

# Thixoforming of aluminium alloy for weight saving of a suspension steering knuckle

**A. Fuganti, Centro Ricerche Fiat, Chassis & Body Design Dept., Italy**  
**G. Cupitò, Centro Ricerche Fiat, Advanced Process Technologies Dept., Italy**

## Abstract

*The employment of light alloys aimed at weight saving is becoming a stringent need in the transport industry due to the environmental and social pressure. Fuel consumption and exhaust emissions are in fact strongly dependent on car weight and for such a reason, the automotive industry is looking at both innovative process technologies which make use of light alloys and new design methodologies.*

*On such a base, after a brief analysis of the approach to be adopted for meeting the environmental goal, the paper describes the development of a suspension steering knuckle through the application of thixoforming technology of an aluminium alloy. It is described the methodology which was used for material/technology choice and component optimisation. A component weight saving of about 30% was obtained, compared to the previous solution made of cast iron.*

*Prototypes of the optimised steering knuckles were manufactured by using a thixoforming Bühler machine.*

*The following metallurgical analysis and bench testing demonstrated the suitability of thixoforming process for the development of aluminium safety parts.*

## Riassunto

L'impiego di leghe leggere finalizzato alla riduzione di peso sta diventando un bisogno stringente nell'industria dei trasporti per effetto della pressione ambientale e sociale. Il consumo di combustibile e relative emissioni sono fortemente influenzate dal peso della vettura e di conseguenza le aziende automobilistiche stanno valutando sia tecnologie e leghe leggere innovative che nuove metodologie di progettazione.

Su tale base, dopo una breve analisi dell'approccio impiegato ai fini di raggiungere questo obiettivo ambientale, l'articolo descrive lo sviluppo di un montante sospensione attraverso l'applicazione del processo di thixof ormatura di una lega di alluminio.

È descritta la metodologia adottata per la scelta del materiale/tecnologia e per l'ottimizzazione del componente. È stata raggiunta una riduzione peso del componente di circa il 30% se confrontato con la soluzione precedente in ghisa.

Impiegando una pressa Bühler, sono stati prodotti un certo numero di prototipi di montanti sospensione ottimizzati.

La successiva analisi metallurgica e le prove al banco hanno dimostrato che il processo di thixof ormatura è adatto allo sviluppo di componenti di sicurezza in lega di alluminio.

## INTRODUCTION

Transport industry represents a really important sector for the economical and social world.

In the last years the need of decreasing the vehicle weight is becoming stronger due to the environmental and social pressure which is backed by legislation.

Fuel consumption and exhaust emissions are directly dependent on engine efficiency and car weight.

Engines have already reached a remarkable efficiency and so the improvement possibilities are limited.

Concerning the weight reduction, the improvement field is by far wider. In fact it has been demonstrated that weight saving has a strong influence on fuel consumption reduction if seen not only on the single vehicle but considering the fleet economy.

There are two ways of meeting these goals:

- optimising the component design employing the same material;
- replacing traditional materials with lighter ones.

In the first case, it is important to acquire high knowledge of employed materials and processes in order to exploit at maximum their capabilities.

Relating to the material replacement, the automotive industry is looking at innovative process technologies, new design

methodologies, development of light alloy applications.

The objective concerns in particular cost reduction and mechanical properties improvement. In fact traditional processes are not all suitable for light alloys application both from a cost and reliability point of view.

First of all the automotive industry is looking at components which permit to obtain an higher added value besides the weight reduction as safety, comfort etc. Structural components like suspension parts are nowadays taken into consideration because their mass reduction (unsprung masses) has a strong influence on the car comfort and handling.

From the process point of view, the research is looking at process which can guarantee Near Net Shape (NNS) parts with the possibility to integrate more functions in order to reduce the manufacturing costs. For such a reason a great effort was addressed at the development of new casting processes.

An example of this new trend is the instrument panel structure of Alfa Romeo 156 made of magnesium alloy by means of High Pressure Die Casting (Meridian). In this case more than 20 steel stamped and welded parts were replaced by just one cast piece which permitted to obtain at the same cost a weight reduction of about 50% with a stiffness increase.

## NEW TECHNOLOGIES FOR NEW MATERIALS FOR SUSPENSION COMPONENTS

Replacement of traditional materials as steel or cast iron with light alloys (Al alloys, Mg alloys and Metal Matrix composites) for manufacturing suspension components determines many problems related to their functional class.

