8th Chinese Industrial Minerals Conference

7-9 September 2009, Qingdao, China

TALC IN AUTOMOTIVE APPLICATIONS

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INTRODUCTION

The automotive industry designs, develops, manufactures, markets, and sells the world's motor vehicles. In 2008, more than 70 million motor vehicles, including cars (52 millions) and commercial vehicles, were produced worldwide: 21.7 million in Europe, 30.2 million in Asia-Pacific, 12.9 million in NAFTA, 3.9 million in Latin America, 1.0 million in the Middle East and 0.5 million in Africa. The markets in North America and Japan were stagnant, while those in South America and the rest of Asia grew strongly. Among the major markets, Russia, Brazil, India and China saw the most rapid growth.

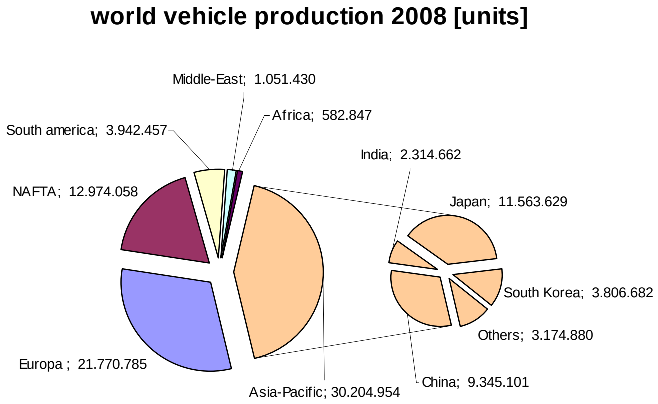

Figure 1: worldwide vehicle production (cars+other vehicles) in 2008.

Around the world, there were about 806 million cars and light trucks on the road in 2007; they burn over 950 billion liters of gasoline and diesel fuel yearly. Numbers are increasing rapidly, especially in China and India.

Despite the huge recent crisis of global and automotive market, vehicle industry is still one of the largest and globalized market worldwide.

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In automotive industry, thermoplastic polymers are even more used to fulfill functional and design requirements for vehicle productions, recording a significant increment in volumes in last 30 years. Because of the important presence (typically 10÷25% w/w) of talc as polymer modifier used in automotive industry, it is pertinent to talk about talc in automotive applications.

THE ROLE OF TALC IN PLASTICS

The concept of cost reduction by means of filling materials has been known throughout the ages. In general, fillers are defined as materials that are added to the (plastic) formulation to lower the compound cost. In such situation, fillers are used as extenders; but extenders generally provide minor mechanical improvements (or some properties degradation). When, using filling materials, certain properties variations are requested, functional fillers must be used. A filler can be considered as "functional" when a certain property will result better in the final composite than in the unfilled material. A typical mechanical property enhanced with functional fillers is rigidity: by adding a functional filler to a certain polymeric matrix, a significant variation in stiffness can be obtained.

Talc is generally considered a functional material because it is able to modify significantly some properties in modified polymeric matrix, when properly dispersed. It is important to highlight that not all talc grades available on the market can be eligible to become "functional fillers". Lamellarity in talc is intrinsic in its structure, but it is fundamental to process it maintaining and, if possible, enhancing the lamella aspect ratio. In order to maximize the final mechanical performances in modified polymeric matrix, the production process must preserve the natural lamellarity of talc. In Figure 2, some images of fine micronized talc are shown. A global production process which is not able to grant such talc peculiarity will produce just a filler. In fact, a generic size reduction process with a generic talc source could not provide the proper final characteristics to fine talc: similar particle size distribution could be reached, but performances in final application could result significantly different. A consolidated know-how in source selection, processing and down stream applications is necessary to produce an effective functional filler based on talc ore.

