Mattei Rotary Vane vs. Screw Compressors

A Technical Comparison for Use in Railway Applications

COMPRESSED AIR SINCE 1919

INTRODUCTION

Since the 1950's Mattei has been designing, developing and manufacturing rotary vane air compressors. Although the majority of the compressor manufacturers and assemblers choose a competing technology for their compressors, (screw technology), the Mattei rotary vane compressor has many years of industry proven advantages which have helped shape its current client base.

- A simple, compact design leads to high resilience in extreme operating conditions.
- The absence of roller and thrust bearings leads to the elimination of the need to overhaul the compressor.
- The extremely low energy consumption leads to impressive running cost savings.

With these advantages, the Mattei brand has grown to be a top contender in industries such as metal smelting, woodworking, cement production, textiles and countless OEM applications of which the vast majority are for Railway applications.

Over the last 15 years, Mattei has stepped up its research and development spending, realizing the untapped potential of its proprietary technology. According to a recent PNEUROP-backed European study[1], Mattei offers the best specific energy performance across its industrial range of compressors compared to any other global manufacturer. To put this performance advantage into perspective, another recent study[2] has shown that if all screw compressor manufacturers attained similar specific energy performances as the Mattei rotary vane compressor, there could be a potential energy saving, at the European level, of 3.5 terawatt hours (TWh).

This on going work has allowed the Mattei compressor to evolve at a rapid pace. In recent years, both geometrical optimisation of the rotor, stator and blades[3] and the more recent introduction of sprayed lubricant injector cooling[4], has led to further improvements in specific energy in the order of 8% over Mattei's currently available state of the art compressors.

Also, this work has allowed Mattei to take its rotary vane concept and diversify into different market sectors such as Oil & Gas, Automotive and Waste Heat Recovery.

In this paper the major differences between the Mattei rotary vane compressor and the screw compressor are outlined, in an effort to explain the advantages listed above.

ROTARY VANE COMPRESSION PRINCIPLE

All components in the Mattei rotary vane compression element are manufactured from a proprietary blend of high-grade cast iron. This avoids problems of unequal thermal expansion, maintaining efficiency throughout the operating temperature range.

The assembly consists of a single offset rotor rotating within a cylindrical stator. The compression element is sealed with two end covers that house two white metal bushings. The rotor has machined longitudinal slots into which fit free sliding blades or vanes. The rotor is generally directly driven usually at standard electric motor speed (1500 rpm for 50hz) causing the blades to make sealed contact with the stator wall thereby forming compression pockets.

Air is drawn in along the length of the stator at the point of greatest volume, becomes trapped in the pocket and the volume reduced (pressure increased) through one rotation. At the point of smallest volume air is discharged from the compression element (maximum pressure setting) [Fig 1] [Fig 2].

Fig. 1

As the rotor turns centrifugal force pushes the blades against the stator wall, sealing the air that is trapped between the rotor and stator wall.

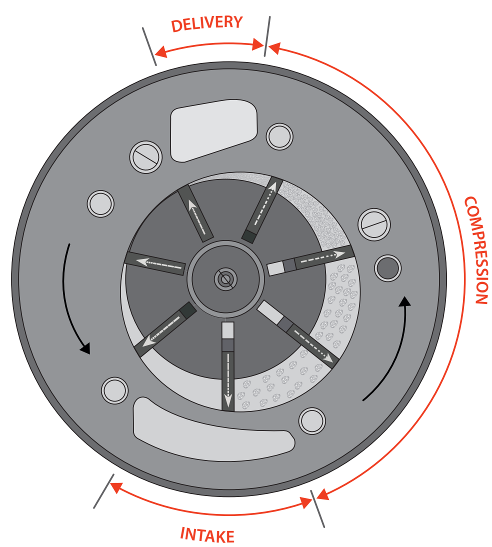


Fig. 2

The volume between the blades increases during the intake cycle and decreases during the compression cycle.

