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Izvedba sistema za avtomatsko končno kontrolo kakovosti elektromotorjev za sesalnike

Implementation of a System for the Automatic End-Quality Assessment of Vacuum-Cleaner Motors

Bojan Musizza[1] - Janko Petrovčič[1] - Dejan Tinta[1] - Joža Tavčar[2] - Gregor Dolanc[1] - Janez Koblar[2] - Đani Juričić[1]
([1]Institut Jožef Stefan, Ljubljana; [2]Domel, Železniki)

V prispevku je predstavljen diagnostični sistem za končno kontrolo kakovosti elektromotorjev za sesalnike. Sistem temelji na novih mehatronskih rešitvah, ki združujejo posebno načrtovano strego testiranih enot, lasersko vibrometrijo, vibroakustične in elektromehanske meritve ter sodobne metode obdelave signalov. Rezultat obdelave izmerjenih signalov so značilke, na podlagi katerih sistem zazna in lokalizira tudi najmanjše napake v električnem ali mehanskem delu motorja. Natančni, zanesljivi in občutljivi diagnostični postopki zagotavljajo popolnoma brezhibne končne izdelke.

(Ključne besede: kontrola kakovosti, odkrivanje napak, avtomatizacija, elektromotorji majhni)

In this paper we present a diagnostic system for the end-quality assessment of vacuum-cleaner motors. The system relies on innovative mechatronic solutions, which combine custom-designed handling of the units under test, vibro-acoustic measurements and electrical measurements as well as advanced signal processing. Processing of the measured signals results in the so-called features, which serve to detect and localize even the tiniest faults, in either the electrical or mechanical parts of the motor. Thus the accurate, reliable and sensitive diagnostic procedure allow for entirely fault-free final products.

(Keywords: quality assessment, fault diagnosis, automation, small electric motors)

0 UVOD

Konkurenčne razmere na trgu malih elektromotorjev silijo proizvajalce k nenehnemu zniževanju stroškov proizvodnje in izboljševanju kakovosti svojih izdelkov. Domel d.d. Železniki je eden izmed vodilnih evropskih proizvajalcev elektromotorjev za sesalnike. Ena izmed možnosti za dvig konkurenčnosti - predvsem v primerjavi s proizvajalci z daljnjega vzhoda in njihovimi nizkimi cenami - je v nadaljnjem dvigu kakovosti izdelkov in učinkovitosti proizvodnje skozi zmanjševanje proizvodnih stroškov. Pomemben korak v tej smeri pomeni modernizacija sistema nadzora kakovosti, in sicer predvsem v smislu popolne avtomatizacije končne kontrole z namenom zagotavljanja 100-odstotno brezhibnih dobavljenih motorjev.

Na trgu obstaja nekaj ponudnikov avtomatskih testnih postaj za manjše elektromotorje, npr. [1] do [3]. Glavni problem je

0 INTRODUCTION

Continuously increasing competition on the market for small electrical motors is forcing manufacturers to reduce production costs while increasing the quality of their final products. Domel Ltd Železniki ranks among the leading manufacturers of vacuum-cleaner motors in Europe. As a way of coping with market competitors, particularly those from the Far East that gain market share by offering low prices, the company is working hard to improve quality and raise the efficiency of production by lowering production costs. A step towards achieving this goal is related to improving the process of quality assurance and, as part of this, fully automated end-quality assessment of the products. In this way, maximum quality and almost 100% fault-free final products are guaranteed.

There are several manufacturers in the market that offer automatic test stands for the end-quality assessment of vacuum-cleaner motors, e.g. [1] to [3].

Sl. 1. *Elektromotor za sesalnike*
Fig. 1. *Vacuum-cleaner motor*

ta, da omenjeni sistemi le delno rešujejo specifični problem kontrole kakovosti Domelovih sesalnih enot. Na primer, sistem Vogelsang & Benning omogoča merjenje vibracij le v eni točki, kar pa ne ustreza zahtevam kupcev. Podobno je s Schenckovim sistemom. Zato z njihovo uporabo ne bi v celoti odpravili potrebe po ročni kontroli.

Izgled elektromotorja za sesalnike, ki ga je treba testirati, je prikazan na sliki 1.

Rešitev, ki jo predlagamo v pričujočem prispevku, ima namen zagotoviti popolnoma avtomatsko končno kontrolo elektromotorjev, tj.:
- natančno ugotavljanje ključnih parametrov kakovosti sesalne enote,
- identifikacijo vseh parametrov kakovosti, ki odstopajo od predpisanih meja ter
- lokalizacijo napake v primeru, da je enota neprimerne kakovosti.

Rezultat omenjenih funkcionalnih lastnosti je zmanjšanje stroškov proizvodnje, ker potreba po dodatnih "ročnih" testih povsem odpade.