In fact structural components as suspension arms, steering knuckle, suspension cross members, etc. are all safety parts which have to guarantee defined mechanical properties with high reliability.

It is known that the mechanical properties of light alloys and in particular toughness are lower if compared with traditional materials. This aspect, as pointed out previously, stimulated the development of new CAE, transformation and assembling technologies such as:

- Developing advanced forming and joining methods;
- Developing codes for process numerical simulation;
- Establishing low cost sheet manufacturing processes, such as slab-casting;
- Improving material strength and corrosion resistance;

### THIXOFORMING PROCESS

Thixoforming process consists of an injection into the component die of material at semisolid state. In order to get the thixotropic behaviour of the material (viscosity which decreases with increase of shear stress and time), its structure before injection has to be composed of solid globular dendrites dispersed in liquid eutectic fraction (rheocast structure). Therefore the material has to be undergone at a preliminary procedure for obtaining billets having the right structure suitable for thixoforming process. More methods are available for reaching this structure: electromagnetic stirring, mechanical stirring, passive stirring, grain refinement. Electromagnetic stirring is the most used for aluminium alloys. During solidification, the stirring breaks the tree dendrites which solidify with spheroidal shape.

- Improving the recyclability;
- **Developing high-quality, high-strength structural castings.**

In particular referring at the last point, considering suspension parts, a lot of effort was addressed to an improvement of casting processes in order to achieve components with high quality and mechanical properties. Hereafter some processes developed lately are reported:

- Thixoforming
- HPDC under Vacuum (Vacural, Premium Die Casting, etc.)
- Squeeze Casting
- KPH (Kobe-Premium High Pressure Die Casting)
- LPDC (Low Pressure Die Casting)
- VRC/PRC (Vacuum Riserless Casting/Pressure Riserless Casting).

It is the case of Al-alloys which from the performance/costs ratio point of view are the most candidate for such applications.

Mechanical properties of the casting are related to its microstructure in terms of defects and grain size distribution. These factors play a fundamental role on toughness and yield strength which influence the component behaviour during impulsive and crash loads.

The following schema (Fig. 1) shows the different steps of thixoforming process.

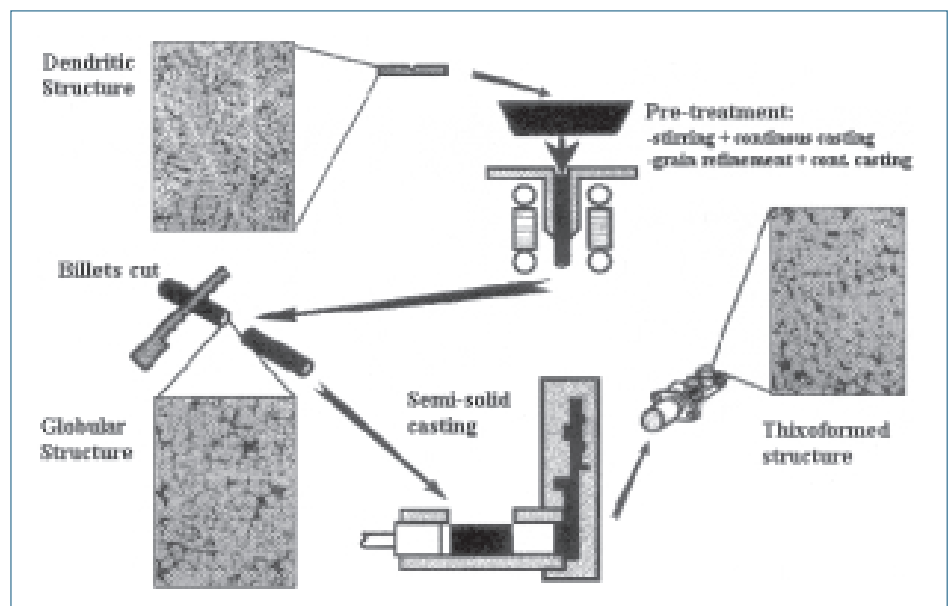


Figure 1

As shown in the schema, the long solid billets are cut in smaller ones according to the final component mass and then they are reheated to the semisolid state (40,60% solid, according to the used process) and then injected into the die.