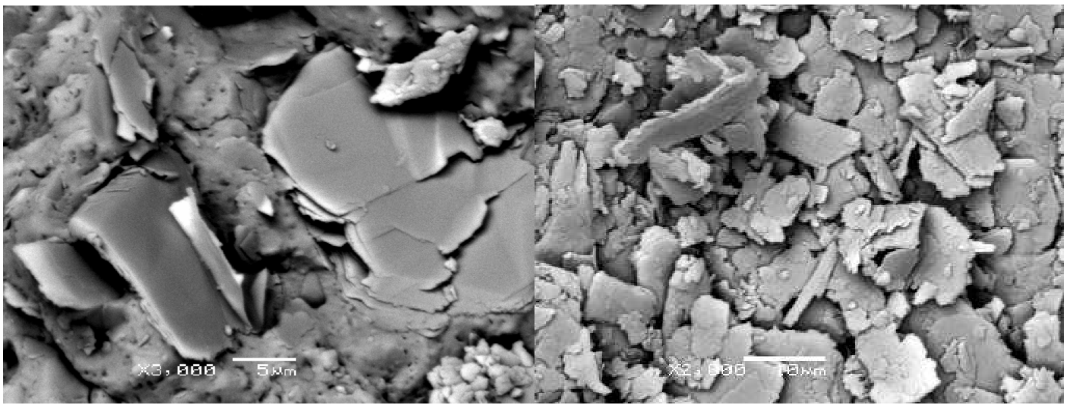

Figure 2: SEM images of talc. On the left fine micronized talc is dispersed in a polyolefin based resin (some talc lamella, surrounded by polymer, are visible), while on the right a small population of fine micronized talc lamella is shown. The high lamellarity of talc is well evident. Each talc lamella shows a high surface compared to the thickness. Because of this high lamellarity, it is possible to achieve a reinforcing effect in polymers. Size reduction process plays a fundamental role in preserving such lamellarity

In Figure 3, some data about polymer rigidity achievable with some industrial minerals modification, is reported. The significant contribution of talc in increasing neat polypropylene rigidity appears evident. On the same graph, the dimensional stability index is highlighted. Talc provides a very low molding shrinkage and a good dimensional stability (as the better ratio between longitudinal and transversal molding shrinkage). In fact, during the shaping process, each talc lamella can be oriented in the molten polymer flow maximizing platy effect of talc. As a direct consequence of high stiffness and low shrinkage, a significant reduction of CLTE can be expected.

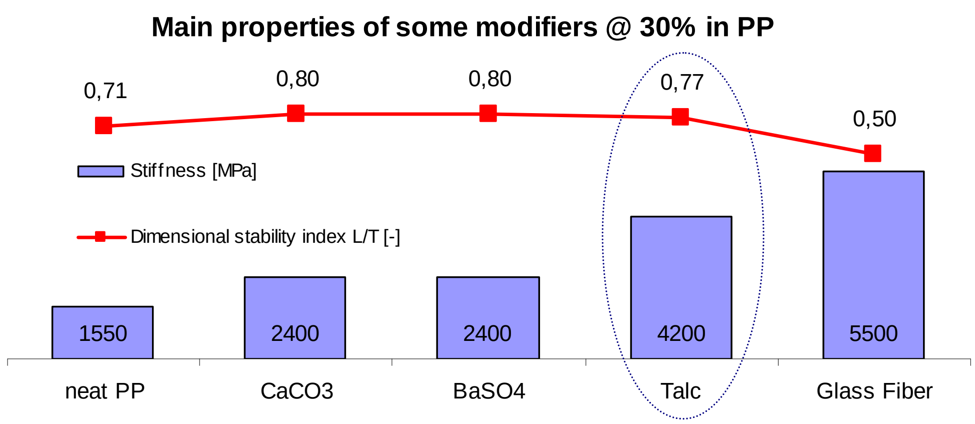

Figure 3: Bars represent the achievable stiffness by loading homopolymer polypropylene with 30% of indicated modifier. Red line highlights the dimensional stability index expressed as the ratio between longitudinal and transversal molding shrinkage. The higher such ratio is, the better the dimensional stability will result. Talc shows a good compromise between high stiffness a good dimensional stability.

Data listed in figure 3 are referred to a specific particle size distribution of industrial minerals used for the modification. Such properties are generally affected by fineness and, considering talc, some information are shown in Figure 4. All these data are referred to fine talc produced with both the latest available technology and the most updated knowledge in processing.

