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AUTOMATIC AIR FILTER CLEANER FOR AUTOMOBILE VEHICLES

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ABSTRACT

Since the automotive industry came into existence there has been a large amount of technology development. One such innovative concept is the automatic air filter cleaning. Air filters are an important part of their air intake system since it removes dust, mould, pollen and other impurities present in the air. The concept of automatic air filter cleaning is to increase the life of the air filter and to generate the cost optimization in customer point of view.

Keywords: Air filter, vacuator, choked filter and air intake system.

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1. INTRODUCTION

In order to get an edge over other competitors a company needs to think in different ways such as bringing up an innovative idea which will be very useful not only for the customers but also it may help the industry to generate clients and better customer satisfaction. Innovation does not mean that it should necessarily include a lot of research and development work over a period of long span or should involve an investment of big budget. It can be something very frugal thinking like a slight change in the design, adding or removing a single or few components in order to optimize the design and provide better efficiency. After going through lots of areas in the automotive engine like the fuel and air intake system, cooling system and exhaust system in order to create something innovative we decided to concentrate more on the air filter present in air intake system which is an equally essential part compared to the others.

2. EXPERIMENTAL SETUP

2.1. Need & Justification

In case of an air filter the life span is decided on the basis of how much kilometer they run or in some cases like a heavy commercial tipper it may be in hours of operation. This situation generate negative effect on the engine performance such as air starvation, reduction in fuel economy, carbon deposits on the cylinder surface, low transient response and damage to engine parts such as pipes, valves and the exhaust system. The main important factor to be kept in mind while creating the mechanism has to be that it should not damage the air filter. The air filter contains a folded paper element media pleats which will easily get damaged once an external force is applied on the surface.

2.2. Air intake system

The main purpose of air intake system is to make sure that it removes all moisture, dust and chaff from the air before it reaches the engine cylinder and piston ring occurs which will directly affect the engine performance and reduces the overall efficiency.

3. ASSEMBLY

The air intake system mainly consists of the following parts mentioned as follows:

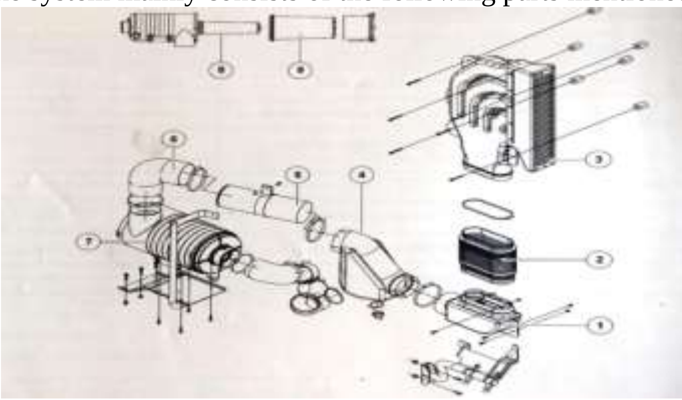

Figure 3.1 Air intake system assembly

1. Snorkel Lower Half
2. Bellow Assembly
3. Snorkel Assembly
4. Assembly duct – Air cleaner to pre cleaner
5. Pipe Duct to Hose
6. Hose Air Filter to Pre Cleaner
7. Air Filter Assembly
8. Safety Element, 9. Primary Element

4. CURRENT METHODS

Generally air filter manufacturers never recommend cleaning of air filters but instead of that they ask to replace the air filters after a prolonged period of time. It can be either on the basis of time, kilometers or hours of operation. In commercial vehicles the replacement is done after 60000 km. The companies do not recommend cleaning of air filter either because of the fact that they want to hold a continuous grip on the market or the air filter may get damaged because of the improper methods which are used to clean the air filter.

Figure 4.1 Clean air filter

The figure 4.1 shows the condition of an air filter when it about to be newly fitted in a system. Once the filter is used for a prolonged period of time and it reaches the maximum pressure resistance limit, dust gets accumulated completely on the air filter in such a way that almost 4-5 kg gets added to the total weight of the air filter. Complete cleaning of the air filter is not possible because dust will be located even at the most inner part of the air filter. In order to clean that use of extra forces have to be made. The methods which individuals or organizations use right now to clean the air filters can be explained as follows.

