Optimization of Flange Sealant: Automotive Applications

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ABSTRACT
Power train is a building block of any vehicle it includes various components such as engine, transmission, differential, axle etc. These components contains various fluids such as engine oil, gear oil, transmission oil, petrol, diesel, cooling oil etc. for propulsion, lubrication, cooling and other applications. Leakage of these fluids can result in power loss, inadequate cooling or any other faults which leads to breakdown of power transmission of vehicle. To prevent all this fluids from leakage and seepage around 20 different grades of liquid gaskets are being currently provided to automotive companies depending on their requirements. These liquid gaskets mainly include different grades of anaerobic and silicone and other form in place gaskets. To provide one product solution for all flange sealing applications in automotive industry optimization of liquid sealant is being done. As a referral different Research papers, previous grades of our companies as well as other companies along with different web sources have been read to know about the applications, grades of sealants and different parameters such as pressure, temperature, and substrates to which bonding is to be provided, their surface coatings, roughness values and other parameters regarding the design of flange and flange sealants used in Automotive. Also various tests are being performed to ensure that all parameters are met. These parameters will be further optimized accordingly to cover as much applications as possible in automotive industry.
***Keywords**: - Sealants, FIPG, Flange Sealant, Gaskets, Liquid Gasket.*

1. INTRODUCTION

Liquid sealant gaskets are widely used in automotive industry for various applications mainly sealing and bonding of flanges. Solid gaskets are being replaced by liquid FIPGs considering various problems associated with it. Various liquid sealants are being used. They are being used in replacement of solid gaskets for most of the automotives applications.

Primarily Liquid FIPGs are dispensed as liquid which ensures they bond flanges strongly as it possesses gap filling ability which is not a case in solid gaskets. Liquid FIPGs eliminates problem of compression set also reduces loosening of bolt over time. Thus problems such as proper bonding strength, compression set etc associated with the use of solid gaskets are solved by liquid FIPGs.

Hence, a need arises to further develop better and optimized liquid sealants. An optimized Flange sealant will have many benefits ranging from cost saving, time efficient, up to logistics management and inventory management. It also saves time of documentation of different sealants being used and keeping track of each one of them separately.

Thus, overall emphasis is given for design of Liquid Flange Sealant for universal application in automotive industry for further optimization and better usage of FIPGs. This solution can be further used to develop a Liquid Sealant which can be used anywhere in automobile industry.

The approach of this study is by understanding the parameters needed for design of a liquid gasket for a number of areas where liquid gasket is used in automotives. These parameters will be compared with already available liquid sealant solutions. To achieve this objective, we will employ a combination of testing results of different kinds of liquid sealants currently available in the market and the parameters needed to apply liquid gasket in automobiles. This research method will allow us to understand the needs of automotive industry as well as the limitations of Liquid Gasket, so that the parameters of optimized liquid flange sealant can be used to develop a universal flange sealant.

2. METHODOLOGY AND PROBLEM STATEMENT

2.1 Methodology

Step 1: To find how are Flanges and sealants designed**.**

Step 2: Finding various application areas of flange sealant in Automotives.

Step 3: Finding Temperature and pressure at the above application areas.

Step 4: Finding Substrates used at the above application areas.

Step 5: Finding the manufacturing processes used to manufacture the above comp6nents of system.

Step 7: Finding the roughness values at application areas of various components.

Step 8: % Strain (Elongation) obtained of various components.

Step 9: Liquid sealants that are currently used in automotives.

Step 10: Comparison of all the above parameters to figure out the exact parameters for development of optimized liquid flange sealant.

2.2 Problem Statement

There are many problems associated with usage of different grades of products for flange sealing. This problems includes -

1. Designing of different grades as per changing requirements of customers for various applications. This requires lots of research work to design each single grade.
2. Customer experiences sorts of confusion while ordering product. As single mistake in understanding of application requirement can lead to great financial loss for customer.
3. Each time application engineer has to visit customer to understand their requirements and do lots of testing before suggesting any product.
4. Manufacturing methodology is needed to be changed each time new product is to be designed.
5. Maintaining of different grades is quite confusing and can sometimes lead to misplacing of different grades and can lead to delivery of wrong product.
6. Inventory management is little complex for different grades when compared to single grade. Thus it becomes difficult for both company and customer.

2.3 Objectives

The Objective of this research paper is –

1. To find the parameters that configured to design a Flange sealant specifically for automotives.
2. To find various data such as Roughness, Temperature, Pressure, Substrate used, etc at the

application area (Where the liquid sealant is going to be applied).
3. To find the various liquid sealants already available in market.
4. To identify the parameters for development of Universal Flange sealant.

