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Advances in Thermoplastic Plate Materials for Compressor Valves

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ADVANCES IN THERMOPLASTIC PLATE MATERIALS FOR COMPRESSOR VALVES

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This paper will discuss recent developments in Thermoplastics and how they have been adapted for compressor valve components in order to obtain more reliable plates with a longer service life and provide a broader parameter for engineering design.

Compressor valve plates are one of the most demanding applications for any material. Operating conditions vary considerably in regards to temperature, differential pressures, and chemical environments. The costs of valve plate failure can be considerable, damage to related equipment and the resulting downtime can be extremely expensive.

After several years of laboratory analysis and field testing a successful new material has been selected.

Introduction:

The operating conditions that reciprocating gas compressors experience can vary greatly. Temperatures can range from sub-zero to greater than 400°F, differential pressures often exceed 1000 psi, and the chemical environment can vary. Compressor valves and their sealing elements are a key component that must be capable of withstanding these variables.

Further complicating this application is that with the ever increasing cost of energy, valve designers have attempted to increase the efficiency of their valves. Often this has translated into more stress being placed on the valve plate in the form of higher lifts.

Traditionally metal, nylon, and thermosets have been used with varying degrees of success in this application. Each material has it's own strengths and weaknesses. By focusing on these one can analyze the wide range of new materials available and arrive at a baseline for new valve plate materials.

One additional aspect of this program is that with the ever increasing costs of carrying inventories. It would be beneficial to reduce duplicate inventories. One material covering a broad range of applications would be extremely attractive.

Material Analysis:

<u>Metal</u> valve plates have a long track record in this industry and perform well in numerous applications.

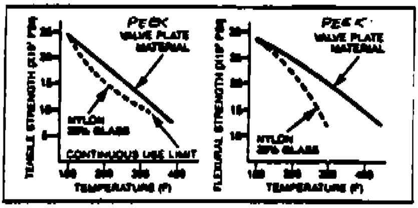
There are however some major drawbacks to using metal plates. The presence of corrosive contaminents (including sour gas, hydrogen, and moisture) can severely detract from the plates performance. Hydrogen embrittlement is a major problem for metals and can significantly reduce plate life.

Metal plates can undergo corrosion and pitting that can ultimately lead to fractures. Metal failure can be devastating, fragments that break off can cause serious damage to other parts of the compressor. Non-metallic fragments tend to disintegrate without causing as much damage.

Scratches on the surfaces of metal plates can impede the sealing capabilities of the plate, in addition plastic plates are softer and cause less wear on the valve seat. Plastics are lighter than metals, this results in lower impact velocities, which in turn can allow for a higher lift in the valve.

<u>Glass reinforced nylon</u> has been used for years as a valve plate material, it too has several short comings.

One of the major drawbacks of nylon is the temperature limitations. The continuous use limit of nylon is under 300°F, making it unsuitable for numerous applications. (Figure 1)



[illegible]

Another limiting factor for glass nylon if its susceptibility to moisture. The moisture absorption rate of nylon is 1.0%. Nylon will absorb moisture causing a loss of dimensional stability and strength (Figure 2). At temperatures above 200°F the nylon begins to degrade and can be attacked by acids and bases. Nylon also embrittles in the presence to oxygen. Nylon valve plates do not perform well in hot, moist gas service - a major compressor application.

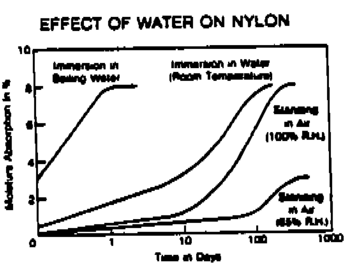
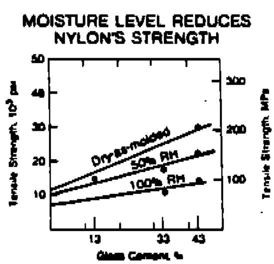


Figure 2



<u>Thermoset compounds</u> at one time looked promising. The key drawbacks with thermosets is that they tend to delaminate in service and their physical strengths tend to be low. Tensile Strengths ranging from 12,000 - 14,000 psi and flexural strengths ranging from 21,000 - 22,000 psi are approximately 50% for glass nylon, which has a 24,500 psi tensile strength and 35,000 psi and a flexural strength of 35,000 psi.[2]