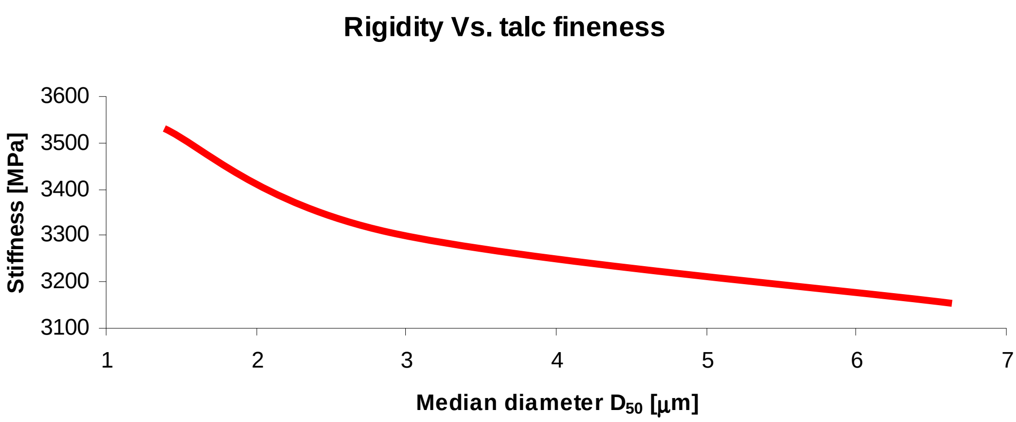

Figure 4: Rigidity achievable on 20% talc filled polypropylene according to the talc fineness. It appears that the finer the talc is, the higher the stiffness will result in polymeric composite.

The ability of talc to enhance stiffness in combination with good aesthetic, hydrophobic character, and reasonable price, makes such industrial mineral one of the best candidates for polypropylene modification. In table 1, a list of main talc properties (in polymer modifications) is shown.

The largest single application for polypropylene is for sure the worldwide automotive market, one of the most globalized industries. Although a number of plastic materials were used in automobiles as far back as the 1950s, most of plastic components were developed when more advanced process and tool design became available to engineers. Early targets were metal, rubber, wood and glass components; they all contributed heavily to the weight of the vehicle. Replacing these parts with a lighter material such as PP provided an immediate weight saving without loss in performances.

Main limitation of polypropylene is the poor stiffness of neat resin and, in particular, high impact resistance polypropylene shows a very low rigidity. In Figure 5, stiffness of some neat thermoplastic materials is highlighted.

Either for structural applications or for replacing some other materials, a minimum rigidity is generally required. Talc is perfectly joining polypropylene in achieving required stiffness.

Table 1 : Talc is a functional filler. Some of the main talc functions are listed with some practical examples. As main property, talc is primarily known as stiffness increaser, but it exhibits several other important properties

Talc function	Examples
Improvement in rigidity	20% of talc in homopolymer PP doubles elastic modulus
Increase in tensile strength	40% of talc in polyamide 6 improves tensile strength by 25%
Nucleating effect	500 ppm of fine talc in semi-crystalline polymers significantly increases the crystallization temperature
Reduction of Shrinkage	20% filling in polypropylene lowers moulding shrinkage by 30÷40%
Improvement of thermal properties	40% of talc in Polyamide 66 almost triples HDT value
Improvement of dimensional stability	Talc filling provides a certain equalization between cross moulding shrinkages, improving the overall dimensional stability and minimizing warpage effect.
Lower permeability	20% loading in polypropylene increases by 50% moisture barrier

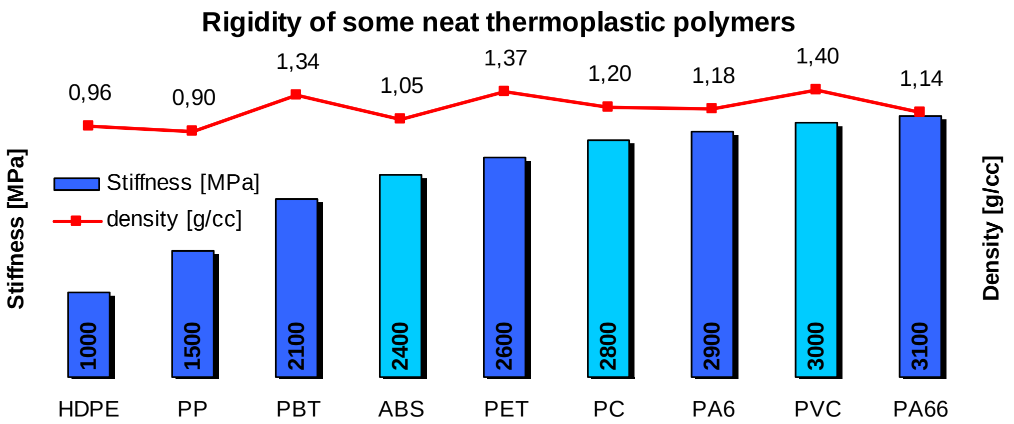

Figure 5: Rigidity of some neat polymers used in automotive industry. It clearly appears that polypropylene (PP) shows a limited stiffness if compared to other thermoplastic materials. Lighter colored bars represent amorphous thermoplastic polymers, while darker bars are semi-crystalline polymers. Another advantage of polypropylene is the lightness, even if modified with talc.

