COMPARISON OF TECHNICAL AND COMMERCIAL ASPECTS REGARDING COLD FORMING, SPF AND HOT DEEP DRAWING

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Abstract

Titanium parts can be very expensive or can be a good compromise between cost and efficiency. Parts can be very satisfactory regarding the benefit for the customer especially if expected cost and weight reduction is reached or exceeded. Titanium properties are always well desired. The high level of material cost and the cost of manufacturing are of course not appreciated. But there are rather big differences concerning material waste, cycle time, process cost, intelligent tool design, overweight from minimum wall thickness requirements not well possible by the individual process restrictions. The paper describes decision guidelines to find the right process for a given inquiry asked by the client concerning alloy, service loads, number of load cycles, temperature, quantity, optical appearance, etc. etc. The total picture has to include the following assembly processes. Some representative solutions are described.

Keywords:
Titanium alloy, sheet metal, hot forming, laser beam welding, cost reduction

1 INTRODUCTION

The following paper characterises the advantages and disadvantages of SPF in general and specifies appropriate SPF-applications. Additional FormTech process technologies such as hot bending, hot calibration hot stamping/hot deep drawing/hot isothermal forming and advanced combination of these processes are described. Geometrical requirements and needed follow-on processes like LBC and LBW (Laser Beam Cutting/Laser Beam Welding) require an optimized and improved forming process. The combination of advanced forming together with LBC/LBW contribute to a considerable added value.

2 PART 1

SPF-advantages and disadvantages in general

SPF is a relatively expensive process and the cost saving potential is limited. However, it has some unique advantages: It is a one-step-process with large strain and the stress relaxation occurs in the process itself. Complex shapes and the combination with DB (Diffusion Bonding) for sandwich parts are possible. Nevertheless, there are also several disadvantages: The materials itself suitable for SPF such as Titanium are expensive. The long cycle time due to the low SPF strain rates causes on one hand high manufacturing costs of the process. The long cycle times effect on the other hand a relatively thick α-stabilized layer that is expensive to remove. Even distorsions from handling and cooling may occur. But the biggest disadvantage of SPF parts is the varying wall thickness that make follow-on processes as automated LBC/LBW very difficult. For SPF parts there are some possibilities to enhance the cost reduction potential. Optimized forming parameters and the choice of more appropriate material regarding part geometry, temperature and strain rate will reduce the costs. Improved sequences of work steps in part handling or tool change hot/hot show a benefit. Nevertheless, the decision for SPF process is restricted to geometries where no other process option is existing.

Parts from Ti-6Al-4V well suited for SPF-process

Some special parts like hemispheres (Fig.1) or heat shields (Fig.2) for high performance sports cars from Ti-6Al-4V are well suited for the SPF process. Hemispheres SPF-formed from a premachined blank are featuring the required targeted wall thickness in equator, pole and membrane. For parts like hemispheres, SPF is the most economic process compared with alternative forging and heavy machining. Parts like heat shields show a complex pattern of reinforcing ribs but only a limited forming depth. So no critical wall thickness reduction appears. Including the possibility of forming multiple parts in one cycle SPF can be the cheapest solution if a complex geometry is required at a low part quantity.

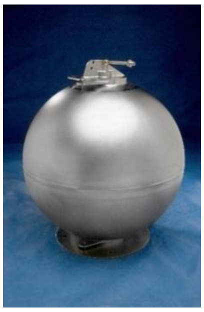

Fig.1: Hemisphere Ti-6Al-4V

Fig.2: Heat shields Ti-6Al-4V

Hot forming processes at FormTech besides SPF

Hot bending and hot calibration

In all hot forming processes for sheet metal shaping, the avoidance of residual stress from strain hardening as in cold forming processes is important. Parts like fitting shields for aerospace application (Fig.3) are exposed to varying temperatures and have to keep their shape during the entire operating time. The main advantage of a hot bending process is the achievement of very small bending radii with a ratio of radius r to thickness t around $r/t \approx 1$to 2 in Ti-6Al-4V.

Hot calibration as the next hot forming technique can be applied even on big parts such as leading edge structures for wings and vertical tail planes (Fig.4). Due to a modular tooling and handling concept any length seems to be imaginable. Hot formed parts feature close tolerances of their 3D-surface and therefore automated trimming and assembly with LBC/LBW is possible without manual rework.

