New Modular 10m-Bench System for Traceable Measurements of Steel Tapes and Rulers at TUBİTAK UME

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Abstract

Traceable line standards (tapes and rulers) measurements are one of the major parts of the dimensional metrology. Following the old 5m-Bench system which has been used since 2003, it was decided to establish a new 10m-Bench system at the new industrial measurement laboratory of TÜBİTAK UME. The idea behind this new system was a modular construction that could be extended up to 50 m long when requested.

The modular 10m-Bench system was designed and constructed by TÜBİTAK UME Dimensional laboratory for calibration of all types of rulers and tapes up to 10 m long (20 m long with stitching methods). The new system is mainly composed of 13 m rail system, mechanical parts, optical units and laser interferometer. The carriage movement is supplied with DC mini motor which is controlled either by measurement software user interface or by a joystick. The motorized carriage, on which a camera for probing of the scales and an optical reflector for the reference laser is placed, is located on rails. The image of the scale on tape or ruler taken by the camera is viewed on the computer screen with the help of home-made software. Therefore the system can perform the probing process by simply placing the measured scales on the viewed target cross line with the help of a motorized carriage. The carriage movement is measured by a laser interferometer. Effects resulting from angular errors have taken into account in the uncertainty evaluations. The developed software also performs temperature measurement for required corrections. The measurement values are evaluated according to (OIML R35-1), European legal metrology (73/362/EEC) standards, or with the user specifications.

The overall uncertainty for the system is $U_{k=2} = [(75)^2 + (5xL)^2]^{1/2}$ µm, where L is the measured length of the tape or rule in meters.

1. INTRODUCTION

In TÜBİTAK (The Scientific And Technological Research Council Of Turkei) UME (National Metrology Institute of Turkei), due to the incoming calibration requests of tape and rulers, initial work on bench system has started in 2000-2003 and first generation system (5 m tape comparator) which was called 5m-Bench was constructed [1] at old building of UME. Calibration services of tapes and rulers up to 5 m long (10 m long with stitching methods) has been performed using 5m-Bench according to the requirements in OIML R35[2] and 73/362/EEC standards[3] since 2003. The stability of the first generation system was validated by intercomparison, “EUROMET.L-S17 Supplementary Comparison, Project 875, Steel tape measure” in 2005-2006 [4]. A national comparison has been conducted in 2012-

2013 with 18 participating secondary laboratories with UME being the pilot laboratory [5]. This first generation system has been served to the industry as a reference calibration system between 2003 and 2013.

Most of the National Metrology Institutes (NMIs) designed and manufactured their own equipment for calibration of tapes and rules using laser interferometers. Detailed information about such devices is given in EUROMET.L-S14 final report [6]. The maximum length of the designed equipment in the first place depends on available laboratory size. Smaller size measurement devices can also used. Larger tapes can be measured in several intervals and the measurement results are connected and reported with higher uncertainties.

There are 22 national metrology institutes having service for steel tapes in calibration measurement capabilities (CMC) database of Mutual Recognition Arrangement of the CIPM (CIPM MRA). Two NMI's have smallest expanded uncertainties; The Physikalisch-Technische Bundesanstalt (PTB, DE) $U=\sqrt{(13.4^2 + 2.6^2L^2)}$µm and Federal Office of Metrology (METAS, CH) $U=\sqrt{(12^2+3.3^2L^2)}$µm where L is measured length in meters.

After the completion of the national comparison, it was decided to extend the measurement range and thus establish second generation 10m-Bench system in order to maintain the calibration service to serve the industry for longer range tapes and rulers. The idea behind the new system was a modular system design and production that could be extended up to 50 m long when requested.

The new generation modular 10m-Bench system has been designed and constructed at the new industrial measurement laboratory. As in the previous 5m-Bench system, this new 10m-Bench also provides measurements that comply with the International (OIML R 35-1) [2] and European legal metrology (73/362 / EEC) [3] standards. The system is placed in an air-conditioned laboratory consist of a 50m-long corridor and equipped with two industrial type air conditioning systems which are located and operated in different rooms. Air is distributed to the laboratory through large air nozzles at the ceiling and exhausted from wall unit near the floor. The laboratory is in the middle of the whole building, therefore the location is very conservative. The materials and instruments used on the bench are considered to be insensitive to vibration, nevertheless the new building of UME as well as the 50 m long laboratory is designed and constructed as a vibration-proof concept. The geographical location where UME is established is very far from the industrial facilities, busy traffic roads and rail ways.

