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Naprava za merjenje oplaščenih vrvnih vlekov

Device for the Measurement of Bowden Pulls

ANTON KROPEC - ANDREJ NIKITENKO - TANJA KOCJAN-STJEPANOVIČ

Merilna naprava je razvita in narejena za izdelovalca oplaščenih vrvnih vlekov (Bowdenovih vlekov, v nadaljevanju vlekov) in plastike iz Lenarta. Vključena je v proces proizvodnje vlekov in z delovnim ciklom 8 s omogoča 100-odstotni zadnji pregled izdelkov. Z uporabljenima servomotorjema in ustreznimi regulacijami zagotavlja nateg plašča žice in tlačenje plašča po zahtevanem protokolu z natančnostjo enega odstotka. Meri 4 dolžine z natančnostjo 0,1 mm njihove elastične in plastične deformacije. Razponi sil so do 5000 N, dolžin pa do 2000 mm. Vse dolžine so spremenljive, različne referenčne točke pa si naprava poišče pri vstavljenem etalonu in umerjanju. Potek merjenja je avtomatski. Rezultati so pregledno izpisani na zaslonu in shranjeni v datoteke za nadaljnjo statistično obdelavo.

Ključne besede: vleki Bowdenovi, naprave merilne, konstrukcije naprav, metode merilne

The measuring device is developed and produced for the company TBP in Lenart. It is included in the producing process for bowden pulls. With a measuring period of 8 seconds, it is possible to ensure the 100 % control of products. Regulated servo drives assure an accuracy of 1%, while stretching the wire and pressing the bowden. It measures four lengths, with an accuracy of 0,1 mm, in their elastic and plastic deformations. All lengths are changeable and reference points are taken automatically when the etalon is inserted, and then the process of calibration begins. The whole process is done automatically. The results are displayed on the screen and also saved in the data base for further statistical processing.

Keywords: Bowden pulls, measuring devices, design of devices, measuring methods

0 UVOD

Tovarna TBP iz Lenarta izdeluje oplaščene vrvne vleke za tovarni VW in AUDI. Uporabljajo se za ročne zavore. Naročnik je povezoval nadaljnji nakup vlekov s končnim preverjanjem, ki zagotavlja, da so po ustreznem protokolu izmerjene dolžine, njihove elastične in plastične deformacije, v določenih tolerancah. Meriti je treba dolžine L1 na vrvi ter L2, L3 in L6 na plašču, ki so označene na sliki 2. Prvič merimo dolžine pri sili natega vrvi 98 N in enaki sili tlačenja plašča. Po prvi meritvi povečamo obe sili na 1760 N in glede na prvo meritev izmerimo elastični deformaciji. Tretjič sili ponovno zmanjšamo na 98 N in izmerimo plastično deformacijo glede na prvo meritev. Pri tretji meritvi morajo tolerancam ustrezati tudi absolutne dolžine.

Tolerance absolutne dolžine so v območju 3 do 5 mm, v enakem območju je tudi dopustna elastična deformacija. Plastična deformacija vrvi sme znašati največ 0,5 mm, za plašč pa do 1 mm.

Naprava je izdelana tako, da lahko meri dolžine vrvi od 1000 do 2000 mm in plašč dolžine 600 do 1500 mm.

0 INTRODUCTION

The company TBP in Lenart produces Bowden pulls, for use as hand brakes for factories VW and AUDI. The client negotiated an additional purchase of Bowden pulls with total quality control. The final result indicates that the device is suitable for measurement of lengths including their elastic and plastic deformations with a fixed tolerance. One must measure L1 on the cord and also L2, L3 and L6 on the coat, as shown in figure 2. We first measure the length of the stretched cord (force 98 N), and then the compressed length of the coat. With the 1st measurement we increased both forces to 1760 N and with the 1st measurement we measured the elastic deformation. The 3rd time we decreased the forces to 98 N we measured the plastic deformation by checking it against the 1st measurement. In the 3rd measurement the tolerances must correspond with the exact length.

The exact tolerances lengths range from 3 to 5 mm, with elastic deformation included in the same range. The plastic deformation cord can add up to a maximum of 0.5 mm and the coat up to 1 mm.

The device is produced so that it can measure cord lengths from 1500 to 2000 mm and the coat lengths from 600 to 1500 mm.