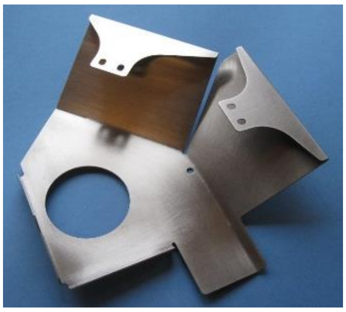

Fig.3: Fitting shield Ti-6Al-4V

Fig.4: Leading edge structure

<u>Hot deep drawing (HDD) with a double action press</u>

An apparently old-fashioned cold forming technology has been upgraded with a double action press and blankholder with advanced equipment (Fig.5). FormTech has a successful cooperation with the company “Schuler AG”. In addition to the omnipresent requirement of elimination of residual stress HDD has several more advantages accumulating in considerable weight and cost saving. The process allows a controlled material flow to achieve parts with constant wall thickness (Fig.6). This is the basis for automated follow-on manufacturing steps and generates low material waste. Due to short cycle time and a possible lower temperature there is only a thin surface layer that can be removed easily with a rather cheap process. With HDD it is possible to produce parts from Titanium alloys with a very high precision in addition to cost and weight saving.

Fig.5: Upgrade in HDD

Fig.6: Angle Ti-6Al-4V, constant wall thickness

<u>Combined process of HDD together with SPF</u>

A highly developed forming technology for Titanium alloys is the ground-breaking combination of HDD together with SPF. The double action press for HDD has to be equipped with the additional integrated SPF control station to allow advanced part design (Fig.7). In this case advanced part design means the combination of a “primary geometry” which is optimized for HDD with a “secondary geometry” that can be very complex and thus suitable for SPF forming (Fig.8).

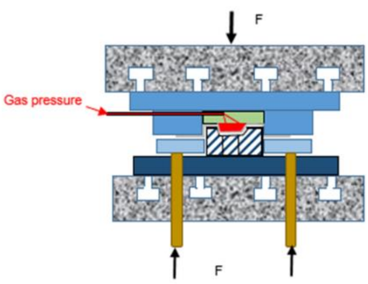

Fig.7: Principle of the combined process HDD/SPF

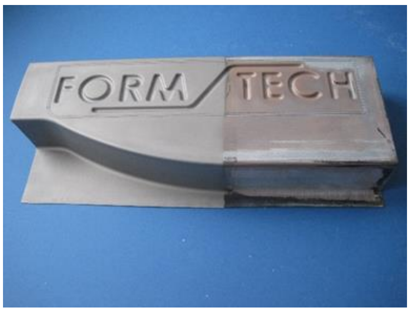

Fig.8: part with primary and secondary geometry, Ti-6Al-4V

The combined process is e.g. also applicable for aircraft “housing” (Fig.9) or “cap-type”-parts (Fig.10). Preforming of the ”primary geometry” is the first step done by HDD. Subsequently the final geometry is carried out by SPF. The combined process is successfully described by FEM simulation: The cycle time is around 60% shorter and in addition to this cost saving aspect there is another from weight saving also around 60% due to a thinner starting gauge. The new combined process allows an initial wall thickness near t_{min} (Fig.11) because the wall thickness reduction is negligible.


Fig.9: Aircraft housing

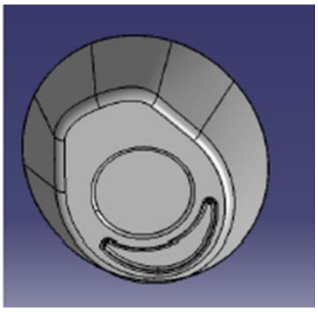
Fig.10: Aircraft cap

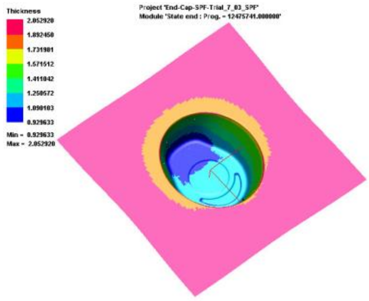
Fig.11: FEM simulation

Value chain: HDD in combination with automated welding process LBC/LBW

Because of its close tolerances of their 3D geometry parts manufactured by HDD offer perfect conditions for automated follow-on processes like LBC/LBW. A good example shows the evolution of a “Bleed Air” T-duct from the design as 3D-model (Fig.12), the FEM-simulation (Fig.13) and the hot formed, trimmed and LB-welded T-duct (Fig.14).