2. 10m-BENCH MEASUREMENT SYSTEM STRUCTURES AND FUNCTIONS

The modular 10m-Bench system (Figure 1 and 6) was designed and constructed by TUBİTAK UME Dimensional laboratory for calibration of all types of rulers and tapes up to 10 m long (20 m long with stitching methods). The system is traceable directly to the laser interferometer. The 10m-Bench measurement system is a prototype of the 50-meter bench measurement system, which is expected to be built in the coming years. Thus the work done for the 10m-Bench measurement system simulates all the features of the 50-meter bench measurement system. The system is located in the 50 m long industrial measurement laboratory of TUBİTAK UME, the temperature specification of which is (20 ± 0.5) °C. General view of 10m-Bench system is illustrated in Fig.1. System is approximately 13 m long, 0.54 m wide and 1 m high.

Figure 1. General view of 10m-Bench system

A CCD camera with imaging optics is placed on carriage unit using a linear translation stage with positioning adjustment made using micrometer head. Live image is adjusted using this stage and transferred from CCD camera to the user interface screen. Laser interferometer and distance optics are used as a reference in the system for calibration of tapes and rulers. The laser interferometer position indication is set to zero at the beginning of the measurement. The distance read on the laser interferometer is the distance between a laser interferometer optic fixed on the main body of the bench and a retro-reflector optic that is able move using carriage unit driven by DC micro motor.

2.1. Main Body and Rail System

System main body was designed to be modular such that separate tables made of aluminum bars (Figure 2) are connected to each other with a gap between them in order to allow relaxation of the stress due to the thermal difference between tables. Tables are on adjustable screw base which allows to adjust the tilt. There are six of these modular tables (4 x 2 m and 2 x 2.5 m) which form the main body with a total length of 13 m. On this body, there are carriage unit, 12 m rail system, mechanical holding and special design tensioning units.
12 m rail system is constructed such that one 12 m long rail is assembled by combining four linear rails of 3 m square cross section. Two of these rail assemblies are separated by 315 mm in parallel and are supported in slots on tables which enable vertical and lateral adjustment of the rails. The modular tables and the rails have been adjusted during construction to improve the straightness of the system such that a fixed point on the carriage stays within the area of a 0.5 mm diameter cylinder over the 11 m measurement range. Height, parallelisms of the tables and the rails are adjusted using optical tooling equipment, angular deviations are determined and minimized using laser interferometer and angular optics.

Figure 2. Modular tables made of aluminium bars and main body

2.2. Carrier Car Mechanism

The carriage moves along the rail with 4 ball bearing sliding beds. Each rail has 2 sliding beds. The motorized carriage carries a precise XYZ-translation stage with micrometer head on each axis, laser optics and CCD camera with magnifying lens. The XYZ-translation stage is used for fine adjustment of the optical unit and the magnification of the view during construction and alignment as well (in the case of manual measurements) (Fig.3). Laser optics provides the measurement values when the optical unit is positioned on the scale marks. The laser interferometer optic (retro-reflector) is placed onto the XYZ-translation stage and close to the tape surface in order to reduce the Abbe offset.

Figure 3. Carrier System

The movement of the carrier is motorized. It moves on the rails with the help of a DC motor with a special driving mechanism consisting of a rack and pinion gear. DC motor can be controlled either by a joystick or embedded software buttons. In order to drive the carriage in a linear motion, pinion gear is directly connected to the DC motor. Proper electronics and the resolution of the DC motor provides rotation in very small steps producing high precision movement for positioning of the carriage. Thus, CCD camera is able to locate the images of the scale marks on the target within the cameras sensor area. It should be emphasized that the precise movements in smaller steps are the advantages of the system.

2.3. Ruler and Tape Support and Tensioning Unit

Test tape and ruler to be measured has to be located on the bench system table and below the camera for optical probing (Fig. 5). A special design has been made and manufactured for this to raise and adjust the height, hence the distance between the measurement surface and the camera for focus adjustment. Tape is stretched out on this height adjustment design on the bench.