Glavni namen prispevka je predstaviti avtomatski diagnostični sistem za sesalne enote, ki je uveden na proizvodnji liniji v Domelu. Prispevek je organiziran takole. V sledečem poglavju je najprej prikazana zgradba diagnostičnega sistema, sledi opis merilnih celic. V četrtem poglavju je prikazano delovanje obravnavanega sistema, na koncu pa so podani sklepi.

These systems, however, are only able to fulfil some of the requirements set by Domel. For example, the system of Vogelsang & Benning [1], and that of Schenk, only allows the measurement of vibrations at a single point. According to the quality standards of Domel, as well as the requirements imposed by various customers, vibration measurements should be carried out at three different points on the motor's body. Therefore, if installed, these systems would only partly solve the problem of full quality assessment and hence additional (manual) measurements would still be needed.

The device to be tested is shown in Figure 1.

The solution presented in this paper attempts to provide fully automatic quality-assessment tests that comprise:
- determination of the key quality parameters for vacuum-cleaner motors,
- identification of all the parameters of the motor's quality, which exceed pre-defined thresholds,
- fault localization once a motor of improper quality is identified.

These features lead to a reduction of production costs as no additional manual checks are needed.

The main purpose of the paper is to present a system for the automatic end-quality assessment of vacuum-cleaner motors at the end of the assembly line. The paper is organized as follows. In the section to follow the structure of the diagnostic system is described first. After that the diagnostic cells are explained. In the fourth section the performance of the system is presented and, finally, concluding remarks are given.

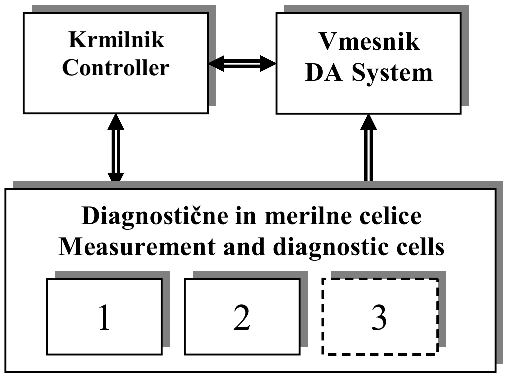
1 ZGRADBA DIAGNOSTIČNEGA SISTEMA

Diagnostični sistem (sl. 2) je sestavljen iz petih glavnih modulov (sl.3):
- treh merilnih in diagnostičnih celic,

1 SYSTEM ARCHITECTURE

The system (Fig. 2) is composed of five major parts (Fig. 3):
- three measurement and diagnostic cells,

Sl. 2. *Diagnostični sistem za sesalne enote*
Fig. 2. *End-quality assessment system installed on the assembly line*



Sl. 3. *Zgradba diagnostičnega sistema*
Fig. 3. *Architecture of the diagnostic system*

- krmilnika za strego in
- računalnika s karticama za zajem podatkov.

Diagnostični sistem temelji na neposrednem merjenju devetih fizikalnih veličin, in sicer: napajalne napetosti na motorju, toka, podtlaka, moči, hitrosti vrtenja, in vibracij, za korekcijo meritev pa še temperaturo zraka, vlažnost in atmosferski tlak. Pozneje bo mogoča še meritev zvoka, ki ga za zdaj merimo le v preizkusne namene.

Glavni testi kakovosti se opravijo na treh merilnih modulih, ki delujejo vzporedno. Vzporednost je v tem primeru potrebna iz dveh razlogov:

a) zaradi razmeroma velikega števila različnih testov, ki jih je treba izvesti ter
b) zato, da se ujame takt proizvodnje, ki znaša 9 s.

Za usklajeno delovanje vseh operacij diagnostičnega sistema in strego skrbi zmogljiv Mitsubishijev krmilnik MELSEC-Q. Le-ta daje takt diagnostičnemu sistemu, ki mora ustrezati taktu preostalega dela proizvodne linije. Z uporabo informacij, ki jih dobi s pozicijskih zaznaval na liniji, ter pnevmatskih izvršilnih organov skrbi za pravilno vmeščanje in vklapljanje testiranih sesalnih enot v različnih fazah testiranja. Obenem pa skrbi tudi za transport enot skozi diagnostični sistem.

Sistem za zbiranje podatkov temelji na merilnih karticah NI 6220 in NI 6221, ki sta namenjeni za vzorčenje merjenih veličin. Zbrani podatki se predhodno obdelajo in potem pošljejo skozi algoritme za izračun značilk, od koder sledi vektor značilk. Vsaka značilka odraža nek vidik kakovosti tako, da s preverjanjem, ali je le-ta v predpisanem območju, sklepamo o tem, ali naprava ustreza zahtevanim standardom kakovosti. Če ne ustreza,

- a control unit for mechanical handling of the motors,
- a data-acquisition system.

