

Hot Stamping of a B-Pillar Outer from High Strength Aluminum Sheet AA7075

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ABSTRACT

This work demonstrates the feasibility of hot stamping a B-pillar outer panel from aluminum alloy 7075. AA7075 is characterized by a high strength to weight ratio with yield strengths comparable to those of DP and TRIP advanced high strength steels. Applications using AA7075 have typically been limited to the aerospace industry due to the high variable cost associated with forming and joining of these materials. A primary key to implementation in the automotive industry is the development of metal forming methods that produce non-compromised stamped parts at automotive manufacturing volumes and costs. This work explores the feasibility of die quenching a hot blank within a cold die as a means of delivering high strength aluminum sheet parts. A die made from kirksite was used to evaluate the hot stamping process for a B-pillar outer. After the forming/quenching operation, the parts were subjected to an artificial aging process to regain the properties of the T6-temper. The results show that hot stamping, followed by an adequate artificial aging treatment, produces a high strength component with material properties equivalent to the as-received T6 properties delivered by the material sheet supplier. In addition, the hot stamped B-pillar component demonstrated limited springback with a high level of dimensional accuracy.

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INTRODUCTION

Several researchers have documented various applications for AA7xxx-series alloys within the aerospace industry such as fuselage stringers and lower wing skins for jetliners [1, 2] and bumper reinforcements within the automotive industry [3]. These alloys remain attractive because they demonstrate strength characteristics similar to HSLA steels [4]. In addition, these alloys possess high fracture toughness and resistance to stress corrosion cracking. These characteristics make this family of alloys ideal for automotive components that require high specific strength. Vehicle mass savings continues to be an approach of automotive manufactures toward improved fuel economy. With alloys of this level of performance capability, strategic light weighting becomes even more promising.

7xxx-series aluminum alloys in a fully hardened temper have minimal formability at room temperature. However, tensile properties for the AA7075-T6 alloy are shown to improve when temperature is introduced. Previous work has shown percent strain of this alloy to be approximately 13 % at 20°C and upwards of 20% at 220°C [5]. The positive elevated temperature response was further pursued through preliminary

formability studies evaluating hot forming process as a possible technique for forming AA7075-T6 [6, 7]. Hot stamping is a process commonly used to form boron steel [8]. In this process, the steel blank is brought to an elevated temperature in the range of 950°C and then quenched in a die during the forming process. Hot stamping was specifically developed to simultaneously form boron steels and achieve high tensile strengths with the martensitic transformation induced by the die quench. For 7xxx-series aluminum alloys, the hot stamping process yields formed solutionized panels in a rapidly quenched W-temper. After forming, the aluminum requires an artificial aging cycle to achieve a high strength T6 or T7 temper [6, 7].

This work provides a detailed look at the manufacturing feasibility of a 7xxx-series aluminum alloy using the hot stamping process. The results show that the hot forming process, with regard to formability and part accuracy, is successful for forming this alloy. Additionally, the results presented indicate that the performance of the alloy after subsequent thermal exposure is capable of demonstrating material and microstructure properties similar to the as-received material.

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 Contours of Shell Thickness
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 max=2.58059, at elem# 134464

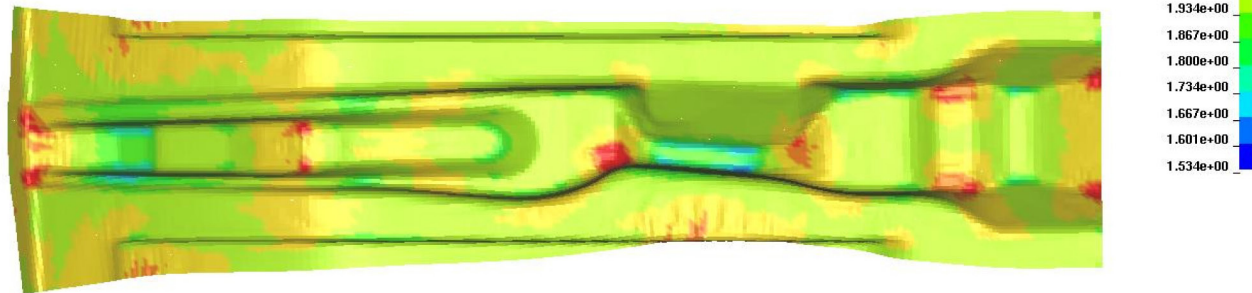


Figure 1. A blank size of $1430 \times 375 \times 2$ mm with a 17.5mm offset from the center of the die. Areas of thickening ($t > 2.0$) and thinning ($t < 2.0$) are highlighted, where t is the blank thickness.