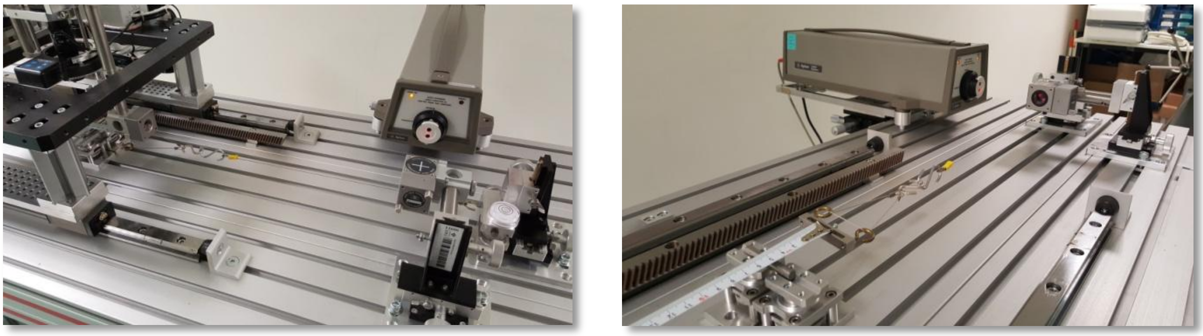


Figure 4. Special design height adjustment for tape support

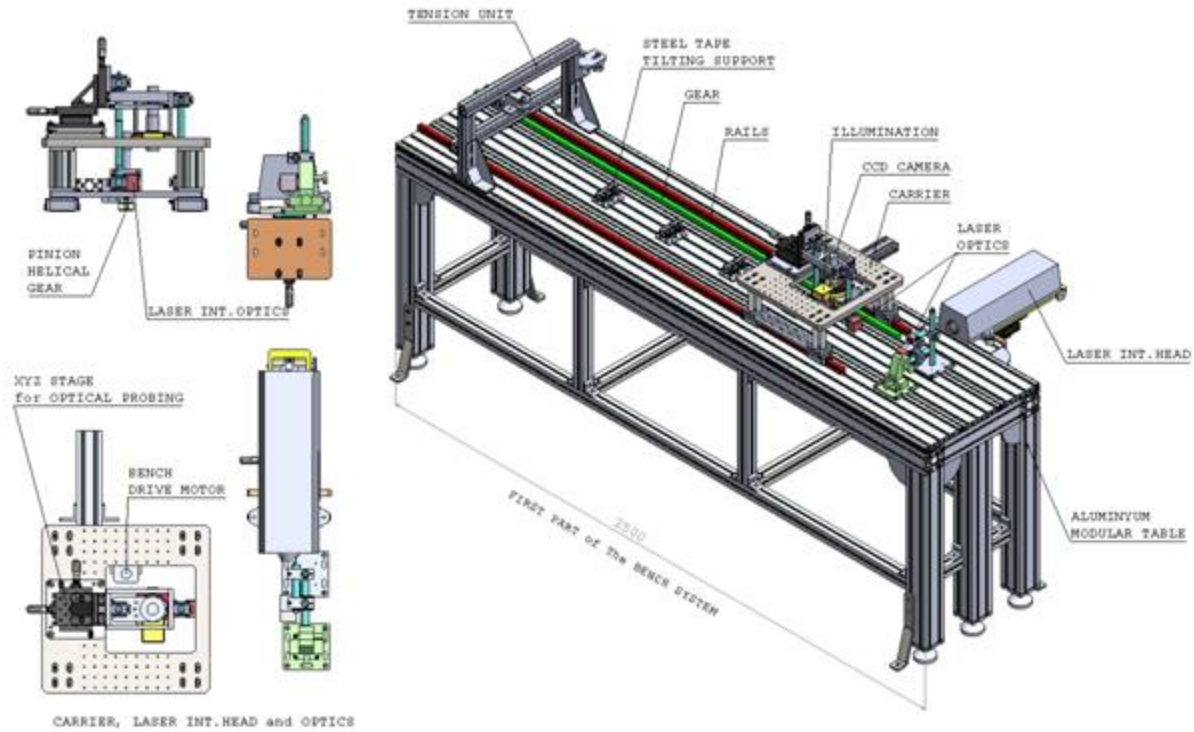


Figure 5. General view of 10 m bench system design

Figure 6. shows the tape clamping–tensioning system in which one end of the tape is securely fixed while the other end is connected to a hanging weight located on the left side of the bench by a wire which is a thin and sufficient strength to withstand tension. The fixed end of the tape is fastened by a strip of steel tape with a special design adjustable fixture (Fig. 4) which minimizes torsion forces to the tape and allows sideways alignment on the reflector's path. The wire is passed over five pulley wheel, which have low friction bearings.