The semi-solid metal is able to fill the die with a laminar flow, preventing any gas entrapment (porosity) in the final component. Therefore, besides the high quality reachable in

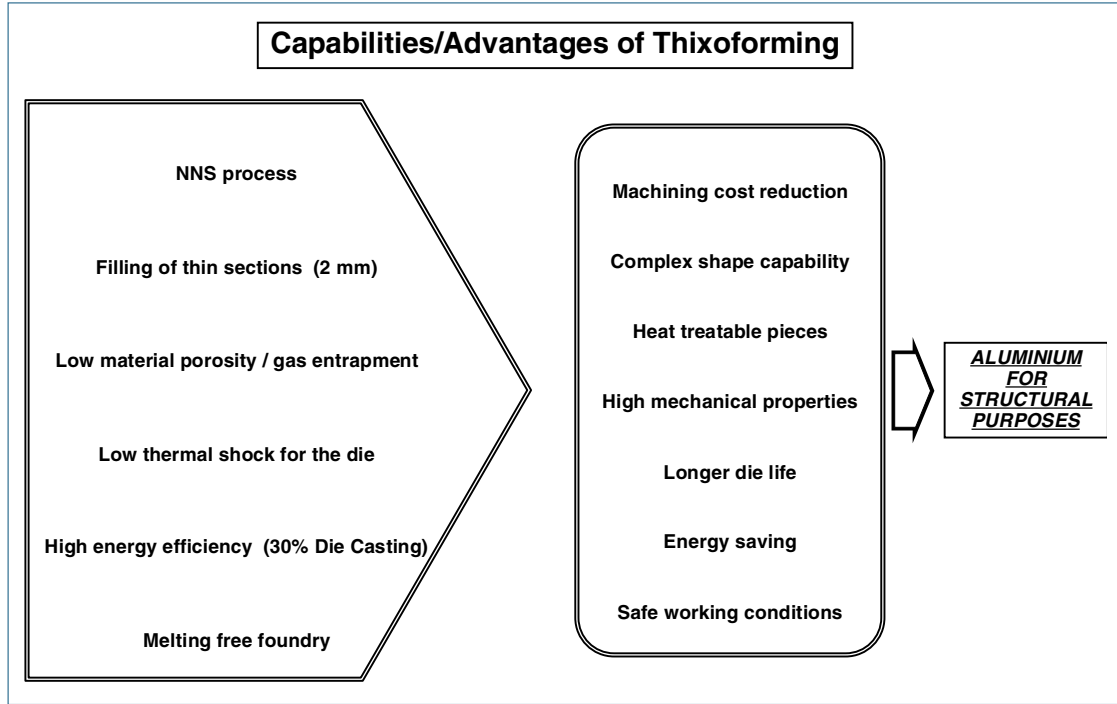


Figure 2

## COMPONENT DEVELOPMENT

The Fig. 3 reports the flow-chart used for the development/optimisation of components.

The main steps are:

- Original design verification
- Process and material choice
- Design optimisation
- Experimental analysis
- Cost analysis

Taking into consideration the required targets (Ex.: weight reduction, performances increasing, cost reduction, etc.), the requirements of the component are evaluated in terms of performances and costs, necessary for the following analysis. Here in fact starts the simultaneous analysis for both process/material choice and design optimisation.

The mechanical and geometrical characteristics needed by the component point out the limits for the choice of material and also a range of available processes. Using databases and results from experimental tests the right material and its heat

the as cast part, it is possible to improve the mechanical properties by heat treatments, not possible for castings made of HPDC.

Other big advantages are achievable by thixoforming, due also to the fact that the material is heated and injected at a temperature of about 100°C below the melting point: energy saving, tighter part tolerances (less shrinkage in the die, less

residual stress, less component distortion), less machining operations (near-net shape process), no dangerous molten metal handling etc. In the Fig. 2 process capabilities and advantages are reported.

Thixoforming process was selected for the development of a suspension steering knuckle, as described subsequently.