MATERIAL OF STUDY

Industrial use of AA7xxx-series alloys is motivated by a high specific strength, good fracture toughness, and resistance to stress corrosion cracking [9]. The material evaluated for this study was AA7075-T6. Material properties for the as-received material are given in Table 1 and the chemical composition limits are given in Table 2 [10].

Table 1. Material properties of aluminum alloy 7075-T6.

Ultimate Yield Strength	577 MPa
Yields Strength	531 MPa
Uniform Elongation	8.6%
Thermal Conductivity	32.2 %IACS
Rockwell B Hardness	91

Table 2. Chemical composition for aluminum alloy 7075-T6.

Elements	Wt. %
Al	87.1-91.4
Cr	0.18-0.28
Cu	1.2-2.0
Fe	Max. 0.5
Mg	2.1-2.9
Mn	Max. 0.3
Si	Max. 0.4
Ti	Max. 0.2
Zn	5.1-6.1
Other, each	Max. 0.05
Other, total	Max. 0.15

The thermo-mechanical processing of AA7075 for this study was initiated with a solution heat treatment temperature of 475°C. Holding the material at this temperature allows for

resolutionizing of the as-received AA7075-T6; solution heat treatment typically occurs between 460-500°C [11, 12]. After the resolution, the material was quenched by the forming of the sheet within a cold die; the post-formed material was analogous to a W-temper. To regain the T6-temper properties, the material was artificially aged at 120°C for 24 hours [11, 12].

FINITE ELEMENT ANALYSIS

Finite element simulations were conducted using the commercial software LS-DYNA. Hypermesh was used to create the finite element mesh, assign the boundary conditions and to build the LS-DYNA input deck for the analysis. In the simulation a friction coefficient of 0.06 was used along with various material model assumptions; constitutive behavior was characterized using Hockett-Sherby, strain rate sensitivity was incorporated using Cowper-Symonds model, and the Barlat-89 criterion was utilized to account for non-quadratic yield exponent and in-plane and transverse anisotropy. Constants were determined through previous work. Modeling the hot stamping or die quenching for aluminum has not been fully developed. Therefore, the modeling approach applied was based on isothermal warm forming with regard to the material model and anticipated behavior. The analysis provided direction as to the blank size and location of the blank on the die for optimal formability.

A blank size of $1430 \times 375 \times 2$ mm, which is 17.5 mm offset from the center of the die, is shown in Figure 1. Areas of thickening ($t > 2.0$ mm) and thinning ($t < 2.0$ mm) are highlighted in the image according to the colored scale; where t is the blank thickness. The target thickening, used as an indication of possible wrinkling, was limited to 20% ($2.0 < t < 2.4$ mm) and thinning was limited to 30% reduction ($1.4 < t < 2.0$ mm). Various iterations were conducted that modified blank dimensions, blank offset, and die face features in an attempt to control these two parameters. Further discussion of FEA modeling can be found in a subsequent publication [14].



