THE SUCCESSFUL UTILISATION OF THE VERSATILITY AND COST EFFECTIVENESS OF REINFORCED ENGINEERING POLYMERS IN ENGINEERING APPLICATIONS

C WEINERT

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Paper written by : Charlotte Weinert

Manager : New Business Ventures
Plastamid (Pty) Ltd
43 Coleman Street
Elsies River
7480

Tel : (021) 592-1200

May 1990

1. INTRODUCTION

We have seen an honest commitment and much needed innovation in the use of reinforced Engineering Polymers in the major industries in South Africa. The versatility and cost effectiveness of Engineering Polymers has been utilised most successfully in filling existing market niches as well as in the development of new market applications. This versatility in performance is achieved by a combination of the characteristics of the Engineering Polymers with the properties of the numerous specialised modifiers that are available.

The field of engineering materials covers a very broad range of materials, namely metals, ceramics and polymers. There is a fair degree of overlap between these groups regarding applications. Each group in itself offers endless opportunities and it is impossible to cover even only one of these groups today, but I would like to increase awareness of the polymer group, specifically thermoplastics. Special reference will be made to Nylon, one of the most versatile polymers currently used extensively in engineering applications.

2. THE VERSATILITY OF ENGINEERING POLYMERS

A very extensive range of thermoplastic engineering polymers is available to the design engineer. Within each group the number of modified grades is quite overwhelming. Where does one start?

2 / Firstly ...

Firstly, let us look at some of the properties that are readily achievable :

(a) High strength to mass ratio (tensile and compressive)
(b) High modulus
(c) Low flexural fatigue
(d) Low creep under high loads at elevated temperatures
(e) Good impact behaviour even at low temperatures
(f) Dimensional stability
(g) Abrasion resistance
(h) Good weatherability
(i) Electrical insulation
(j) Electrostatic dissipation/EMI shielding
(k) Low wear/good frictional properties
(l) Low flammability
(m) Chemical resistance

The versatility of thermoplastic engineering polymers allows for the successful modification of properties. Polymer systems can therefore be tailor-made for a specific application. The correct initial choice of polymer is critical to the success of any modified polymer system in its final application. Polymers have in the past at times had a poor reputation, resulting in a resistance amongst some engineers to specifying them for new applications. Many of these incidences can be traced back to an incorrect choice of polymer or a mismatch of material and design. This point is stressed as it is so important, but unfortunately it is often overlooked.

3. PROPERTY ENGINEERING : WHAT CAN BE ACHIEVED WITH GLASS FIBRE REINFORCEMENT

The theory of reinforcement is a very interesting subject that has application in all the material groups mentioned earlier, but it will not be discussed in this presentation. The resultant changes in properties will rather be shown and compared by the more visual means of graphs and photographs.

3 / The ...

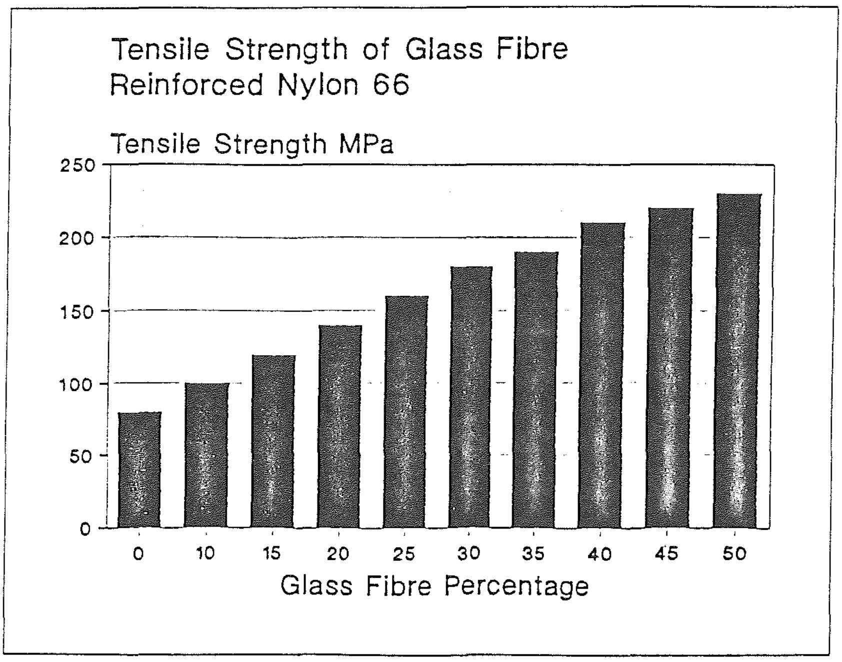
The reinforcement workhorse of the plastic industry is glass fibre in all its physical forms. These include rovings, chopped strands, woven mats, chopped strand mats, milled fibres and non-fibrous types could include flakes and beads.