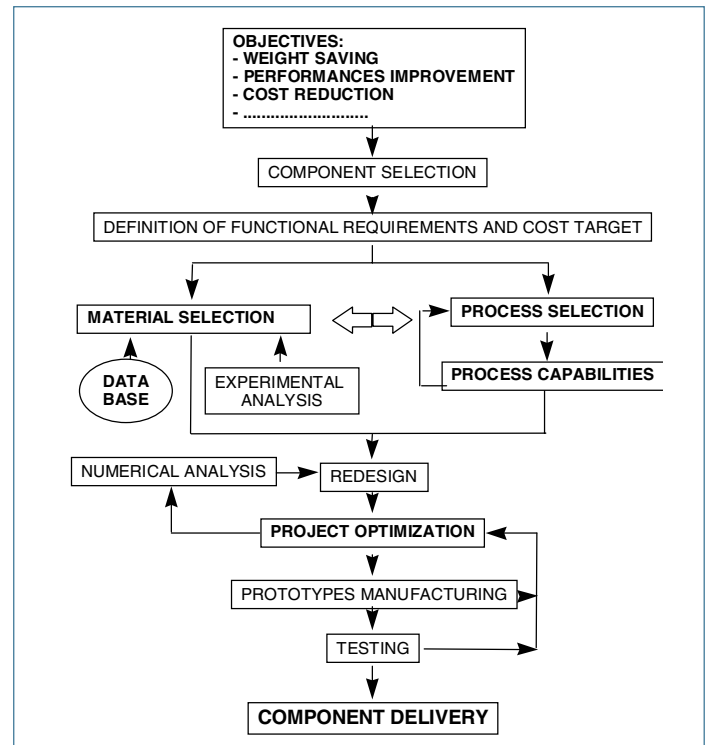


Figure 3

treatment are then definitively chosen. In the same time the process capabilities and limits are evaluated for defining the most suitable process.

The geometry of the component is then optimised on the base of the mechanical properties coming from the defined process by means FEM structural analysis whereas the process parameters

are defined with the help of process numerical simulation.

The next step is the prototypes manufacturing, taking a great care of the metallurgical aspects in order to reduce possible defects and in order to simulate the real production conditions, and finally component testing which has to represent the real working conditions.

## DEVELOPMENT OF AL-ALLOY STEERING KNUCKLE FOR A FRONT SUSPENSION

The Fig. 4 shows the component which was taken into consideration in this analysis. It is the steering knuckle of a front Mc-Pherson suspension made of cast iron.

The flow-chart followed for the component development is reported in Fig. 5.

In this case, the objectives were weight saving, vehicle performance increase at sustainable cost. Looking at the flow-chart, the component is subjected to fatigue loads, impulsive and crash loads; therefore it is important to guarantee min. mechanical properties of the material with high reliability.

On the base of the geometrical features, thixoforming was defined as candidate process because it was studied to guarantee to obtain high strength and toughness properties, as required by the application. A357 treated T5 was chosen as most suitable material because it guarantees good mechanical properties without having a complete solution treatment.

