inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 12.4.4

NOISE GENERATION BY A SUCTION UNIT IN DIFFERENT OPERATING CONDITIONS

M Cudina & E Zelezic

Faculty of Mechanical Engineering, University of Ljubljana, Askekeva 6, Ljubljana, Slovenia

1. INTRODUCTION

The noisiest part of a household vacuum cleaner is the built-in suction unit consisting of a two-stage centrifugal blower (1) and driving electric motor (2), see Fig. 1. The total emitted noise from the suction unit is generated partially by the blower and partially by the electric motor, and has three characteristic noise origins: aerodynamic, mechanical and electromagnetic. Their contributions to the total emitted noise level depend on the geometry of the suction unit and on operating conditions, i.e., on the load and rotational speed.

The aerodynamic noise is mainly the consequence of the fluctuating forces on the rotor blades of the blower that are provoked by the interaction of the rotor blades with the inflow distortion, nearby stationary objects, turbulence, etc. This mechanism of noise generation, also called rotational noise, has the tonal nature and is linked with rotational frequency and/or blade passage frequency (BPF) and their higher harmonics. The aerodynamic noise has its origin also in pressure fluctuations due to blade stalls generation, by rotor interaction with the vortex in radial and axial clearances and by laminar boundary layer vortex shedding as well as by the air flow through the passages between the rotor and stator of the electric motor. This mechanism, called non-rotational or turbulent noise is not related to the rotational speed or BPF.

Mechanical noise is caused by friction in the bearings and between brushes and the collector of the electric motor, as well as by unbalanced rotating masses (rotors) of the blower and motor.

Electromagnetic noise is generated by the magnetostriction and magnetic forces fluctuation between the poles of the electric motor.

In the present work a visualization, localization and quantification of the noise sources of the suction unit were performed using the sound intensity measurement technique in order to find out a prevailing mechanism of noise generation. A new redesigned suction unit with a lower emitted noise level was also made and discussed.

2. TEST PROCEDURE

A DOMEL 1000 W dry suction unit was used in the experiment. Performances and noise characteristics of the suction unit were measured simultaneously on a test plenum (4) placed into an anechoic room, according to the DIN 44956 Part 2 for the performance measurement, ISO 3745 for the sound pressure level measurement and ISO 9614 Part 1 for sound intensity (SI) measurement. The sound pressure level of the suction unit was measured by the B&K 2032 FFT analyzer and microphone placed at a distance of 1 m. The SI was measured with the B&K FFT analyzer, Type 2133, and a B&K SI Probe, Type 3520, successively running in 204 discrete points on an imaginary cylinder with a 460 mm diameter, see (3) in Fig. 1 and 3. To avoid the effects of the air flow with a velocity that was also above 2 m/s (up to 8 m/s on the cylindrical coat and up to 18 m/s on the cylindrical top surface) on the sound intensity results, especially at the frequency range below 1000 Hz, a spherical windscreen on the SI probe was used and A-weighted SI measurement was performed.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Performances and noise characteristics are presented in Fig. 2. In the paper only three characteristic operating points are discussed: point A at the maximum pressure rise (Δp_{max}, Q=0), point B at the best efficiency point or design point with minimal noise level (η_{max}, Q_{des}, L_{pmin}), and point C at the free delivery (Δp_{min}, Q_{max}). The rotational speed of the suction unit was changeable, from n_{max} in point A, to n_{min} in point C. The differences are up to 30 %.

Fig. 3 shows A-weighted noise level around the suction unit at the corresponding operating points A, B and C. It can be seen that the suction unit cannot be discussed as a point source, its directivity patterns depend on the operating conditions. Maximum noise level occurs in the direction of axis of the brushes for operating points A and B, whereas the operating point C has in this direction its minimum.

Noise spectra of the suction unit on the same measurement position of the SI measurement surface and at different operating points A, B and C are presented in Fig. 4. These spectra are broadband in nature with superimposed tones of discrete frequencies at the 6th, 12th and 24th harmonic of the rotational frequency or at the 1st, 2nd and 3rd harmonic of the BPF at all operating points. From this figure it can also be concluded that the low frequency noise (up to 1 kHz) steeply increases when the flow rate increases towards the free delivery in operating point

C. This noise has its origin in the turbulence of the air flow in the motor outlet opening.

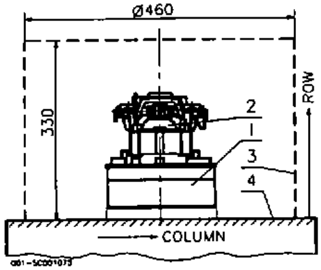

Fig.1. Measurement lay out.