This is the most common methods which can be seen in garages and workshops. In order to avoid unnecessary cost for the customer by purchasing and installing a new filter they try to clean the air filter by hitting it on a hard surface so that a sudden jerk is induced upon the element and the dust dislodges.

Since the dust particles which are situated at the external part of the air filter are not there for a long time, they can be removed easily with external jerks. In this method an individual will hold the air filter in one end and would continuously hit on a surface which is fixed. Due to the sudden jerk which is applied on the filter, the dust particles on the surface will get easily dislodged and removal of dust takes place. Later on such jerks are provided more continuously to clean the filter. This will cause the particles which are inside the air filter to further get dislodged from the surface. This procedure removes almost 50% of the dust, even though it is not recommended.

The main disadvantage of this method is air filter can be damaged in ease. The primary and secondary elements of an air filter are covered with small metallic wire mesh. The wire mesh is generally made up of aluminum or stainless steel. The diameters of wire mesh will not go more than 1 mm. Due to the fact that these wire mesh have such a small diameter and have very low capacity to withstand stress it gets deformed by the continuous impact made by the user on a fixed surface.

The filter structure contains 2 main parts are the primary and secondary element and in that the primary element contains the highest number of dust. The inside portion of the filter has paper pleats which are very soft material and can be easily teared. In this method compressed air is used to remove the dust particles. The dust particles mentioned in the earlier method are in terms of micron particles which are in ranges from 0.1 to 10 μm.

The element seen in the interior is called secondary element. As said above the secondary element virtually contains no dust. The primary element contains more amount of almost up to 5 kg dust. Generally the mounting of secondary filter is made directly with the body so while removing the secondary element stays at the same position while the primary filter comes out easily.

After removing the air filter and keeping it at a side compressed air is used to clean the air filter. Sometimes it is applied directly on the external surface or sometimes it is applied through the interior part. While applied on the external surface the dust will be removed easily. As mentioned before, dust on the external surface can be removed easily as compared to that on the interior portion of the pleats. Once compressed air is applied the complete dust on the external surface is removed. This removes almost 30 - 40 % of the dust.

In case the air is applied from the interior hollow portion of the air filter the dust will be removed but it will be requiring more force of air because of the fact that the dust on the interior portion is adhesively bonded to the paper pleats. Therefore it is difficult to dislodge the dust particles from the surface of pleats. The interior portion of the filter also contains wire mesh and pleats are more closely meshed with each other as compared with the exterior. Though this method cleans dust which is less effective as compared to the method in which the air is applied from the exterior.

The main disadvantage of this method is that compressed air can damage the air filter. Even if pressure is applied in the range of a single bar there are chances of pleats can get damaged. As said earlier the wire mesh is of very small diameter and due to that even if a little extra force is applied the mesh may bend. If the bending of mesh occurs then there will be a change in the pattern of the filter paper pleats arrangement. Due to that the dust will be collected unevenly on the pleats. This can cause uneven airflow which can increase the load on the engine. This will directly affect the engine performance and efficiency.

This is least recommended method which is used to clean the air filter. Neither the manufacturers nor the operators recommend this method because when water mixes with dust mud and clay will be formed.

Generally due to the unawareness and lack of training or guidance, the person who remove the air filter from the casing and either sprinkle water or use pipes at high pressure to clean the filter. Even though the dust is removed from both the elements in a similar content as compared to those by using compressed air or jerks on the filter.

During the cleaning process, some dusts are removed but the dust which stays on the filter gets mixed with water and forms clay or mud. This gets covered on the entire filter surface and blocks the pores on the filter. Due to this air flow is restricted, even though virtually there is no dust in the air filter a higher pressure drop is attained. This happens because the clay formed due to the mixture of water and dust has blocked the pores on the entire air filter. It will reduce the CFM rate at which the air is flowing into the system.

If the required amount of air is not received by the system then incomplete combustion will take place which will affect the engine performance. Due to incomplete combustion the unburnt particles will contaminate the smoke with oxides of nitrogen (NOx) and particulate matter. Even if the compound is partially oxidized it is dangerous, if ethanol undergoes partial oxidation then it will produce acetaldehyde and if the same is undergone by carbon then it will produce carbon monoxide (CO). Both these gases are considered very harmful. The efficiency of an engine is always determined by the rate at which the combustion takes place. Therefore it is always necessary to maintain the required airflow.

