# ROTARY SEAL OF TURBOCHARGER AND THE REASONS OF ITS MALFUNCTIONS

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**Abstract**

Diesel internal combustion engines intended for cars, but also petrol internal combustion engines are in some cases fitted with turbocharged to increase some effective parameters of the engine and at the same time reducing of the pollutant content in the engine exhaust. Means of transport automobile transport exploit, as part of an internal combustion engine power train, even if the effort to restrict the using of internal combustion engines. Turbocharger as an option supercharge-internal combustion engine apparatus, affects the operation of the internal combustion engine. Rotary seals on the turbocharger of the fault on the consumption of lubricating oil combustion engine. In the case of failure of the turbocharger, it is affected by the ability to accelerate the combustion engine, while increasing smoke emission diesel engine, the consumption of lubricating oil, and other factors that affect accompanying fault turbocharger combined with diesel, petrol engine as well.

**Keywords:** turbocharger, compressor, oil, rotary seal, turbine, internal combustion engine, impeller, rotor, shaft.

## 1 Introduction

Trend of development of the internal combustion engines and increasingly more stringent emission regulations cause that car makers use turbocharged internal combustion engines to drive cars. Turbocharging internal combustion engine does not guarantee the fulfillment of strict emission limits for internal combustion engines, but creates only a part of a whole which as complex can affect the increasingly stringent emission limits. Significant influence of using of supercharging in internal combustion engines can be seen in addition to cars with internal combustion engines various manufacturers. In comparison, describing influence of turbocharged diesel and gasoline has more significant character in diesel engines. Diesel engines produced today are supercharged by the turbocharger. A small percentage of all manufactured diesel engines for cars are not equipped with turbocharging. Looking at petrol internal combustion engines not affect the use of turbocharging as significant as in diesel engines, although in terms of forecasting the development of petrol engines, turbocharging is a growing trend. In the case of a turbocharger, supercharge devices such as internal combustion engine occur during operation of using the internal combustion engine turbocharger certain failure conditions. Reasons for failure are different, but the result of any failure of the turbocharger effect activity, not only a turbocharger but also the internal combustion engine. The sequels of turbocharger failures cause a decrease or loss of ability of acceleration of the car (when used supercharged internal combustion engine), change structure of the exhaust gas, the increase of consumption of lubricant oil, the increase of noise level internal combustion engine etc.. In certain cases of the fault of turbocharger can have the character of such a magnitude that results in failure of the turbocharger causes a failure of the internal combustion engine.

## 2 Changes affecting functionality rotary seal of turbocharger

Reasons of failures of turbochargers are not always the same, and do not always originate with the same number of working hours of the internal combustion engine (described fact arises from interaction internal combustion engine - turbocharger). Malfunctions turbochargers with the largest number of occurrences malfunctions include rotating parts of the turbocharger. In addition to malfunctions rotating parts of the turbocharger can also occur to the malfunctions of a part of the stator and the turbocharger etc.. Absolute need for lubrication of rotating parts of the turbocharger (fluid pressure lubrication) during operation of the turbocharger causes dependence on the flow of lubricating oil through a system of lubricating conduits in the bearing housing of the turbocharger (lubricating system of conduits depending on the design of the turbocharger). In the most cases, the lubricating oil in order to lubricate the rotating parts of the turbocharger used lubricating circuit of the combustion engine at a given operating pressure. Connection bearing housing of the turbocharger to the lubrication circuit of the engine seen in Fig.1.

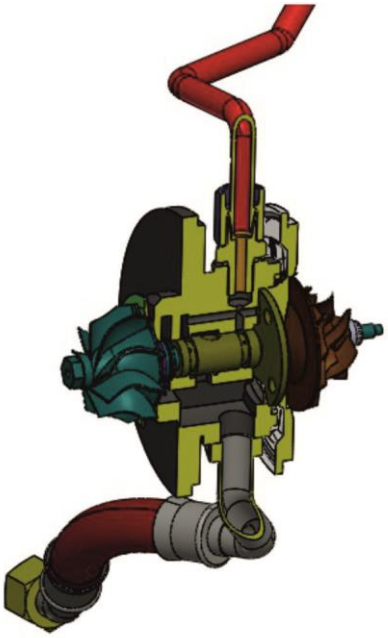

***Fig. 1*** *Bearing housing and lubrication circuit of the engine*

If the turbocharger (bearing housing) is connected to the lubrication circuit of the engine, turbocharger can actively influence the consumption of lubricating oil of internal combustion engine. It follows that if a fault of turbocharger occurs (e.g. lubricating oil leakage through the rotating seals, some turbocharger, or a decrease in the value of the desired boost pressure min. value, etc.), the effect exhibits of turbocharger malfunction on a change in operation capacity of the internal combustion engine. The case may also be in reverse order, malfunction of the internal combustion engine will drastically affect the ability of turbocharger operation. For example of a turbocharger malfunction seen in Fig. 2. Turbocharger interaction with a diesel engine (Pe = 66 kW at n = 4000 min-1 [7]).