3. DESIGN CONSIDERATIONS

3.1 Design Considerations for Flange sealant.

1. Flange Parallelism:

Alignment of the flange with respect to central axis is necessary to achieve proper sealing. In order to get even compression (for solid gaskets) and required sealing in liquid gaskets, the flanges have to be parallel. Improper alignment could be caused by improper design, faulty installation or by distortion due to heat.

1. Manufacturing process of flanges:

The manufacturing process of Flanges decides the surface roughness and other surface properties of flanges. This roughness is a deciding parameter for both FIPG as well as solid gaskets.
Note: - For Flatness, Flanges are generally designed to have a maximum gap of 0.01 inches (0.25mm) between flanges and not more than that.

3.2 Design Consideration for sealant design.

1. **Substrate**:

Substrate on which sealant is to be applied is an important parameter to be considered for sealant.
For example: Anaerobic requires at least one substrate to be metallic whereas silicone can be used for plastic substrate.

2. **Temperature**:

Temperature refers to temperature which is to be sustained by sealant during application.

For example: Anaerobic are desired for temperature requirement less 150°C some grades can be used till 200°C. Silicones can be used for temperature over 300°C.

3. **Chemical resistance**:

Sealant should not react with fluid which is being protected from leakage & seepage.

4. **Gaps sealed:**

Sealing ability means the ability of a material to resist the micro-leakage through its entire thickness.
For example: Anaerobic are used if gaps are less than 0.25 mm and below whereas Silicone sealants are used when gap to be sealed is till 3.175mm.

5. **Adhesive strength**:

Some bonding strength is required to resist seepage of products beneath the surfaces. Sometimes the sealant also improves structural rigidity and for this higher bonding strengths are necessary.
For example: Anaerobic adhesives can provide strength in the range of 2 - 9 N/mm² whereas RTV Silicones: 0.5 – 2.5 N/mm².

6. **Curing mechanism**:

Whether cures in absence of air or at room temperature or other mechanism.

7. **Open time or Before assembly time**:

Anaerobic Sealants will not start curing unless confined between two metallic surfaces so as to exclude the oxygen of the air which poisons the reaction.
Thus, for all practical purpose a bead of Anaerobic Adhesive applied can stay uncured for up to 60

minutes.
RTV Silicones will start to cure immediately up on dispensing and hence the assembly must be completed with 5-10 minutes to avoid 'shimming' action due to partial cure.

These are all the parameters that are used in design and testing of sealants, further tests will also done to test the performance of universal flange sealant and to verify the data which is obtained by the above methodology.

4. RESULTS

4.1 Application areas of flange sealants in automotives:

System	Application Area
Engine	Timing Gear Casing
	Oil Sump (Engine)
	Intake Manifold
	Cylinder Head (Bikes)
	Throttle Body Casing
	Oil Pump Casing(Engine)
	Rocker Cover
	Valve Covers
Transmission (With Torque Converter)	Oil Pan (Transmission)
	Transaxle Casing
	Transmission Case
	Engine Block & Transmission Case
	Bell Housing
	Differential Casing
	Clutch Covers (Bikes)

Coolant System	Water Pump Cover
	Thermostat Housing
Miscellanous	Fuel Tank
	Steering Gearbox Casing
	Air Compressor

4.2 Operating Temperature and Pressure of the application areas:

Application Area	Operating Temp (°C)	Pressure (Bar)
Timing Gear Casing	50 to 55	1 to 1.5
Oil Sump (Engine)	110 to 126	1 to 0.5
Intake Manifold	35 to 100	1 to 1.8
Cylinder Head (Bikes)	65 to 122	1 to 50
Throttle Body Casing	35 to 100	1 to 1.8
Oil Pump Casing(Engine)	110 to 127	1 to 4.5
Rocker Cover	120 to 150	0.17 to 0.4
Valve Covers	160 to 240	0.17 to 0.4

Oil Pan (Transmission)	80 to 110	1 to 25
Transaxle Casing	70 to 95	1 to 25
Transmission Case	80 to 110	1 to 25
Engine Block & Transmission Case	80 to 110	1 to 25
Bell Housing	-30 to 80	1 to 25
Differential Casing	64 to 68	1 to 1.2
Clutch Covers (Bikes)	65 to 93 (<240)	-0.1 to 0.1
Water Pump Cover	90 to 105	0.3 to 2.75
Thermostat Housing	80 to 90	0.3 to 2.75
Fuel Tank	-40 to 80	0.01 to 1
Steering Gearbox Casing	25 to 68.6	0 to 35
Air Compressor	10 to 35	6 to 8

