HOT FORMING

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Part 1

Application of Advanced High Strength Steel alloys (AHSS) has largely increased, especially in the automotive industry. Due to its low formability at room temperature and their considerable springback, alternative solutions in sheet metal forming of AHSS are being developed and studied. The process known as “Hot Forming” or “Hot Stamping” has gained visibility as a suitable solution and has fostered many areas of research aiming to improve this method.

The main difference between hot and conventional stamping method is the heating of the material above austenitization temperature, before forming. Since the material ductility increases with temperature, it is easier to form high strength materials by hot stamping. After heating, the material is transferred to the press where it will be formed and subsequently quenched while the part is still placed in the tool. The heat treatment process consists in quenching the material by dies that are internally cooled by water flow through internal ducts. Afterwards, the part is cooled by the air until it reaches room temperature. When maximum strength is desired one strives to obtain a fully martensitic microstructure. However, if that is not the case a mix of the other microstructures may be the goal.

The use of AHSS allows thinner pieces being manufactured without losses in mechanical resistance. This way a wide range of possibilities opens with the application of hot forming process, especially in sectors where a good weight-mechanical strength ratio of parts is decisive for the use of a given process or material. There are two different techniques of hot stamping: direct and indirect method, and this will be covered in the next topic of our series of posts about Hot Forming.

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Part 2

As discussed in our first post of this series, hot stamping is a forming method where the material is first heated above the austenitization temperature, formed and quenched by the tools. There are two methods of hot stamping: direct and indirect, and this will be the subject of the part II of our series on hot forming.

In the direct method, first the blank is austenitized at temperatures between 900°C and 950°C for 4 to 10 min in continuous-feed furnaces. Next, the blank is transferred from the furnace to the press, where it will be drawn and then quenched by the contact with cooled dies. The transfer of the blank must be agile to avoid corrosion and heat loss, this way it usually takes less than 3 seconds to complete the action. The total forming cycle, including transferring, drawing and cooling, takes around 15 to 25 s. Finally, the part is extracted from the tool between 150°C and 200°C, and it's cooled by the air until room temperature for 10s to achieve a tempered microstructure.

The indirect method consists of a cold pre-forming operation, where the part achieves 90 to 95% of its final geometry, followed by a trimming operation. Then the part is heated until austenization and finally subjected to a second drawing and a quenching step. By using the indirect method, the formability is extended and therefore more complex geometries can be hot formed.

Corrosion occurs when high temperature steel comes in contact with oxygen forming a high mechanical resistant coat on steel's surface. This phenomenon takes place while transferring the blank from the furnace to the press. This should be avoided because final mechanical properties of the part may be altered and accelerated tool wear may occur. As an alternative to minimize these effects, AlSi coated steels are usually applied on hot forming, as well as furnaces with oxygen-free atmosphere on the heating step.

The greatest advantage of hot stamping is the possibility of manufacturing highly complex parts, in addition to forming thinner parts with higher mechanical resistance. Higher dimensional accuracy is obtained because of the minimum springback when there is good process control. Another great advantage of the process is the increase of the acceptable thinning percentage as a consequence of the increase in the material's ductility when formed at high temperatures.

Automotive industries take advantage of all these benefits of hot stamping. They are highly concerned with improving vehicle crash performances and reducing structure parts weight without losing mechanical resistance. In order to achieve these goals, the combination of hot forming with advanced high strength steels has been one of the most applied solutions. Besides, there are many other techniques that can be tied to hot forming in order to improve the performance of the parts such as tailored blanks, and this will be the next topic covered in our series of posts on Hot Forming.

