# INNOVATIVE COLD FORMING TECHNIQUES FOR THE PRECISION MANUFACTURING OF LIGHTWEIGHT ALLOY SHEETS IN ADVANCED ENGINEERING APPLICATIONS

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## ABSTRACT

To enable the manufacturing of intricate shaped panel components, significant trial has been undertaken to find better results at room temperature for low ductility of lightweight alloys of aluminum and to get higher formability. Aluminum alloys are progressively being used to reduce vehicle weight in the automotive and aerospace sectors. To that purpose, this work offers a thorough study of broadly adopted forming technologies for light weight alloys of aluminums in cold conditions, and also the material response and overall setup used in each technology. This review article aims to provide creators of process engineering with such a systematic approach to identifying the appropriate sheet metal forming methodology which suits particular demand in industry.

**Keywords:** Forming, light weight alloys, Modeling, complex components, alloys, Composite

## 1. INTRODUCTION

Aluminium alloys are one of the advanced composites that have been broadly utilized in automotive and aircraft anatomical structures [1]. Light weight alloys of aluminum have such a number of favourable properties that make it a most reliable, premium, and aesthetic metal alloys for use in wide range of areas for application. For example, one can use it for soft as well as for wrapping foil which requires more flexibility in this field of engineering. In terms of use structural engineering, light weight alloys of Aluminium are used at most after steels. Carbon emissions and rigorous greenhouse gas emission regulations have pushed transportation industries to reduce the weight of their products [2]. Depending on the size of the vehicle, full Aluminium chassis can save 70–140kg (or 30–40%) in weight [3]. Panel components, that account up a large portion of the bulk of body structures, have been the focus of much study for automotive applications, as presented in Figure. 1.[4]. Lightweight materials such as steel with very high strength [5], light weight alloys of titanium [6, 7], and light weight alloys of Aluminium [8] are mostly have applications in the automotive and aeronautics industries, resulting in increased demand in technologies related current forming science, as existing techniques and process can't meet demands for lightweight structures. Numerous researchers and industry related research and development utilities offered so many types of new reliable forming ways to cope with this challenge in the twenty-first century in the metal forming domain. In terms of application area for varied types of forming processes for sheet metal, these particular methods of forming have both advantage and drawbacks.