5. AUTOMATIC AIR FILTER CLEANING

The objective of this project is to develop a methodology that will automatically clean the air filter once it gets chocked up. Nowadays every modern air filter has a service indicator which will give indication that the filter has been chocked or the maximum allowable pressure drop has been reached. As mentioned earlier the performance of the air filter will not be affected for almost 60000km or until it reaches a restriction of 6.25 kPa.

5.1. Practical considerations

The considerations which were made during the development of concepts for air filter include,

- The air filter should be maintained as it is. Even though the cleaning takes place the quality of the air filter should not be affected, in terms of both from physical point of view as well as the efficiency part.
- The air flow rate should be maintained. The concepts may require adding few extra mountings on the interior of the air filter. The mounting will act as a restriction to the inlet air but it should not be such that it will reduce the airflow CFM which will lead to incomplete combustion.
- The size of the mountings should be as smaller as possible. They mountings should be in a way that it can be easily fitted in the air filter housing and also not to create any unnecessary disturbance in the working of the air filter.

5.2. Using exhaust gas suction

The first method tried for the automatic air filter cleaning was with the help of vacuum suction. The idea was conceived after going completely through the work of a vacuum cleaner. The purpose of the vacuum cleaner is to clean the dust from the surface of the floors with the help of vacuum. The dust particles which are situated on the floors are heavier in size compared to the dust particles which are placed on the surface or interior of the air filter. The vacuum cleaner performance depends upon the following factors

1. Air speed – The speed at which the air enters the system. It can be measured either in metre per second (m/s) or miles per hour (mph).
2. Airflow rate – It can be measured in Cubic Feet per metre (CFM).
3. Weight – The quantity of dust and the capacity with which it can perform.

It is basically depends upon the suction power of the system, in which the efficiency of an instrument or machinery which generates vacuum is called Air watt. It depends upon the amount of airflow generated with reference to the power used by the system.

The suction can be defined as the maximum pressure difference which can be created. In general case a household model of vacuum cleaner can generate a suction of about 20 kPa in negative. More suction rating means that the cleaner is more powerful. Since higher dust particles on floor require 20 kPa, the particles in air which are placed on the filter require less pressure.

Now since a vacuum effect had to be created on the air filter a place where it can be implemented had to be found. After many areas and consideration it was decided that the suction will be made through the vacuator valve. The reason behind the selection of vacuator valve is,

- That there is no need to create an extra portal in order to create the suction.
- Maximum amount of dust in an air filter will be near the vacuator valve only because the air filter dust is discarded from that particular portion only.
- The vacuator valve has an optimum diameter of 51.25 mm which is neither too much small nor large for suction to take place.

Now the task was to create a suction effect. The suction has to be something which can dislodge the dust even from the extreme corner of the air filter. But the suction effect has to be limited so that it should not damage the air filter.

After some consideration it was decided the suction effect will be created with the help of exhaust system. The exhaust pipe has a standard diameter of 101.59 mm. The idea is to connect the vacuator valve by extending it to the exhaust pipe. Before applying this concept in actual a stimulation was created with the help of ANSYS. The following considerations were made in the stimulation

- The diameter of the exhaust pipe was taken as 101.59 mm.
- The diameter of the vacuator valve was taken as 51.25 mm.
- The airflow rate in the exhaust system was taken as 550 CFM.
- Three values were taken at which the mounting vacuator valve was connected with the system. The values are 30º, 60º and 90º.

The test results can be shown as follows:

