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CUTTING-POLISHING DEVICE FOR TILECAL WLS FIBER BUNDLES PROCESSING

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Abstract

A new device is constructed in 1997 for cutting and polishing of WLS fiber bundles of TILECAL. Device is designed to work inside the girder tubes of Central Barrel (CB) and Extended Barrel (EB) modules (5.86m and 2.88m long, respectively). After tests done at YERPHI and CERN, two EB modules have been processed at ANL (Argonne) and BCN (Barcelona). Description and concept of the device as well as the experimental results are presented.

1. Introduction

In TILECAL the readout of plastic scintillator tiles is realised by WLS fibers [1]. Each calorimeter cell consists of a group of tiles, so the signal from the cell is extracted by a bundle of fibers. Fiber bundles are introduced into the girder interior (Fig.1) where the PMT readout is positionned in the drawer system. The bundles are passed through the holes on the axes of the PMMA girder rings into plastic tubes closed from one end. The fiber ends are glued together by means of epoxy compound injection. The girder rings are precisely positioned by means of a special mounting tool and then glued within the holes in the girder walls. This design provides a good rigidity and precision of appr. 0.1mm/m both in vertical and horizontal plains. Left and right side chains of the girder rings are purposed to serve as a precise conductor and support of the drawer system, where PMT blocks, HV distributors and FE electronic boards are located. The period of the girder ring installation is 116 mm and left and right sides are shifted by half period. Not all of these rings are active, carrying bundles inside.

The purpose of this work was to design a device for making an optical surface of the fiber bundle end, cutting appr. 10 mm of composite (plastic tube, glue and fibers) and leaving 0.5±0.3 mm thick excess above the face of the girder rings. The important requirement on the quality of the bundle surfaces was to ensure more than 95% of the light transmission. At the same time the design was complicated by specific conditions for processing, derived from the deficit of the room (see Fig.1) along the whole significant length of the girder tube (96 rings in 586 cm CB and 48 rings in 288 cm long EB modules).

2. Description and concept

The device consists of three parts: cutting-polishing tool, movement drive and input-output buffers.

2.1 Cutting - polishing tool

The cutting-polishing tool (see Fig.2) consists of the following parts:

- precise spindle with cutting-polishing head driven by electro-motor
- polished steel guideways for the tool positioning and glassing
- the springy base side-roller providing a side pressure needed for the positionning of the tool-plate
- a duraluminium plate of a trapezoidal form, where these components are mounted.

The cutting head (Fig.3) presents a massive steel holder, instrumented with a standard milling saw (R=62.5 mm, 2 mm thick), two tungsten alloy knifes, locating on the radius of R=28 and 29mm respectively and soft polishing head on the springy base implemented at the central part (R<15mm). The size of the tool is: $492\times164\times110mm^3$ ($L\times W\times H$).

The concept of the precise spindle and massive head with two knifes (crystal and hard alloy) was already used in the tool developed at CERN (UA2) in 1993 for TILECAL prototypes [2]. The combination of milling saw and corund knifes was used in the first YERPHI prototype [3] as a need to make rough and fine cuts on CB module 0. However hard tungsten alloy knifes were preferred now instead of the crystal ones (diamond or corund), ensuring the possibility to maintain better sharpness of the blades. Design of the knifes shown in Fig.4 is convenient to sharpen the blade in-situ, simply using a turning steel ball and abrasive diamond paste. At the same time the knifes are hard enough, not to be sharpened frequently. The round cut edge design of the knife allows to obtain smooth surface during overlapping knife passes. As a material for the polishing head felt and soft leather were tested as well as different types of polishing pastes.

2.1.1 Concept

The tool is designed to work in continuously movement mode. The tool weight (~9 kg) and the side pressure force (~2.5 kg) provide precise positioning of the guideways on the top and faces of the girder rings during the movement. These forces are enough to suppress vibrations, so no additional pressure is applied. During cutting, the tool-plate is located on top of three girder rings, two in the cutting and one in the opposite side. Lengths of the guedeways are chosen to be 135 mm with a curved ends to provide smooth transition from one to another girder ring. Cutting is started when the transition is finished and ~20 mm of guideways are passed over the rings. At first the saw begins to work, leaving ~0.75mm thick excess above the girder ring surface. This is the most power consuming operation, defining the power of electro-motor.