Due to the immense scope of a discussion based on the abovementioned reinforcements, I will limit my paper to the form that has the best performance versus cost application in the thermoplastic industry, namely chopped strand glass fibre.

Very dramatic improvements in mechanical properties such as tensile strength and modulus can be achieved by increasingly higher levels of chopped strand glass fibre reinforcement.

The following graph shows the tensile strength of Nylon 66 reinforced with various levels of glass fibre.

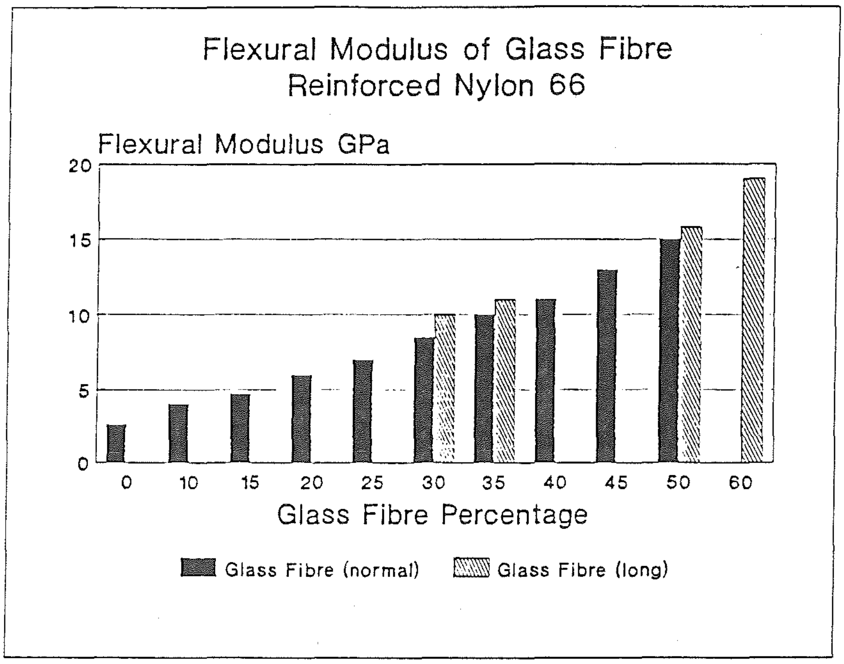
Figure 1 Tensile Strength of Glass Fibre Reinforced Nylon 66



Until a few years ago, only short glass fibres were used for the reinforcement of thermoplastics. Today there is a definite trend towards long fibre reinforcement for more demanding applications. A typical average fibre length for a "long" glass fibre reinforced Nylon 66 moulding is 800 micron as opposed to 200 micron in the case of conventional "short" glass fibre reinforced systems. In the accompanying graphs the effect of the longer glass fibre on the mechanical properties is shown quite clearly.

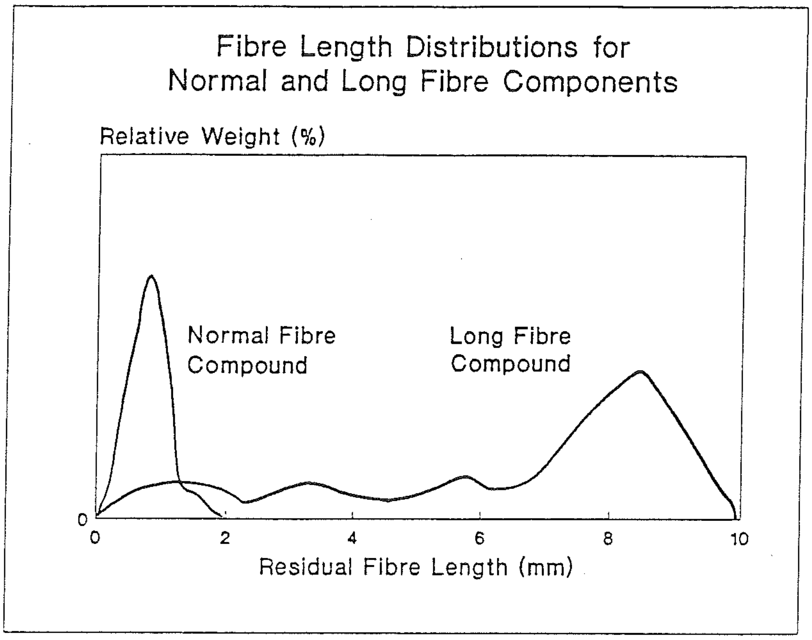
The following graph compares flexural modulus for various levels of glass fibre in Nylon 66.