Figure 6. Special design portable tension system

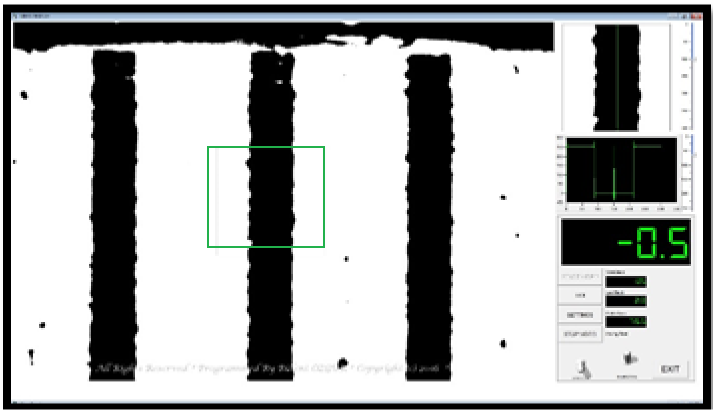
The whole tensioning system is portable and can be fixed to any needed position on the main body depending on the length of the test ruler or tape. Also, the pulley wheels on the tensioning system are adjustable in lateral and vertical position. Swivel joints are used at the connections to the tape at both ends in order to minimize the torque transmitted to the tape via wires. The test rulers are placed on the flat tape support without stretching and the tapes are required to be stretched out using the weights according to manufacturer specifications or international standards. The tapes are usually loaded by forces of (10–50) N. The desired force is produced using special design ring shape 5 pieces of calibrated load cells (Figure 6). The weights are chosen according to specified loaded force (from 10 N to 50 N) and hang to the wire that is anchored to the end of the tape.

2.4. Layout of target lines on ruler scale lines and optical probing

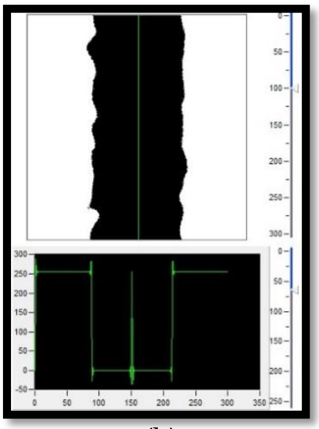
Scale mark detection is realized with an optical imaging system comprised of a CCD camera attached to an imaging lens assembly with variable magnification (0.5X to 2X). This optical probing system is assembled on the carriage with a fine tuning XYZ-translation stage. A corner cube retroreflector for the interferometer is mounted on the same structure. Detection of the scale marks is carried out with this optical probing system and corresponding CCD camera image is transferred to the computer and shown on the computer screen for further evaluation.

Before the measurement, the carriage is moved from the beginning to the end of the tape several times and imaging system CCD camera is used for aligning straightness of the tape with respect to the reference laser with the help of the side of the tape or upper part of the scale line marks. The imaging system with reflector is moved with the micrometres on XYZ-translation stage to superimpose the scale mark of the tape on the targeting area on the screen. The ruler or tape must be aligned parallel to the measurement axis and in focus with the CCD camera along the full length. Ruler or machinist scale can be supported by Bessel-points with the movable supporting aparatus.

Two different optical targeting methods can be used, with the help of the software screen. For the first targeting method, the area of measurement on tape line is marked by a rectangle (ROI) (Fig. 7). Then, the image on selected region is switched to binary mode by applying a binarization filter. With the help of binary mode, the threshold value is determined automatically at which the midpoint of the line by image processing. The determined threshold value is visually displayed on the software screen. With the help of the threshold value, the carrier is allowed to operate at the specified point throughout the entire measurement.



(a)



(b)

(a) Determination of ROI area (b) Determination of the midpoint of the width of the line
Figure 7. The Scale Marks on software screen

The second targeting method is a classical method on which target lines are used on the software screen directly. This system generally is used a ruler on which a clear image cannot obtain with binarization method.

In both targeting systems, the operator can perform the optical probing process by translating the CCD camera image over the scale marks while observing computer screen in order to place the marks on the ROI with the help of the determined threshold value. For this, the operator simply uses the joystick or embedded buttons to move the motorized carriage. Another probing mechanism is micrometers on the XYZ-translation stage for fine adjustment of the optical unit. This system is very useful calibration of ruler shorter than 2m. For a calibration of the longer tapes, DC motor is much better for probing. Because the DC motor is rotated in smaller steps producing very precise movement for positioning of the carriage with the help of suitable electronics.

2.5. Length Measurement System

The meter is defined as "the length of the path travelled by light in a vacuum during the time interval of l/c=1/299792458 of a second." This definition establishes a fixed value for the speed of light, "c", in a vacuum. Laser interferometers [7] are metrological and traceable length measurement system.

Laser interferometer and distance optics are used as a reference in the system for calibration of steel tape and rulers. In the 10m-Bench measuring system, He-Ne HP 55292A Laser interferometer with a display screen, environmental sensors and distance optics are used as a reference device. Michelson interferometer is the method of measurement and reference for the system. Laser interferometer has a reference laser with a wavelength of 633 nm with an accuracy of 3 ppm.