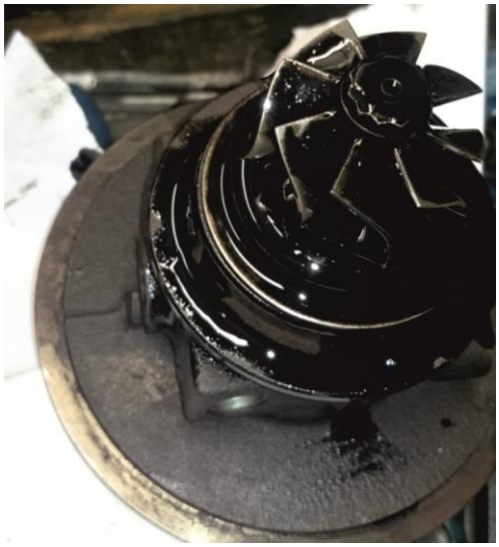

***Fig. 2*** *Turbocharger with damaged rotary seal*

To assess the situation and the consequences of failure to view rotating seal turbocharger, it was sufficient to show turbocharger partly, without the turbine housing (Fig.2). From the picture we can see that, in the turbine housing began to leak more lubricating oil. The presence of lubricating oil is proved by a layer of certain thickness (black) deposited on the inside surfaces of the turbine. Because the described fact is related to the turbocharger turbine, the operation of which depends on temperature, flow rate and pressure of the exhaust gas of the internal combustion engine, comprises a layer of certain thickness other than the lubricating oil, and deposition of exhaust gas, prevent to infiltration of the lubricating oil (between different cabinets) in the places

of the rotating part of the turbine and the fan, have the task of rotating seals. Turbocharger rotor seal K. Hofmann describes "To seal the rotor on both sides use the piston rings. (Hofmann K., 1981, p.124) ” Example of location the rotary seals in selected parts of the turbine impeller is seen in Fig. 3.

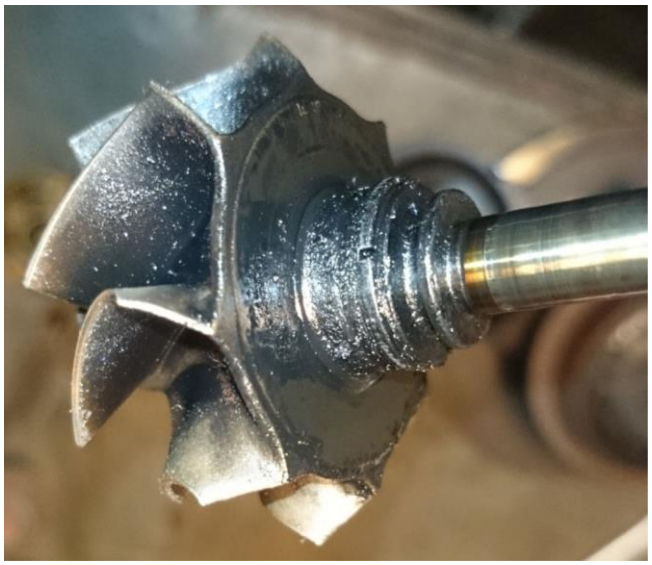

***Fig. 3*** *Impelller of turbine with shaft*

Fig.3. illustrates impeller of turbine rotor with shaft of a turbocharger, which has already been described above. Also here you can see a layer of certain thickness (black - blend of lubricant oil and sediments from the exhaust system) deposited on the surfaces of the impeller and partially extending into the transition between the wheel and the shaft (a place to housing a rotating impeller turbine seal). Rotating seal of the impeller of the turbine is a seal of circular shape with a rectangular cross section in the center in the axial direction by cutting the seal (so-called. lock) [3]. At the production of rotary seals the metal material from the group of super alloys was used. The cause of penetration of lubricating oil from the housing of the bearing, via the sealing faces of the rotary seal into the turbine housing, there was the decrease of ability to closely (in the case described rotary seal was not able to prevent large-scale penetration of lubricating oil) rotating seals of impeller turbines and up to a level that larger the amount of lubricating oil received in the turbine during operation of the turbocharger in full operation. The role of each of the rotary seals designed for application of turbochargers is to prevent the penetration of lubricating oil in some places, while it is recognized as the design and lubrication, sealing material used and other factors, a certain amount of penetration (small volume) of lubricating oil in the above locations during the operation of the turbocharger after a certain number of operating hours.