The system operation relies on the direct measurements of nine electrical and mechanical quantities, i.e., power-supply voltage, motor current, air-pressure drop on the motor, speed of revolution, electric power, vibrations, as well as air temperature and humidity (needed for data conditioning). This set of measurements will soon be complemented by sound measurement.

The key assessment tasks are performed within three measurement modules running in parallel. The parallelism was needed in this case for two reasons:

a) a relatively large number of different tests that need to be performed,
b) to ensure the 9 s production cycle.

The control unit is built around a Mitsubishi MELSEC-Q PLC, which takes care of the mechanical handling and the tasks synchronization. The cycle of the diagnostic system is adapted to the cycle of other parts of the assembly line. Based on information from position sensors located on the line and pneumatic actuators, the control system generates signals for motor positioning as well as motor start-up and shut-down during the test. In addition, it takes care of transport of the motors through the diagnostic system.

The data-acquisition system is based upon the National Instruments NI 6220 and NI 6221 data-acquisition modules. The acquired data are first pre-processed and then passed to the feature-extraction algorithms that calculate a vector of features. Each feature (reflecting a particular aspect of quality) is checked in order to verify whether the device meets

Sl. 4. *Operaterski vmesnik*
Fig. 4. *Control panel*

potem algoritem ugotovi izvor napake. Vsa programska oprema je izdelana v grafičnem okolju LabVIEW.

Uporabljeni krmilnik je prek vodila RS 232 povezan z računalnikom. Slika 4 prikazuje operaterski vmesnik za upravljanje s celotnim diagnostičnim sistemom.

2 DIAGNOSTIČNE CELICE IN NJIHOVE FUNKCIJE

Prva merilna celica je namenjena preverjanju karakterističnih veličin sesalnih enot in kakovosti komutacije. Karakteristika motorja je definirana z naslednjimi podatki: električni tok motorja, električna moč, podtlak in hitrost vrtenja. Ob tem se nadzirajo tudi merilni pogoji, in sicer napajalna napetost, temperatura okolice, vlažnost ter atmosferski tlak. Pri tem se podtlak najprej korigira glede na atmosferski tlak in temperaturo okolice, nato pa se vse karakteristične veličine korigirajo še glede na razliko med nazivno (230 V) in dejansko napajalno napetostjo.

Kakovost komutacije se preverja na podlagi merjenja korena povprečja kvadratov (KPK - RMS), vrednosti toka v 12 frekvenčnih področjih širine 2,5 kHz. V ta namen tok vzorčimo s frekvenco 60 kHz, izračunamo njegov frekvenčni spekter in iz tega določimo vrednosti KPK posameznih pasov (sl. 5).

to the quality requirements. If this is not so, detection and localization of the tentative defects are performed. The entire application software is realized in LabVIEW.

The data-acquisition system is connected to the controller unit via an RS 232 communication line. Fig. 4 shows the control panel.

2 DIAGNOSTIC MODULES AND THEIR FUNCTIONS

The first diagnostic module serves for measuring the characteristic parameters of the motor on the one hand, and for assessing the quality of commutation, on the other. The motor's characteristic is defined by the following data: the electrical current, the electrical power, the pressure difference and the speed of revolution. As it is very important that these data are obtained under a nominal supply voltage, the measurement conditions are fully supervised in order to compensate for possible fluctuations. Based on a sampled actual voltage as well as the air temperature and humidity, the system is able to provide corrected values of the characteristic parameters, i.e., normalized to the nominal supply voltage (230V) and standard atmospheric conditions.

The quality of the commutation is verified by calculating the root-mean-square (RMS) values of the current signal in 12 consecutive frequency bands that are 2.5 kHz wide. The current signal is sampled with 60 kHz and the Fourier spectrum is calculated from the samples (Fig. 5).

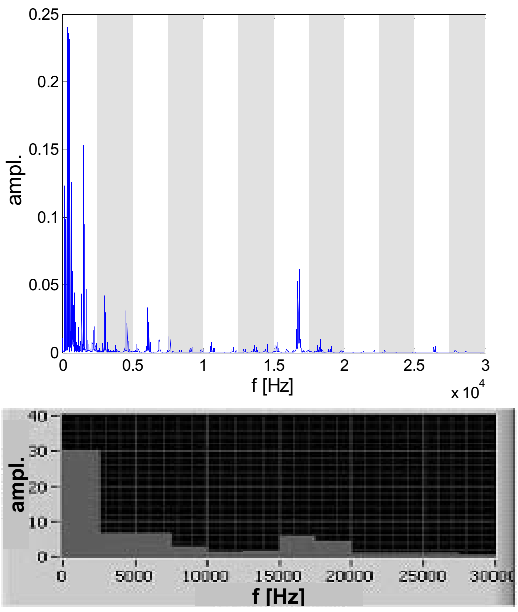
Druga merilna celica, ki je prikazana na sliki 6, je namenjena merjenju vibracij. Le-te je na zahtevo kupca treba pomeriti v treh točkah, in sicer: na turbini v osni smeri, na turbini v radialni smeri in na ohišju sesalne enote zopet v radialni smeri.