WHERE TALC IS USED IN AUTOMOTIVE APPLICATIONS

Talc is normally used to modify several polymeric matrixes used in automobile production. Whenever a stiffness increase is required in combination with good aesthetic and dimensional stability, talc is used. Besides polypropylene, talc is also used in polyamides, polyesters and other thermoplastic polymers.

Talc is introduced into thermoplastic materials during a specific processing step, generally known as compounding. During such phase, also other modifiers (pigments, impact modifiers, stabilizers, lubricants) are introduced into the final product. Compounded material, in pellet form is then transformed through an injection moulding machine (or other shaping equipments) into the final item and assembled for final application. In fact, most of plastic parts used in automobile construction are composite products.

Main car applications where talc filled thermoplastics are used can be ranked according to the final destination as: interiors, exteriors and under the hood.

In interiors, instrument panels, door panels, arm rests, pillar covers, consoles, seat backs, head liners, mirror housings are normally made with talc filled polypropylene. For most of these grades a good aesthetic associated with high mechanical resistance is required. Additionally, scratch resistance for long term appearance is also required. In general materials for interiors must be stabilized to resist to high temperature and UV irradiation.

Main exteriors applications are represented by bumper fascias, rocker panels and grills. For all these application a strong impact resistance and a very low thermal expansion are required to be jointed with metal parts having a very low dimensional variation with temperature. Most of these items are painted to mach car body aesthetic.

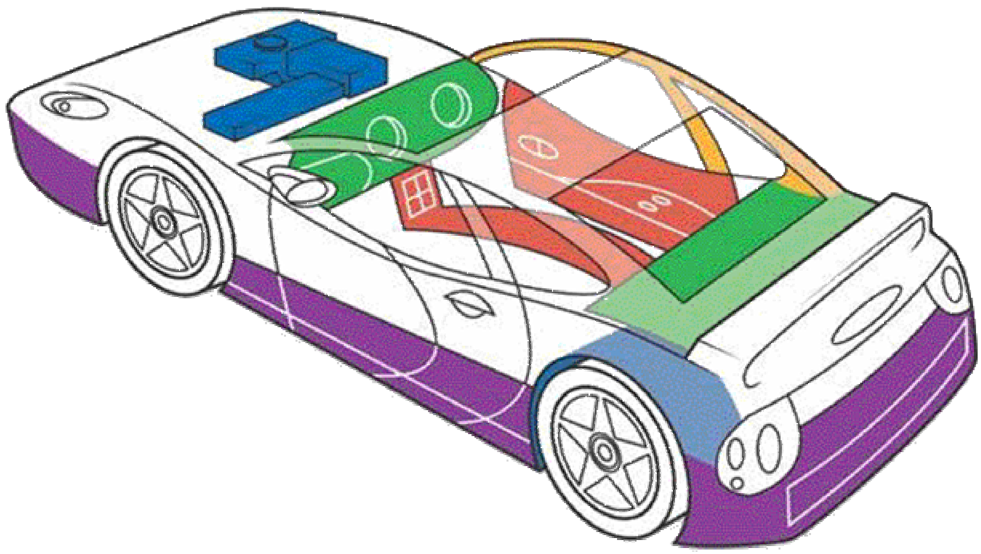

Figure 6: Typical car parts produced in talc modified thermoplastic polymer. Most of such parts are polypropylene based composite.

Talc filled composites are also used in under the hood applications. In this case, good thermal properties are generally requested. Not only polypropylene, but also polyamides are used because of their higher service temperature. In case of talc filled polypropylene used in heating units and air conditioning housings low odour formulations are generally required to minimize the interior odour impact in vehicles. Such kind of requirements (low odour emission and low fogging) is also required for items addressed to interior applications. Talc filled composites are also used in cooling fans, housing of headlights and wheel arc liners.

In Figure 6, the main applications where talc is extensively used are highlighted. In such items, according to the specific final requirements, talc can be used up to 40% in weight. Typical usage of talc is normally in the range of 10÷25% w/w.