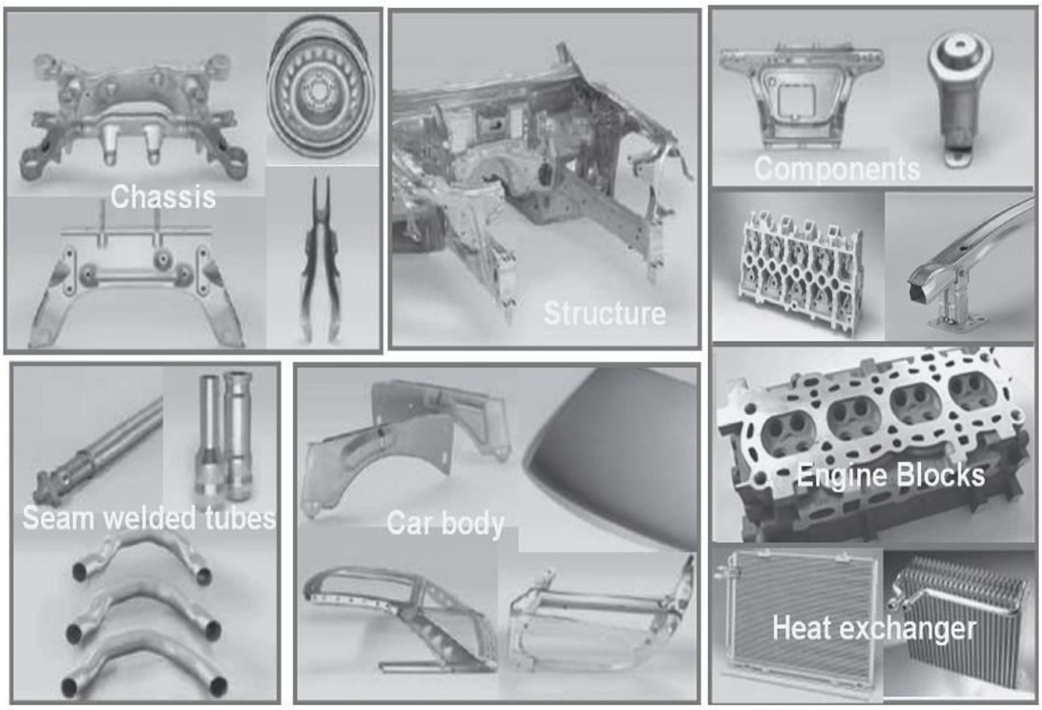



**Fig. 1. Currently used light weight alloys of aluminum under areas of automobile [4].**

Because panel components make up a major amount of the bulk of body structures, as illustrated in Figure 2 [9], they have attracted a lot of attention in the aerospace industry. Heat treatable AA6xxx, AA7xxx, and AA2xxx, as well as non-heat treatable AA5xxx, are popular choices in the automotive and aerospace sectors. The most common raw material options for panel structures are wrought aluminum alloys.


**Fig. 2. Different parts of airbus 380 made up with light weight alloys of aluminium [9].**

## 2. LIGHT WEIGHT ALLOYS AND MATERIALS

### 2.1 Alloys of Aluminum

Light weight alloys of aluminum are most demanding materials for decreasing automobile weight, and their demand are increasing day by day. Naka et al. used test for stretch forming at various speeds and temperature to conceptualize its effect on forming limit diagram for alloy of AlMg sheet of fine grains. [10,11]. Li et al. used the torsion test method to examine the behaviour of deformation of uniaxial tensile of three light weight sheets of Aluminium alloys: Al 6111-T4, Al 5182 and Al 5754 and in the temperature limits for hot forming [12, 13]. Also hot and warm formability of the 2618 Aluminium alloy was investigated, with precipitation being discovered during deformation. [14]

### 2.2 Alloys of Titanium

Alloys of titanium have particularly very good strength and great resistance to corrosion, which are both advantages. Titanium alloys are used in aircraft applications because of its strength, weight, corrosion resistance, and stability under high temperature limits [15]. The Airbus A340/330 has a fuselage made up of roughly two-thirds Aluminium. Titanium alloys account for around 7% of structural weight, which is comparable to steels. But titanium is next to other materials that are used in jet engines, after Ni-based super alloys, with almost a third one of the structure weight and alloys of titanium are most used materials in engines by volume [16].

### 2.3 High-strength steels

The growing usage of best steels of high strength such as 27 MnCrB 5, 22 MnB 5, and 37 MnB 4 in the areas of automobile has been trending which cannot be avoided under application of reducing weight of vehicle and must give a high level of security [17]. Boron steels and martensitic steels are trend setter for renowned AHSS materials [18]. Individual vehicle models and firms have accepted the use of steels of next generation in a very pace rate than the fleet average and the C body class of Mercedes are redesign in about 37 percent to 73 percent steel of high strength, while the BMW X 6's body and closing structures are made up of 31 percent AHSS [19]. According to Ducker Worldwide, the automotive application will expect an annual growth of about 11% in AHSS from now from the year 2020 [20].

## 3. COLD FORMING

### 3.1. Cold stamping

Stamping under cold conditions with dies used having good stiffness is thought to be the most basic and famous process of forming for light weight alloys of Aluminium, particularly for AA5xxx which not a heat treatable alloy. The ductility of AA 6111 alloys which is heat treated, such as illustrated in Figure 3, is quite low in the T6 state, which is not ideal for manufacturing intricate structures. Forming of W temper [24] or under T4 temper conditioned stamping are employed to overcome this problem. The extremely saturated solid solution condition following solution heat treatment is referred to as W-temper [25].