1 OPIS STROJNE KONSTRUKCIJE NAPRAVE

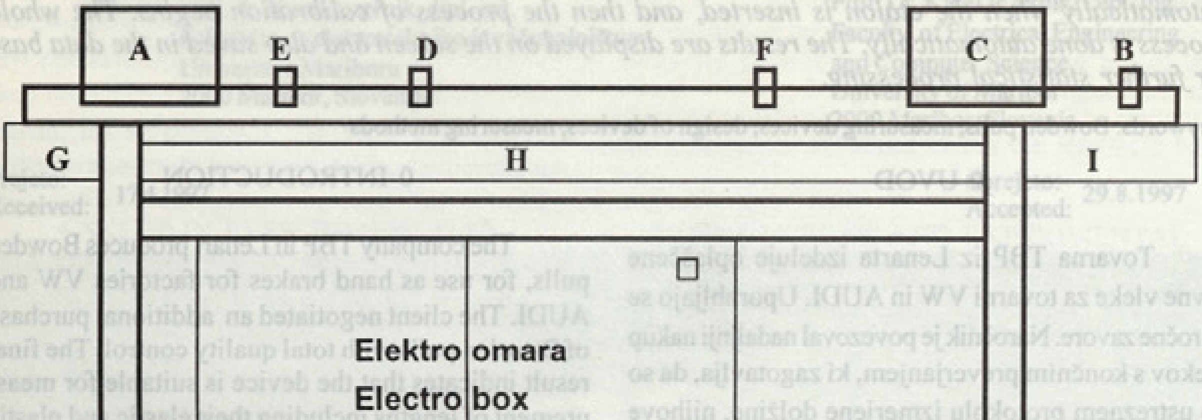
Nosilna mehanska konstrukcija je izdelana iz standardnih aluminijskih profilov. Nanjo so pritrjeni merilniki, pogona in vložno mesto. Vsi ti elementi so pritrjeni z vijaki, tako da se je mogoče prilagajati različnim dolžinam vlekov. Pogonska sklopa sta dva. Eden se uporablja za nateg vrvi, drugi pa za tlačenje plašča. Pogonski sklop je sestavljen iz servomotorja s tahogeneratorjem, zobatega prenosnega jermena in kroglične vijačnice, ki zagotavlja brezzračni pomik merilnih sani. Merilne sani, gnane prek vijačnice, so sestavljene iz merilnika sile in poti. Ker trenje sani vpliva na natančnost meritve sile, ga je bilo treba s konstrukcijo minimizirati.

Na sliki 1 je shematsko prikazana merilna naprava. Sklopi A, B, C, D, E in F so na vodilih. Njihovo lego prilagajamo posameznim dolžinam na vlekih.

1 DESCRIPTION OF THE MECHANICAL STRUCTURE OF THE DEVICE

The supporting mechanical structure is produced from standard aluminum profiles. On it are placed the approved sensors, drives and compartments. All these elements are fastened with screws so that different length bowdens can be adapted. There are two drive connections. One is used to stretch the cord, the other is used for the compress on the coat. The drive connection is put together from the servo motor with a taho generator, a toothed belt and round screws which assure airless movements while measuring sledges. Measuring sledges are driven over screws and put together with force and length sensors. Because friction affects the accuracy of the measurements it had to be minimized with the design.

Figure 1 shows an outline of the device for measuring bowden pulls. Connections A, B, C, D, E and F are movable. Their positions are adapted to individual lengths on the bowden pulls.



Sl. 1. *Shema naprave za merjenje vlekov*
Fig. 1. *Outline of the device for measuring bowden pulls*

Legenda:
A - pogonski sklop za nateg vrvi z merilnikom sile in poti,
B - točka vpetja vrvi,
C - pogonski sklop za tlačenje plašča z merilnikom sile in poti,
D - točka vpetja plašča,
E - zaznavalo za merjenje L3,
F - zaznavalo za merjenje L6,
G - signalizacija (dober, slab, zamenjaj),
H - zalogovnik,
I - signalizacija (dober, slab, zamenjaj).

Instructions:
A - drive connection for the stretch cord with force and length sensors,
B - strung cord point,
C - drive connections for the compression coat with force and length sensors,
D - strung cover point,
E - sensor for measuring L3,
F - sensor for measuring L6,
G - signals (satisfactory, unsatisfactory, replace bowden),
H - storage compartment,
I - signals (satisfactory, unsatisfactory, replace bowden).