Meritev vibracij poteka takole. Najprej posebne klešče primejo sesalno enoto (sl. 7). S tem jo vibracijsko ločijo od okolice (palete) in tako preprečijo, da bi na meritev vplivale vibracije, ki jih povzroča proizvodna linija. Vibracije enot se merijo z laserskim merilnikom Ometron VQ-500-D. Le-ta je pritrjen na vmeščalni mehanizem, ki omogoča njegovo navpično premikanje, in meri vibracije v vodoravni smeri. Meritev v osni smeri enote (navpični smeri) se izvede z uporabo zrcala, ki laserski žarek preusmeri v omenjeno smer. Nato pozicionirni mehanizem premakne laserski merilnik v še dve točki, tako da se lahko izmerijo še vibracije v radialni smeri, in sicer na turbini ter na ohišju. Po končanih meritvah se laserski merilnik vrne v začetno lego, klešče pa izpustijo sesalno enoto.

Vibracije sesalne enote se ovrednotijo na podlagi njihovih vrednosti KPK v 15 frekvenčnih pasovih širine 1 kHz, in sicer od 0

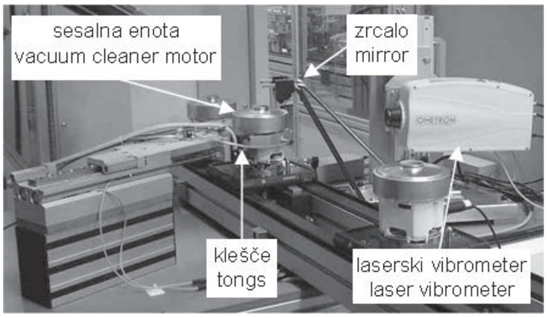
The second measurement and the diagnostic cell shown in Figure 6 serve for the vibration measurements. According to the customer's requirements the vibration must be measured at three points: on the cover, in the axial direction; on the cover, in the radial direction; and on the housing of the vacuum-cleaner motor, again in the radial direction.

The vibration measurement is carried out as follows. First, specially designed tongs grip the motor under test (see Fig. 7). In this way the motor is vibrationally isolated from the environment (i.e., transportation pallet) and so the vibration originating from the assembly line cannot affect the vibration measurement of the motor itself. The vibrations are acquired with an Ometron VQ-500-D laser vibrometer. The vibrometer is fixed on a positioning mechanism, which allows for movement of the vibrometer in the vertical direction, thus allowing measurement of the vibration in the radial direction. The measurement in the axial direction of the motor (in the vertical direction) is carried out by using a mirror, which redirects the laser beam in the appropriate direction. Then the positioning mechanism moves the vibrometer in another two points in order to measure the vibrations in the radial direction, i.e., on the cover and on the housing. As soon as the measurements are finished the vibrometer returns to its initial position and the tongs release the motor.

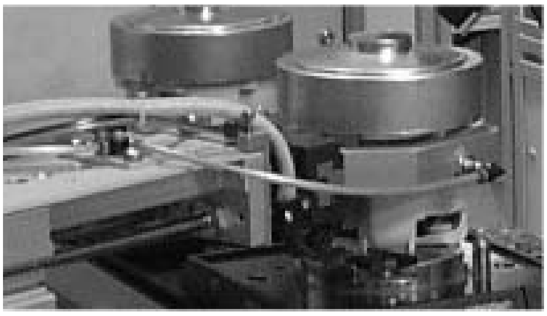


Sl. 5. *Primer frekvenčnega spektra toka (zgoraj) in pripadajočih značilk oz. vrednosti KPK posameznih pasov (spodaj)*

Fig. 5. *An example of the current frequency spectrum (above) and the corresponding features, i.e., RMS values of the individual bands (below)*