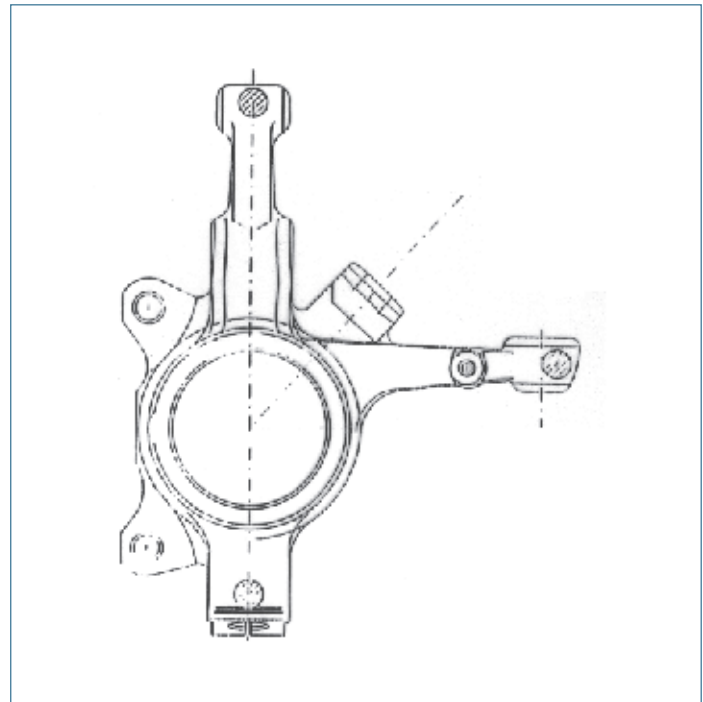


Figure 4

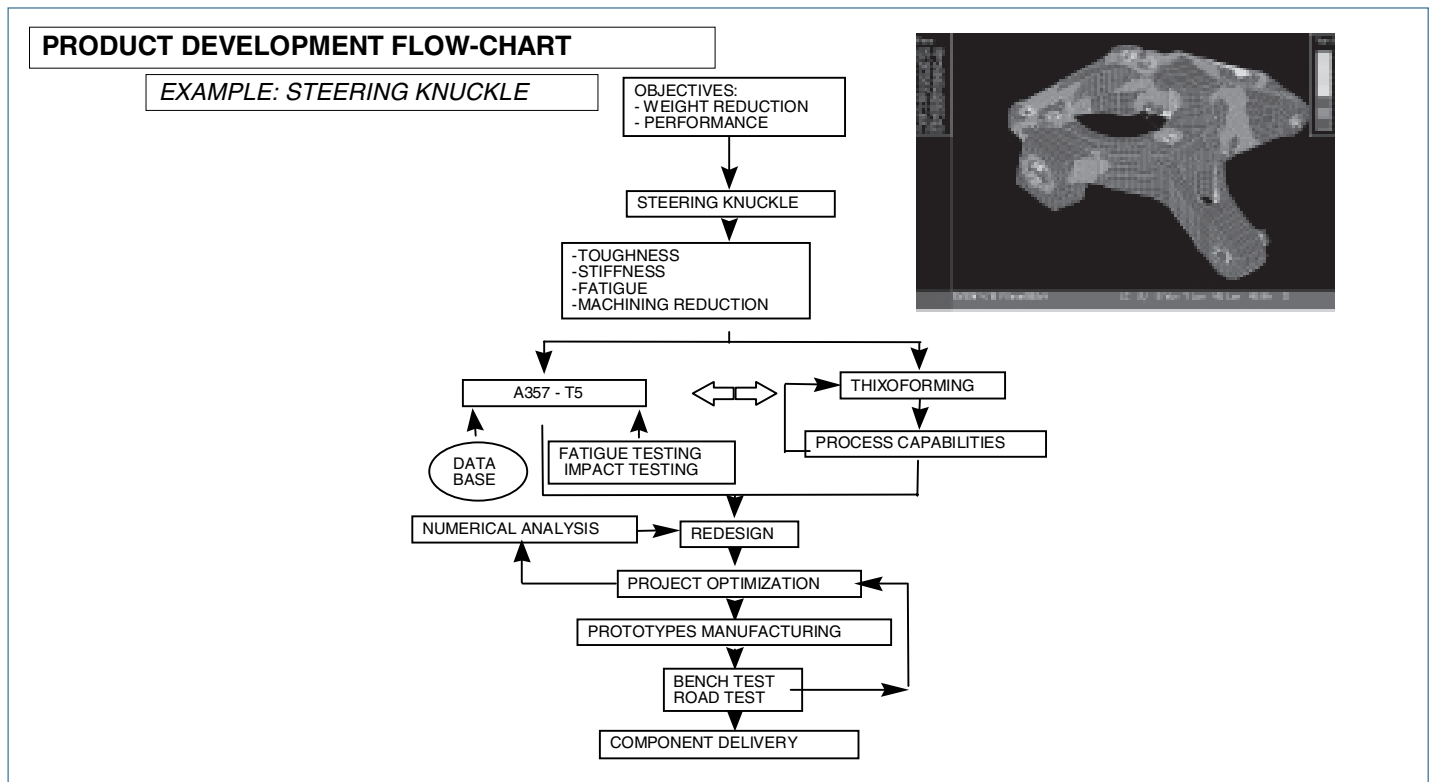


Figure 5

This assures remarkable advantages because, besides to be more economical than T6 thermal treatment, the component deformation during quenching after solution treatment is reduced. For such a reason thinner machining allowance are necessary and therefore it will be possible to exploit completely the Near Net Shape capability of process transformation at semisolid state. This aspect is important for minimising the cost for obtaining the finished component, ready for assembling.