Internally generated air pressure is used as the lubricant pump. The lubricant is circulated internally by pressurised air [Fig 4, Point 3] to the cooler [Fig 4, Point 5], to the filter [Fig 4, Point 6] and into the compression element to seal and lubricate all moving components. The cool clean lubricant is also injected directly into the compression process.

The heat generated in compression is transferred to the lubricant [Fig 3], which is cooled by the cooler and sent to the oil tank. The air-oil mixture that leaves the compression area is subsequently passed through a two-stage in-built labyrinth system [Fig 4, Point 7] that removes 99.9% of the lubricant before it passes through the final coalescing element [Fig 4, Point 10] resulting in a typical carry over content of <1 ppm. The total system is internal with no external pipes or maintenance.

The in-built self-modulating valve that allows the compressor to draw in and compress only the air required controls air delivery [Fig 4, Point 2].

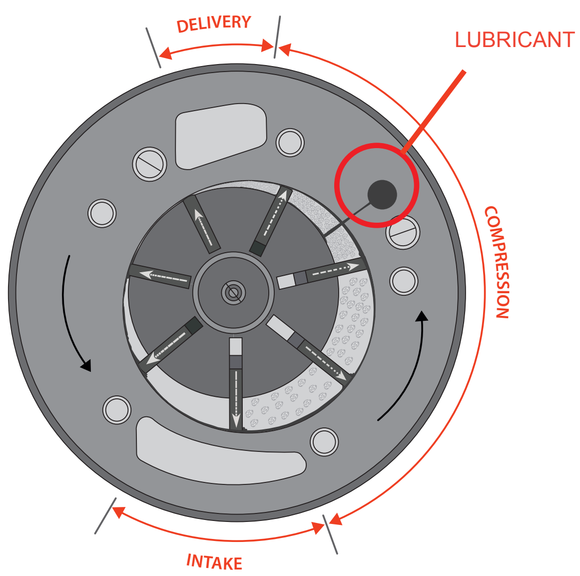


Fig. 3

The lubricant injected into the stator lubricates the moving parts and absorbs the heat of compression. All operational clearances (ends of rotor and blade tips) are completely sealed with the lubricant preventing high to low pressure leakage.

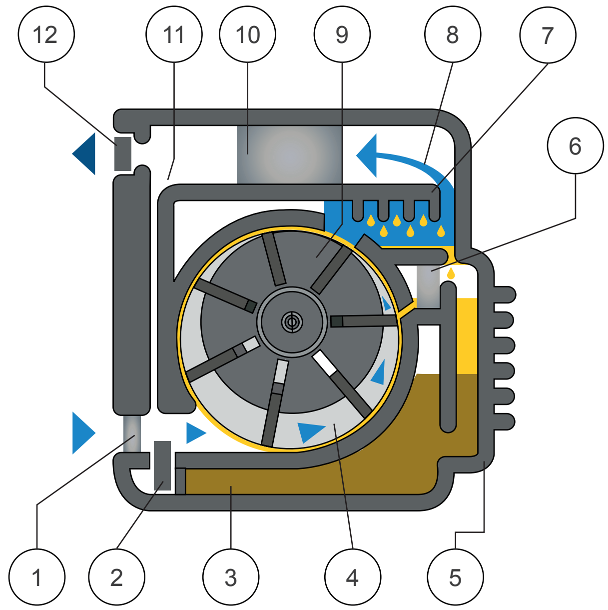


Fig. 4

Major components of a Mattei Rotary Vane Integrated Compressor.

1. Air intake filter
2. Intake valve
3. Lubricant chamber
4. Compression chamber
5. Lubricant cooler
6. Lubricant filter
7. Primary air-lubricant separation
8. Compressed air
9. Rotor
10. Final separation
11. Lubricant return valve
12. Minimum pressure non-return valve

ROTARY SCREW COMPRESSION PRINCIPLE

The rotary screw compressor design consists of a pair of meshing helical lobed rotors. The rotor shafts are supported by roller and thrust bearings and generally one rotor drives the other by means of the helical profiles.