Sl. 6. *Merjenje vibracij*
Fig. 6. *Vibration measurement*



Sl. 7. *Prijemalo za motor*
Fig. 7. *A motor gripped by tongs*

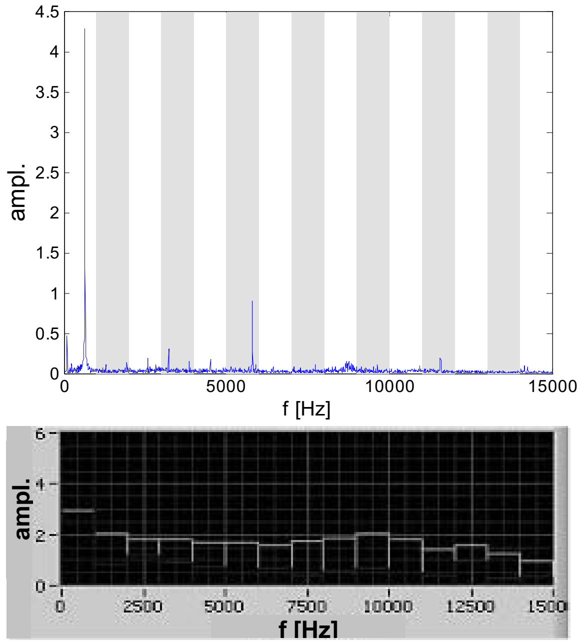
do 15 kHz. V ta namen se signal vibracij vzorči s frekvenco 60 kHz, izračuna njegov frekvenčni spekter in iz tega določi vrednosti KPK posameznih pasov (sl. 8).

Tretja merilna celica, ki je v fazi uvajanja, bo namenjena merjenju zvoka sesalnih enot pri majhnih hitrostih vrtenja (okrog 40 vrtljajev na minuto). Zaradi nizke jakosti zvoka pri omenjenih vrtljajih bo treba meritve izvajati v akustično izolirani komori, s čimer se bo zmanjšal vpliv motilnega hrupa iz okolice.

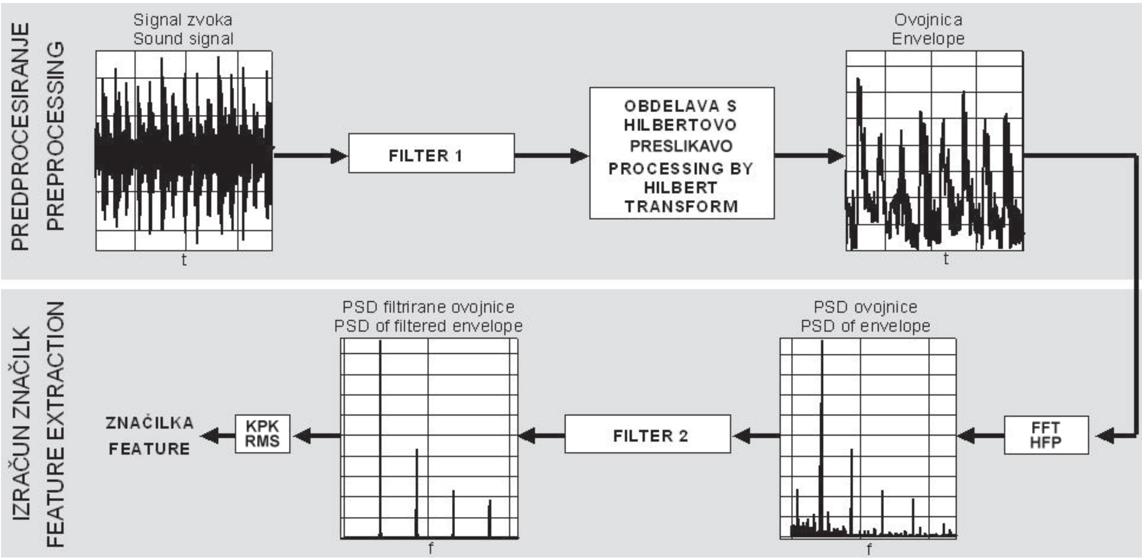
Pri majhnih hitrostih vrtenja sesalnih enot pridejo v signalu zvoka do izraza značilni vzorci,

The vibrations of the vacuum-cleaner motor are evaluated with the RMS values of 15 1 kHz wide frequency bands in the range from 0 to 15 kHz. For this purpose the vibration signal is sampled at 60 kHz. Then its frequency spectrum is calculated, and from this the RMS values of the individual bands are defined (Fig. 8).

The third measuring cell, which is still in the implementation phase, is intended for measuring the sound emitted by vacuum-cleaner motors at low rotational speeds (app. 40 revolutions per minute). Due to the low intensity of the sound at these revolutions the measurements have to be carried out in an anechoic chamber in order to cut down the influence of disturbing noise from the environment.



Sl. 8. *Primer frekvenčnega spektra vibracij (zgoraj) in pripadajočih značilk oz. vrednosti KPK posameznih pasov (spodaj)*
Fig. 8. *Example of vibration frequency spectrum (above) and the corresponding features, i.e., RMS values of the individual bands (below)*



Sl. 9. *Obdelava signala zvoka*
Fig. 9. *Processing of the sound signal*

ki so posledica napak v ležajih ali drgnjenja med vrtečimi se in mirujočimi deli. Ti vzorci imajo obliko izbruhov, katerih pogostost pojavljanja je v primeru napake v ležaju odvisna od izmer ležaja in hitrosti vrtenja enote, v primeru drgnjenja pa ustreza frekvenci vrtenja enote oz. njenim večkratnikom [7]. S Hilbertovo preslikavo najprej določimo ovojnico signala zvoka, nato pa izračunamo njen frekvenčni spekter [8]. Določena napaka se kaže v vrednosti KPK ovojnice v ustreznih frekvenčnih pasovih, ki so značilni za posamezno napako. Postopek prikazuje slika 9.