The component redesign and optimisation suggested to modify heavily the component geometry in order to exploit at maximum process capabilities. The CAE analysis envisaged a

weight saving higher than 30% if compared with the actual steering knuckle made of cast iron.

On the base of CAE analysis the thixoforming mould was produced and then the prototypes (Fig. 6) were manufactured by employing a Bühler thixoforming machine, by Stampal SpA plant. Some of the prototypes were analysed from a metallurgical point of view, showing fine and homogeneous globular structure and nearly zero porosity (Fig. 7).

Some other components were bench tested; the positive results confirmed the results of virtual analysis and demonstrated the suitability of thixoforming process for manufacturing safety parts in aluminium alloys.

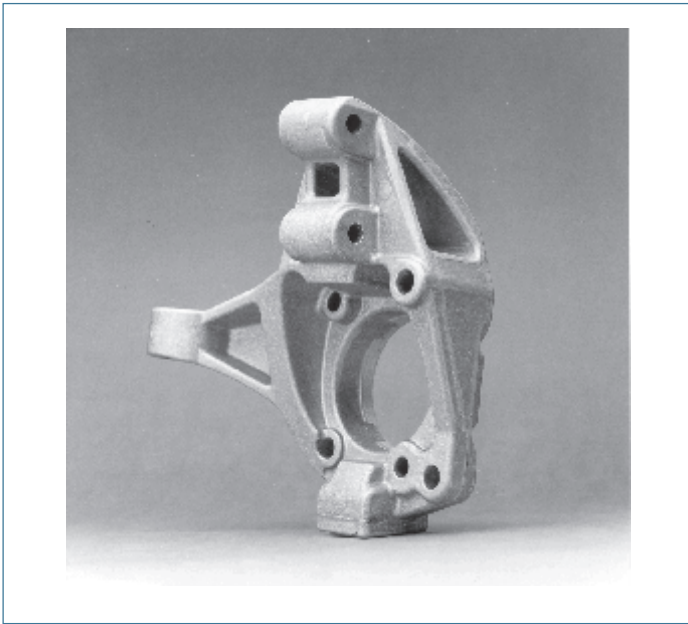


Figure 6

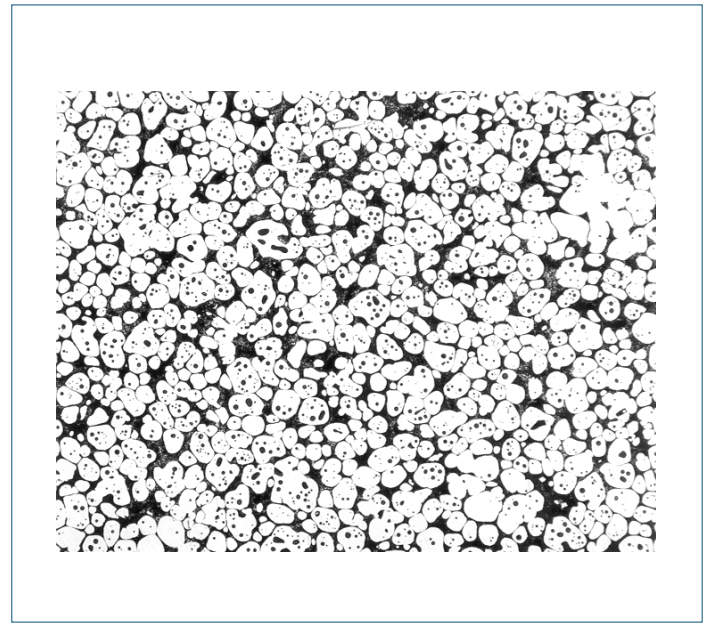


Figure 7

## CONCLUSION

The design and optimisation of components requires more and more a simultaneous engineering approach in order to reduce as much as possible the time to market. This aspect appears fundamental when new material as light alloys are considered.

This paper demonstrates that the material choice cannot be done without considering the final process for its transformation and the designer cannot be unaware of material features and process capabilities. Only by means of this route it is possible to really optimise the component, minimising the cost of manufacturing.

## ACKNOWLEDGEMENTS

The authors would like to take this opportunity to thank the EC which founded this work through the BRITE Euram Project “Advanced semisolid forming of complex structural components”, contract BRPR-CT96-0220 and the other partners in this contract.