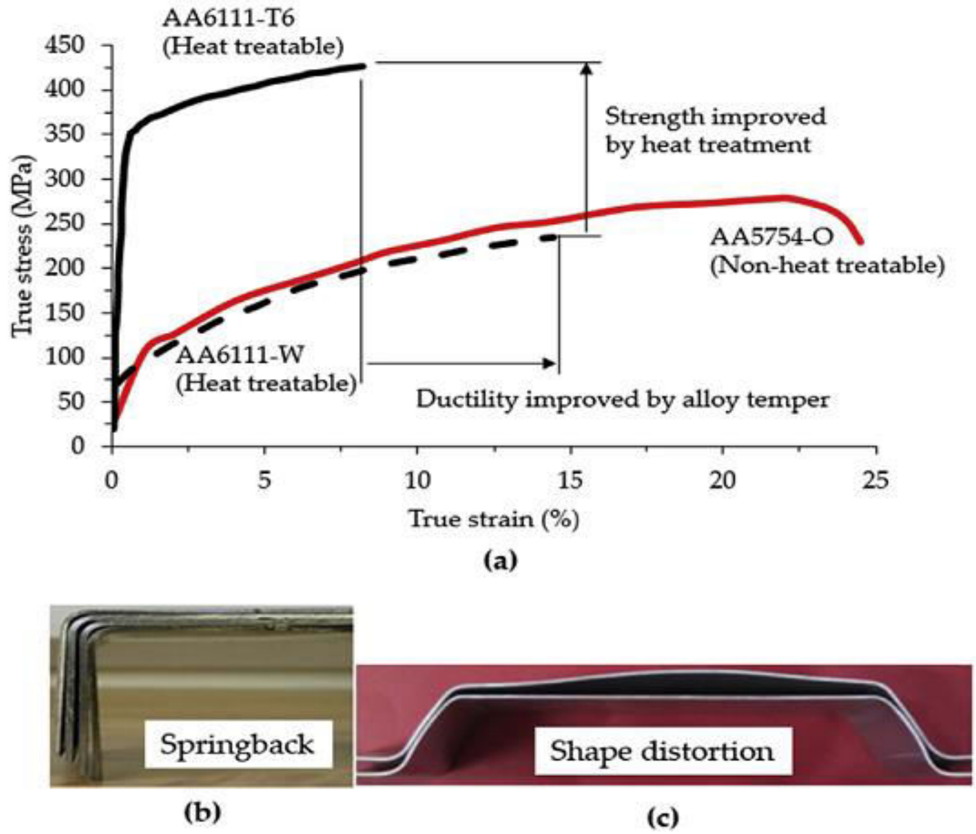
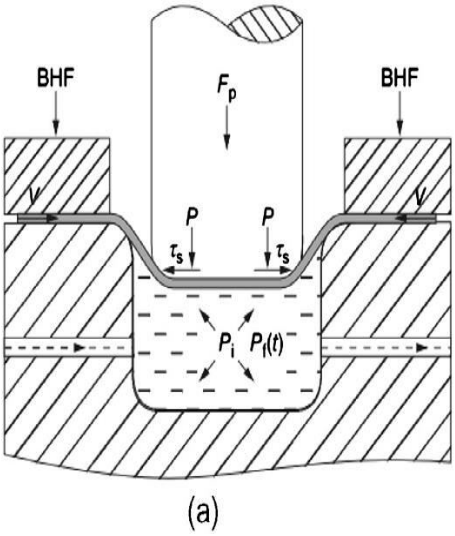



Fig. 3. Cold stamping with stiff dies has the following characteristics: (a) Curves of stress-strain for various alloys [35,36], (b) defect of Spring back [26] (c) Additional heat treatment causes shape deformation [27].

As demonstrated by the dashed line in Fig. 3, alloys in this condition have decreased strength but enhanced ductility. To recover the microstructure and mechanical qualities of T6 temper, extra heat treatment is required to strengthen the strength under tension of W temper or T4 produced parts. During the extra heat treatment, however, defect of spring back [26] and distortions due to quenching [27] may occur for most alloys of high strength [28].