During rotation the screw profiles uncover an intake orifice at one end of the stator, through which the air enters and fills the volume between the profiles. On the opposite side the profiles penetrate into each other, thereby reducing the volume, which compresses the air until the delivery ports become uncovered.

Lubricant is injected to seal, lubricate and absorb the heat from the compressed air. After the lubricant is cooled, it is then re-inserted into the tank. The compressed air coming out of the screw assembly gets filtrated by a final coalescing element. The compressor is started and stopped through the system pressure switch set to the maximum and minimum settings [Fig 5], [Fig 6].

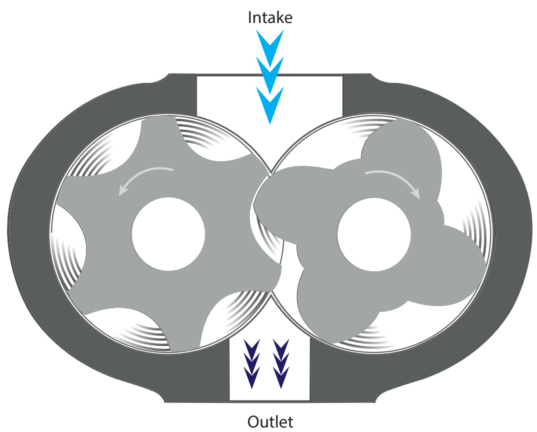


Fig. 5

The rotors are fitted in a stator made from two cylinders that intersect longitudinally and in which the rotors turn with a minimum clearance.

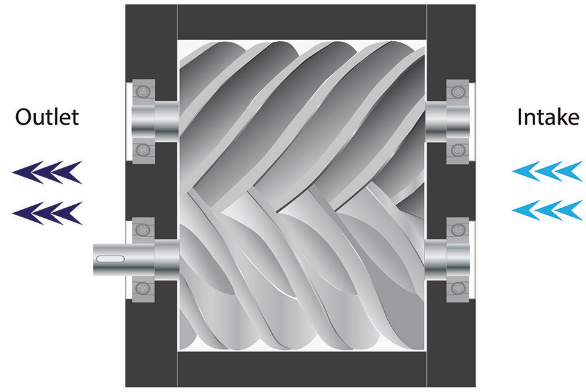


Fig. 6

The intake and outlet ports are set at opposite ends of the compressor in the axial direction, giving rise to an unbalanced pressure profile along the compressor length.

GENERAL DESIGN DIFFERENCES

Typically, a Mattei rotary vane compressor has an integrated design and is driven directly via means of a flexible coupling. The direct drive ensures low frictional losses, reliability of all moving components and optimised energy consumption. In the integrated design all components are contained within a lightweight aluminium casing. There are no external connecting pipes. All that is required is a power supply and air outlet connection.

The Mattei rotary vane compressor does not use any roller or thrust bearings. The rotor sits on two continuously lubricated bush bearings that never need changing. As there is no bearing wear and no vane wear, there is no possibility of performance loss over the compressor lifetime.

To function, a screw compressor needs both roller bearing (rotor positioning and support) and thrust bearings (to take the axial thrust forces). High rotating speeds means, high noise, high stress and high rates of wear. Therefore bearings in industrial screw compressors need to be changed every 20,000 to 30,000 running hours. This interval decreases to 12,000 hours in the rail industry[5] due to the extreme operating conditions. This is known as a complete compressor overhaul.

If the overhaul is not done the rotors could touch and this could mean a complete compression block. Also, as bearings wear, the internal leakage path area increases and the compressor performance is significantly reduced[6].

The de-integrated screw design is composed of a series of individual components; motor, gears or belts, screw block, valve block, reclaimer tank, separator tank, final coalescing element, lubricant cooler. Each component has to be connected with air or lubricant pipes resulting in many connections and many potential leak points. Each component needs to be located and connected adding assembly time and complexity.