THE INCREMENT OF PLASTIC PARTS IN CAR PRODUCTION

With the evolution of automotive industry, the amount of plastic parts in car construction has increased a lot. For example, by considering Volkswagen Golf in the past 30 years the evolution is evident (Figure 7).

Figure 7: design evolution of Volkswagen Golf from 1974 up to now. The strong presence of plastics in exterior design is clearly visible starting from 90'.

A strong design and technological evolution occurred in car industry in three decades. In particular, it is possible to observe the style solution for bumper starting from Golf IV (late 90s), where a "zero-gap" concept was used. To achieve such result a very low CLTE (Coefficient of Linear Thermal Expansion) is required. Considering that for neat polypropylene CLTE is several times higher than steel (it means that with temperature variations polypropylene varies its dimension more than steel creating some problems for jointing), the modification with talc becomes fundamental to lower the CLTE of the final compound.

The redesign of the entire bumper system to pass legislative impact tests eliminated huge chrome bumpers in favour of a complex energy absorbing hydraulic system or an energy honeycomb and/or foam system , each one covered with a fascia moulded from plastic resin. First the end caps, and than the entire bumper fascia converted to rubberized talc modified block copolymer (TPO). Nowadays, more than 90% of all bumper fascias on passenger cars are molded in TPO. In figure 8, an example of modern bumper fascia is shown.

It is interesting to have a look to the evolution of plastic materials for interior applications. Always with reference to Golf, in Figure 9 it is shown the growth of use in plastic in automobile interiors with reference to the example of the Volkswagen Golf. It is possible to see how polypropylene usage has increased (and talc too) over thirty years.

Figure 8: A modern front bumper fascia for a small car. Painted plastic fascia is generally realized with a composite made with block copolymer polypropylene, metallocene plastomer, fine talc and additives (stabilizers, lubricants,…)

For example, until few years ago no injection moulded polypropylene parts were used for surfaces in the higher vehicle classes because of problems as scratch resistance, stress whitening and odour emission. With the latest available polymer grades, modified with proper talc, now polypropylene based materials are extensively used in interiors.

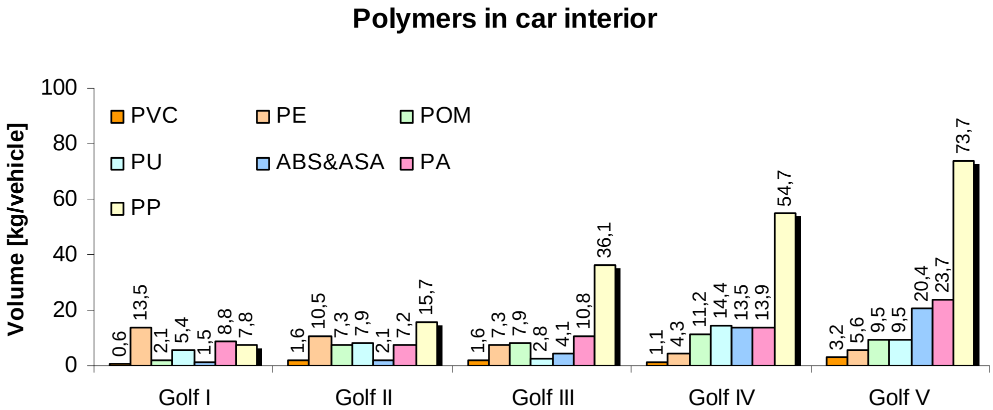

Figure 9: Growth in the use of plastic in automobile interiors with reference to the example of Volkswagen Golf. Total amount of polymers used in Golf V are 145.6 kg Vs. 39.7 kg of Golf I (almost 4 times more!)

In smaller cars, the usage of polypropylene (modified with talc) is really intensive. In table 2 some data are listed. The incidence of polypropylene usage on smaller cars is generally higher than in medium/large cars (5.5÷7.3% vs. 4.2%). It is possible to observe that at least 40% of plastics used in small/medium cars are polypropylene (and talc) based. Only for Europe (Figure 10) cars produced in 2008 were over 21 millions of units and almost 40% of the market is represented by small vehicles; it clearly appears how large the market is for polyolefins, and hence for talc, in automotive field.