When the bundle is roughly cutted the knifes fine cut is started, ensuring already satisfactory quality of the surface at the expected level of ~0.5mm from the girder ring face. If the soft polishing element is implemented, the combined pass is finished with fairly acceptable quality of the surface.

2.1.2 Assembly and adjustment

First of all two polished steel guideways are aligned and fixed on the tool-plate in the cutting side with an interspace of three periods (3*116mm). The third guideway is installed in the opposite side of the tool-plate. There are no special requirements for their adjustment on the horizontal plane. For the spindle and knifes adjustment an auxiliary tool is used. This tool is a micrometer with a clock-type indicator mounted on the turning hand, attached on top of the tool plate (Fig.5). Tool is aligned using as a reference the vertical planes of the polished guideways. The knifes are adjusted at the level of ~0.25mm above the saw teeths, and the head as a whole is positioned to provide required depth of the cut. Distance from the top of the knifes till the vertical plane of guideways is set to be ~0.5 mm. At the same time there should be a small bend of the spindle around vertical axis (~3'- 4') providing cut only by forward front of the moving head. Axial play of the spindle shaft is also controlled to be less than one micron. The accuracy of the cutting depth setting was established to be ~0.05mm.

2.2 Input-output buffers

For introduction of the tool-plate into the girder an input-output buffers were constructed, which present a continuation of the girder ring periodic chain out of the girder tube. This structure also provides additional reference rings to be served as a guide for cutting the girder two first and last bundles, and carry the tool movement drives. The PMMA rings are mounted on the buffers with the same accuracy, as in the girder, so one needs to install and adjust buffers as a whole at the entrance and exit of the module. Buffers are made from duraluminium and are open from the top and bottom. Each buffer contains 10 PMMA rings. The structure of the buffers allows to install and cut different samples providing the check of the tool before entering the girder. So the buffers are important not only as a part of the device, but also serve as a maquette for different tests.

2.3 The tool movement drive

The speed of the tool movement within range 0.5–1.5 mm/sec is achieved by means of a steel cable loop and electro-motor with reduction of ~50.000. The cable was installed on two pulleys (one of them is leading), mounted on the ends of the buffers (Fig.6). Cable ends were joined together by means of a special join, allowing to reach desirable tension. Join is fixed on the tool, shifted to the cutting side, to equalise the momenta of applied forces.

3. Test results

Tests have been done primary at YERPHI maquette and then continued at CERN in more realistic conditions. YERPHI maquette (Fig.6) presents a short imitation of the girder tube with length of 0.7m, opened from top and bottom for convenience. Total length of the maquette with buffers was 2.25m. The CERN maquette presents a 3m long piece of the original girder tube, equipped similar to CB or EB modules and has a total length of 4.5m with buffers. Samples of plexiglass, polystyrene and original composite (glued bundle in plexiglass tube) have been used. The following questions were the subject of investigations:

a. Unhomogenity of the movement

The origin of this phenomenon arises from the combination of the friction fluctuations and the springy feature of the steel cable. The knifes cut quality is mostly sensitive to the movement unhomogenity. To decrease it one need to make the friction force weaker, or take a thicker steel cable, choosing an eligible cable tension. The dry friction at rest was measured to be ~3.5–4.0 kg. One may reduce it by factor of two, putting a thin layer of technical vazelin on the guiedways. Nevertheless even with dry friction no noticeable appearance of unhomogenity was observed. The role of the cable tension in the range of 40–100 kg has been investigated, and no influence on the quality was observed. Also no effect was distinguished in consequence of increasing the steel cable length from 4.5m at YERPHI maquette to 9m at CERN one. Thus for the further tests as well as for the work with EB modules, a 3mm thick steel cable (cross-section is ~2.26mm^2) at tension force of 50–70 kg and low friction mode (f=1.5–2.0 kg) of the tool glassing were recommended as reasonably save.