LEAKAGE PATHS

In vane compressors the vanes are always in contact with the lubricant film on the internal surface of the stator. This keeps the two metal surfaces apart and seals between adjacent cells. A lubricant wedge exists at the leading edge of the sliding vane.

The precisely machined vane tip radius, adhesion of lubricant to the sliding element and the supporting surface (the stator) increases the lubricant pressure and creates a hydrodynamic lubrication film between the two surfaces. The viscosity increase that occurs in the lubricant, when extremely high pressure is applied, allows the lubricant to avoid being squeezed out from in between the surfaces, maintaining a constant film in time. The lubricant also behaves as a perfect seal [Fig 7].

To ensure perfect hydrodynamic lubrication a specific vane tip radius has to be machined for each stator size and pressure ratio. To do this Mattei has developed a lubricant film thickness simulator and can calculate the film thickness at every angle of rotation for any given operating conditions [Fig 8].

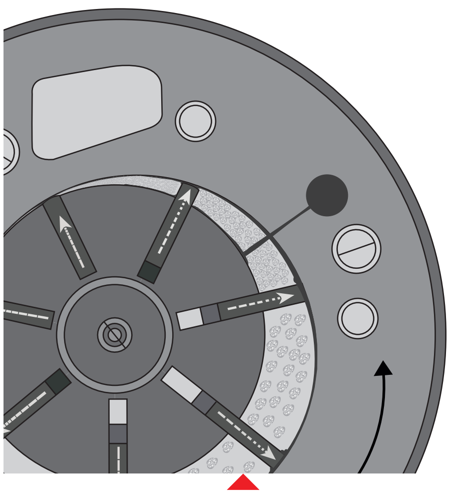


Fig. 7

The vanes move freely in the rotor slots and always seal against the stator wall. Performance does not deteriorate even after many thousands of operating hours.

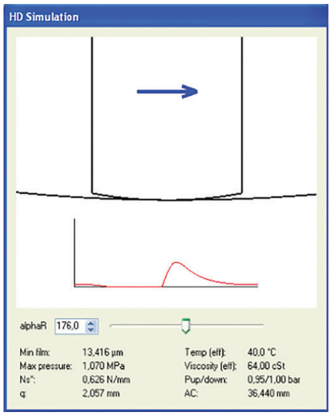


Fig. 8

In house lubricant film thickness simulator. This tool is used to calculate the perfect vane tip radius for any given stator size and pressure ratio.

Another potential leakage path is via the compressor end covers. The vane compressor has no axial thrust pushing the rotor against either end cover. It is, therefore, unnecessary to control its axial position by means of bearings or thrust bearings. The rotor is free to move axially and is kept equally spaced from the end covers by means of the lubricant which is injected, under pressure, through dedicated injection ports in the end covers, thus preventing contact and providing efficient sealing [Fig 9].

In a screw compressor there must be a minimum clearance between the external profile of the rotors and the internal surface of the stator, to allow the rotors to turn without touching the stator wall. When designing the clearances the thermal expansion effect on the rotors, at the operating temperatures, must be taken into account. The result is that the clearances are extremely close.

As roller bearings wear the rotors are pushed against the stator and the lubricant sealing becomes less and less effective. It is unavoidable that a certain volume of air escapes from the high pressure to the low-pressure area. This can only be limited, but never eliminated by high precision machining [Fig 10].