### 3.2. Hydroforming process

Hydroforming is a method in which a medium of fluid is used to create a soft and slow punch to obtain sheets. This method is a famous and used in varied applications of engineering where light weight alloys predominates. Asper to the different methods property characteristics and the use of numbers of blanks as original the process of hydro forming are categories with two headings that are tube hydro forming and sheet hydro forming [28]. Hydraulic deep drawing is a normal sheet hydro forming process, as seen in Fig. 4. When force due to the punch applies in the sheet metal into the die chamber, which may include hydraulic oil used for this application, the sheet metal is punched in required shape of die due to application of high pressure. Due to this action a complex shaped parts can be produced with good accuracy and features. Another approach (see Fig. 5) is standard sheet hydroforming, in which a punch made up of rigid material is changed by pressured fluid and the blank is shaped as per shape of die.



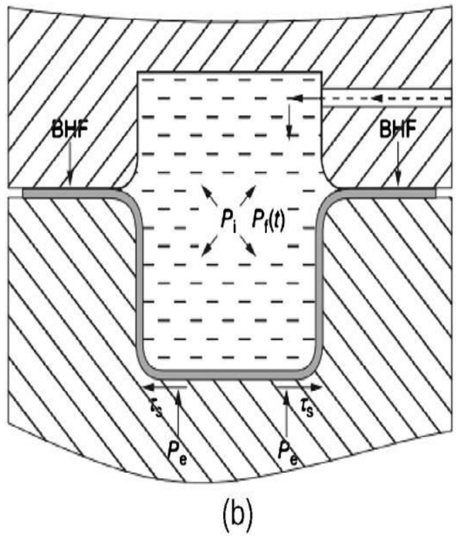




**Fig. 4.** Deep drawing by haudralic pressure [29].

**Fig. 5.** Traditional Hydroforming of sheets.

### 3.3. Viscous pressure forming (VPF)

Rigid punches are changed and high pressure are applied with help of some viscous fluid medium and it is applied in one of the side of leight alloy blank.Apart from this back pressures are also applied simultaneously to get better result in forming of light weight metal alloys sheet in the VPF process (see Fig. 6). The VPF method are used to produce intricate shaped parts having a good surface finish features and also the process produces a high of dimensional accurate product while also reducing leakage [30]. Furthermore, the VPF technique has the benefit of manufacturing better strength and other light weight alloy parts that are very critical to form using traditional forming process of sheet metals [31, 32].

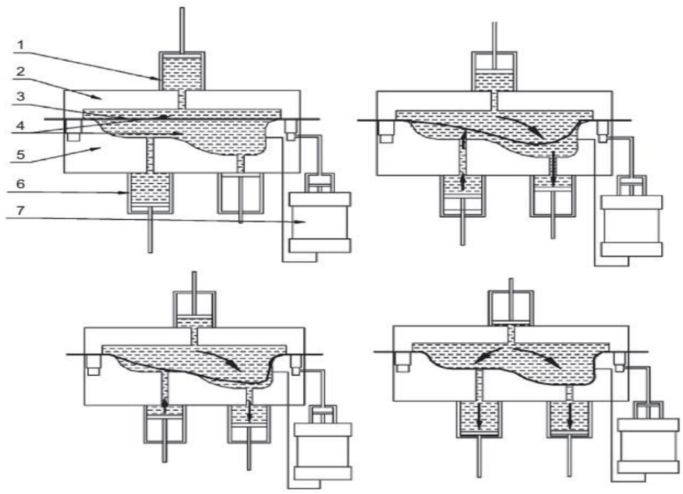



**Fig. 6. Figure for VPF [23]: (1) cylinder for injection (2) die used in upper side (3) sheet blank (4) viscous fluid (5) die (6) outer cylinder (7) cylinder holding blank.**