(a)At 30º

The results obtained at 30º can be written as follows

Force which is generated towards the inner side of the air filter

= 1.966e + 006 = 0.000001966 kPa

Suction effect created near vacuator valve towards the direction of exhaust

= -6.495e + 006 = -0.000006495 kPa

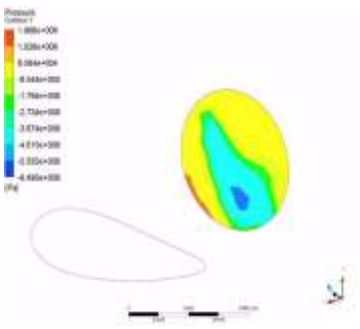

Figure 5.1 Suction effect at 30º

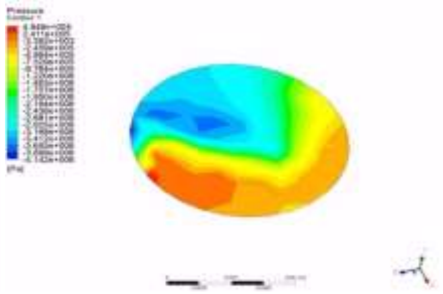

Figure 5.2 Suction effect at 60º

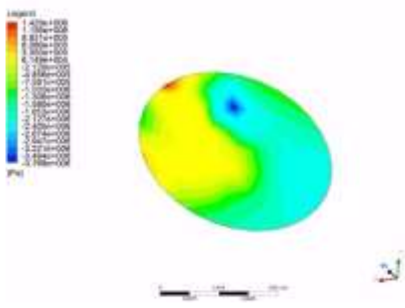

Figure 5.3 Suction effect at 90º

(b)At 60º

The results obtained at 60º can be written as follows

Force which is generated towards the inner side of the air filter

= 4.846e + 005 = 0.00004846 kPa

Suction effect created near vacuator valve towards the direction of exhaust

-4.142e + 006 = -0.000004142 kPa

(c) At 90 º

The results obtained at 90º can be written as follows

Force which is generated towards the inner side of the air filter

= 1.429e + 006 = 0.000001429 kPa

Suction effect created near vacuator valve towards the direction of exhaust

= -3.768e + 006 = -0.000003768 kPa

The suction and intake pressure generated in all the above cases can be shown in the table 5.1 as follows.

Table 5.1 Suction pressure at different angles

Angle	Suction Pressure	Inlet Pressure
30º	-0.000006495 kPa	0.000001966 kPa
60º	-0.000004142 kPa	0.00004846 kPa
90º	-0.000003768 kPa	0.000001429 kPa

As it can be seen that the maximum suction pressure is generated at 90º this is equal to -0.000003768kPa. The value is very less as a counter pressure towards air filter is generated which is of almost half the magnitude as compared to the suction pressure.

5.2. Reverse blow using exhaust fan

This method included creating a reverse flow of air in the air filter. The intention was to dislodge the settled dust particles with the help of air at high force. For this particular method an exhaust fan was used which had a size of 4 inch. The other relevant details of the fan are listed in the table 5.2 as follows.

Table 5.2 Exhaust fan specification

Size	4 inches
Supply	AC
Voltage	220 – 240 V
RPM	2900
Current	0.125 A
CFM	95

Since the fan using Alternating current the cables were extended in order to avoid things getting complicated. A normal 3 phase plug with a long wire was used to connect the exhaust. It can be shown as follows.

Figure 5.4 Choked filter mounting

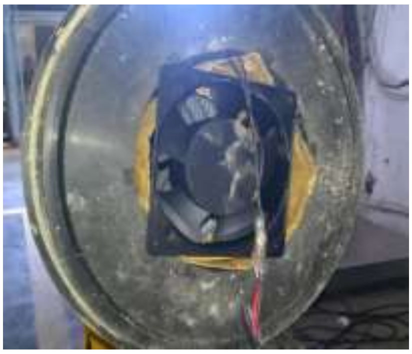

Figure 5.5 Exhaust fan mounting on choked filter

Out of the choked filter the primary filter was removed since it has the maximum amount of dust. While weighing it had a dust of almost 7.94 kg. Now for purpose of conducting the test the primary element was placed on a plane surface with the help of 2 stands which can be shown in the figure 5.4.

Now the exhaust fan was placed at the outlet of the air filter as shown in the figure 5.5. In order to make sure that the air flow remains unharmed and loss of air will not take place, certain cardboard fillings were made. The diameter of the air filter outlet is larger than 4 inches. The diameter of an air filter primary element is 4.3 inches. So to cover the remaining portion fillings were made.

After the correct placement of all the equipments the exhaust fan was made to rotate. But due to low CFM the dust will remain at the same place. Thus no dust was removed from the air filter.