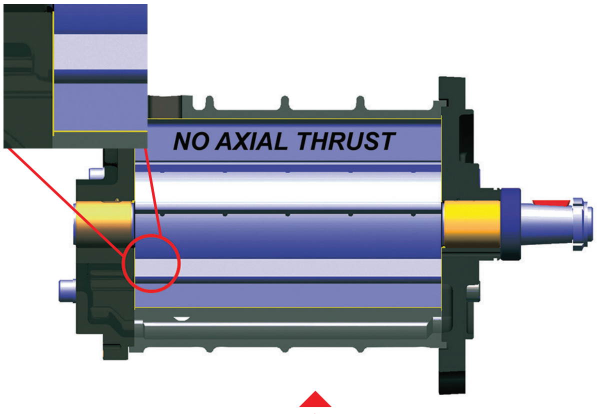


Fig. 9

There is no axial thrust in a rotary vane compressor. The rotor is free to move axially and is kept equally spaced from the end covers by means of the lubricant, which is injected under pressure. The injected lubricant prevents the air from escaping along the side planes.

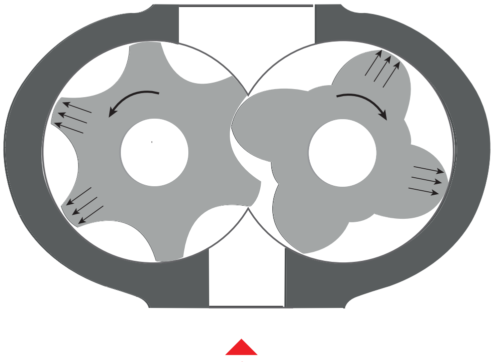


Fig. 10

As soon as the roller or taper bearings start wearing, radial pressure pushes the rotors against the diametrically opposite sides of the cylinder.

Due to its geometry, the pressurised air in a screw compressor produces an axial thrust making the rotors reduce the side clearance at the intake side and increase the clearance at the delivery side, where sealing is most critical. The side thrust is borne by thrust bearings, preventing the rotors from touching the surface of the end cover. A correct sealing is, therefore, due to the quality and resistance of the thrust bearings, as well as the machining accuracy of the couplings. As a result the sealing accuracy will deteriorate as the thrust bearing life increases and their effectiveness also deteriorates, leading to potential failure when the rotors touch the intake side cover [Fig 11]

On assembly, screw rotor pairing plays a vital role in the reliability and performance of a screw compressor. This time consuming and often difficult procedure is necessary to optimise the gap between any two rotors (clearance distribution). The effects of misalignment, gas forces and rotor-induced transmission errors, could lead to undesirable phenomena such as friction, buzz, rattle, and associated distortions, which could have alarming results. Also, it has been shown that small changes in the clearance distribution, and hence the behaviour of the contact bands, can have a major effect on reliability[7].

Even when rotors are paired correctly, the precision and efficiency of the compressor is once again a function of the roller bearings quality and precision. Due to the nature of the screw compressor design there is a default leakage path between the meshing rotors know as the blow-hole. Over the years the blow-hole leakage has been decreased significantly both by adopting ever more complicated rotor profile designs and by using more precise bearing tolerances.

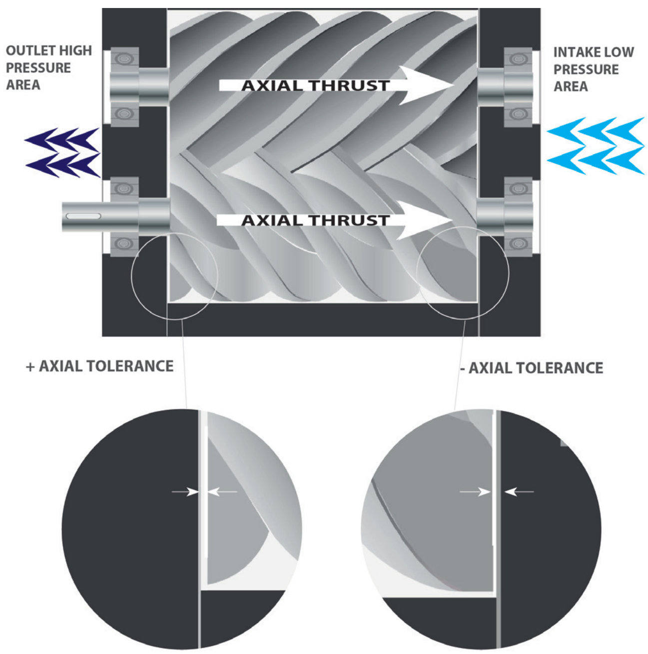


Fig. 11

The pressurised air produces axial thrust, which reduces the clearance at the intake side and increases the clearance at the delivery side where sealing is most critical.