b. Turning (TS) and movement speed (MS) selection

As it was established the choice of TS and MS is not unambiguous and strongly depends on the material used. Definitely there should be a positive correlation between TS and MS, so the choice of one of them certainly ranges the value of another. On the one hand MS value must be selected to provide an overlapping knife passes, ensuring smooth and clean surface. On the other hand the multiple overlapping passes should be limited, because they are potential source of the friction and therefore of the surface heating and damaging. Due to the lower melting point, polystyrene is more sensitive to this requirement as compared to another samples. Main tests have been done at the TS range of 1300–1900 rot/min (RPM) and RS range of 0.5–0.9 mm/sec. It was established that for the milling and cutting modes combinations of speeds TS/MS=1600/0.5 or 1900/0.7 are optimal. Choice of higher values was not investigated due to the limited power of the spindle electro-motor.

c. Polishing mode

The friction is a working mechanism of the polishing process and generates a heat which should be removed. This is regulated through the choice of lower TS (higher MS), that somehow is contradictory to the cutting mode requirement or by lower pressure of the polishing head and also by frequency of paste lubrication. Tests have been done for TS range of 1000–1600 RPM, MS range of 0.5–1.5 mm/sec and different pressure of the polishing head. As was mentioned, pure polystyrene is more sensitive to the heating among the samples investigated. In spite of the fiber polystyrene base, the composite (glue + fibers) is more termo-resistant than pure polystyrene. However we selected the conditions for polystyrene, to be guaranteed from the current or delayed damage of the bundle surface. Tests have been done with different types of the paste and materials of the polishing head. It has been established that the polystyrene samples need in a few lubrications during the combined pass along of full 3m long girder length. However it is difficult to realize this procedure due to restricted access to the girder interior. The TS=1300 RPM and MS=1–1.5 mm/sec were recommended at low pressure of polishing head. In these conditions one combined pass is not sufficient to provide good quality, so one assumes that the tool should work separately in polishing mode making the job by 2–3 passes. This choice is partly due to the available range of TS and MS values in existing design. On the other hand it is difficult to find fully acceptable common conditions for cutting and polishing. Polishing by hand has also been tested through the access from the downward holes of the girder. Less than one minute operation by hand provided fairly good optical quality of the bundle surface.

d. Tests with compressed air

Air cooling was investigated for different samples and separately for different stages of bundle processing. There was practically no access of the air flow to the bundle surface during polishing. It was established, that air cooling improves slightly the quality of the saw cut for the polystyrene samples, while no noticeable effects were observed in other cases. On the other hand the traction of the massive and long air tube by the same movement drive is a source of MS unhomogenity and requires a special feeding system.

4. Tool management

The tool management electrical scheme is shown in Fig.8. This scheme allows to set different MS modes, but mainly is purposed to protect the bundles from damage, in case the spindle is suddenly stopped during the cut. When the tool movement is breaked by the bundle, the cable tension starts to increase leading to the increase in current of the cable drive motor. The protection chain switches off the movement drive when overloading threshold is exceeded. The threshold selector has a set of pressure values 3–7–11 kg, and 3 or 7 kg are recommended as nominal for use.

5. The experience of EB modules processing in ANL (Argonne) and BCN (Barcelona)

Two EB modules were processed in ANL and BCN during April-97. Tool head has been equipped with one knife, polishing element was not implemented and polishing has been done by hand. Some principal comments and remarks are following:

- tool worked properly and reliable, and his concept is accepted as final
- knifes fixation on the head should be done more reliable to prevent frequent time consuming adjustment. Some cutting depth loss cases were observed
- simplest tooling should be foreseen for buffers adjustment to reduce this time consumming procedure
- provide increase of MS
- design the separate polishing head or a tool within the same concept
- system of cables feeding should be foreseen to avoid possible movement unhomogenity.

Some of these problems have been seen during the tests and already some preliminary study is done to find possible simplest solutions.

6. Conclusions

Presented design of the device has been tested at YERPHI and CERN maquettes and then used for EB modules processing in ANL and BCN. Tool worked reliable and its concept was recommended as a basic for the work at full scale TILECAL modules assembly. On the base of already gained experience, some improvements are expected to be introduced in the design of new tools.