5.4 Current based pulse vibration

In this particular method the objective was to remove the dust using pulse vibration. The equipment would contain the following items:

- A control unit
- Electrode pads
- 3 AAA batteries
- AC adapter

The advantage of this method is that we can use either direct or alternating current depending upon the availability.

For our purpose we decided to use DC supply with the help of the 3 AAA batteries available. Similarly as done in the earlier case the primary filter was removed but instead of using a choked filter a damaged filter was used to check whether enough vibration is created or not. The arrangements of electrodes were made in such a way as shown in the figure 5.6.

Figure 5.6 Electrode mounting on air filter

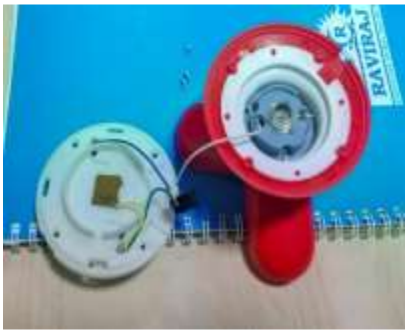

Figure 5.7 Dismantled massager

Later on after the vibrations were started it was seen that the pulses generated were very much low in frequency. It was not enough to remove or dislodge the dust from the surface of the filter.

5.5. Using vibration motor

The main intension in this method was to create vibration on the surface of the air filter primary element by directly getting the wire mesh in contact with the vibration motor.

The vibration motor to be used had a voltage of 6 volts and a current rating of 5 A. The supply was given with the help of DC source. The motors generally used for vibration massager purpose were used for this experiment.

The figure 5.7 shows a massager in dismantled condition. Since the massager motor can be used with the help of DC supply there was no need to keep the extra wires other than the positive and negative wires were removed. Since it was obvious that in order to create more vibration more than one motor was required. Finally it was decided that four motors would be required to create the necessary vibration effect. Similarly as shown above massagers were dismantled only keeping the positive and negative terminal.

Figure 5.8 Vibration motor

Figure 5.9 Vibration motor after extension

The figures 5.8 & 5.9 represents four dismantled vibration motors which will be mounted on the primary element of the air filter. The power supply was made with the help of USB.

In order to create an ease of operation for the motors the cables were extended so that the wires can be pulled easily out of the filter.

Now the task is to decide the placement of motors in order to generate the maximum vibration effect. There are three possibilities:

- Placing all the four motors at an equal distance around the filter with the help of an elastic band.
- All motors will be kept at unequal distance with respect to each other.
- Two separate elastic bands will be made which will be placed at distance from each other. Both the elastic bands will be having two motors each.

After going through experimentation of the motors the following decisions were made regarding the placement of motors.

- No two motors will be placed exactly at opposite direction to each other, because a damping effect was created due to the same magnitude from both directions.
- Placing motors at uneven distance provided more vibrations compared to the motors which are at equal distance.
- Also even more vibration effect was noticed when two separate elastic bands were used and two motors were mounted on each band. No two motors were used exactly facing each other.

Now to hold the motors at a respective position an elastic band of 1.5 inches width was used to mount on the surface of the filter. The circumference of the primary element surface is around 80 mm, so an elastic strip of 60 mm was used. To mount the motors over the elastic again an elastic strip of 0.5 inches was used. Four small bands were made in circular size to be mounted on the main elastic strip.

Figure 5.10 Vibration motor mounted using elastic harness

Figure 5.11 Initial choked filter weight

Figure 5.10 shows a motor which is mounted on the elastic band. Similarly like this three more motors were mounted. In order to implement the concept a completely choked filter was required, which was obtained from the workshop. The filter shown in figure 5.11 contains only primary element of the air filter. The choked filter weighs 7.90 kg. The objective was to remove dust as much as possible from the element. The element was mounted with the help of two stands as shown in the figure 5.12.

Particular care was taken to make sure that the dust remained as it is on the filter and all the dust particles which were removed during the placement of the filter during the mounting on stands and also while placing the elastic bands on the surface.

Figure 5.13 shows how the two particular set of bands were mounted on the surface of the primary filter. It can be seen clearly that no two vibration motors were coming in exactly opposite direction. If the motors were placed at opposite direction then a damping effect would be created which would reduce the vibration frequency.