4.3 Finding Substrates used at the above application areas.

Application Area	Substrate 1	Substrate 2
Timing Gear Casing	Polycarbonate, Plexiglass, Steel, Aluminium Alloys	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Oil Sump (Engine)	Stainless Steel, Cast Iron, Aluminium Alloy	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Intake Manifold	Aluminium Alloy, Cast Iron, Polypropylene	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Cylinder Head (Bikes)	Aluminium Alloy, Cast Iron, Magnesium Alloy	Aluminium Alloy, Cast Iron, Magnesium Alloy
Throttle Body Casing	Aluminium Alloy, Steel,	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Oil Pump Casing(Engine)	Cast Iron, Stainless Steel	Cast Iron, Stainless Steel
Rocker Cover	Polyamide, fluorosilicone rubber, Aluminum Alloy, Cast Iron, Stainless Steel	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Valve Covers	Aluminium Alloy, Bronze, Brass, SS, CS, CI, Forged Steel	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Oil Pan (Transmission)	Cast Aluminium Alloy, Cast Iron, Cast Steel	Nylon 6, Cast Aluminium, Sheet Steel
Transaxle Casing	Aluminium Alloy, Cast Iron	Aluminium Alloy, Cast Iron
Transmission Case	Cast Aluminium Alloy, Cast Iron, Cast Steel	Cast Aluminium Alloy, Cast Iron, Cast Steel

Engine Block & Transmission Case	Cast Aluminium Alloy, Cast Iron, Cast Steel	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Bell Housing	Cast Aluminium Alloy, Cast Iron	Cast Aluminium Alloy, Cast Iron, Cast Steel
Differential Casing	Ductile Iron, Aluminium Alloy, Cast Steel	Ductile Iron, Aluminium Alloy, Cast Steel
Clutch Covers (Bikes)	PA, PVC, PU, PC, Aluminium Alloy	Cast Iron, Forged Steel
Water Pump Cover	Stainless Steel, Aluminium Alloy, Mild Steel	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Thermostat Housing	Aluminium Alloy, Nylon, Cast Iron	Cast Iron, Steel, Aluminium Alloy, Stainless Steel
Fuel Tank	HDPE, PP, recycled polyethylene, EVOH, Steel, Aluminium	HDPE, PP, recycled polyethylene, EVOH, Steel, Aluminium
Steering Gearbox Casing	Aluminium Alloy (6082)	Aluminium Alloy
Air Compressor	Cast Aluminium Alloy, Cast Iron	Cast Aluminium Alloy, Cast Iron

4.4 Finding the manufacturing processes used to manufacture the above components of system.

Application Area	Manufacturing Processes
Timing Gear Casing	Stamping, Die Casting, Injection Moulding, Surface Finish(Powder Coated, Painted)
Oil Sump (Engine)	Die Casting, Deep Drawing
Intake Manifold	Blow Molding, Die Casting, Forging, Hot Rolled, Surface Finish(Sand Blasting, Polished)
Cylinder Head (Bikes)	Die Casting, CNC Machining(Milling, Drilling, Turning)
Throttle Body Casing	Die Casting, Surface Finish(Polished, Galvanised, Painted)
Oil Pump Casing(Engine)	Casting, Sintering, Surface Finish(Grinding)
Rocker Cover	Die Casting, Gravity Casting, Surface Finish(Polished)
Valve Covers	Casting, Molding, Stamping, CNC Machining, Surface Finish(Vibratory Polishing)
Oil Pan (Transmission)	Die Casting, Deep Drawing

Transaxle Casing	Die Casting, Perm. Mold Casting
Transmission Case	Perm. Mold Casting, Shell Molding
Engine Block & Transmission Case	Perm. Mold Casting, Shell Molding, Casting, Surface Coating(Milling)
Bell Housing	Sand Casting, Surface Finish(Powder Coated, Painted, Polished)
Differential Casing	Casting, Turning
Clutch Covers (Bikes)	Molding, Forming, Stamping, Turning, Drilling
Water Pump Cover	Die Casting, Stamping, Surface Finish(Anodization, Milling)
Thermostat Housing	Injection Molding, Machined Casting, Milling
Fuel Tank	Injection Molding, Blow Molding, Stamping, Surface Finish(Powder Coating, Galvanisation)
Steering Gearbox Casing	CNC Machining, Surface Finish(Honing)
Air Compressor	Casting, Stamping, Forming, Injection Molding, Surface Finish(Painted)

