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THE PROPER OPERATION OF THE HIGH VACUUM PUMPING SYSTEM

PRAVILNO DELOVANJE VISOKOVAKUUMSKEGA ČRPALNEGA SISTEMA

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The proper operation of high vacuum pumping systems with oil diffusion pumps and backing rotary pumps is very important, otherwise the contamination of vacuum chambers by backstreaming oil vapours is extremely high as well as the oxidation and the loss of diffusion pump oil. The forepressure switching point, where the diffusion pump is put into the operation by opening the high vacuum and forepressure valves is discussed. There are three possible situations: the pumping throughput is just adapted, or it is to low, or to high. What is going on, when the pumping troughput is adapted, it is illustrated using the troughput-pressure diagrams. At the end some practical advices are done, how to recognize that the operation of the HV pumping system is correct.

Key words: high vacuum pumping system, contamination, loss of diffusion pump oil, tolerable forepressure, switching point

Pravilno upravljanje in delovanje visokovakuumskega črpalnega sistema z oljno difuzijsko črpalko in rotacijsko predčrpalko je zelo pomembno, kajti v nasprotnem primeru pride do močno povečanega povratnega toka oljnih par iz difuzijske črpalke v vakuumsko komoro in s tem do njene kontaminacije. Izguba olja v difuzijski črpalki in njegova pospešena oksidacija sta spremljajoča pojava. Pri ročnem ali avtomatiziranem upravljanju črpalnega sistema je zelo pomemben trenutek oz. točka preklopa, ko prenehamo črpati s predčrpalko po obtočnem vodu in odpremo visokovakuumski in predvakuumski ventil in začnemo črpati z difuzijsko črpalko. Možna so tri delovna stanja: delovanje obeh črpalk je usklajeno, predčrpalka ima premajhno ali preveliko črpalno hitrost. Usklajeno stanje smo ponazorili na diagramu. Podani so tudi praktični napotki, kako spoznamo, ali je črpalni sistem pravilno upravljan.

Ključne besede: visokovakuumski črpalni sistem, kontaminacija, izguba olja difuzijske črpalke, mejni predtlak, preklopna točka

1 INTRODUCTION

Most usual, the high vacuum pumping systems consist of diffusion pumps and corresponding rotary backing pumps. The basic sheme is shown on **Figure 1**. Normally, all producers of such high vacuum systems give the prescription how to work with them at the begining, when the vacuum chamber is pumped from atmospheric pressure, down to 10^{-4} and 10^{-5} mbar, respectively, when the technological process is started (e.g. evaporation). In practice this procedure is never exactly followed by users. Only in the case, when the high vacuum system is fully automatized, the users can avoid the mistakes in the pumping procedure. Usually it happens that not skilled persons change the programme by moving the pressure switching points of valves. The results of that action are:

- by backstreaming oil vapours from the diffusion pump the vacuum chamber as well as all material in it are contaminated
- the oxidation, deterioration and loss of the diffusion pump oil are very intensive.

The service and cleaning work of the system is required.

2 EXPERIMENTAL

The procedure of pumping from atmospheric pressure to the high vacuum is well known. The action of both pumps has to be adjusted to minimize the pumping time, which is very important in the industrial production. If shorter time is required ("The time is money!"), we have to know all effects which influence on it. One of them is the time switching programme of valves, which

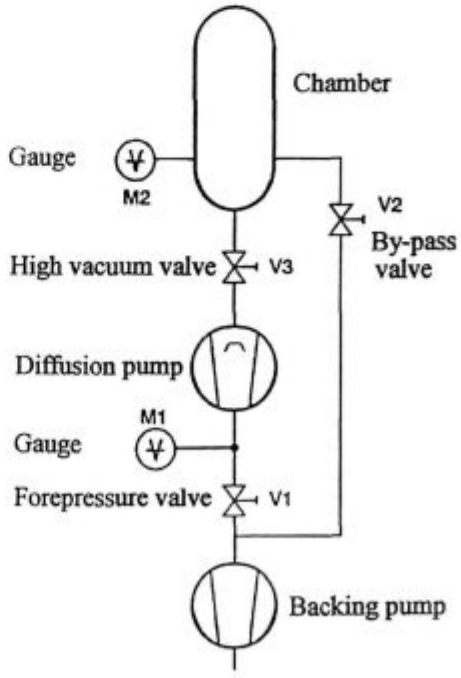

Figure 1: High vacuum pumping system
Slika 1: Visokovakuumski črpalni sistem

is also depended on the pumping characteristics of both pumps.

The most evident way, how to explain the interrelation between diffusion and backing pumps, are their throughput-pressure characteristics. As an example let us use the throughput characteristics of DI 12000 diffusion pump (Leybold) and corresponding backing pump (a combination of Roots pump WA 250 and the one stage rotary pump S 60A). From the diagram (**Figure 2**) it is evident that both throughput characteristics have the cross-section point M at the throughput Q_M and pressure p_t. The pumps are selected so that the end of the diffusion pump curve is just on the throughput curve of backing pump. The pressure p_t is called the tolerable forepressure. Practically, this forepressure is a limit of the diffusion pump operation. The total air flow from the vacuum chamber is now depended only on the backing pump and conductivities of connected lines, valves etc. When the tolerable forepressure takes place the oil vapours which are generated in the diffusion pump boiler and ejected through the jet system do not reach the water cooled walls of the pump, where the condensation of them is expected, but one part escapes in the direction of vacuum chamber, where it condenses (contamination!), the other part of oil vapours is pumped by the backing pump (the loss of the oil from diffusion pump). The oxidation and deterioration of the oil in the boiler of the pump and on the surface of jet system (temp. approx. 200°C) is accelerated.