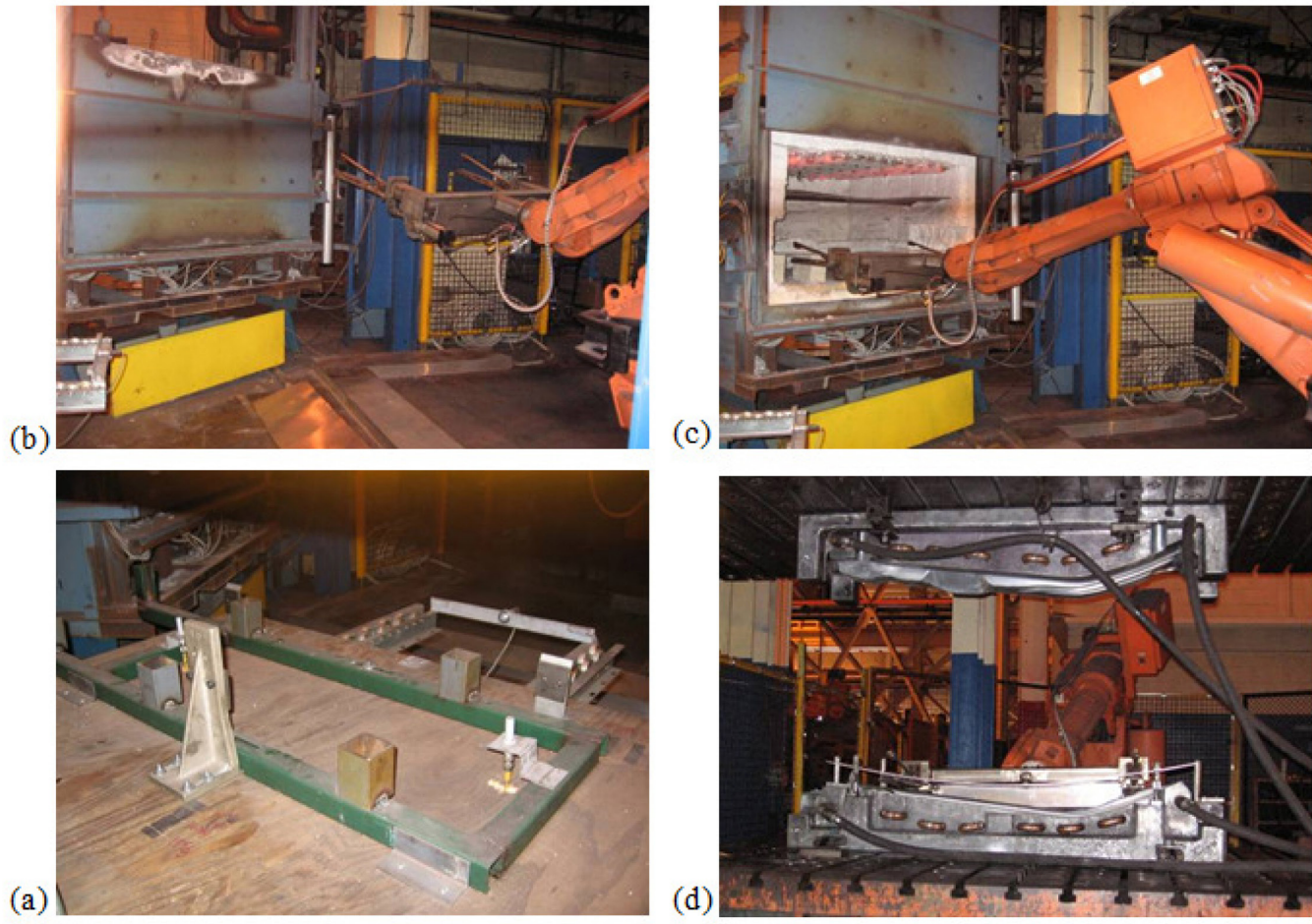


Figure 2. Images of the hot stamping process: (a) blank loading station, (b) heating of the blank in the furnace, (c) robot removal of the heated blank, (d) positioning of blank on the die by the robot prior to forming.

PRODUCTION PROCESS

The steps of the hot stamping cell are shown in [Figure 2](#) with production images. The blank was retrieved from the loading station by the robot and loaded into the furnace. The loading station ensured that the robot retrieved the blank from the same position for each cycle. The blank was then heated in the furnace for 1800 seconds. After heating, the robot retrieved the blank from the furnace and transferred it to the die. The total time between retrieval of the blank from the furnace and actual forming was ~10 seconds. The die closing took ~4 seconds and then held for 15 seconds to ensure the quench of the material. The time to complete each step once the blank was loaded into the furnace is given in [Table 3](#); the total process took 1829 seconds, 30.5 minutes. When the part was removed, it was fully cooled to room temperature. The die was lubricated with Fuchs - Forge Ease 278, a warm forming lubricant. This lubricant is a solid lubricant which was diluted with alcohol in a 1:4 ratio. The lube was applied to the die with a brush and allowed to dry prior to each forming. Further development of lubricants well suited for this process is desired.

Table 3. Time required for each production step.

Process Step	Times (s)
Blank loading	--
Blank heating	1800
Transfer (furnace to die)	8
Delay before forming	2
Die quenching/forming -die closing +quenching/forming	4
Hold time	15
Total Time	1829

KIRKSITE DIE DESIGN

The B-pillar die, shown in [Figure 2d](#), is a matched tool cast from kirksite, a zinc-aluminum alloy. Kirksite is a typical die prototype tooling material [15] that can readily be machined,