The laser interferometer optics is located onto the XYZ-translational stage to be as close as possible to the tape surface in order to reduce the Abbe offset. Abbe offsets are measured 18 mm on the pitch-direction and 2 mm in the yaw-direction.

2.6. Temperature measurement system

Three platinum resistor thermometers Pt100, that are separately placed on the tape support surface along the 10m-Bench, are used to determine the temperature of the tape and the environment. Temperature corrections can be applied to the laser results automatically The temperature is only monitored for tapes and rulers to ensure the temperature stability and limits of (20 ± 0.5) ^{o}C.

2.7. Software

Calibration software has been developed in Visual Basic 6.0 that have ability work under MS Windows in order to provide prompts to the operator. Software (Fig.8) is composed of three main part; Motion Module, Laser Interferometer Module and Image Processing Module.

- Motion Module provides control of the DC micromotor that moves the system and also control for the speed parameters of the DC motor. It activates/deactivates the DC micromotor for motion thus controlling the motion of the system. Motion of the carrier can be controlled either embedded buttons on the software or joysticks
- Laser Interferometer Module provides a connection between the PC and the laser interferometer. It reads the data from laser interferometer unit for the reference distance value and the flow of the data from the environmental equipment for temperature measurement. At the same time, compensated distance values are obtained by using the refractive index of the air and the environmental parameter values corresponding to this distance value. The operator can see the corrected measurement values of the laser interferometer on the computer screen simultaneously. This module has been imported into software.
- Image Processing Module provides video image and detection of the midpoint of the scale on the obtained image.

Figure 8. General view of calibration software

2.8. Data collection and evaluation

Calibration of the tapes and rulers are performed in 10 equally spaced intervals unless specified and requested by the customer for measurements on extra points. Temperature measurements are performed continuously during the measurement. The temperature values are transferred to the software automatically from laser interferometer. The operator then follows the commands from the software and positions the carriage to the target points (laser position) shown on the screen. The measurement results have already been corrected to the reference temperature of 20°C in the laser interferometer software and send to the device monitor.

During the measurement process, the carriage is first moved and set over the zero graduation line at the beginning and also laser is set to zero, then sequentially at each line up to the maximum. The sequence is then repeated in reverse order ending on the zero mark. Finally, the carriage is displaced and returned to the maximum graduation again. In measurements process, uni-directional data collection method is applied.

The distance value at each point is taken from the software screen and added to the manually generated excel spreadsheets. Measurements repeated three times and the average value is taken as the results.

3. VERIFICATION OF THE SYSTEM

The verification of the 10m-Bench system has been performed in different steps. We can examine them in the following steps.

1. Detection of angular (Pitch and Yaw) errors of the carrier. It has been investigated using a laser interferometer angular optics.
2. The affected measurement accuracy due to the design of the carrier.
3. Detection of error in the optical probe with a micrometer. It shows optical probing performance that has been performed in order to determine the accuracy of the system.

3.1. Detection of angular (Pitch and Yaw) errors of the carrier

The pitch and yaw error of the carriage along movement range of 10 m have been determined using laser interferometer with angular optics. Determined maximum deviations are 600 arc seconds for Pitch and Yaw error. When the angular errors are studied, it is seen that the largest angular error is in the Pitch-direction. The reason for the large deviations is found due to bending of the rails on some particular region along the full range.

The displacement errors, which will be caused by these angular deviations, are estimated and included in the uncertainty budget. If the Abbe offset value on the Pitch-direction is assumed to be 18 mm, and 2 mm on the Yaw-directions than the maximum displacement error values can be calculated as

$e = \mathrm{Sin}\ (600/3600) * 18 = 52.4\ \mu m$
(which will result in the uncertainty budget $52.4 / (3)^{1/2} = 30.23\ \mu m$) for Pitch.

$e = \mathrm{Sin}\ (600/3600) * 2 = 5.82\ \mu m$,
(which will result in the uncertainty budget $5.82 / (3)^{1/2} = 3.36\ \mu m$) for Yaw.

3.2. The affected the measurement accuracy due to the design of the carrier.

It is impossible to coincide the laser interferometer optical axis to the ruler and the tape measurement axis during the measurement process. However, for the new device, the carrier was designed so that the interferometer optical axis is as close as possible to tape or ruler measurement axis (max. approx. 18 mm) in order to decrease the influence of the angular motions on measurement results. It was illustrated on figure 9.