<u>Polyetherimide,</u> Ultem, due to its high tensile strength (15,200 psi), elongation <u>(7-8%), flex modulus</u> (480,000 psi) and heat distortion temperature (392°F) looked like a promising candidate.[2]

The problem with polyetherimide is that is is an amorphous polymer. Amorphous polymers are little more than very viscous fluids and behave as such under continuous stress. They feature low creep and fatigue properties. These polymers perform well in static applications but perform poorly in fatigue. They show a decline in the level of stress they can handle with an increase in the number of times they are stressed (Figure 3).

FATIGUE RESISTANCE (73F)

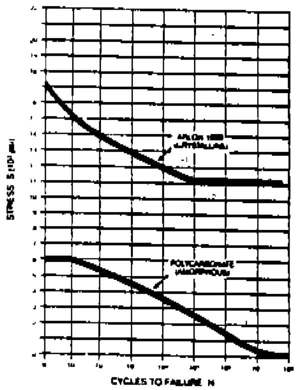


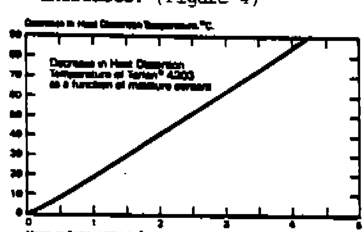
Figure 3

Crystalline polymer such as Arlon 1161 (a glass reinforced polyetheretherketone) contains a relatively high level of crystalline lattice, which enables the thermoplastic to exhibit elastic behavior and thus perform well under the continuous and frequent loading that a valve plate has to endure.

This fundamental difference in polymer structure is one of the main reasons that amorphous polymers have not been successful in the application.

Polyamideimides, Torlon, were other materials considered for valve plates. They have excellent mechanical and thermal properties.

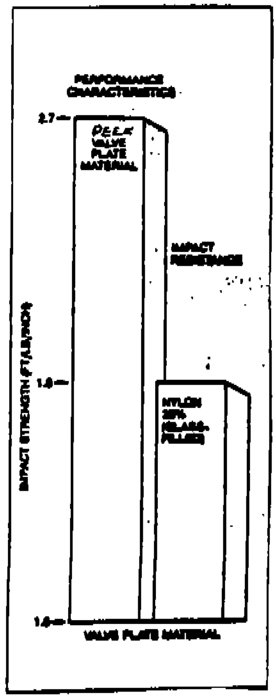
The major drawback of polyamideimides is that like nylon they too absorb moisture. Absorbed water limits the rate at which polyamideimides can be heated. Sudden exposure to high heat can distort the part unless the absorbed moisture is allowed to diffuse from the part. The HDT of this polymer will also decrease as the amount of absorbed water increases[3] (Figure 4)



The performance of Torlon as a valve plate material is very dependent on how it is processed. Torlon is an amorphous polymer and derives its fatigue properties from cross-linking. With a low level of cross-linking the polymer is very weak and cannot handle repeated stress. If the amount of cross-linking is high the polymer becomes very brittle.

In the mid 1980's people began experimenting with a new polymer PEEK - Polyetheretherketone, as a plate material. The physical properties of this material looked very promising. An analysis was initiated to compare the physical and technical data available on this new polymer to that available on previous materials.

PEEK, being a crystalline polymer will not experience the problems that polyetherimide had. It also exhibited the fatigue behavior and elastic characteristics that were so attractive in metal plates. The chain bonding being somewhat looser than that of metal allows it to have high impact strength and to absorb a considerable amount of energy. PEEK resists radial cracking and seat edge wear, thus increasing service life. The impact strength of PEEK is also much higher than that of nylon. (Figure 5)



Glass reinforcement has been added to increase the strength and heat distortion temperature of the polymer and reduce the coefficient of thermal expansion (Figure 6). This is important in preventing the plates from expanding during thermal cycling and thus hanging up in the valve.