2 OPIS POGONOV IN DAJALNIKOV

Kot dajalnike za meritev poti smo uporabili merilnike poti podjetja ASM, tip WS 1.1 z merilnim območjem do 50 mm, linearnostjo 0,1 % in napetostnim izhodom 0 do 10 V. Ti dajalniki imajo za zaznavalo žico, ki se izvleče in deluje po uporovnem načelu. Po zagotovilih izdelovalca prenesejo 5 do 10 milijonov delovnih gibov skozi celotno območje pri polni dopustni hitrosti in tako pri 4000 krat na dan ocenjujemo njihovo dobo trajanja na 4 leta ali več.

Za meritev sile smo uporabili Hottingerjevi sondi U2A, razreda točnosti 0,1% (5 kN≙2mV/V in 2 kN ≙ 2 mV/V) ter ustrezen merilni pretvornik z napetostnim izhodom -10V do +10V.

Nateg žice in tlačenje plašča smo izvedli z enosmernimi servomotorji podjetja CONTROL TECNIQES, in sicer tip DCM 2C 30/03 za tlak (Mn = 0,47 Nm) in za nateg DCM 3B 35/06 (Mn = 0,93 Nm); oba imata reduktor in polžasto gonilo s prestavo 1:20.

Za meritev dolžin L3 in L6 je izvlek žice merilnika poti izveden s pnevmatskim pogonom, za meritev dolžin L1 in L2 pa je merilna žica povezana neposredno na mehanizem za nateg ali tlačenje.

3 MERILNA METODA ZA MERJENJE DOLŽINE

Meritev posameznih dolžin je primerjalna. Merimo tako, da najprej v stroj vstavimo etalon enake oblike, kakršno ima vlek, in vpišemo vse štiri dolžine etalona, ki jih potem merimo. Potem sprožimo umerjanje in stroj si poišče izhodiščne (ničelne) lege merilnikov poti. Sila natega in tlaka je pri umerjanju minimalna (98 N), etalon pa je umerjen in iz ustreznega materiala. Na podlagi teh ničelnih leg in izmerjenih vrednosti se potem izračunajo posamezne dolžine.

2 DESCRIPTION OF ACTUATORS AND SENSORS

Sensors for measuring lengths we used are incorporated inside of the devices from the company ASM, type WS 1.1, with a measuring range of up to 50 mm, a linearity of 0.1% and a voltage output of 0 to 10 V. These sensors have a wire which pulls out and works on a resistance principle. According to the assurances of producers they take 5 to 10 million workable movements through the whole range at full decreased speed and at 4000 a piece per day; we estimate their life span to be 4 years or more.

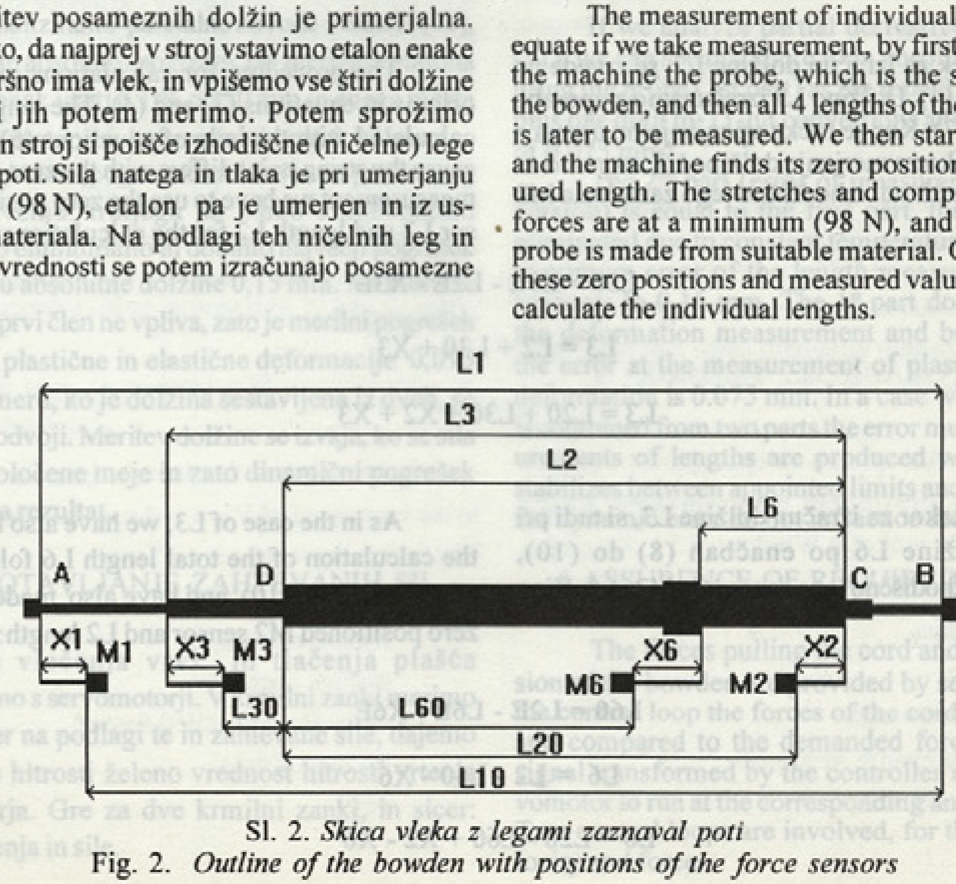
For the measurement of forces we used Hottinger's probe U2A, with a class accuracy of 0,1% (5 kN ≙ 2 mV/V and 2 kN ≙ 2 mV/V) and suitable measuring transformer with voltage output -10V to +10V.