Since the bearings start deteriorating as soon as the compressor is started, the manufacturers clearance also starts deteriorating and the blow-hole area starts increasing. With time the rotors contact point will increase leading to increase of temperature because of friction and consequently deformation of the rotors, increased contact forces and ultimately rotor seizure[8] [Fig 12], [Fig 13].

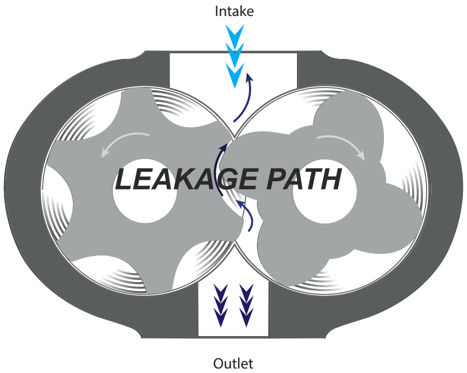


Fig. 12

The “blow hole” in a screw compressor is where the external profiles of the rotors meet at the intersection of the cylinders in which they rotate. The pressurised air returns to an area of lower pressure through this leakage path.

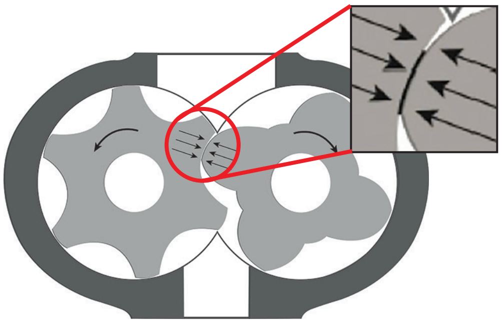


Fig. 13

In screw compressors the rotors are subject to friction on the lobes due to the thrust caused by the male rotor on the female rotor. With bearing deterioration, the pressure can increase so high as to break the lubricating film and lead to rotor seizure.