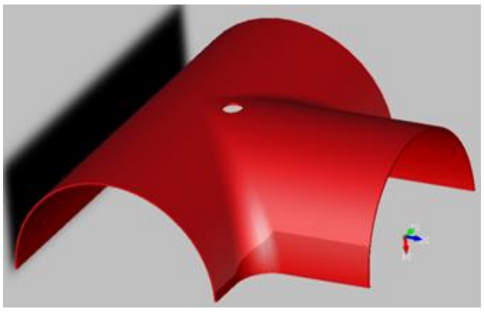
Fig.12: T-duct 3D-model

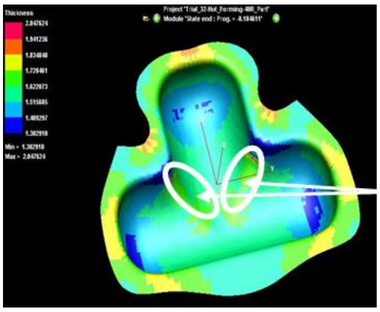
Fig.13: FEM-simulation

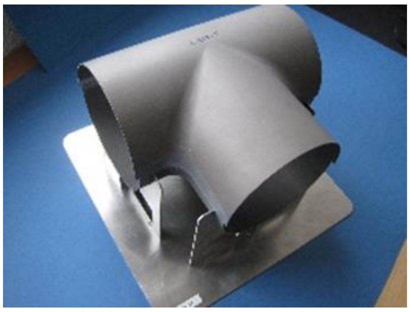
Fig.14: T-duct LBC/LBW

The conventional process involves multiple draws at ambient temperature with intermediate trimming, annealing and pickling. The cold forming process is limited to CpTi and Ti-3Al-2,5V and causes a high amount of scrap. With HDD, only one draw is sufficient for each half shell. The geometry is very precise so that any manual rework is needless. LBC is applied only once for the final trimming in a combined set-up for automated LBC/LBW. The removal of the thin surface layer is easy and relatively cheap, so that the total amount of cost saving is around 30%.
Another application for precisely formed parts suitable for automated LBC/LBW-process in an aircraft engine exhaust cone, the 3D-model is shown in Fig.15 and the finally assembled part in Fig.16.

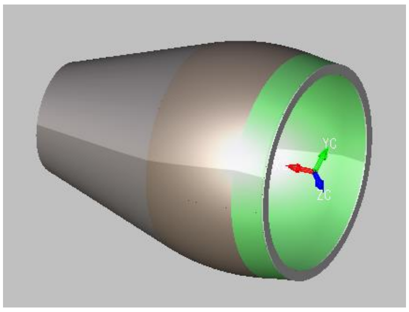

Fig.15: Aircraft engine exhaust cone 3D-model

Fig.16: Finally assembled part

The engine exhaust cone consists of a cold rolled conus with reinforcement rings and a “coke bottle”-shape from three 120°-segments (Fig.17) made with HDD. The assembly of the details is carried out completely with automated LBC/LBW. In comparison to the conventional part in IN625, a cost reduction of 20% and weight reduction of around 33% can be achieved.

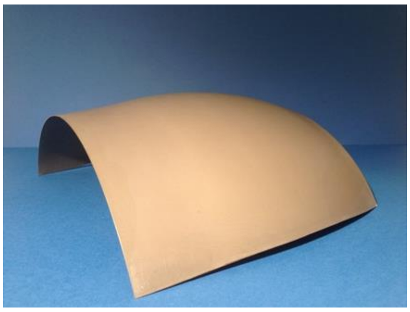

Fig.17: 120°-segment produced by HDD

An ingenious example for cost and weight saving by HDD and subsequent LBC/LBW is a part located in aircraft door surrounding (Fig.18). For the door surrounding part there is no weight reduction achievable because of the identical wall thickness. But in difference to the conventional manufacturing process of machining a tremendous material saving of 92% is attainable. The total cost saving adds to around 38%.

Fig.18: Aircraft door surrounding Ti-6Al-4V

FormTech´s forward-looking activities in R&D are aimed at offering a benefit for the client and simultaneously protecting the environment by saving material. The approach is realized by continuous improvement of SPF-process, also SPF/DB and the development and industrial application of advanced forming processes.