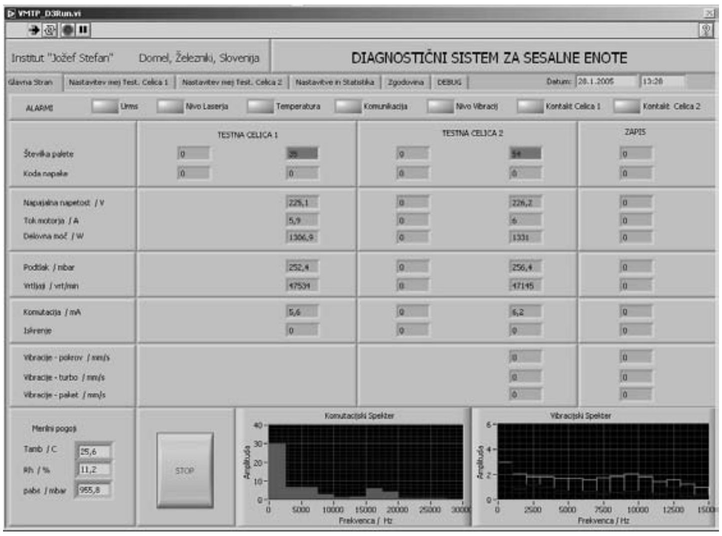
At low rotational speeds of vacuum-cleaner motors typical patterns occur due to bearing faults or rubbing between rotating and static parts of the motor. They are shaped like bursts. The frequency of bursts depends on the dimensions of the bearing and on the rotational speed of the motor in the case of a bearing fault, while in the case of rubbing it depends on the rotational frequency of the motor or on its higher harmonics [7]. First, the envelope of the sound signal is obtained by using the Hilbert transform. Next, the frequency spectrum of the envelope is calculated [8]. The presence of a certain fault is reflected in the RMS value of the envelope in corresponding frequency bands, which are typical for an individual fault. The procedure is illustrated in Figure 9.

3 DELOVANJE DIAGNOSTIČNEGA SISTEMA

Na vhodu v diagnostični sistem se najprej prebere številka palete, na katero je postavljena sesalna enota. Pod to številko se nato v računalniku shranjujejo diagnostični rezultati določene sesalne enote. S tem se zagotovi sledenje enoti medtem, ko le-ta potuje skozi posamezne merilne celice diagnostičnega sistema. Številka palete se ponovno prebere na izhodu sistema in primerja s tisto v računalniku. Če se številki ujemata, pomeni, da je bilo testiranje opravljeno uspešno. V nasprotnem primeru se sproži ustrezni alarm. V zadnji operaciji diagnostičnega sistema se v čip na paleti testirane sesalne enote vpiše, ali je le-ta brezhibna oz. ustrezno kodo morebitne napake.

3 DIAGNOSTIC SYSTEM PERFORMANCE

Each vacuum-cleaner motor in the production line is associated with a label. First, the code of the transporting pallet is read at the entrance of the diagnostic system. Then, the diagnostic results of the particular vacuum-cleaner motor are saved in the computer under this code. In that way the tracking of the motor through the individual measuring cells of the diagnostic system is ensured. At the exit of the system the pallet code is read again and it is compared with the code in computer. If the two codes match, it means that the testing was performed successfully. In the opposite case, the appropriate alarm is triggered. In the last operation of the diagnostic system the condition of the tested vacuum-cleaner motor is recorded on the chip mounted on the pallet. The record contains information on the motor's health; if the



Sl. 10. *Uporabniški vmesnik*
Fig. 10. *User interface*

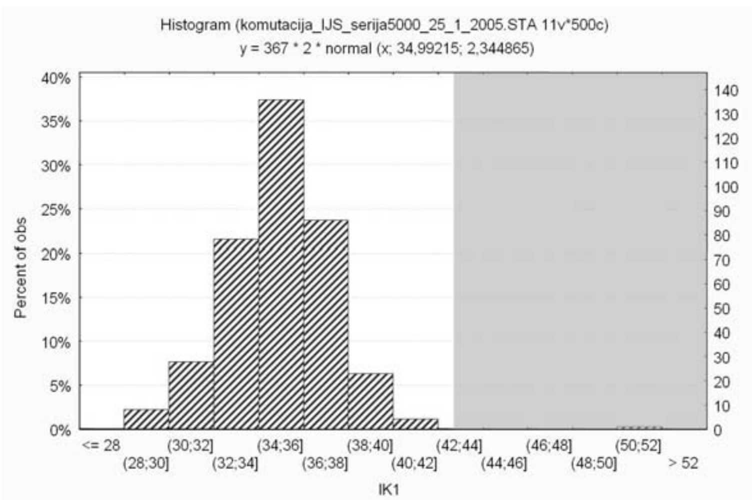
Uporabniški vmesnik obravnavanega sistema (sl. 10) je namenjen prikazu diagnostičnih rezultatov testiranih sesalnih enot. Poleg tega omogoča še nastavitev mejnih vrednosti značilk v obeh merilnih celicah, izračun nekaterih statističnih parametrov na izmerjenih vrednostih in pregled preteklih rezultatov testiranj.