We achieved the stretches of the wire and the compression of the bowden with DC servo motor form the firm Control Techniques', and with a type DCM 2C 30/03 for the pressure (Mn = 0.47 N m) and for the stretches DCM 3B 35/06 (Mn = 0.93 N m). These both have reductors and slow drives with a 1:20 gear.

For the measurement of lengths L3 and L6 the pullout of the wire is produced by means of an pneumatic drive, and for the measuring lengths of L1 and L2 the wire is connected directly to the mechanism for stretching and compression.

3 THE METHOD FOR LENGTH MEASUREMENT

The measurement of individual lengths is adequate if we take measurement, by firstly putting into the machine the probe, which is the same shape as the bowden, and then all 4 lengths of the probe, which is later to be measured. We then start calibrations, and the machine finds its zero position on the measured length. The stretches and compression of the forces are at a minimum (98 N), and the measured probe is made from suitable material. On the basis of these zero positions and measured values we can then calculate the individual lengths.



Sl. 2. *Skica vleka z legami zaznaval poti*

Fig. 2. *Outline of the bowden with positions of the force sensors*

Na sliki 2 je shematično prikazan vlek z legami merilnikov M1, M2, M3 in M6. Med točkama A in B je vrv vleka. V točki B jo vpnemo in v točki A vlečemo z ustrezno silo. Plašč je odebeljeni del. V točki D je vpet in v točki C ga tlačimo.

Zaradi pogreškov bi bilo bolj ugodno vpetje v točki C, ker pa bi bila takšna izvedba veliko dražja, smo se odločili za sedanjo izvedbo. Naprava kljub takšni izvedbi ustreza zahtevam. Definirane so dolžine L1, L2, L3 in L6, ki jih merimo. Neposredno izmerjene vrednosti so označene z X1, X2, X3 in X6.

Po sliki 2 je izračun naslednji:

Fig. 2 is an outline showing bowden pulls with positions of sensors M1, M2, M3 and M6. In between points A and B lies the bowden cord. At point B we tighten it, and at point A we pull it with appropriate force. Note that the cover shows the widest part. At point D it is tightened and at point C the pressure is exerted on it.

Because of the errors, it would be more appropriate for there to be tightness at point C, but in this case the product would be more expensive; hence we decided to persist in the existing variant. Thanks to the achievements of the existing variant, this device is suitable for most demands. Defined are the lengths L1, L2, L3 & L6 which are measured. Directly measured values are indicated as X1, X2, X3 and X6.