<u>Figure 2</u> <u>**Flexural Modulus of Glass Fibre Reinforced Nylon 66**</u>



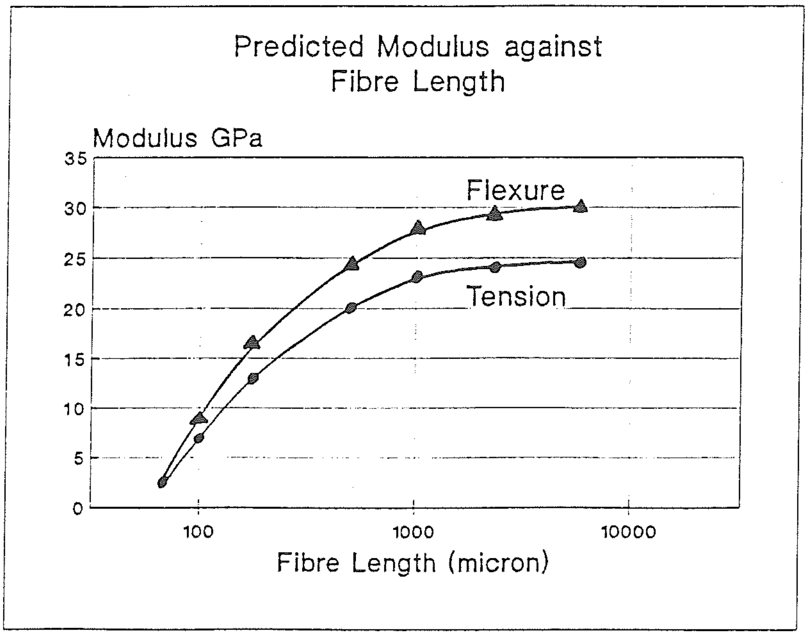
The average distribution of glass fibre lengths of "long" and "short" glass fibre is shown in Figure 3.

Figure 3 Average Distribution of Glass Fibre Lengths



A graphic demonstration of modulus versus fibre length is shown by the following plot (1).

Figure 4 Predicted Modulus Against Fibre Length



Ref (1) Bailey RS, Davies M, Moore DR, 1989
Processing property characteristics for long glass fibre reinforced polyamide. Composites, 20, 5 Sept, 453 - 460

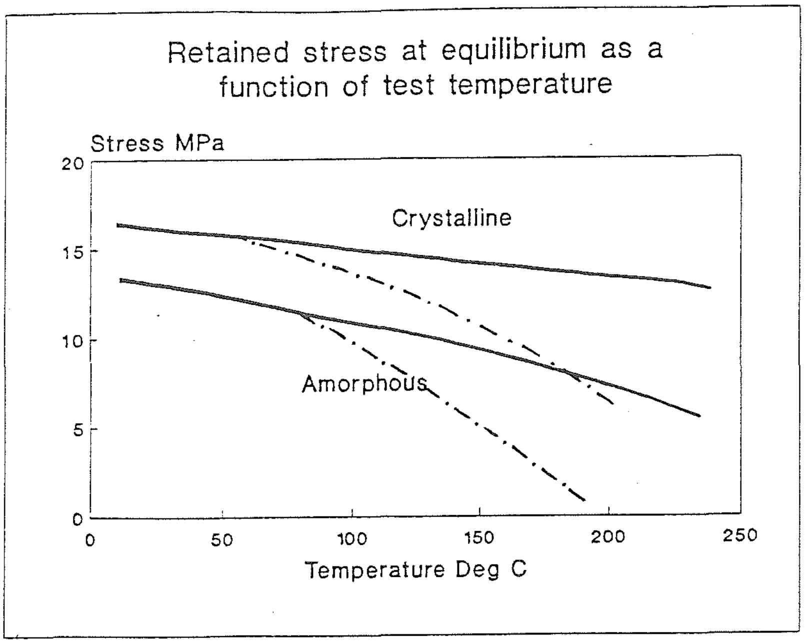
Stress relaxation behaviour of engineering polymers is crucial to the ultimate performance of the material in severe environments, especially those related to elevated temperatures. With these values available, the design engineer can make the correct materials choice on a performance and cost effective basis.