### 3.4. Cryogenic forming

Reduced discontinuous deformation of stamping AA5xxx at ambient temperature promotes cryogenic forming [33]. Discontinuous deformation is characterised by the production of deformation bands, which not only create unsightly imprints on panel surfaces, but also impair the alloy's ductility [34]. The Portevin-Le Chatelier (PLC) effect [35] is the name given to these phenomena. Aluminum alloys may be manufactured preferentially at temperatures at cryogenice range (lower than room temperature) to decrease the harmful influence of the PLC effect. In most cases, formed sheet metal blanks will suffer tensile deformation in one direction. The Portevin-Le Chatelier effect generated by Cottrell environment and displacement motions is thought to be the process of cryogenic formation. The diffusivity of pre-dissolved extra atoms is often decelerated whenever the light weight alloy with a W temper is under cryogenic conditions, due to which it create Cottrell atmospheres of nearly equal intensity over the equal amount of time improbable. Due to above result, the magnitude of force required to move the displacement across a lattice of crystal can be increased. Precipitates with conditions produced over time are able to supporting the origination and further development of atmospheres of Cottrell for T6 and T4, are unfavorable conditions for process of forming under cryogenic environment as discussed in the previous explanation [36]

### 3.5. Solid Granular Medium Forming

Due to some disadvantage of Hydro forming such as leakage and resistance to heat is low, a new method was developed for cold processing of light weight alloys that is Solid Granular Medium Forming [37-39]. A granular media substitutes liquid or any viscous fluid for transfer of force to the sheet blank in this method. As it is well known that most of the fluids that are utilized under process of hydro forming methods works only upto 350 C and above this temperature these fluids are unstable and can affect the working parameters of the process. To solve these problem granular forming method uses solid granular medium due to which process can be worked under elevated temperature conditions and also selection of such materials can completely solve the problem of leakage in the previous discussed methods. This process, like the hydroforming approach, can produce both tube and sheet pieces as shown in Fig. 7 and 8. Furthermore, as distribution of solid granule is uneven or non uniform distributed so inside pressure may dramatically enhance process formability, and work piece does not become so thin as the contact of the metal surface of blank sheet and solid granule medium was maintained throughout the process [38].