On the basis of fig. 2, the following is calculated:

$$L10 = L1E - X1E \quad (1),$$

$$L1 = L10 + X1 \quad (2).$$

Z enačbo (1) iz dolžine etalona in z uporabo izmerjene dolžine X1E izračunamo izhodiščno lego zaznavala. Sledi izračun (enačba 2) dolžine L1 iz izhodiščne lege zaznavala M1 in izmerjene dolžine vrvi X1:

With equation (1), from the length of the probe and with the help of measured lengths X1E, we calculate the zero point of the sensor. The following (equation 2) length L1 is from the zero point of the sensor M1 and measured lengths of the cord X1:

$$L20 = L2E - X2E \quad (3),$$

$$L2 = L20 + X2 \quad (4).$$

Postopek za izračun dolžine L2 se izvede po enačbah (3) in (4). Dolžino L3 izračunamo z uporabo enačb (5) do (7). Ker se točka vpenjanja ne ujema z izhodiščno točko za merjenje dolžine L3, moramo za izračun uporabiti tudi izhodiščno lego zaznavala M2 in dolžino L2:

The procedure for calculations of length L2 origins in equations (3) and (4). The length of L3 is calculated with the help of equations (5) to (7). Because the string point differs with the zero point of the measurement we have to use the zero positioned sensor L2 and length L2 for the calculations:

$$L30 = L3E - L2E - X3E \quad (5),$$

$$L3 = L2 + L30 + X3 \quad (6),$$

$$L3 = L20 + L30 + X2 + X3 \quad (7).$$

Enako kakor za izračun dolžine L3, si tudi pri izračunu dolžine L6 po enačbah (8) do (10), pomagamo z izhodiščno lego zaznavala M2 in dolžino L2:

As in the case of L3, we have also included in the calculation of the total length L6 following the equations (8) to (10), and have also made use of the zero positioned M2 sensor and L2 length:

$$L60 = L2E - L6E - X6E \quad (8),$$

$$L6 = L2 - L60 - X6 \quad (9),$$

$$L6 = L20 - L60 + X2 - X6 \quad (10).$$

Legenda:

L10, L20, L30, L60	ničelne dolžine, označene na sliki 2,
L1E, L2E, L3E, L6E	dejanske (tudi vpisane) dolžine etalona,
L1, L2, L3, L6	izmerjene (izračunane) dolžine merjenca,
X1E, X2E, X3E, X6E	izmerjene vrednosti na dajalnikih pri merjenju etalona,
X1, X2, X3, X6	izmerjene vrednosti na dajalnikih pri merjenju merjenca.

4 VPLIVI POGREŠKOV NA MERJENJE DOLŽIN

Na merilni pogrešek pri merjenju dolžine vplivajo predvsem:
- pogrešek pri določitvi ničelnih točk,
- pogrešek pri meritvi merjenca.

Ugotovimo lahko, da pogrešek določitve ničelnih točk, glede na dopustne tolerance zahtevnika, vpliva samo na prvo meritev, meritvi elastičnih in plastičnih deformacij pa sta relativni glede na prvo meritev, kar je zaradi manjše tolerance pri meritvi plastične deformacije ugodno:

$$|\Delta L| = \left|\frac{\partial L}{\partial X_E}\right|\Delta X_E + \left|\frac{\partial L}{\partial X}\right|\Delta X + \left|\frac{\partial L}{\partial L_T}\right|\Delta L_T \quad (11).$$

Če analiziramo parcialne odvode v enačbi (11), vidimo, da je absolutni pogrešek pri merjenju etalona (prvi člen) enak vsoti 0,1 % od 50 mm in enega mesta pri 11-bitni pretvorbi, kar znaša skupaj 0,075 mm.

Drugi člen (pogrešek merilnika in pretvorbe) je enak prvemu, tretjega pa lahko s konstantno temperaturo eliminiramo in dobimo največji pogrešek pri merjenju absolutne dolžine 0,15 mm. Na meritev deformacij prvi člen ne vpliva, zato je merilni pogrešek pri meritvi plastične in elastične deformacije 0,075 mm. V primeru, ko je dolžina sestavljena iz dveh, se pogrešek podvoji. Meritev dolžine se izvaja, ko se sila uravna v določene meje in zato dinamični pogrešek ne vpliva na rezultat.

5 ZAGOTAVLJANJE ZAHTEVANIH SIL

Silo vlečenja vrvi in tlačenja plašča zagotavljamo s servomotorji. V krmilni zanki merimo silo vrvi, ter na podlagi te in zahtevane sile, dajemo regulatorju hitrosti želeno vrednost hitrosti vrtenja servomotorja. Gre za dve krmilni zanki, in sicer: hitrosti vrtenja in sile.