Na sliki 11 je prikazana porazdelitev vrednosti KPK signalov tokov v frekvenčnem področju od 0 do 2,5 kHz za poskusno serijo sesalnih enot, ki so bile izdelane v fazi testiranja proizvodne linije. Vidimo, da je pri večini sesalnih enot kakovost

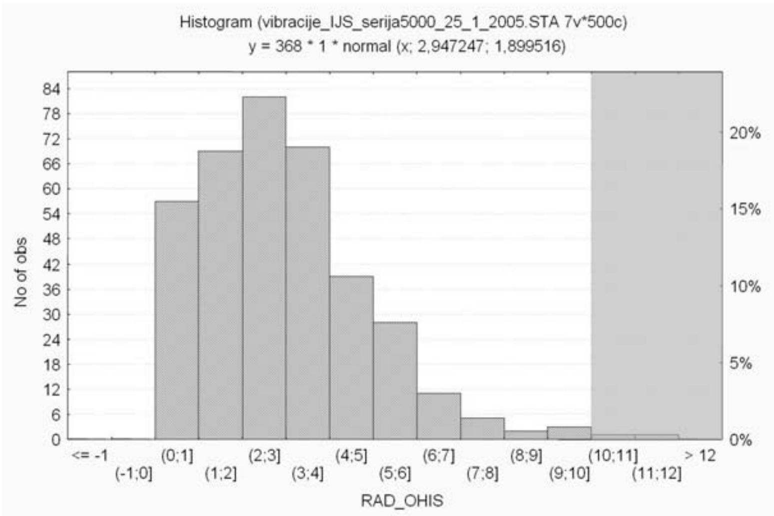
motor is not fault-free, the appropriate code of the eventual fault is provided.

The user interface of the system (Fig. 10) is used to display all the essential diagnostic results of the tested vacuum-cleaner motors. In addition, it makes it possible to set the thresholds of the features in both measuring cells, to calculate some statistical parameters of the measured values and to review past results of the tests.

Figure 11. shows a distribution of the RMS values of current signals in the frequency band from 0 to 2.5 kHz obtained on a series of vacuum-cleaner motors. It can be seen that the commutation quality of almost all of the motors falls within the required



Sl. 11. *Porazdelitev značilke kakovosti komutacije za serijo 367 sesalnih enot*
Fig. 11. *Distribution of the commutation quality feature for a series of 367 vacuum-cleaner motors*



Sl. 12. *Porazdelitev značilke vibracij za serijo 368 sesalnih enot*
Fig. 12. *Distribution of the vibration feature for a series of 368 vacuum-cleaner motors*

komutacije ustrezna. Le pri nekaterih značilka preseže še dopustno mejo (osenčeno področje na grafu).

Slika 12 prikazuje porazdelitev značilke vibracij, tj. vrednosti RMS signalov vibracij v frekvenčnem pasu v okolici frekvence vrtenja sesalnih enot (600 do 800 Hz) za serijo 368 enot. Predstavljene so vibracije na ohišju v radialni smeri. Vibracije večine enot so v še dopustnih mejah (pod 10 mm/s), le pri nekaterih enotah jo prekoračijo (osenčeno področje na grafu). Pri tem je treba omeniti, da je srednja vrednost vibracij precej pod postavljeno mejo.

Oba primera kažeta dobro kakovost postopka montaže na liniji kakor tudi stabilno kakovost sestavnih delov, ki jih izdelujejo poddobavitelji.

band (the forbidden band is displayed in grey). Only in a few cases does the feature exceed the threshold (shaded area in the graph).

Figure 12 shows the distribution of vibration feature, i.e., RMS values of the vibration signals in the frequency band around the rotational frequency of the vacuum-cleaner motors (600-800 Hz) for a series of 368 motors. In this figure the vibrations on the housing in the radial direction are presented. The vibrations of most of the motors are below the threshold (10 mm/s); just in some cases the threshold is exceeded (shaded area in the graph). It should also be noted that the mean value of the vibration features is, generally, well below the threshold.

