteria							
Process	Yield / Tensile	Elong	Weld	Hollow	Wall T	Size	Volume / Invest
Sand + Chills and HIP	▲	▲	•	•	•	•	•
GDC	▲	x	•	•	▲	▲	•
UHVHPDC	•	▲	▲	x	•	▲	x
LPDC - VRC / PRC	•	▲	•	•	▲	•	▲/x

The high level comparison of processes available to make aluminum cast body nodes indicated that no current process met all the criteria established. Without changing the node construction or target values, a new method was needed to manufacture body nodes for the 2016 NSX. Therefore, investigation into new / novel casting methods was completed. The focus of the investigation was to find a new casting process that combined the strengths of the traditional casting processes listed in [Table 1](#).

One process, Ablation Casting, was found to meet all of the requirements by combining the shape flexibility of traditional sand casting along with the high cooling rates of die casting. This allowed for a thin wall hollow aluminum node that also met functional requirements.

Ablation casting is described in “Mold-Removal and Casting Apparatus” patent by J. Grassi et al. [1]. In this process, molten metal is poured into a sand mold held together by a water soluble binder. While the metal is still molten, water is sprayed on the sand mold causing it to be removed. Once removed, the water directly chills the metal, which causes rapid solidification. By controlling this aspect of the process, parts with highly refined structure and integrity can be manufactured.

GENERAL PART DIMENSIONS

To achieve the most efficient shape and provide proper connection points in the space frame, the ablation nodes had to be large. For efficiency, sand cores were used to ensure the nodes were as lightweight as possible while still maintaining performance. [Figure 1](#) shows the location of the ablation cast nodes in the 2016 NSX body structure.

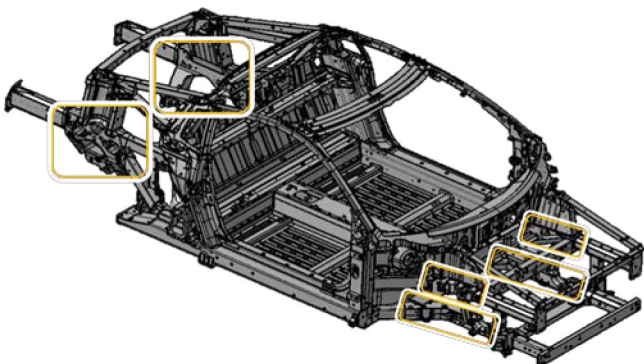


Figure 1. Two ablation nodes are in the front of the structure. They are the Front Upper Node and the Front Lower Node. [Figures 2](#) through [3](#) are images of the Front Upper Node. This node is 18 inches, or 457 mm in length.