Similar assumptions is stated by Kožoušek "In addition to the aforementioned influences of the effect of sealing depends lubricated seals, oils, contaminated by oil, penetration of dirt from the air, radial or axial vibrations, pressure in the sealent area, on the material, surface roughness and hardness gaskets and stiffness . (Kožoušek J., 1983, p.187)” The basic shape of the rotary seal turbine impeller used in the damaged turbocharger is illustrated Fig. 4 shows ..

***Fig. 4*** *Rotary seal of the impeller turbine*

From Fig. 4 that the sealing faces of the rotary seal representative of the external and internal circumferential surface of the seal. Such shape of seal is suitably designed for turbocharger described. Still, there is the possibility to make the design changes of the rotary seal, which may provide a smaller amount of lubricating oil through the imbued sealing surfaces, the ability to extend the operation of a rotary seal, the ability to create a self-cleaning of the sealing surfaces from dirt, and so. The theory of calculation of the rotary seal there is a metal in order to modification the original seal, or draft a new rotary seal turbine impeller. Design for a new rotary seal provides only one way of dealing with disorders described turbocharger. Other possible solutions disorders also have a major character. Basic dimensions of a rotating metal seal are determined according to the literature.

Average radial contact pressure p of the wall of the cylindrical surface [4]

$$p = 0{,}76\frac{P_d}{vD} \tag{1}$$

The maximum clearance in the lock $s_{min}$ rotary seal compressed to the nominal diameter D [4]

$$s_{\min} = \varphi D + \pi D\left[\alpha_k\left(t_k - t_0\right) - \alpha_v\left(t_v - t_0\right)\right] \tag{2}$$

Bending stress $\sigma_o$ rotary seals in cross section to lock in the compressed state [4]

$$\sigma_o = 3p\left(\frac{D}{t} - 1\right)^2 \tag{3}$$

"The hight of the sealing ring is 2,4 to 6,4 mm with a tolerance of -0,025 to -0,05mm.(Kožoušek J.,1983, p.187)"

"The maximum radial width of the ring is within the limits t (0,05 to 0,045) D+ 0,123 with a tolerance of ± 0,25 mm. (Kožoušek J., 1983, p.187) "

There are calculation of seal dimensions other parameters - friction conditions, temperature conditions, pressure action of the lubricating oil, exhaust gas pressure effect, the value of max. circumferential speed seals, vibration gasket in the groove, roughness and hardness of the sealing surfaces, properties of, sealing and material, etc.. These factors also influence the final shape of the seal. The estimated shape of the new designed rotary seal on the theory is illustrated Fig. 5.