Such very positive result has been achieved through a continuous improvement of polymeric material properties, followed and supported by talc process enhancement. In fact, most of the existing applications where talc is used have been developed also through the huge research and developmental activity of main talc producers, that followed and are still following, with large investments, the car industry evolution with more and more performing products. A continuous attention to talc source, to size reduction process, to constant quality and to strong technical assistance grant the car industry to receive proper talc modified composites.

Table 2 : Smaller cars are PP intensive. Polypropylene is extensively used in small and medium size cars. Its incidence per car weight is over than 5%. Most of used polypropylene is generally modified with talc to fulfill final mechanical requirements.

Vehicle	PP per vehicle [kg]	PP/plastics per vehicle	PP/vehicle weight
Citroen C4	90	56%	6.5%
Toyota Aygo	47	52%	5.6%
Toyota Auris	71	51%	5.5%
Toyota Yaris	64	47%	6.1%
Oper Corsa	65	44%	7.2%
Ford Mondeo	72	41%	4.2%
Fiat 500	60	49%	7.3%
Mercedes C-Class	72	34%	4.2%

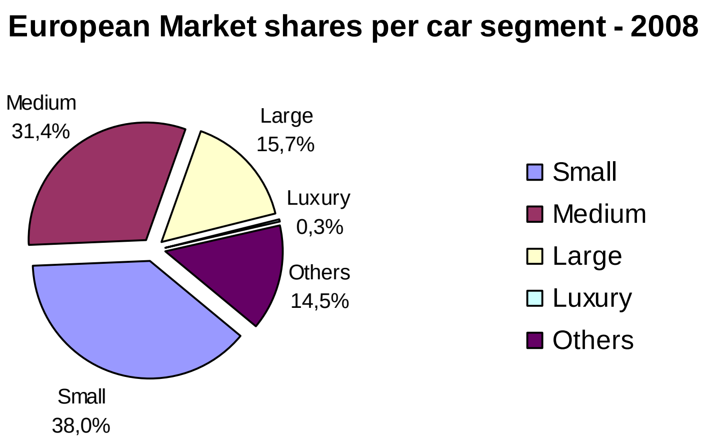

Figure 10: European market shares divided per car segment. Almost 70% percent of the European market is constituted by small and medium cars. In such segments, talc filled composites are extensively used.

TRENDS IN AUTOMOTIVE (AND TALC APPLICATIONS)

A strong driver for new developments is the current legislation. In Europe, for example, emissions and recycling legislation have a strong impact both on vehicle technologies and construction.

Concerning environmental legislation, the EU emissions standards are compulsory in all EU Member States. The current Euro IV standard covers emissions of CO_2, N_2O, and hydrocarbon particulates for both diesel and petrol engines. This requires more efficient vehicles and lower weights, and also the development of market-oriented measures such as improvements in the information level of the final consumer.

Future market in automobile is oriented to ecological vehicles. Besides the logical development of new engines and fuels to minimize pollutant emissions, the weight reduction of automobiles becomes fundamental. The development of new technical solutions as well as new materials can lead to achieve this important objective.

For new applications, the trend in talc filled polypropylene is addressed to lower the final compound density (neat polypropylene has a density lower than 0,9 g/cc and talc modification increases such value) to minimize the weight contribution to the vehicle. This means that final users request polypropylene formulations having same or better performances than in the past, with a lower density and possibly with a lower cost. From talc side, these requests drive the research to develop more and more performing grades to fulfil such requirements.

In past years talc micronized grades were developed to satisfy new applications and now new solutions are necessary to fulfil new requirements.

The second main area addressed by law is recycling and the End-of-Life Vehicle Directive (or ELV Directive). Member States must set legislation increasing re-use, recycling and other forms of recovery of 'end-of-life vehicles' (ELVs) and components, and they must phase out certain hazardous substances. About 15% of each ELV currently goes into landfills; the target is to reduce this to below 5% by 2015. From thermoplastic polymer side, it leads to the need of harmonization of the polymer types used in the car production. Because of the overall set of properties (included lightness and cost) polypropylene based compounds have been used as standard for many car items. It explains the reason of large growth of polypropylene based compounds in car production. Talc follows such trend.

Another important future application field will be related to biopolymers modifications. With the logic of zero footprint approach, already used from some Japanese car producers, new polymeric materials will be introduced in vehicle construction. Nowadays, such new polymers are exhibiting relatively poor mechanical performances and they will require the proper modification. Talc could be a good candidate for such new approach, giving a good properties trade-off.