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REFERENCES

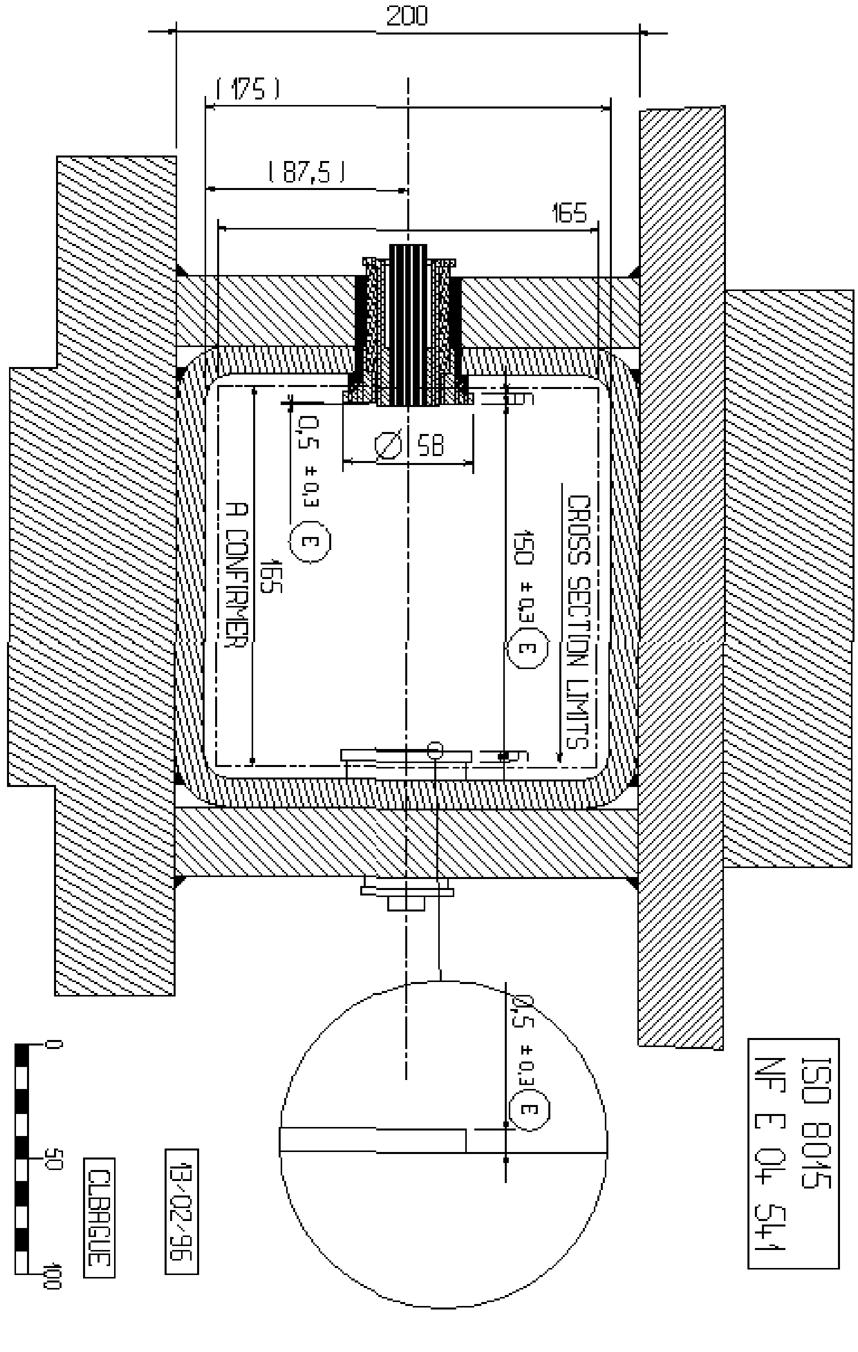
[1] ATLAS, Tile Calorimeter Technical design Report, CERN/LHCC/96-42