Both examples reflect the high quality of the assembly process and the stable quality of the assembly parts delivered by subcontractors.

4 VREDNOTENJE DIAGNOSTIČNEGA SISTEMA

Diagnostični sistem je po naravi podoben običajnemu merilnemu inštrumentu, saj ga lahko obravnavamo kot navidezni inštrument, ki "meri" stanje motorja. Zaradi tega lahko diagnostični sistem vrednotimo podobno kakor običajne merilne inštrumente. Slednje običajno vrednotimo na podlagi primerjave z odzivi vzorcev. V primeru diagnostičnega sistema žal ni vzorca, na katerega "referenčno" vrednost bi se lahko oprli. Zato je edina "referenčna" vrednost mnenje operaterjev. Žal so mnenja operaterjev subjektivna in zato včasih protislovna, predvsem v primerh, ko napaka ni

4 DIAGNOSTIC SYSTEM EVALUATION

The performance of the diagnostic system is closely analogous to the performance of any classical instrumentation. Indeed, the former can be viewed merely as a virtual instrument that "senses" the motor's condition. Therefore, it could be evaluated in the same way as classical measuring instruments, i.e., according to the reference value from the ethalon device. In this case, however, the ethalon device, which would give the reference value for the motor's condition, does not exist. The only available "reference" is the operators' judgements. Unfortunately, the operators' judgements happen to be non-uniform in some "grey" cases in which izrazita. Problem uglaševanja diagnostičnega sistema smo rešili tako, da smo uporabili iterativni postopek v fazi preizkusne proizvodnje elektromotorjev. Pragovne vrednosti so bile izbirane upoštevajoč naslednje vidike:

- skladnost z uporabnikovimi zahtevami,
- enotno mnenje operaterjev, ki so zadolženi za nadzor kakovosti,
- izkušnje iz preteklosti, ki se nanašajo na podobne motorje,
- statistika, dobljena v fazi preizkusne proizvodnje.

a defect is not particularly obvious. The reason for this is the operators' subjectivity and the limitations of human perception. Therefore, the diagnostic system was tuned and evaluated in an iterative procedure during the test production of the motors. In this phase the feature thresholds were set in deference to several aspects:

- full compliance with customers' requirements,
- consensus of opinion between the operators responsible for quality control,
- past experience on quality assessment with similar motors,
- available statistics obtained during the test production.

5 SKLEP

V prispevku je predstavljen sistem za avtomatsko končno kontrolo sesalnih enot, ki omogoča ovrednotenje vseh njihovih najpomembnejših parametrov kakovosti. Njegova odlika je neprimerno večja zanesljivost in natančnost v primerjavi z ročno kontrolo. Sistem daje tudi globlji vpogled v stanje sesalne enote. Spremljanje trendov kakovosti pa omogoča hitre reakcije na proizvodni liniji.

Popolna avtomatizacija končne kontrole in zagotavljanje visokih standardov kakovosti posledično omogočata zmanjšanje stroškov postopka zagotavljanja kakovosti ter dvig zaupanja kupcev.

5 CONCLUSION

In this paper a system for the automatic end-testing of vacuum-cleaner motors is presented. It makes it possible to evaluate all of the most important quality parameters of the motor. Much better reliability and accuracy are its main advantages, compared to manual testing. The system also gives us a better insight into the condition of the vacuum-cleaner motor. Moreover, tracking the quality trends means that early corrective actions can be taken on the production line.

Complete automation of the end-test and high-quality standard assurance consequently make it possible to reduce the costs of the quality-assurance process and to raise customers' confidence.

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Naslova avtorjev: Bojan Musizza
dr. Janko Petrovčič
dr. Gregor Dolanc
mag. Dejan Tinta
doc.dr. Đani Juričić
Institut Jožef Stefan
Jamova 39
1000 Ljubljana
bojan.musizza@ijs.si
janko.petrovcic@ijs.si
gregor.dolanc@ijs.si
dejan.tinta@ijs.si
dani.juricic@ijs.si

doc.dr. Joža Tavčar
Janez Koblar
Domel d.d.
Otoki 21
4228 Železniki
joza.tavcar@domel.si
janez.koblar@domel.si

Authors' Addresses: Bojan Musizza
Dr. Janko Petrovčič
Dr. Gregor Dolanc
Mag. Dejan Tinta
Doc.Dr. Đani Juričić
Jožef Stefan Institute
Jamova 39
1000 Ljubljana, Slovenia
bojan.musizza@ijs.si
janko.petrovcic@ijs.si
gregor.dolanc@ijs.si
dejan.tinta@ijs.si
dani.juricic@ijs.si

Doc.Dr. Joža Tavčar
Janez Koblar
Domel Ltd.
Otoki 21
4228 Železniki, Slovenia
joza.tavcar@domel.si
janez.koblar@domel.si

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