Instructions:

L10, L20, L30, L60	zero lengths shown in figure 2,
L1E, L2E, L3E, L6E	actual probe lengths (also written),
L1, L2, L3, L6	measured (calculated) length of item,
X1E, X2E, X3E, X6E	measured value on sensors of the measured probe,
X1, X2, X3, X6	measured value on sensors of the measured item.

4 INFLUENCE OF ERRORS ON MEASURED LENGTHS

The accuracy of the measurement of lengths depends on:
- errors at appointed zero points,
- errors at the measured item.

We can find out that the errors occuring at appointing zero points influence only the 1st measurement. The measurements of elastic and plastic deformations are relative to the 1st measurement which is suitable for the smaller tolerancies at plastic deformations:

If we analyze partial derivatives in equation (11), we can see that there is an absolute error measuring the probe (1st part) as the total 0.1 % to 50 mm plus one digit by 11-bit convertions and makes a total of 0.075 mm.

The 2nd part (error of measurement and conversion) is equal to the first part, the third can be eliminated due to constant temperature and we get a maximum error of the length measurement which amounts to 0.15 mm. The 1st part does not rely on the deformation measurement and because of this the error at the measurement of plastic and elastic deformation is 0.075 mm. In a case when the length is combined from two parts the error multiplies. Measurements of lengths are produced when the force stabilizes between appointed limits and consequently the dynamic error do not influence the result.

5 ASSURENCE OF REQUIRED FORCES

The forces pulling the cord and the compression of the bowden are provided by servomotors. In the control loop the forces of the cord are measured and compared to the demanded forces. The error signal transformed by the controller makes the servomotor to run at the corresponding angular velocity. Two control loops are involved, for the angular velocity and force.

Notranja je izvedena z lokalnim PI krmilnikom, zunanja pa je izvedena z mikroračunalnikom. Tu na podlagi identifikacije dejanske vrednosti sile in na podlagi želene vrednosti spreminjamo tudi parametre, tako da je krmiljenje adaptivno. To je potrebno, ker se parametri v odvisnosti od delovnih točk spreminjajo, te pa so razporejene znotraj zelo velikega območja.

Na mikroračunalniku zaradi velikega območja merjenja sile pri silah do 400 N oziroma do 150 N vklopimo 1 V območje analognega vhoda, da dobimo pri majhnih silah dovolj dobro rešitev.

6 MIKRORAČUNALNIŠKA SESTAVA

Za izvedbo smo uporabili mikroračunalnik A120 podjetja AEG s centralno procesorsko enoto ALU 201 in moduli za 8 analognih vhodov, 4 analogne izhode, 32 digitalnih vhodov in 32 digitalnih izhodov. Program je napisan v programskem paketu DOLOG.

Ta sistem prek že prej opisanih pogonov zagotavlja delovanje naprave, parametre, ki so potrebni za delovanje pa dobiva prek kanala RS 232. Ali je kos dober ali ne, sporoči signalizacija na napravi, vse rezultate pa mikroračunalniški sistem pripravi za nadrejeni računalnik.

Da je čas izračunov na mikroračunalniku čim krajši, se izračuni, ali je vlek v toleranci, ter podatki za nadrejeni računalnik dajejo v besedah, v dvojnih besedah pa se podajajo le parametri za dolžine etalona in za zahtevane vrednosti dolžin ter rezultati ničelnih dolžin.

7 UPORABNIŠKI VMESNIK

Programska oprema za uporabniški vmesnik je napisana v grafičnem programskem jeziku LabView in teče v okolju Windows 3.11. Ko ga poženemo, si lahko izberemo naslednje postopke:

- umerjanje,
- meritev,
- ročno delovanje,
- vpis zahtevanih vrednosti,
- pregled datotek,
- konec.

The internal loop is equipped with a local PI controller and the external one with a microcomputer. On the basis of the identified actual forces value and the desired value, the parameters change so that the adaptive control take place. This is needed due to the parameters change depending on the working points, which cover a wide range.

Owing to the wide range of measured forces at forces up to 400 N viceversa up to 150 N the 1 V analog input is switched on to get a satisfactory resolution at small forces.