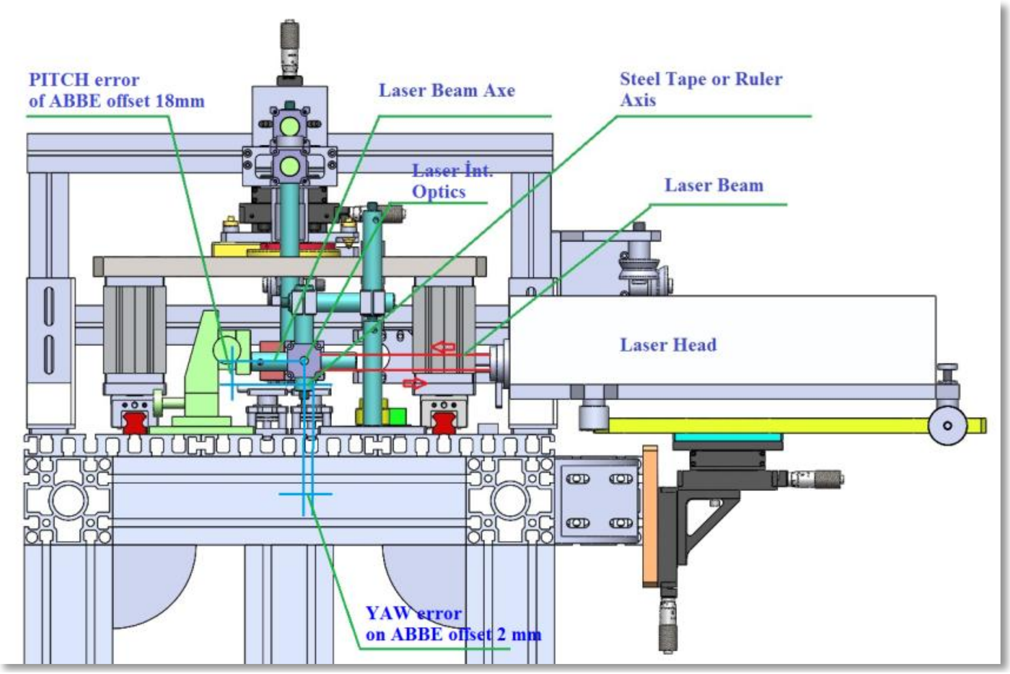


Figure 9. Front view of the whole system.

3.3. Detection of error in the optical probe with a micrometer.

To determine the influence of movement of the micrometers, mounted on XYZ table, the test has been performed when the carriage is positioned at different locations along the rails by moving the micrometer from different directions and distances.

As a result of these tests, it was determined that the maximum optical probing accuracy is obtained as 20µm and the repeatability is obtained as 5µm. Accuracy value are included in the uncertainty budget as $20 / (3)^{1/2} = 11.54$µm. Repeatability value are included in the uncertainty budget as $5 / (3)^{1/2} = 2.87$ µm. These determined values are also included in the total uncertainty budget.

4. Perfomans Test of 10m-BENCH System

The performance of the 10m-Bench has been checked by measuring reference 10 m steel tape that was calibrated by METAS in 2015.

The results of deviations are evaluated by applying “E_n” formula . Measurement results taken immediately after the measurements. (Table 1)

$$E_n = \frac{(X_{UME} - X_{METAS})}{\sqrt{(U_{UME}^2 - U_{METAS}^2)}}$$

It is also seen clearly in (Table 1) that UME-METAS results are in good agreement in a full range of bench except at 1500 mm range which has slightly bigger E_n values.

Figure 10 illustrates the results of this informal comparison in a graph fulfilling the degrees of equivalence condition by checking the calculated E_n values.

UME and METAS Steel tape measurement results evaluated with respect to En Value			
Nominal Length (mm)	En Value	Nominal Length (mm)	En Value
500	0.00	5500	0.20
1000	0.71	6000	0.16
1500	0.69	6500	0.02
2000	1.09	7000	0.10
2500	0.06	7500	0.12
3000	0.36	8000	0.40
3500	0.72	8500	0.60
4000	0.65	9000	0.16
4500	0.21	9500	0.44
5000	0.01	10000	0.73