The mechanism of stress relaxation in a moulded part is very complex and it depends on many variables, namely

* the ratio of applied stress versus ultimate stress
* the flexibility of the polymer modulus
* moulded-in stresses in the part
* molecular mass
* degree of crystallinity
* melting point and glass transition temperature
* the presence of reinforcing agents

The relative performance trends of crystalline and amorphous engineering thermoplastics over a wide temperature range can be demonstrated by means of the following approximation.

Figure 5 Retained Stress At Equilibrium As A Function Of Test Temperature



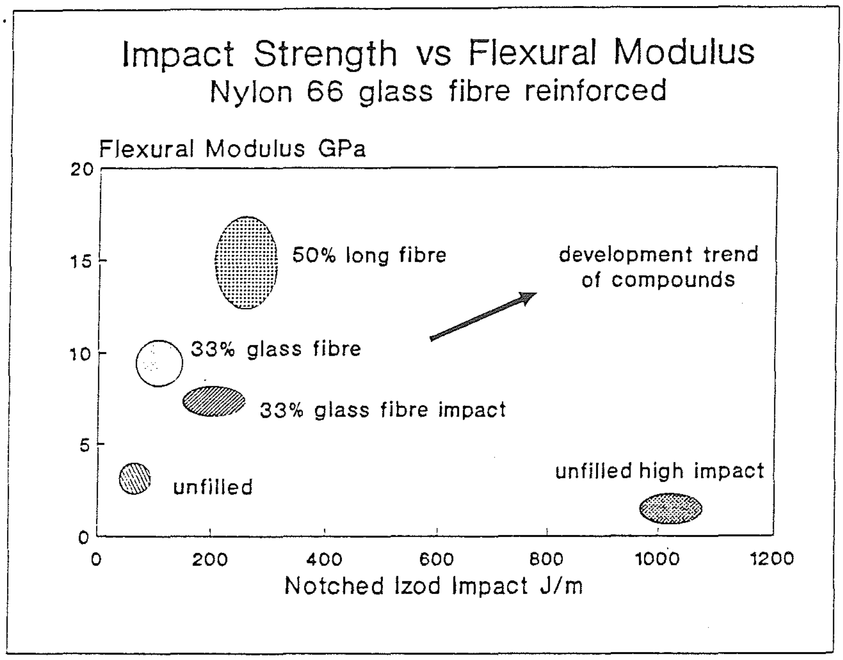
7 / When ...

When one looks at glass reinforced Nylon 66 specifically, the performance for the various levels of glass fibre show that the reinforcing capabilities of glass fibre are immense. Note should also be taken of the effect of long glass fibre.

There may be applications where strength and stiffness are required in combination with improved low temperature impact behaviour. The versatility of engineering plastics allows for multiple modifications. This will be demonstrated by using Nylon 66 as an example. There is always a give and take situation when attempts are made to modify two opposing properties. Impact modification will reduce the strength somewhat, but a good balance of properties can still be maintained.

The graph below shows how impact strength and flexural modulus are affected.

Figure 6 Impact Strength vs Flexural Modulus
Nylon 66 Glass Fibre Reinforced



Dimensional stability is one of the properties that design engineers most often quote as being inadequate in polymer systems. One does understand this concern, but this property of polymers can be modified significantly by the incorporation of reinforcements.

The two main issues are :

* shrinkage
* coefficiant of linear thermal expansion

Shrinkage is reduced significantly by the incorporation of reinforcements and fillers, but the resultant anisotropic properties of fibres must be kept in mind when designing a component. Flow paths, wall thicknesses, inserts and the positioning of gates affect the final dimension of the component.

Some comparisons for various reinforcements for Nylon 66 and Polycarbonate are listed below.

Table 1 Coefficients of Linear Thermal Expansion

Reinforcement Type		%	Expansion Coefficient
Nylon 66	- unfilled	0	80
	- short glass fibre	30-35	15-54
	- long glass fibre	30	23
	- carbon fibre	30	11-16
	- carbon fibre	40	9
	- aluminium flakes	40	22
Polycarbonate	- unfilled	0	68
	- glass fibre	30	22
	- graphite fibre	30	9
	- carbon fibre	40	11-14

The effect of polymer crystallinity shows up clearly when the unfilled values are compared.

Engineers are often concerned about the long term behaviour of polymers at elevated temperatures. It is well known that polymers can withstand high peak temperatures. The UL Temperature Index Rating is often quoted when the long term behaviour of polymers is compared. These ratings predict the temperature at which 50 percent of the measured property will be retained after 11 000 hours' exposure under static conditions. Table 2 shows values for a range of polymers.