6 MICROCOMPUTER CONFIGURATION

The computing facility we used was the microcomputer A 120 from the AEG, with a central process unit ALU 201, modules for 8 analog inputs, 4 analog outputs, 32 digital inputs and 32 digital outputs. The program has been written using a program package called DOLOG.

This system, through the previous described actuators, provides the functioning of the device, parameters which are necessary for the operation, are communicated by the RS 232 channel. The quality of the item is communicated by the device signalization; all results from the microcomputerised system are prepared for a master computer as well.

Aiming at the shortest computation time all calculations of the Bowden pull tolerances, and data for the master computer are performed in simple words. Double words are used for the parameters of the lenghts of the etalon, for the demanded and the initial lenghts.

7 USER INTERFACE

The software for the user interface is written in the language LabView and runs in Windows 3.11. The following menus are offered:

- calibration,
- measurements,
- manual operation,
- entry for demanded forces,
- review of data,
- end.

Pri umerjanju vpišemo dejanske mere etalona, računalnik pa vrne pozicije vseh štirih merilnikov glede na izhodiščni točki.

V izboru meritve je prikaz števila dobrih in slabih kosov ter za vlek, ki je bil zadnji izmerjen, naslednji podatki:

- vse sile natega vrvi in tlačenja plašča,
- vse štiri dolžine, njihove plastične in elastične defomacije.

Parameter, ki ne ustreza, je pobarvan rdeče.

Izbor ročno delovanje se uporablja predvsem za preizkuse in preverjanje merilnih pogreškov. V izboru vpis zahtevanih vrednosti vpišemo:

- sile natega v območjih 80 do 120 N ali 1500 do 5000 N,
- sile tlačenja v območjih 80 do 120 N ali 1500 do 2000 N,
- vse štiri dolžine, njihove absolutne tolerance, dopustne plastične in elastične deformacije,
- tip vleka.

Podatke lahko vpisujemo, pregledujemo, popravljamo ali izpisujemo s tiskalnikom.

8 SKLEP

Naprava za merjenje vlekov je vključena v nadzorno linijo od januarja 1996. Omogoča 100-odstotni nadzor proizvedenih vlekov in s tem zelo hitro opozarja na pomanjkljivosti, ki se pojavijo pri proizvodnji, ter omogoča takojšnje posege.

Namesto šestih delavk, ki so delale pri nadzoru istih parametrov, delata sedaj dve, naprava pa zagotavlja merjenje s predstavljenimi mejnimi pogreški, katerih z ročno primerjavo ni bilo mogoče doseči.

Poleg tega se podatki lahko shranjujejo in statistično obdelujejo.

At calibration the actual probe dimensions are entered and the computer returns the positions of all 4 measuring devices with regard to the zero point.

In the measurement menu both good and bad items for the bowden which was the last to be measured are shown, including the following data:

- all stretched forces of the cord and compres sion on the coat and
- all 4 lengths and their plastic and elastic deformations.

The parameter which is not suitable is red in color.

The manual operation menu is used prevalently for testing of errors, in the menu entry for demanded forces we note:

- a stretch force in the range of 80 to 120 N or 1500 to 5000 N,
- a compression force in the range of 80 to 120 N or 1500 to 2000 N,
- all four lengths including their absolute tolerances, allowed plastic and elastic deformations,
- type of Bowden pull.

The information can be entered, checked, corrected or printed.

8 CONCLUSION

The device for measuring bowden pulls has been connected to the line control since January 1996. It enables 100 percent control on the production of a bowden pull, and through this a decrease is quickly noticed which comes up in production and enables quick intervention in production.

Instead of the six workers who used to control the parameters, only two of them are busy now and the measuring device assures an accuracy which could not be reached when manually measuring the item.

Apart from all this, the information can be stored and statistically processed.

9 LITERATURA
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Naslov avtorjev: mag. Anton Kropec, dipl. inž.
Andrej Nikitenko, dipl. inž.
mag. Tanja Kocjan-Stjepanovič, dipl. inž.
EM.TRONIC
Ptujska c. 184
2000 Maribor

Authors' Address: Mag. Anton Kropec, Dipl. Ing.
Andrej Nikitenko, Dipl. Ing.
Mag. Tanja Kocjan-Stjepanovič, Dipl. Ing.
EM.TRONIC
Ptujska c. 184
2000 Maribor, Slovenia

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