COMPRESSOR RUGGEDNESS, RELIABILITY AND PERFORMANCE OVER TIME

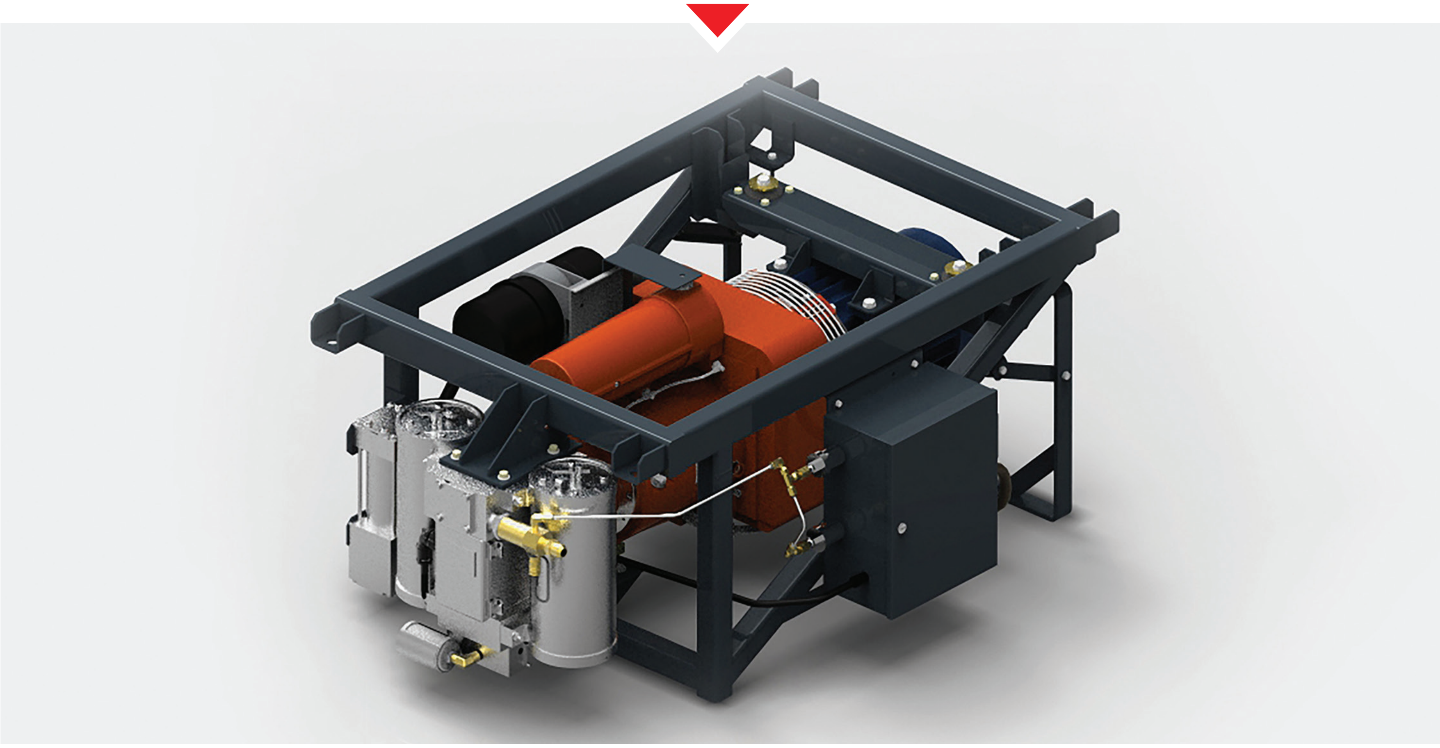
As the Mattei vane compressor is a self-adjusting, self-balancing machine floating on two bush bearings and driven by a flexible coupling, it is not affected by external vibration, temperature and environmental conditions.

The working life of industrial Mattei rotary vane compressors has been proven to go well above the 200,000 hour mark. In rail applications there are currently Mattei compressors with over 35,000 hours of operation with the original factory fitted vanes and bush bearings. This makes the compressor ideal for any on-board application. Also, there is no degradation of performance over the working life of the compressor.

A screw compressor's performance and service life is dictated by precision clearances and bearing quality. An industrial screw compressor may have 20,000 to 30,000 hours between bearing overhauls installed in a clean, cool controlled stationary environment, this life expectancy is drastically reduced, to between 10,000 and 12,000 hours when subjected to vibration, heat and dirt – typical of any rail application.

MAINTENANCE PLANS

As with screw compressors, consumables such as lubricants, filters and separators have to be changed regularly for optimal rotary vane compressor performance. Mattei develops customised service kits with all their OEM's, working around their preferred maintenance intervals, aligning compressor maintenance with other maintenance functions. Mattei service kits have all the necessary parts under one part number. Mattei offer specially formulated lubricants to withstand arduous conditions, for non-toxicity and biodegradability.



WARRANTY

Due to the design features described above, Mattei has been able to offer extended warranties on their compressors for many years. The longest industrial warranty on a Mattei compressor is for 10 years (unlimited hours) on the compressor air end, subject to correct ordinary maintenance and the use of original spare parts and lubricant.

In a screw compressor, 10 years of industrial operation would necessarily require one or possibly two complete overhauls therefore it is unlikely any screw compressor manufacturer would be willing to back up their technology with such a warranty.

SUMMARY

The following table summarizes the characteristics of Mattei rotary vane air compressors as compared to standard screw air compressors.