Ablation Casting of Aluminum Nodes

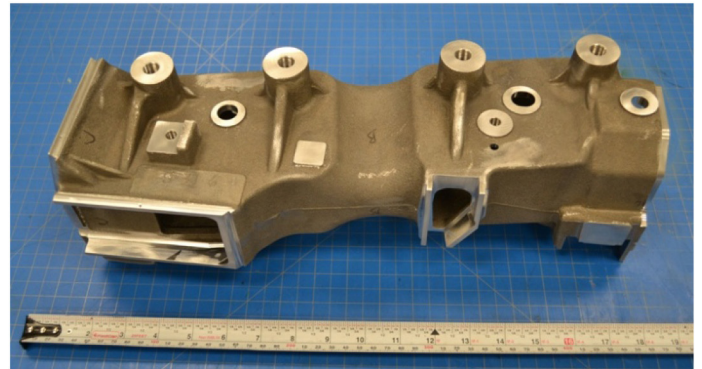


Figure 2. Front Upper Node - Top View

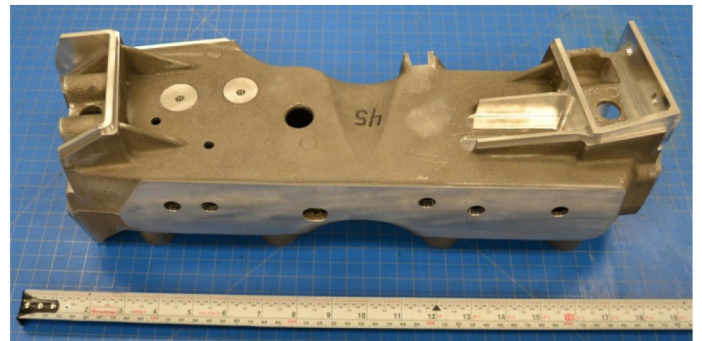


Figure 3. Front Upper Node - Bottom View

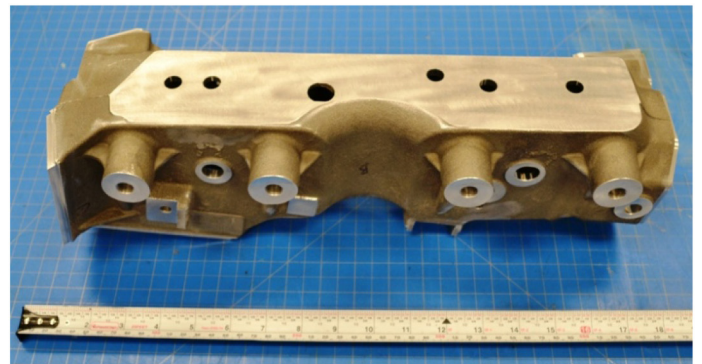


Figure 4. Front Upper Node - Side View

[Figures 5](#) and [6](#) are images of the Front Lower Node. This node is 24 inches, or 609 mm in length.

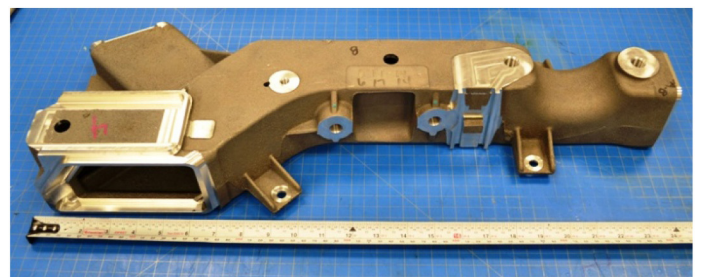


Figure 5. Front Lower Node - Top View

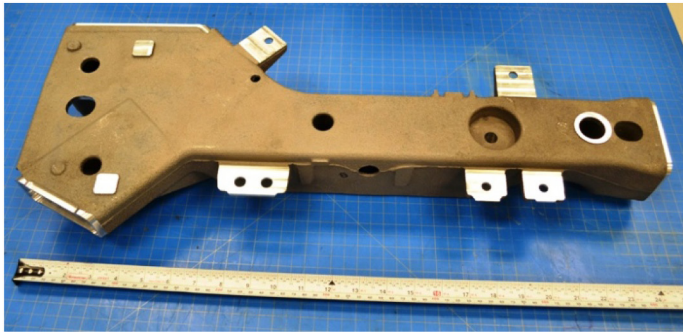


Figure 6. Front Lower Node - Bottom View

In the rear of the vehicle there are two ablation nodes, one on each side of the engine. These are referred to as the Rear Nodes. The hole through center of the node is for the drive shaft to pass through to the rear wheels. [Figures 7 and 8](#) show the Rear Node. This node is approximately 20 inches, or 500 mm long and wide.