Table 1 : Steel Tape measurement results evaluated with respect to En Value

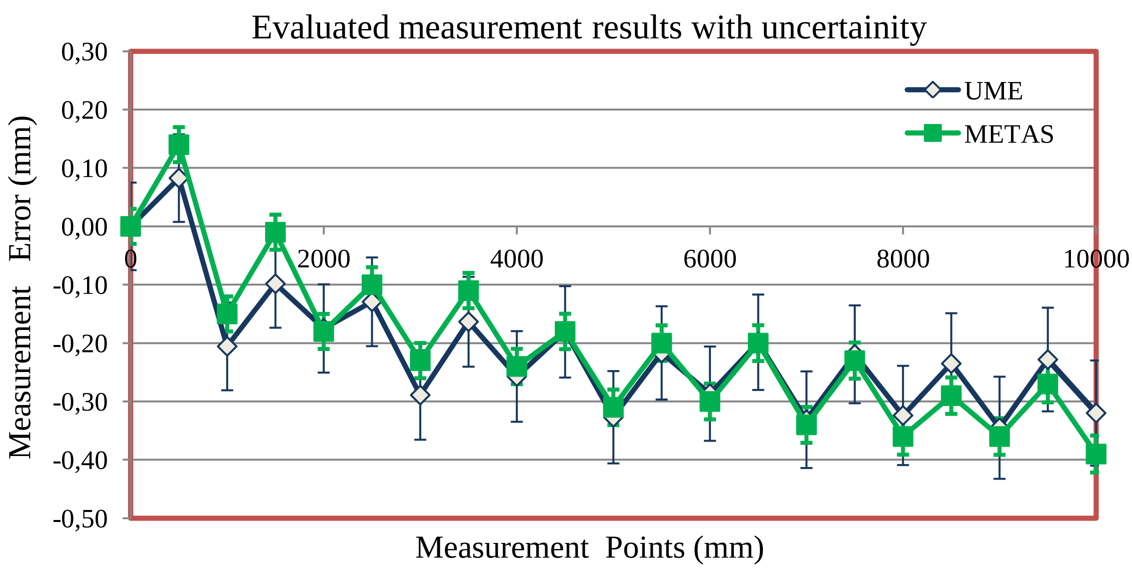


Figure 10 : Evaluated measurement results with uncertainity”

5. Measurement Uncertainty

In the following, the main error sources of the bench are characterized and their uncertainty contributions are estimated. The uncertainty of measurement has been estimated according to the “ISO Guide for the Expression of Uncertainty in Measurement” [7] and has been expressed in a length dependent form of $U_{k=2} = [(a\ \mu m)^2 + (b\ x10^{-6} \cdot L)^2]^{1/2}$ using a coverage factor of k=2. Here, *a* is the constant value, *b* is the length dependent value and *L* is the measured length in meter. Analysis of the uncertainty contributions has been investigated in detail and has been combined with the length dependent format. The uncertainty budgets are given below for calibration of test tape using a laser interferometer.

The accuracy of laser interferometer:

Agilent HP5529A laser interferometer [8] used as a reference of the bench has an accuracy of $3.0x10^{-6}$x L for displacement measurements in laboratory conditions. This length dependent value is considered as rectangular distribution resulting in $(3.0x10^{-6}$ x L$)/\sqrt{3} = 1.73x10^{-6}$ x L

Resolution of laser interferometer:
The resolution of the interferometer is 0.1 μm. This value is taken as digital resolution resulting in $0.1/(2 \times \sqrt{3}) = 0.0288$ μm uncertainty contribution with rectangular distribution.

The standard deviation of the mean value of Laser:
The standard deviation of the mean value of typically 3 series of repeat measurements is better than 30 μm for tape measurements. Uncertainty contribution is estimated as $30/\sqrt{3} = 17.32$ μm

Uncertainty contribution from pitch angular error:
Maximum peak to peak angular pitch error is 600 arcseconds. The measurement axis is measured in ±18 mm in the vertical direction. Abbe error due to pitch error can be calculated as Sin (600/3600) x 18 = 52.4 μm. This leads to $52.4/\sqrt{3} = 30.23$ μm uncertainty contribution with rectangular distribution.

Uncertainty contribution from yaw angular error:
Maximum peak to peak angular yaw error is 600 arcseconds. The measurement axis is measured in ± 2 mm in the horizontal direction.
Abbe error due to yaw error is Sin (600/3600) x 2 = 5.82 μm, resulting in $5{,}82 / \sqrt{3} = 3.36$ μm uncertainty contribution with rectangular distribution.

The accuracy of optical probing:
It was determined that the maximum optical probing accuracy obtained was 20 μm, resulting $20 / \sqrt{3} = 11.54$ μm uncertainty contribution with rectangular distribution.

The standard deviation of the optical probing mean value:
The standard deviation of the mean value of typically 3 series of repeat measurements is better than 5 μm for the optical probing test. Uncertainty contribution is estimated as $5 / \sqrt{3} = 2.89$ μm.