[2] J.M.Chappuis, private communications

[3] E.Mnatsakanian, Contribution to TILE-TR-062, June-96-Atlas week

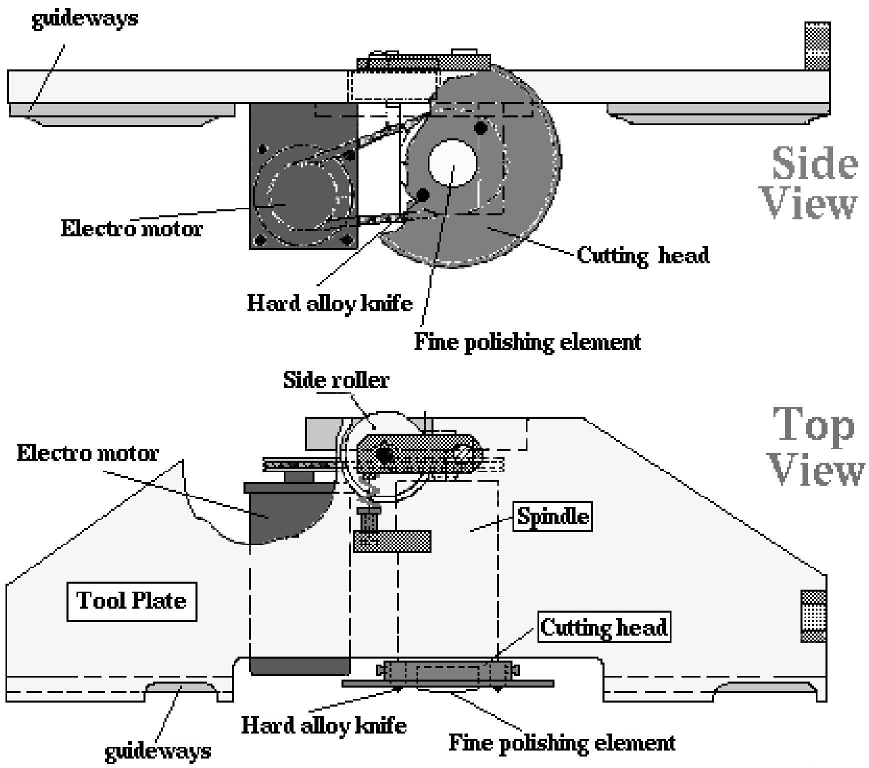
Figure captions

Fig.1 Schematic view of the fiber bundles in girder tube
Fig.2 Scheme of the cutting-polishing device
Fig.3 Scheme of the cutting head
Fig.4 Scheme of the tungsten alloy knifes and the sharpening tool
Fig.5 Photo of the auxillary tool for adjustment
Fig.6 Photo of YERPHI maquette during the tests
Fig.7 Photo of cutting-polishing device during BCN EB module processing
Fig.8 Electronic scheme of the device managment



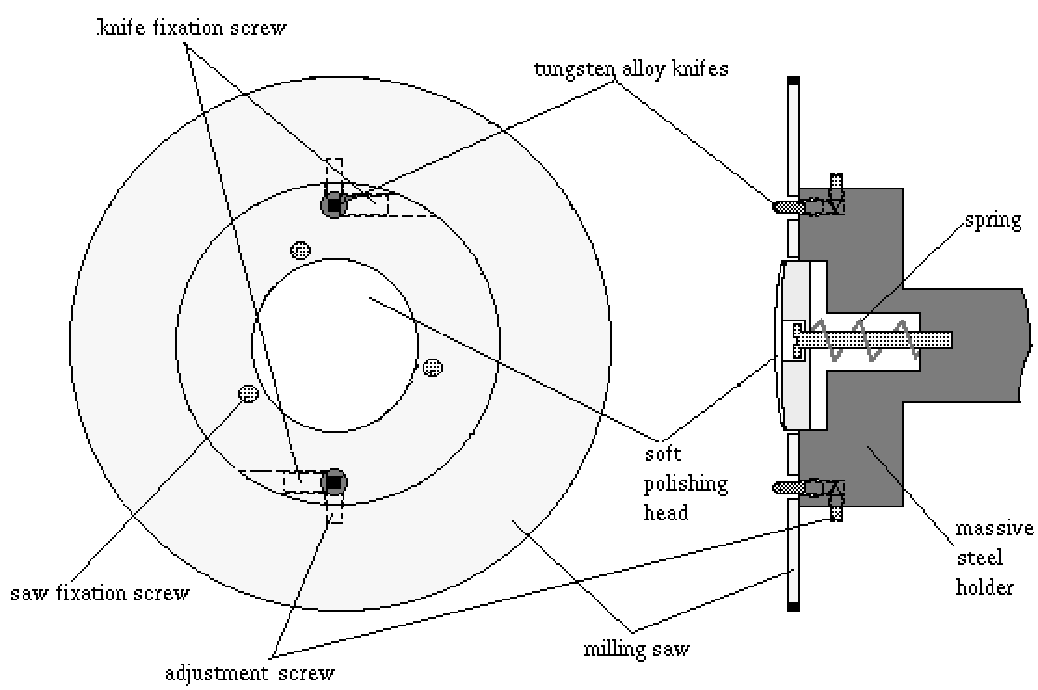
200
(175)
(87,5)
165
Ø58
0,5 ±0,3 E
A CONFIRMER
165
150 ±0,3 E
CROSS SECTION LIMITS
0,5 ±0,3 E
0
50
100
CLBAGUE
13-02-96
ISO 8015
NF E 04 541