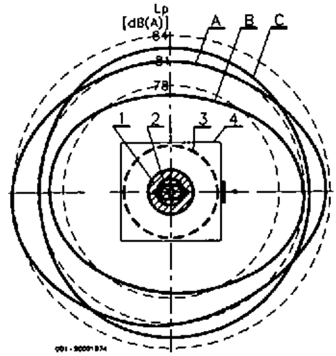

Fig.3. Sound pressure levels around the suction unit at different operating points A, B and C.

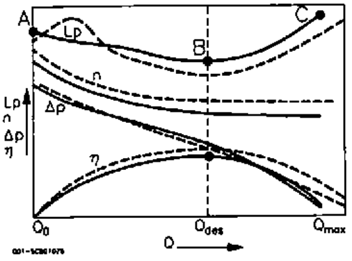

Fig.2. Performance and noise characteristics of the suction unit. Δp-pressure rise, Q-flow rate, L_p-noise level, η-efficiency.
— before, —— after redesigning.

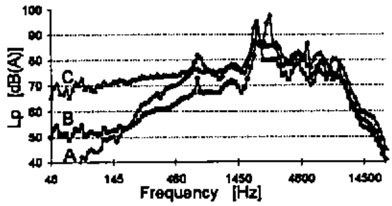

Fig.4. 1/12-octave A-weighted noise spectra of the suction unit at different operating points A, B and C.

The A-weighted sound intensity patterns emitted from the suction unit at all three characteristic operation points (A, B and C) are shown on 3-D plots in Figs. 5.a. From these figures we can see that the main part of the emitted sound intensity radiates from the air flow outlet opening in the vicinity of commutator brushes of the electric motor at all operating points A, B and C (see COL 4 and 10, ROW 9÷10). Minimum sound intensity radiates from the part representing the turboblower, which is located at the bottom side of the suction unit, and in the direction perpendicular to the brushes (COL 1÷3 and 6÷8, ROW 1÷3). Analyzes of the sound intensity measurement results have shown that the sound intensity level from the electric motor is by approximately 5 dB(A) higher than that from the section representing the blower. According to this the electric motor radiates more noise than the blower, however this conclusion could be misleading.

The SI measurements carried out on the suction unit with rotors of the blower being dismantled, and the aerodynamically generated noise eliminated, have shown that the emitted noise is lowered by approximately 20 dB and more in comparison with the blower at zero flow rate. Therefore we can conclude that the mechanically and electromagnetically generated noise can be regarded as negligible, and that the aerodynamically generated noise is the prevailing noise origin in all parts of the suction unit and within the entire range of the operating conditions. The analyses of the sound pressure and intensity spectra of the complete suction unit as well as the electric motor alone have also shown that the peaks of the spectra are at the BPF of the turboblower and its higher harmonics for all three operating points, A, B, C. This statement has led to the conclusion that the emitted noise is related to the turboblower.

Therefore, the turboblower was aerodynamically redesigned. Its performance characteristics are presented with a dashed curve in Fig. 2 and its sound intensity patterns are presented in Figs. 5.b. The new suction unit emits lower sound power by 2,5÷3 dB(A) and has the best efficiency point better by approximately 4,5 %.

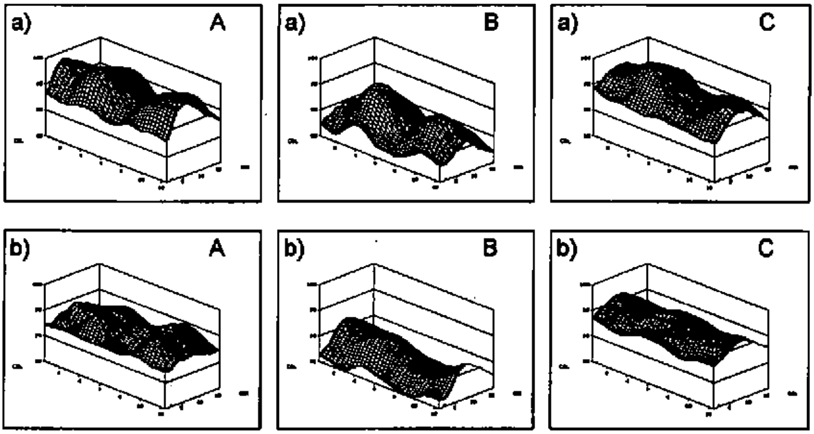

Fig. 5. A-weighted sound intensity patterns on measurement surfaces in the frequency range from 160 to 5000 Hz on the cylinder coat with ∅460 mm. a) before and b) after redesigning at operating points A, B and C.

4. CONCLUSIONS

Detailed analyses of the noise emitted from the suction have shown that the turboblower is the predominant noise source in all operation conditions. This also means that the aerodynamically generated noise is the main origin of the noise, whereas the mechanical and electromagnetic noise can be neglected.