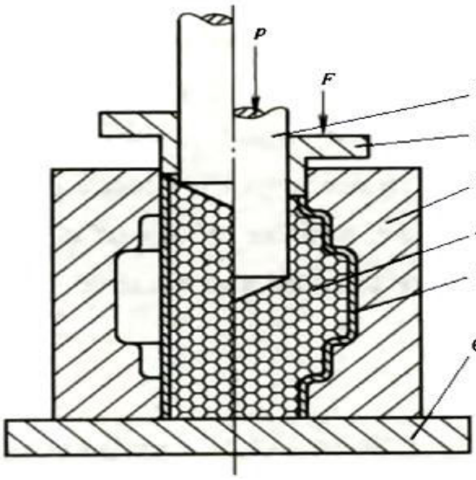



**Fig. 7. Photo of deformed typical parts [37].**

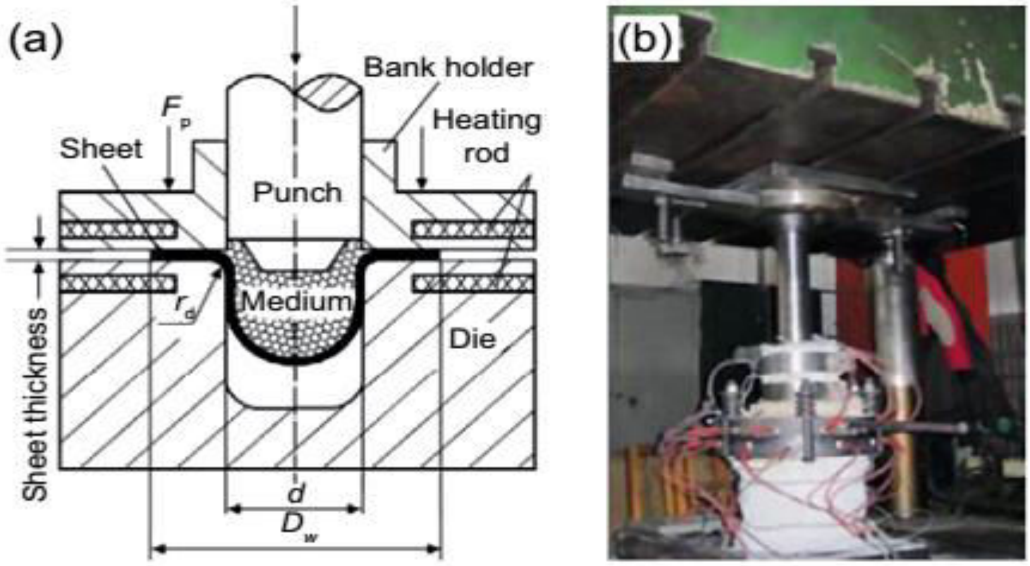



**Fig. 8. Experimental setup for drawing of AZ 31 B light weight alloy of magnesium [39]. (a) Deep Drawing, (b) Exp. setup of Drawing.**

### 3.6. Gradual Sheet Forming

Matsubara was first to implement incremental forming in Japan in 1993 [40], while Emmens et al. [41] published a detailed study of incremental sheet forming advancements. As illustrated in Fig. 9, the process may be classified into distinct kinds based on tool setups [42]. Single point gradual forming is one of the most often utilised among them. The blank holder is used for clamping and holding the sheet in place when the process of Single point gradual forming. The backing plate holds the sheet blank in place and the operating area is defined by single point tool used for this forming. A CNC machining centre generates the route for the revolving single point tool for forming, which is used to gradually shape the part from the sheet blank. Backup die is not used that maintains a bottom surface of distorted sheet blank during the forming process [43].

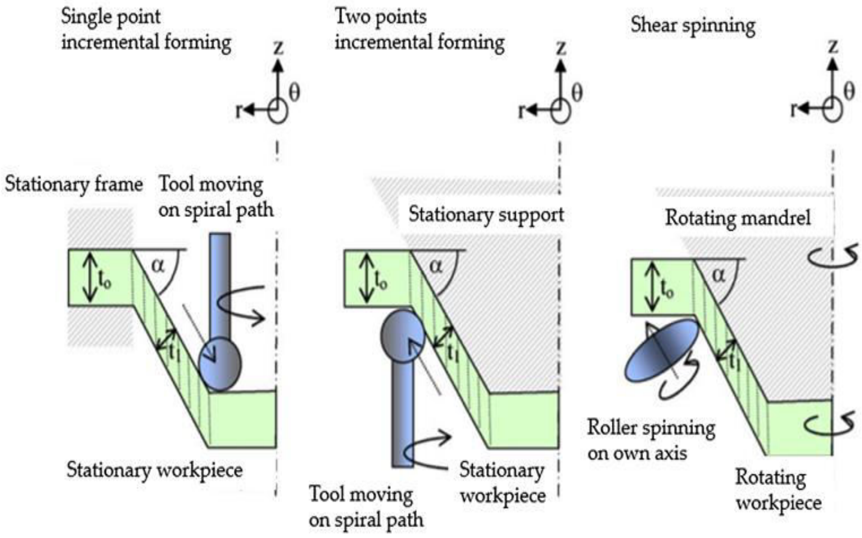



**Fig. 9.** Incremental sheet forming schematics using variable tooling configurations [42].

## 4. CONCLUSION

To assist accomplish the aim of emissions and energy reduction, light weight alloys for example high strength steel, light weight alloys of titanium and aluminum are commonly employed. Recent breakthroughs on several specific sheet blank forming technologies and their sheet forming principle are critically presented in this study. Goal are for assessing various results of conducted research so far and showing current uses in the aeronautics industries and automotive applications.Generally,some techniques, such as hydroforming, are widely employed in construction of difficult to form and complex shaped parts when traditional forming processes fail to meet the manufacturers' criteria. Other approaches are still in the laboratory and need to be perfected before they can be used in modern enterprises.

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