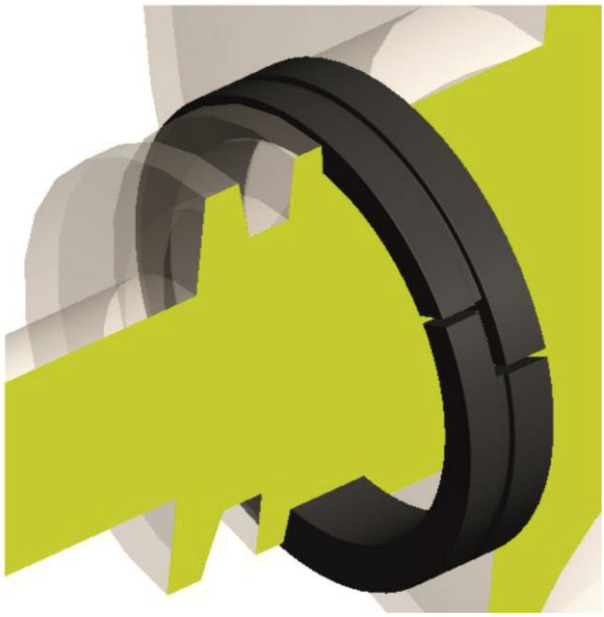

***Fig. 5*** *Rotary seal impeller of the turbine – design*

Looking at Fig. 5 we can see certain basic shapes of rotating seals. The outer surface of the rotary seal received of the design a larger number of sealing surfaces and circumferential grooves. On the side surfaces of the seal precipitate rised that (trapezoid shape). In the middle, in the axial direction of the rotary seal cutting rised (so-called lock) [3], which has the shape of S. The purpose of the slit shape change, compared with the original seal was to reduce the risk of penetration of lubricating oil in the described location. A prerequisite at the design of rotary seal in addition of improving the ability to seal, it was necessary to ensure self-cleaning of sealing during operation of the turbocharger. This stems from the fact that can be seen in Fig. 3. Pollution by deposits on the functional stretches of rotary seals as an option, it could cause a described malfunction of the turbocharger. The task of the grooves and chamfers is preventing clotting or parties affect deposition of sediments sealing in some places, but also in places of the housing and shaft (seat of rotary seals). Diversity in the forms designed rotary seal and the original Fig. 6 shows rotary seals.

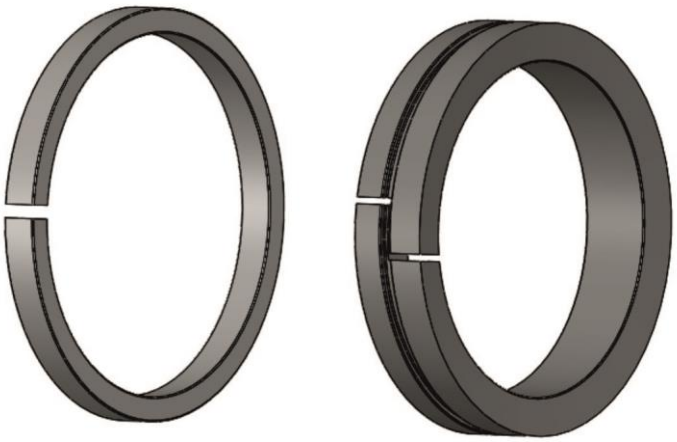

***Fig. 6*** *Comparison form of rotary seals*

The comparison shows, that the shape of the designed seal has the certain assumptions, that meet its purpose functional properties. During designing of the new seals there are changed in a comparing with the original seal, some seal dimensions (width, internal diameter) to secure the previously mentioned criteria. If the design seal is used for turbocharger described, there will be a need for construction change to the turbine impeller (place of seats seal) and the bearing housing of the turbocharger. In addition, there is a need for further changes attributable to changes in the dimensions of the proposed seal on the original seal. Resize causes a change in resistance of the friction surfaces of the rotary seal turbine impeller.

## 3 Description of achieved results constructive changes rotary seal

Using of designed rotary seals for the turbine impeller (impeller with the shaft) causes the necessary design change of the place of the seat rotary seal, which have already been described in chapter 2. For precise results there is a need to perform additional calculations, and also a group of experiments with designing rotary seal. The calculations will need a more accurate determination of mechanical, thermal, hydraulic and friction conditions of the rotor - seal - stator. The design should be considered together with the impact of lubricating oil (lubricating oil temperature under varying conditions of the internal combustion engine), with flowing exhaust gases through a turbine casing (temperature, exhaust gas pressure at various operating conditions of internal combustion engine) etc.

## 4 Conclusion

The results tell us about the suitability of the design solution of the turbocharger rotary seals of rotor if gained the conditions resulting from the calculation and recommendations described in chapter 2. be secure. Excessive penetration of lubricating oil through the sealing faces of the rotary seal of turbocharger rotor on which the findings were made, not only caused the failure of the turbocharger, but also adversely affected the operation of the internal combustion engine. Leaks caused that in the turbine casing and the fan started to appear more lubricating oil. With proper function of rotary seals it is to allowed for some small amount of lubricating oil, which penetrates into the turbine housing and compressor housing. Design changes of rotary seal (described in chapter 1.) was intended to seal of the turbine impeller. This design change can also be used to rotating seal of compressor impeller. The designed changes of the rotary seal can prevent leakage of lubricating oil, but such solution needs to be verified by further calculations, simulations and perform certain number of experiments and measurements on several test samples of rotary seal with the proposed amendments. It is impossible from the point of design while maintaining certain conditions to provide such a solution of the rotary seals to prevent penetration of lubricating oil through the sealing surfaces into the seal housing and of the turbine and of the compressor. Because the turbocharger is the user of car in order and expensive, if the user wants to prevent premature failure of the turbocharger (under certain conditions linked to the automobile mileage) he must observe appropriate service intervals. At the same time he must also follow certain rules of operation of car with turbocharged engine.

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