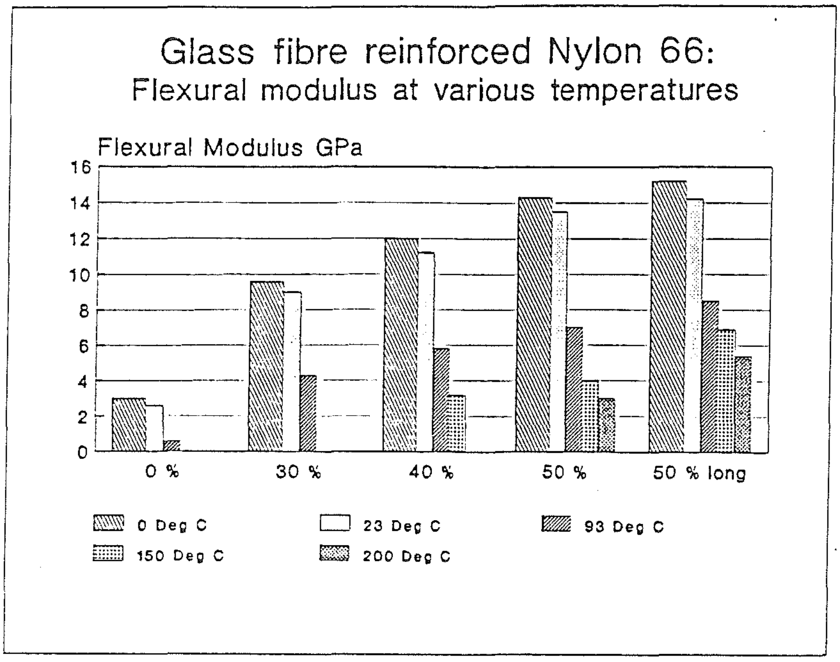
Table 2 UL Temperature Index Ratings

Polymer	Degrees Celcius
Polyetherketone PEK	250
Polyetheretherketone PEEK	220 - 240
Polyphenylene sulphide PPS	200 - 240
Polyamide-imide PAI	220
Polyetherimide PEI	170 - 180
Fluoropolymers	150 - 180
Polysulphones	140 - 170
Silicones	105 - 260
Phenolics and Melamines	150
Epoxy	130 - 180
Unsaturated Polyester	130
Thermoplastic Polyesters PET & PBT	130
Ureas	100
Polycarbonate	100 - 120
Nylons	65 - 120
Polyphenylene oxide PPO	50 - 105
Polypropylene	80 - 120
Acetals	50 - 95
Polystyrene, SAN, ABS	50
Vinyls	50
Polyethylenes	50

The second figures refer to reinforced polymers. These figures reflect the power that reinforcements have in improving thermal properties. This can be demonstrated in Figure 7 by using glass fibre reinforced Nylon 66 as an example.

10 / Figure 7 ...

Figure 7 Flexural Modulus at Various Temperatures



Earlier it was mentioned that many other properties and combinations of properties could be achieved by compounding the polymer with suitable additives. Examples of these properties are :

* weathering resistance
* electrostatic dissipation properties
* low frictional properties
* low flammability

These properties cannot be discussed in detail, but their possibilities should be kept in mind when designing for plastics.

4. EXAMPLES OF SOME SUCCESS USING ENGINEERING POLYMERS

It thus becomes clear that the possibilities and variations available to engineering polymers are endless. Material and design decisions that need to be made are therefore becoming more and more complex. An understanding as well as a "feel" for these materials is necessary.

In this section numerous applications from the various industries in South Africa will be demonstrated by means of slides. Key material requirements and the ultimate material choice will be discussed. It is hoped that these examples may help the audience to develop their interest further for these versatile and cost effective materials.

5. CONCLUSION

Numerous opportunities and challenges for the use of reinforced thermoplastic engineering polymers are available to the South African mining industry. Engineering polymers have replaced many traditional metal components and quite often found to be the better material for a certain application. It might all sound too good to be true, but the polymer industry is not unrealistic, there is a best material for every application and design, be it metal, ceramic or polymer. It is becoming more and more difficult to make the correct choices, based on performance, ease of manufacture and cost. A reliance on the expert in the particular field is one way of finding a path through this maze of materials. Engineering polymers are the late-comers in this game, but the plastics industry can boasts its creativity and far-sightedness quite openly.

I hope that I have created an optimism with those members of the audience, if any, who still feel a little uncomfortable using plastics in true engineering application. It will not be long before Engineering Polymers take their deserved place in the mining industry.

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