SUMMARY OF PROPERTIES

	ARLON 1000	ARLON 1161
Tensile Strength (at yield) psi	13,500	21,000
Tensile Strain (at yield) %	6	
Elongation (at break) %	35	4-5
Flexural Modulus, psi	570,000	1,300,000
Flexural Strength, psi	16,000	31,000
Shear Strength, psi	12,000	
IZOD Impact (notched)		2.1
IZOD Impact (unnotched)		16-17
Heat Distortion °F @ 264 psi	360	610
Thermal Conductivity BTU-in/hr.ft^2-°F		
Coefficient of Thermal Expansion in/in/°F x 10^{-5}	>302°F-5.99 ∠302°F-2.61	1.6

Water Absorption % 24 Hours	.14	0.06
Sp. Gr.	1.30	1.55
Compressive Strength, psi (ULT.)	17,110	22,400
Coef. of Friction	.34	

As discussed earlier, moisture has a very detrimental effect on many plate materials. PEEK has a water absorption of .06%[4] this compares to 1% for nylon[5] .28% for polyamideimide[6], and 1.5% for laminates . With a moisture absorption rate at 1/4 to 1/25 that of competitive materials, PEEK has improved dimensional stability, it will not expand and lose strength.

PEEK has excellent chemical resistance and withstands the gases and contaminents present in the oil field. Hydrogen and H_2S have no adverse effect on the polymer. PEEK's only known solvents are concentrated nitric and sulfuric acid. It contains no fluorocarbons and is thus compatable for process compressors for the tobacco industry. In the field, PEEK valve plates have survived over 12 months service in an environment consisting of 97% H_2 with impurity levels of H_2S, methane, and other hydrocarbons at an average operating temperature of 280°F.[8] Because PEEK is less likely to embrittle from chemical attach it will continue to seal over a long period of time.

PEEK exhibits higher dimensional and load bearing properties than other valve (Figure 6) plate materials at elevated temperatures. With a continuous use temperature of more than 100°F high than nylon, PEEK is ideal for "hot gas" applications. Most non-metallic plates suffer a drastic reduction in physical properties above 300°F. This does not occur with glass filled PEEK until temperatures exceed 400°F. The coefficient of thermal expansion of glass filled PEEK is 1.6 in/in/°F x 10. This is lower than nylon at 1.8[9], making PEEK more resistant to deformation at higher temperatures and less likely to expand due to temperature.

One of the key tests for valve plates is how the plate performs due to repeated impact. PEEK has more impact fatigue resistance than metals[10] and is able to withstand twice their impact velocity. The impact strength of PEEK is also 50% higher than that of nylon (Figure 5).

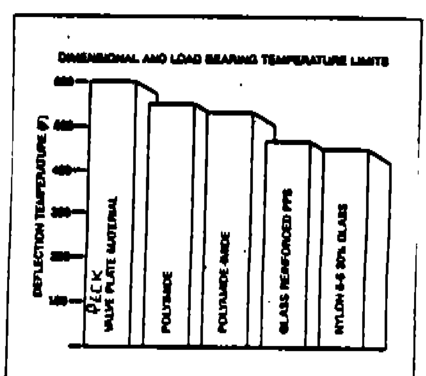


Figure 6

The next step was to submit PEEK valve plates to a rigorous test. This was accomplished with the cooperation of Dresser-Rand Engine Process Compressor Division. Sample plates were run on their Valve Endurance Tester. This equipment stimulates compressor service and provides a quick way of determining the effect of material and design variables on plate service[11]. The results were very encouraging, glass filled PEEK plates were stress tested at 375°F for over 10,000 cycles without failure[12].

In field test PEEK has operated at 1,400 psi differential pressure for over 10,000 cycles without failure. Nylon, by contrast, rapidly loses physical properties at temperatures above 280°F and is generally limited to differential pressures under 1,000 psi[13].

In another field test, valve lives of 8,000 plus hours have been recorded. This compares favorable with only 600 hours for metal plated valves in the same application[14].

Conclusion:

Since the introduction of PEEK as a valve plate material the efficiency, reliability, and operating parameters of compressor valves has improved dramatically. The success of this material has encouraged designers to look at new applications. There are currently test programs underway to analyze different PEEK blends for poppets, piston rings, rider bands, rod packings, vanes, and labirinth seals.

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Figure 2 - R.S. Klein, "Synergism in Compressor Valve Design."

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(2) - Ultem An Introduction to Material Properties and Processing General Electric ULT-301.

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