Fig. 1



guideways
Side View
Electro motor
Cutting head
Hard alloy knife
Fine polishing element
Side roller
Top View
Electro motor
Spindle
Tool Plate
Cutting head
Hard alloy knife
Fine polishing element
guideways

Fig. 2



knife fixation screw
tungsten alloy knifes
spring
soft polishing head
massive steel holder
saw fixation screw
milling saw
adjustment screw

Fig. 3

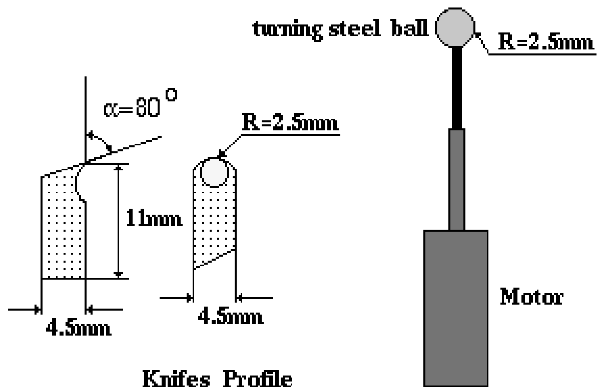


Fig. 4

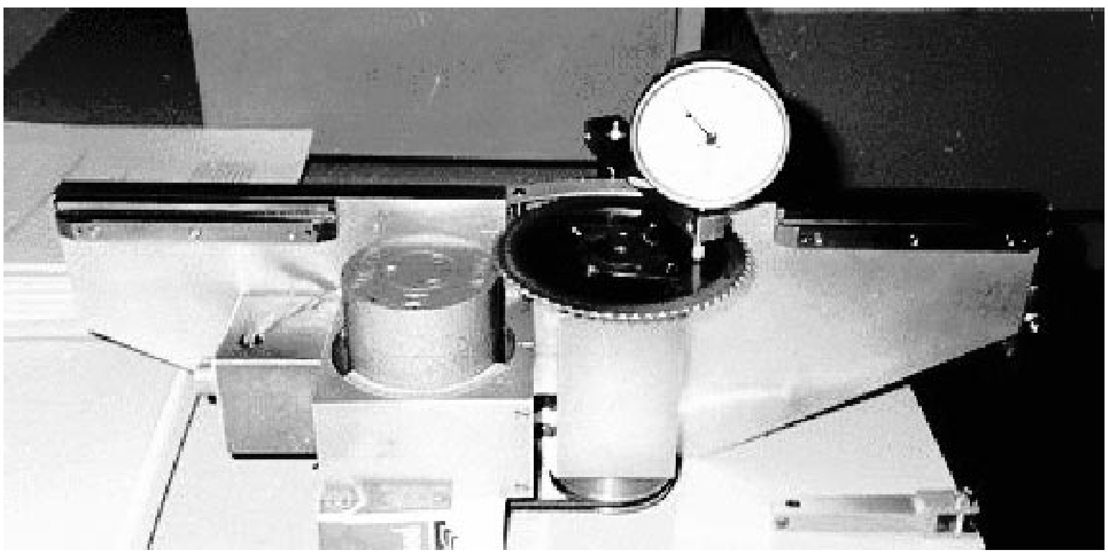


Fig. 5

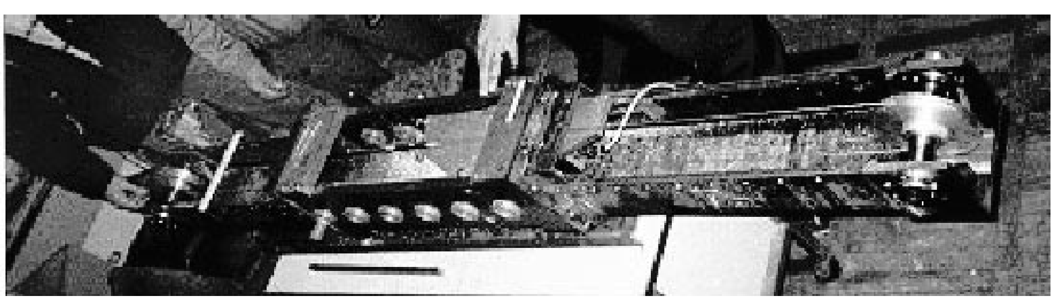
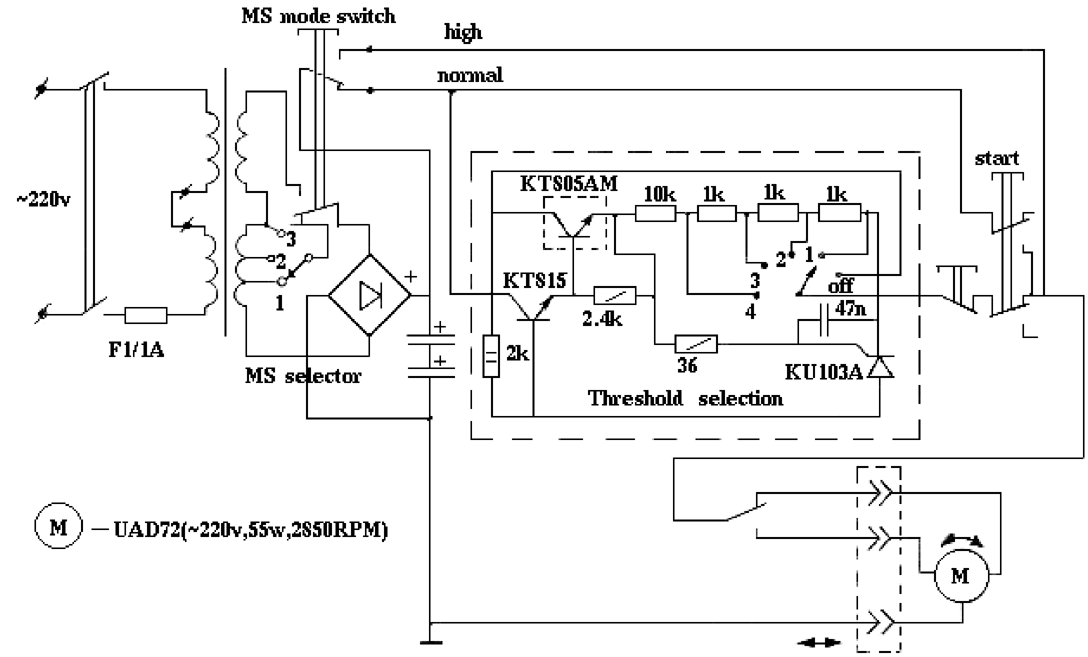


Fig. 6

Fig. 7



MS mode switch
high
normal
~220v
F1/1A
3
2
1
MS selector
KT805AM
10k
1k
1k
1k
KT815
2.4k
2k
36
2
1
3
4
off
47n
KU103A
Threshold selection
start
M
M — UAD72(~220v,55w,2850RPM)

Fig. 8