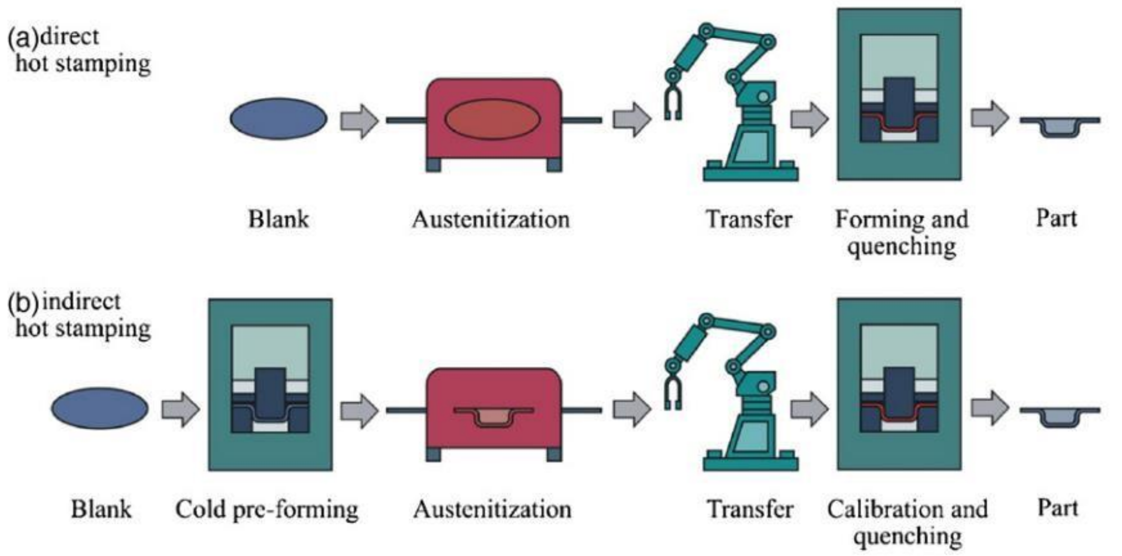

Figura 1 – Basic hot stamping process chains: (a) direct hot stamping (b) indirect hot stamping (adaptado do artigo "A review on hot stamping", Journal of Materials Processing Technology, H.Karbasian, A.E.Tekkaya, 2010)

Part 3

Nowadays the concern about environmental protection is increasing and the requirements are becoming more rigorous. Therefore, automotive industries are being forced to reduce the emission of CO_2 and are doing so by reducing the total vehicle weight. In order to achieve a considerable weight reduction, hot forming has been successfully applied in combination with AHSS to form lighter and thinner parts with ultrahigh strength.

The most commonly steel grade used in hot forming process is the 22MnB5 grade. The addition of Boron into the chemical composition of this steel alloy increases the weldability and decreases the critical cooling rate to achieve a fully martensitic microstructure. The addition of manganese increases the tensile strength of quenched materials.

A typical application of hot stamping in automotive industry is the manufacturing of body components, such as A-pillar, B-pillar, bumper, roof reinforcements and inner door reinforcements. Body structure of cars are designed to guarantee passengers safety. The passenger compartment must have minimum deformation, while the outermost part of the body absorbs energy by plastic deformation in case of impact.

This way, components with tailored properties and functionalities in different zones of its geometries are desired. In spite of manufacture such components, some techniques are applied to hot forming, like tailored blanks and tailored quenching. The tailored blank technique consists of stamping a blank composed of welded joints. Each joint is made from a different material or different thickness that are defined according to the requirement of each region of the component.

The tailored quenching technique consists of subjecting different zones of the component to different cooling rates. In this case, the die is maintained with zones at different initial temperatures, so that different microstructures can be achieve in each zone. Another way to promote tailored properties is to locally austenitize the part in the furnace, by sectioning the furnace compartment. A-pillars and Bpillars are classic examples of components that require tailored properties along its geometries.

As discussed until now in our series on hot stamping, is clear that hot forming has several advantages and it is a flexible process that allows the introduction of other techniques. But, in the other hand, it has some limitations due to the complexity of the method and to the several influencing parameters. The final post of this series will contemplate the limitations of the process and the implications of computational simulation on hot forming.

Part 4

Hot stamping is a thermo-mechanical forming process that involves several phenomena happening simultaneously during forming, such as phase transformation and plastic deformation. Because this process considers many fields interacting at once, FE simulation is a valuable tool that contemplates the relationship between thermal, mechanical and microstructural fields. Nowadays computational simulation is essential during project stages and to improve process already implemented.

Finite element simulation requires some process characteristics as inputs such as heat transfer coefficient between workpiece and die, material flow stress curve, applied load in the part by the tool during quenching, gap between tool and blank as well as time spent to transfer the blank from the furnace to the press. This way the software can properly model the final microstructure, final geometry and mechanical properties like strength and hardness of the workpiece. An accurate simulation result depends on an accurate modeling of the thermal phenomena during forming and quenching. Nowadays there are several software dedicated to the stamping field, which includes hot stamping, and companies specialized in simulation services.

Another important aspect of the simulation is that tryouts requirement is greatly reduced because simulation results give a better idea of where the corrective action must be taken. This fact is extremally beneficial because it can turn the problem-solving process more dynamic, reduce blank waste, and minimize tooling alterations.

Despite all hot forming advantages, this process also has its limitations. Due to the heat treatment applied on the part, the mechanical strength of the material increases turning conventional trimming processes unfeasible. In this situation conventional trimming process would provide considerable tooling wear, thereby frequent tooling repair and replacement would be required. Another concern is that the press load require for a conventional trimming operation in hot stamped parts would be so high that the equipment would be too expensive. Laser trimming turns out as an alternative for this issue since it does not depend on shear forces and therefore tool wear is not a concern anymore.

However, the laser-cut technique usually increases the manufacturing cycle time and increases the process costs. Therefore, part trimmings should be minimized. One of the alternatives to reduce trimming operations is to use blanks with a design closer to the final profile of the part, decreasing the scraps. Another alternative is to take hand of the indirect hot stamping method. Since this method has a cold pre-forming operation, it allows a conventional trimming intermediate step before hot stamping the workpiece.

Given these points the series about hot forming is concluded. This review showed that hot forming is an innovative and promising process, which its application and visibility has increased in the stamping industry as time passes. It was discussed the several areas of knowledge that this process covers, also its advantages and its limitations. It is clear that Hot Forming process fosters development, optimization and research on several areas. We hope that this series has contributed to all interested readers, and somehow aroused even more curiosity about this important stamping method.