Figure 5.12 Choked filter mounting

Figure 5.13 Final vibration motors mounting

After the entire correct placement, the motors were run with the help of DC supply power banks. The mechanism was made to run for almost 10 minutes with some dust getting removed during the process.

Figure 5.14 Final choked filter weight

It can be seen that as compared to the earlier weight of the filter a total of 100 grams of dust was removed. The earlier weight of the filter was 7.90 kg while the present weight of the filter is 7.80 kg as shown in the figure 5.14. Normally a choked air filter would contain almost 4 kg of dust which is accumulated after running for almost 60,000 km. So, if it is considered that the dust in air filter is 4 kg and with the help of this concept a further 100 grams of dust is reduced. If calculated it can be seen that the filter life is increased by almost 1500 km.

6. CONCLUSION

The project has helped a great deal in understanding the air intake system as a whole, as well as the importance of the air filter. After the above conducted experiments it can be seen that the method in which vibration motors were used are proved to be more effective. The method is almost able to increase the life of air filter by 1500 km. Even though the other methods were not able to produce positive result but improvements can be made.

FURTHER SCOPE

- In the final method were vibration motors were used, can be made more efficient if metal strips were used instead of elastic.
- The elastic bands contain some amount of rubber which in turn would cause damping and minimize the vibration.
- More vibration can be generated if motors of higher G force are used.
- The method of reverse blow can be made more effective by using a fan of higher CFM. More probably something that would come in the range of around 400 CFM.
- A mechanism can be introduced which could create impact from interior of the air filter with the help of a longitudinal member. This method will have a better result in dislodging the dust from air filter.
- The above improvements will target in reducing dust up to 1 kg which can increase the air filter life tremendously.

REFERENCES

[1] Tadeusz Jaroszczyk, Stephen L. Fallon, Scott W. Schwartz, Development of high dust capacity, high efficiency engine air filter with nano fibers, Journal of KONES Powertrain and Transport, Vol. 15, No.3 2008.

[2] Jaroszczyk, T., Liu, Z. Gerald, Schwartz, S. W., Holm, C. E., Badeau, K. M., Janikowski, E., Direct Flow Air Filters – A New Approach to High Performance Engine Filtration, Proceedings of Filtech 2005, Wiesbaden, Germany, October 11-13, 2005

[3] Jaroszczyk, T., Fallon, S. L., Liu, Z. Gerald, Schwartz, S. W., Holm, C. E., Badeau, K. M., Janikowski, E., Direct Flow Air Filters – a New Approach to High Performance Engine Filtration, Filtration, the International Journal for Filtration and Separation, Volume 6, Number 4, pp. 280 -286, 2006

[4] Jaroszczyk, T., Fallon, S. L., Pardue, B. A., Liu, Z. G., Schmitz, K, New Generation Direct Flow Engine Air Filters – Performance Analysis, Proceedings of World Filtration Congress, New Orleans, Louisiana, USA, April 18 – 23, 2004

[5] Gaurav Balpande, Mayur Chaudhari, et. al. Fabrication of Automatic Air Filter Cleaning System, International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 03 | Mar -2017. e-ISSN: 2395 -0056, p-ISSN: 2395-0072.

[6] A.Janarthanan, R.Hariharan, C.Ponvijayan, V.Thirumalairaj, Dr.K.Chandrasekaran, Interfacing of Automation in Air Filter Cleaner, IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 2, February 2015. ISSN 2348 – 7968.

[7] Swapnil M. Dhok, Mahesh A. Meshram, B.D. Sarode, Research on Automatic Air Filter Cleaning System, Journal of Network Communications and Emerging Technologies (JNCET) ,Volume 7, Issue 3, March (2017).

[8] Kartik D. Gandhe, Vivek B. Raut, B.D. Sarode, Review on Automatic Air Filter Cleaning System, Journal of Network Communications and Emerging Technologies (JNCET), Volume 7, Issue 3, March (2017).

[9] Thomas, J., West, B., and Huff, S., Effect of Air Filter Condition on Diesel Vehicle Fuel Economy, SAE Technical Paper 2013-01-0311, 2013.

[10] Borgia, J. and Brown, G., Pressure Drop and Flow Characteristics for a Heavy-Duty Air Filter During Dust Loading, SAE Technical Paper 872220, 1987.