Uncertainty contribution from Cosine error:
The laser is adjusted parallel to the measurement axis better than 2 mm lateral shift in 10 m length. This results in a cosine error of $2\times10^{-7} \times L$, resulting in $(2\times10^{-7} \times L)/\sqrt{3} = 1.16\times10^{-7} \times L$ with rectangular distribution.

Uncertainty contribution from coefficient of thermal expansion (CTE) corrections;
No CTE correction is made for calibration of steel tapes and rulers. However, uncertainty contribution is taken into account due to possible differences in CTE values. CTE of steel ruler or tape is known within ±1 ppm and maximum temperature deviation from 20 °C is less than 0.5 °C. Uncertainty contribution due to CTE correction can be calculated by $0.5\ ^{o}C \times 1 \times 10^{-6} \times L$ resulting in $0.5\times10^{-6} \times L$. Considering this value as rectangular distribution, uncertainty contribution is estimated as $(0.5\times10^{-6} \times L)/\sqrt{3} = 0.29\times10^{-6} \times L$.

Uncertainty contribution from Temperature measurements:
No temperature measurement correction is performed. The uncertainty of temperature measurement for line scale used in 10m-Bench using material sensors is better than 0.25°C. Uncertainty contribution can be calculated as $0.25^{o}C \times 11.5\times10^{-6} \times L$. Uncertainty contribution is estimated as $(0.25^{o}C \times 11.5\times10^{-6} \times L)/\sqrt{3} = 1.66\times10^{-6} \times L$. with rectangular distribution.

Uncertainty contribution from Measurement force (tension load):
Measurement forces, i.e. tension loads are applied during calibration of tapes according to manufacturer specifications. Uncertainty contribution arises due to length variations when there is the difference between applied force and specified force. The correction for different tension from specified can be estimated by Hooke's law;

$$\Delta L_F = \frac{(F - F_0)L}{AE} \text{ , (N)}$$

where ΔL_F is a deviation in length due to applied force F, E is the modulus of elasticity and L is the length. The term (L/EA) is the sensitivity coefficient used to make the connection between measurement force and deviation in length and u(F) is the uncertainty of applied force and $u(\Delta L_F)$ is a deviation in length due to the uncertainty of applied force where F_0 is tape tension at calibration (N), F is tape tension (N), L is the distance measured (mm), E is Young's elastic modulus (N/mm^2) and A is cross-sectional area of the tape (mm^2). The following numerical values for A and E are given by the manufacturer.

$$(F-F_0)=0.5 \text{ N (Estimated), } A=2.25 \text{ mm}^2 \text{ and } E=20.7\text{x}10^4 \text{ N/mm}^2$$

Manufacturers give specifications and even correction values due to the difference in the applied and specified force (tensioning loads). The numerical values obtained from literature is rectangular distribution, the standard uncertainty contribution is calculated as

$$u(\Delta L_F) = (1.07\text{x}10^{-6}\text{x}L)/\sqrt{3} = 6.2\text{ x}10^{-7}\text{x } L$$

The expanded uncertainty value; $U_{k=2} = \sqrt{((75)^2 + (5 \times L)^2)}$ µm : (L = metre) is valid for the length measurements up to 10 m.

6. CONCLUSION

A motorized 10m-Bench constructed in TÜBİTAK UME for calibration of tapes and rulers were described. The device provides traceable calibration of tapes and rulers up to 10 m (up to 20 m with stitching methods) using a laser interferometer with an estimated expanded uncertainty of

$$U_{k=2} = \sqrt{((75)^2 + (5 \times L)^2)} \text{ µm : (L = metre)}$$

The performance of the device was explained with evaluated results and uncertainty budget. The idea behind the new system design was a modular system production that could be extended up to 50 m long when requested.

The 10m-Bench measuring system is a prototype for the 50m-Bench measuring system that is planned to be built in the coming years with the same modular structure. At the same time, the 10m-Bench system provides important information about the portable system design for future work.

The device is suitable for calibration and inspections of reference tapes and rulers in accordance with OIML R35 standards and the regulation prepared by the Ministry of Industry and commerce on the basis of the European Legal Metrology Standard 73/362/EEC Directive.

The evaluation of the bigger measurement uncertainty than predicted value, shows us that the system still needs improvement to reduce the uncertainty. The main objective would be to get better straightness in rails during adjustments process resulting in much less angular tilting errors (pitch and yaw). In order to do that, better adjustment mechanism between the rail and the main body has to be designed. This will allow much better adjustment of rails in terms of straightness and will decrease higher uncertainty contributions. Also, we will work on developing software module which makes online correction and compensation of Pitch and Yaw error or using previously measured Pitch and Yaw values.

7. ACKNOWLEDGMENTS

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