Characteristic	Rotary Vane	Screw
Integrated Design	Yes	No
RPM Min	900	1500
RPM Max	2400	9000
Blow-Hole	No	Yes
Clearance Distribution	No	Yes
Roller Bearings	No	Yes
Thrust Bearings	No	Yes
Bush Bearings	Yes	No
Full Overhaul Required – As Standard	No	Yes
Performance Degradation	No	Yes
Compressor Ruggedness	Extreme	Poor
10 Year (Unlimited Hours) Air End Warranty – As Standard	Yes	No

EXISTING MATTEI TRANSIT AND RAIL APPLICATIONS

Location of Client
Europe
North and South America
China
South East Asia
Middle East
Type of Train
Automatic People Movers
Urban Metro
Overground Metro
Commuter
Regional
Cargo Rail
Cogwheel Railway
Mine Railway
Shunting Locomotives
Locomotives
Hybrid Locomotive
Urban Tramway

Package Design Characteristics	
Flow	160-6000 l/min
Pressure	6 -13bar
Ambient Temp	-35°C + 80°C
Sound Pressure Level	60-80 dBA
Coupling	Belt Drive
	Direct Drive
Drive	Hydraulic Drive
	DC Motor
	Asynchronous Motors
	Permanent Magnet Motors
Voltage	120V-3000V
Frequency	33-100Hz
Relative Humidity	Up to 98%
Extra	High Efficiency Intake Filters
	Dryers
	Soundproofing
	Anti Vibration Dampers
	Custom Inverters

CONCLUSIONS

After an extensive overview of the two technologies there are evident advantages when comparing vane to screw technology. These advantages are compounded if extreme operation conditions are considered, as is the case in most rail applications.

THE MATTEI COMPANY

Mattei is a 100% family owned company that has manufactured vane compressors for over 65 years. All of the air end (compression unit) components are engineered, designed and machined in the state of the art plant in Milan, Italy. Following process inspection of the individual parts, every air end is assembled and computer tested in controlled consistent conditions.

Mattei currently sells about 6000 compressor units a year, of which about 15% are for Railway applications. The forecast is for a strong volume growth in this segment due to Mattei having taken a leading supply position in the emerging market of the electric vehicle (EV) globally.

Learn More   Contact Us

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ITALY - ING. ENEA MATTEI SpA
Strada Padana Superiore, 307
20090 VIMODRONE (MI)
Tel + 39 02253051 - Fax +39 0225305243
Website: www.matteigroup.com/it

www.matteigroup.com

UNI EN ISO 9001:2008

GERMANY
MATTEI KOMPRESSOREN DEUTSCHLAND GmbH
Tel +49 7151 5002560 - Fax +49 7151 5002565
Website: www.matteigroup.com/de

FRANCE
MATTEI COMPRESSEURS Sarl
Tel +33 535 542 205 - Fax +33 972 316 833
Website: www.mattei.fr

GREAT BRITAIN
MATTEI COMPRESSORS Ltd
Tel +44 (0)1789 450577 - Fax +44 (0)1789 450698
Website: www.mattei.co.uk

U.S.A.
MATTEI COMPRESSORS Inc
Tel +1 410 5217020 - Fax +1 410 5217024
Website: www.matteicomp.com

RUSSIAN FEDERATION
ING. ENEA MATTEI SpA
Tel +7-495-739 41 90 - Fax +7-495-739 41 90
Website: www.matteigroup.com

SPAIN
ING. ENEA MATTEI SpA
Tel +34 93 435 03 94 - Fax +34 93 455 26 76
Website: www.matteigroup.com/es

PEOPLE'S REPUBLIC OF CHINA
Mattei (SuZhou) Air Compressors Manufacturing Co., Ltd.
WFOE by Ing. Enea Mattei S.p.A. - Italy
Tel +86 512 66679986 - Fax +86 512 66679989
Website: www.matteisuzhou.com