Case 1: When pumping of the chamber is started through the by-pass valve V2 from the atmospheric pressure (V1 and V3 are closed) the air throughput Q and the pressure are slowly reducing (the direction from point A to M in diagram, **Figure 2**). When the point M on the throughput curve is reached, the theoretical possibility is done to pump with the diffusion pump. If in this moment the by-pass valve is closed, and V1 and V3 are open, from the point M we are "driving" the pumping action of the chamber in the direction of DI 12000 (upper curve) to the next point C, where the pressure is P_c (M2) and forepressure p_c (M1) at the throughput point C'. The pressure p_c is lower than tolerable one p_t, and the diffusion pump can normally operate. After a longer time of pumping we "come" to the point D, where the throughput is Q_D, pressure on high vacuum side P_d and forepressure p_d (point D'). We can continue the pumping procedure as long as the operating (or ultimate) pressure is achieved. The diagram on **Figure 2** is an example, how the diffusion and backing pumps are well adjusted.

Case 2: Supposing that the by-pass valve (V2) is closed and other valves (V1, V3) are open in the point A, where the pressure p_a is higher then the tolerable forepressure p_t. The pump capacity of the diffusion pump is totally lost. The diffusion pump is now like "a cooking pot" for oil. Bad results were described above, although the pumping action of backing pump is continued. The situation is normalized, when the point M is achieved and after that, as described above. This means that on such a way we can not shorten the total pumping time.

Case 3: If the by-pass valve (V2) is closed later, e.g. at the point E, and valves V1, V3 are open in next moment, the diffusion pump as well as backing pump throughput suddenly "jump" to the value at E' and the forepressure (M1) increases from p_e to p_e". If in our pumping procedure is such a case, we had lost the time, which is needed to pump the chamber from E" to E with backing pump.

We have described three characteristical situations in the operating procedure, and now we can ask ourselves, how to recognize that the high vacuum pumping system is operating correct or not. Normally, we have not the

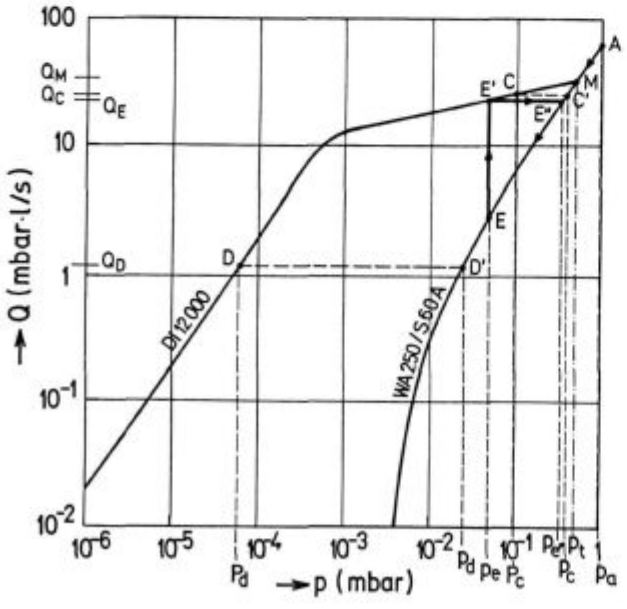

Figure 2: Throughput Q vs. pressure p
Slika 2: Pretok zraka Q v odvisnosti od tlaka p

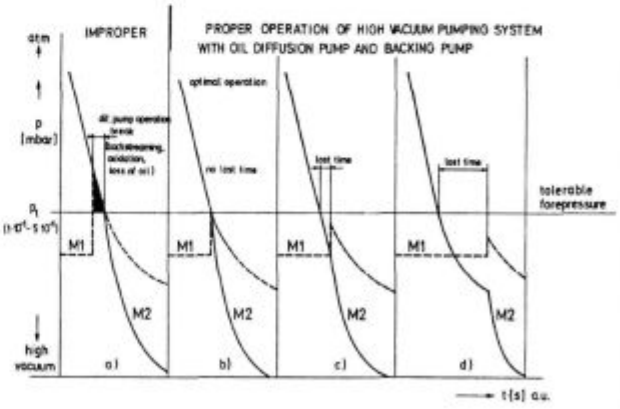

Figure 3: Pumping time characteristics of the adjusted high vacuum pumping system: a) inproper operation, b) proper and optimal operation, c), d) proper but not optimal operation
Slika 3: Črpalna karakteristika usklajenega visokovakuumskega sistema: a) nepravilno delovanje, b) pravilno in optimalno delovanje, c), d) pravilno, vendar ne optimalno delovanje

pumping diagram (like that shown on **Figure 2**) at the hand.

The best way is monitoring of the both pressures readings M1 and M2. If the forepressure (M1) increases to the values, which are higher than the torelable forepressure, when we close V2 and open V1 and V3, the operation of the diffusion pump is stopped (oil backstreaming and contamination of vacuum system, the oxidation and loss of the oil begin) (**Figure 3a**). The situation is normalized, when the pressure (M1) is lower then the tolerable forepressure.

The optimal case is, when after switching of the valves, as desribed above, the forepressure (M1) increases just to the value p_t (tolerable forepressure), **Figure 3b**. All other cases, as we can see on the pumping characteristics, **Figure 3c, d**, are also proper but not optimal, we are loosing time, which is very important, especialy in the production in the industry.

It is also very simply to practically identify the tolerable forepressure. For most types of oil diffusion pumps it is between 0,1 and 0,5 mbar. Many other cases exist, where the pump combinations are not adapted (e.g. the pumping speed of backing pump is to high or to low) which will be described later in a separate paper.

3 CONCLUSION

It is very simple to estimate that a high vacuum system is operating optimaly or not by observing the pressure changes in the vacuum chamber as well as the forepressure of diffusion pump during the switching period of values.