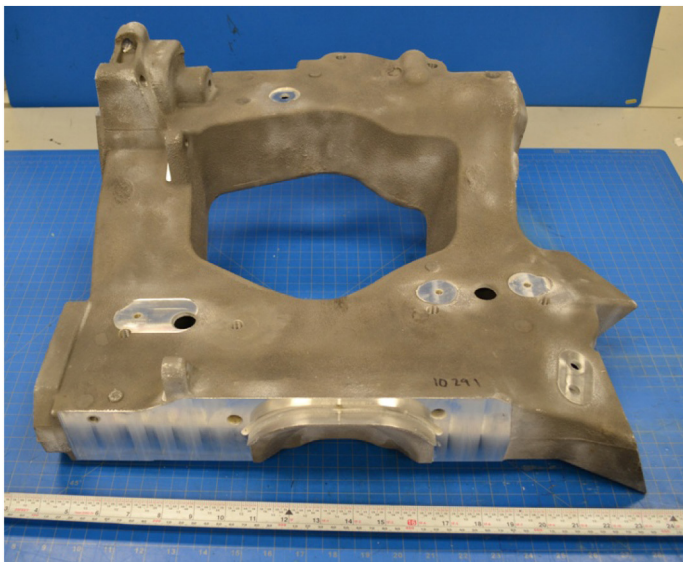


Figure 7. Rear Node - Inboard View

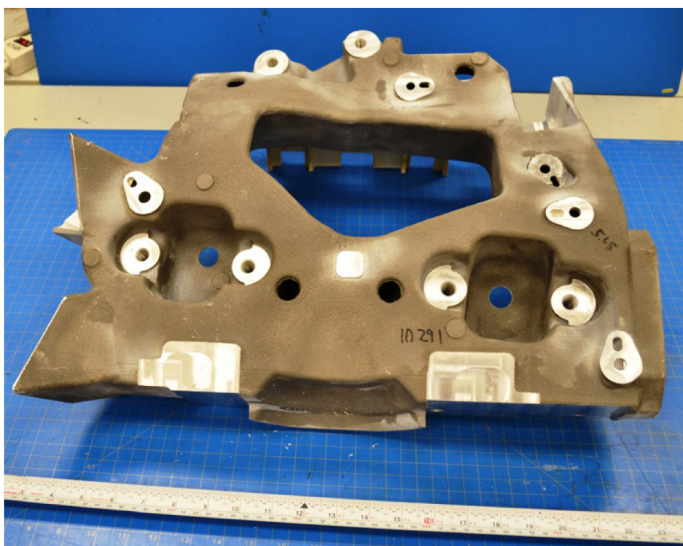


Figure 8. Rear Node - Outboard View

ALLOY SELECTION

For the node application, it was imperative to select an alloy that could provide target mechanical properties, castability requirements, good welding and fit into current mass production systems.

For mechanical properties, the goal was to create a node with Yield, Tensile and Elongation similar to the extrusions they connected to in the system. To meet this requirement, the magnesium levels had to be carefully considered. Enough magnesium was needed to provide optimal strength values, but too much would impact elongation negatively. Also, due to the upper and lower limit restrictions on Yield Strength by design, the magnesium range needed restriction. Through previous testing, it was found that magnesium levels on the lower end of the A356 specification met both the strength and elongation requirements when ablated. Therefore, the nominal magnesium level was set to be 0.27 wt%.

Good castability was also needed to create the large nodes. The long flow distances through thin walls required the alloy to have sufficient silicon content to prevent premature solidification before ablation cooling was applied. [Figure 9](#) shows the traditional fluidity vs. silicon wt% for Al-Si alloys. Increasing silicon content provides greater fluidity; however, excess silicon creates a negative impact on elongation. Therefore, it was determined the silicon would have a nominal level of 7.0 wt %. This would be above the low fluidity trough around 2.5 wt% but not excessively high. This also fits into the traditional A356 specification range.

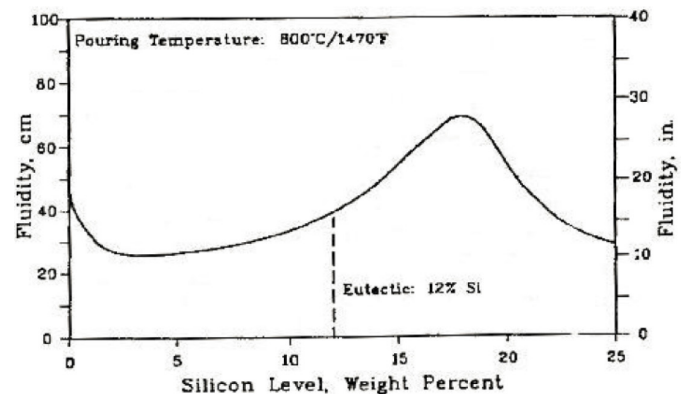


Figure 9. Effect of Fluidity of Al-Si alloy. [2]

The eutectic modifier strontium was also added to the alloy in order to guarantee eutectic refinement. In general when Strontium is not added, the structure would appear similar to the one shown in [Figure 10](#). This structure is closer to an AFS Level 3 where the eutectic is beginning to break up; however, acicular particles remain.

With the addition of approximately 100 ppm strontium or 0.01 wt% to the melt and the application of ablation cooling, significant improvements are made to the structure in terms of refinement. [Figure 11](#) shows an ablated A356 structure with 100 ppm strontium addition.