4.5 Finding the roughness values at application areas of various components

Application Area	Roughness Range (Ra) (um)
Timing Gear Casing	0.05 - 16
Oil Sump (Engine)	0.4 - 9
Intake Manifold	0.012 - 50
Cylinder Head (Bikes)	0.025 - 25
Throttle Body Casing	0.012 - 16
Oil Pump Casing(Engine)	0.025 - 6.3
Rocker Cover	0.012 - 3.2
Valve Covers	0.012 - 25
Oil Pan (Transmission)	0.4 - 9
Transaxle Casing	0.4 - 6.3
Transmission Case	0.8 - 6.3
Engine Block & Transmission Case	0.2 - 25
Bell Housing	0.012 - 9
Differential Casing	0.025 - 25
Clutch Covers (Bikes)	0.025 - 25
Water Pump Cover	0.02 - 25
Thermostat Housing	0.02 - 25
Fuel Tank	0.01 - 9
Steering Gearbox Casing	0.02 - 1.6
Air Compressor	0.04 - 16

4.6 % Strain (Elongation) obtained of various components.

Application Area	Max Strain (%)
Timing Gear Casing	0.8
Oil Sump (Engine)	0.25
Intake Manifold	0.675
Cylinder Head (Bikes)	0.67
Throttle Body Casing	0.17
Oil Pump Casing(Engine)	0.15
Rocker Cover	1.8
Valve Covers	0.5
Oil Pan (Transmission)	0.9
Transaxle Casing	0.15
Transmission Case	0.17
Engine Block & Transmission Case	0.17
Bell Housing	0.12
Differential Casing	0.09
Clutch Covers (Bikes)	5.3
Water Pump Cover	0.17
Thermostat Housing	0.91
Fuel Tank	1.3
Steering Gearbox Casing	0.1
Air Compressor	0.0345

4.7 Liquid sealants that are currently used in automotives.

4.7.1 Anaerobic Sealants used in Automotives and their parameters.

Company Name	Grade Name	Service Temp.(°C)	Strengthin (N/mm2)	Elongation (%)	Pressure Resistance (bar)	Gap Filling (mm)
Metlok	My-T-Lok 205	-50 to 150	6 to 9	-	≥ 100	≤ 0.25
	My-T-Lok 2205	-50 to 150	≥ 4	10 - 20	≥ 100	≤ 0.25
	My-T-Lok 250	-50 to 150	≥ 2	40 - 60	≥ 100	≤ 0.25
	My-T-Lok 274	-50 to 150	5 to 9	10 - 20	≥ 100	≤ 0.25
	My-T-Lok 257	-50 to 150	3 to 6	10 - 20	≥ 100	≤ 0.25
	My-T-Lok 215	-50 to 150	5 to 9	10 - 20	≥ 100	≤ 0.25
	Loctite 510	-75 to 200	5	-	≥ 13	≤ 0.25
	Loctite AA 5182	-50 to 150	-	-	≥ 13	≤ 0.5
	Loctite 518	-75 to 150	5.5	64	≥ 13	≤ 0.25

Henkel	Loctite 573	-50 to 150	1.3	-	≥ 13	≤ 0.25
	Locite 5188	-75 to 150	7.8	186	≥ 13	≤ 0.25
	Loctite 515	-10 to 150	≥ 6.9	-	≥ 5	≤ 0.25
	Loctite 574	-75 to 150	8.5	-	-	≤ 0.25
Anabond	Fast Cure MasterGasket	-40 to 180	-	-	≥ 125	≤ 0.2
	Anabond 610	-40 to 180	-	-	≥ 120	≤ 0.5
	Machined FlangeGasket	-40 to 180	-	-	≥ 120	≤ 0.5
Permabond	A136	-55 to 150	12	-	-	≤ 0.25
	MH199	-55 to 121	8	-	-	≤ 0.25
	HH190	-55 to 150	6	-	-	≤ 0.25
	LH197	-55 to 200	5	-	-	≤ 0.25
	MH196	-55 to 200	10	-	-	≤ 0.25