CONCLUSION

In thermoplastic applications, the largest market is polypropylene modification. Being such resin extensively used in automotive field, the importance of talc for car production market clearly appears. The more and more demanding applications from car industry drove and are still driving research and developmental processes to even more performing talc grades to fulfill new requests.

Being the car industry/market global, also raw material must be global. It means that raw materials, included talc, must offer global availability, global (and high) quality and reliability, global technical support and global price. To grant talc industry such requirements, huge investments in people and technology are necessary. In particular, a constant and global quality becomes fundamental to fulfill automotive industry stringent requirements. Of course, also price is an important characteristic of talc and must be coherent with offered benefits and stable despite of the market situation.

Lightness and recyclability are probably the most important keywords associated to car industry. As direct consequence of vehicle weight reduction, in combination with more efficient engines, there is the minimization of pollutant emissions in the atmosphere. The harmonization of materials used in car production leads to improve the possibility of reuse/recycle car parts minimizing the amount of wasted parts.

Because of rigidity and mechanical strength improvement in talc-filled compounds, it is possible to obtain stronger final items than with other industrial mineral filled products, giving the engineers more instruments in material replacement for an easier and faster harmonization of raw materials. On the other hand, the use of talc for many technical applications could lead the designer to lower the overall thicknesses in final item in order to follow a global saving in weight and money.

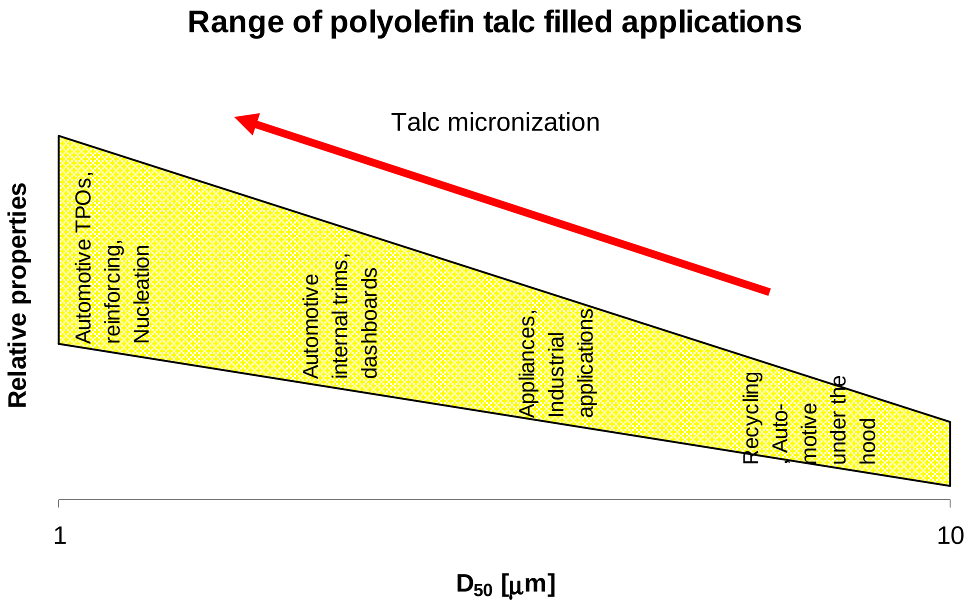

Figure 11: Examples of possible talc applications according to fineness. For most demanding applications (for example, in automotive field) micronized talcs are the best solution.

If properly processed, talc is able to enhance the stiffness of polymers with a moderate loss in impact resistance. When the final applications require high stiffness, low CLTE, good appearance and easy processability, talc can be considered as the best candidate to modify several polymeric matrixes and specifically polyolefins.

In figure 11, a general overview of the typical application of coarse and fine talc is highlighted. It appears that most demanding applications are requiring fine talcs.

Considering the wide range of properties offered by talc, the "simple" identification of talc as a filler is quite reductive while the term "functional filler" is more appropriate.

Bibliography

- OICA International organization of motor vehicle manufactures
- Polypropylene handbook 2nd edition. Edited by Edward P. Moore, Jr. Carl Hanser, Munich, 2005
- Functional Fillers for Plastics. Edited by M. Xanthos,2005 WILEY-VCH Verlag GmbH & Co KGaA
- Kunststoffe International magazine– March 2009
- Proceedings of "SPE TPO 2008 conference" October 2008 Sterling Heights, MI USA.