4.7.2 Silicone Sealants used in automotives and their parameters.

Company Name	Grade Name	Service Temp.(°C)	Elongation(%)	Pressure Resistance(bar)
Metlok	My-T-Sil 912	-65 to 250	250 - 300	≥ 100
	My-T-Sil 913	-65 to 250	≥ 250	≥ 100
	My-T-Sil 915	-65 to 300 (400°C for Short Periods)	≥ 300	≥ 100
	My-T-Sil 9060	-65 to 250	200 - 500	≥ 100
	My-T-Sil 9904	-65 to 250	≥ 500	≥ 100
Henkel	Loctite SI 5901	-65 to 250	400	≥ 13
	Loctite SI 5970	-65 to 250	200	≥ 13
	Loctite SI 5210	-65 to 250	230	≥ 13
	Loctite SI 5240	-65 to 250	530	≥ 13
	Loctite SI 5900	-65 to 250	400	≥ 13
	Loctite SI 5910	-50 to 200	≥ 400	≥ 13
	Loctite SI 587	-50 to 260	≥ 350	≥ 12.7
	Loctite SI 5060	-65 to 250	200 - 500	≥ 13
Anabond	Anabond 676	-50 to 300	≥ 160	≥ 110
	Anabond 673	-50 to 300	≥ 170	≥ 110
	Anabond 683	-50 to 250	300 - 350	90 - 100
Permatex	The Right Stuff	-60 to 260	550	-
	Ultra Black Gasket Maker	-54 to 260	360	-
	W.Pump&T.stat RTVSealant	-54 to 260	≥ 120	-
	Auto Transmission RTV Sealant	-54 to 260	360	-
	Optimum Black Gasket Maker	-54 to 260	≥ 400	-
ThreeBond	TB1215	-60 to 200	320	≥ 100
	TB1216E	-60 to 200	300	≥ 100
	TB1217F	-60 to 200	210	≥ 100
DOW	SILASTIC RBL-9694-30P	-50 to 200	820	-
	SILASTIC RBL-9694-45M	-50 to 200	600	-
	DOWSIL 730 FS	-65 to 200	240	-
	DOWSIL Q3-1566	-50 to 275	340	-
	DOWSIL 3-0115	-50 to 200	375	-
	Dow Corning 3-0100	-55 to 180	455	-
	DOWSIL 3-0105	-50 to 200	375	-
	DOWSIL 7091	-45 to 200	680	-
	DOWSIL 737	-65 to 180	>300	-

4.8 Comparison of all the above parameters to figure out the exact parameters for development of optimized liquid flange sealant.

Parameters	Obtained Results
Service Temperature(°C)	-30 to 240
Pressure Resistance(bar)	25
Bonding Substrates	PC, PP, Plexi-glass, Steel,CI, Aluminum alloys, HDPE,SS, MS, Forged steel,EVOH, Ductile Iron, etc.
Roughness Value Range(Max &Min) (µm)	0.012 to 12.5
Chemical Resistance	Engine oil, Air, Petrol, Diesel, Transmission oil, Gear oil, Coolants, Power Steering Fluid, etc.
Elongation (in %)	0.0345 to 5.3

5. DISCUSSION

As per our methodology, the results section has all the information needed for the development of a liquid sealant which will be universally effective for automotive industry. Our findings for this study are all summarized in tabular form in the results section. As per our approach, all the steps were followed i.e. design considerations for development of FIPGs, finding the application areas of FIPGs in automotives, The temperature and pressure at those areas to find the conditions which the liquid gasket will be exposed to, etc. Finishing at the final parameters for the design of optimized liquid sealant. The Final parameters obtained are doesn’t exactly enable us to develop a liquid sealant universally effective due to the limitations of polymer compounds, some application areas such as Exhaust valve has been excluded as the temperature conditions will melt the polymer gasket.

As per our study, we can say that if a liquid sealant with whatever technology is designed equaling or exceeding the parameters found by us, then it will surely be a liquid sealant which can be used in many application areas of automotives. This will help contribute to the adhesive and sealant industries to develop a product that will be used in automotives as a better alternative for different grades of sealants for different application areas in automotives.

6. FUTURE SCOPE

The future scope of this study lies in the design and development of liquid sealant with the parameters that are obtained in this study. Researchers can even further find more adhesive technologies that will help us to match all the parameters that can be covered by automotives so that one liquid sealant gasket solution will be available for all automotives.

Further development and testing can reveal different problems regarding the limitations of current technologies used in sealants. New technologies might be discovered for fulfillment of parameters that are able to be used in any kind of gasket purposes of automotives.

7. CONCLUSIONS

This study was done to find the parameters needed to optimize currently available liquid sealants and standardize a single solution for different application areas of automotives. The results that were found during and after the study were enough for use to identify the actual parameters needed for design of an optimized liquid sealant gasket. Currently available technologies have many limitations for e.g. anaerobic sealants need metal substrate, Silicones has high temperature resistance but has high risk of seepage than any other solution available, etc. These problems need to be solved for proper design of an optimized liquid sealant gasket.

As stated, our objectives were completed and the parameters that enable development were also found. This study may contribute to development of further optimized and standardized liquid sealant gasket solutions.

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