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A MECHANICAL DEVICE USED TO IMPROVE THE VISION INSPECTION IN SMALL SCALE INDUSTRY

F. Al-Ghathian[1], M. Tarawneh[2], M.A. Nawafleh[3] and N. Al-Kloub[1]
[1]Department of Mechanical Engineering, Al-Balqa' Applied University, Amman, Jordan
[2] Department of Mechanical Engineering, Mutah University, Karak, Jordan
[3]Department of Civil Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan
E-mail: tatmuf@mutah.edu.jo; tatmuf@yahoo.com

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ABSTRACT

The dimentional and quality control tasks have to be performed at the onest of any assembly line. Defected surface even small ones leads to non-conforming of the final product. The automated artificial inspection has proved its acceptance due to its significant advantages. The first aim of this paper, is to describe the operational and design features of the mechanical device that could be integrated in the vision inspection systems. The device contributes positively to improve the inspection efficiency as it is integrated in the vision systems. The designed mechanical device will be used to properly fix, orients, and presents the inspected objects in a vertical and horizontal plans to the acquisition system, in order to provide more accurate feedback information regarding the inspected objects. This arrangement can be achieved by linear and rotary motions provided by the device. The device drives the objects in a linear motion along the measurement direction in the front field of the acquisition system. While the rotary motion is necessry to rotate the object in order to ensure a coplete scannunig of entire surface of the inspected object. It allows the CCD cameras to capture adequite images during each rotation from both vertical and horizontal plans. The design and research has been made on basis of a good understanding of the vision concepts and applications. The device design is relaible, simple in construction and has flexible operation. It was tested with two different shapes: cylindrical and prismatic. The obtained images of the inspected surface (with scanned pits, texture, scratches, cracks, and finishing) demonstrated its capibilty for accurate inspection if integrated with the vision inspection systems. The design and operational characteristics are presented in the next sections.

***Keywords*:** Orientation, Fixation, Presentation, Machine vision inspection, Robot.

1. INTRODUCTION

The traditional methods of visual inspection are still preformed using clasical methods, this might result in inaccurate measurments as the human error is still involved. The demand of performing the dimensional and quality control tasks at the beginning of any assembly line is strongly recommended. Because defects even small ones resulting in a non-conforming of a final product performed by human operators in the small scale industries. The traditional methods of inspection and quality control are usually performed by skilled operators and experts. Recently, skilled operators are difficult to find or to maintain them in the small scale industries Dongik Shin et al.(2002), and Mital et al.(1998). While the un-skilled operators require extensive training that may take time to develop their skills. In certain applications the human inspection tend to be careless, un-economical, time consuming, and not satisfactory. Because the inspection tools become worn and need frequent adjustment and repair, which in turn increases the cost and time of inspection, in addition to the expected range of errors Dongik Shin et al.,(2002), Raghunandan (2007), and Beg (2002). In some applications such as mass inspection or dangerous environments, the human inspection can not provide accurate feedback information even with skilled operators Dongik Shin et al.(2002), Raghunandan (2007), Beg (2202),and Kopardekar et al.(1993). The automated vision inspection techniques have gained the widest acceptance in different fields of measurements, inspection, and control tasks, because they provide more accurate and abundant feedback information regarding the inspected objects Raghunandan (2007), and Elias Malamas et al. (2003). The tight integrated computer models, softwares, hard wares, in combination with the advanced acquisition systems were applied in different inspection activities. The integrated computer softwares and models have satisfied the essential demands for cost effective, high speed of image processing, and efficient inspection. They also demonstrated a significant contribution in developing the inspection efficiency Chen (1995), Delp (1997, and Guangjun Zhang (2005). The reduced cost of skilled technicians was achieved, and great efforts have been made to automate the inspection system by integrating the industrial robots in measurement systems Golnabi (2003).

In comparison with the traditional methods, the automated systems have been demonstrated with significant positive advantages, namely:

- They predict the possibility of the earlier failure prediction, which in turn contribute in reducing the failure rates of products Dongik Shin et al.(2002).

- They provide precise feedback information and instant analysis regarding the inspected object Raghunandan (2007), and Rosati et al.(2009).
- These techniques are relevant in dimensional and quality control tasks, non contact on-line inspection even in dangerous environments Throop et al. (2005), Zhenzhong Wei (2005), and Geary (1996).
- The automated inspection may effectively provide key solutions and replace the need for skilled human inspection, as well as the need for complex gauging fixtures Zhenzhong Wei, (2005) in their academic and industrial fields. Much effort has been done to automate.

The above mentioned advantages were highly considered by several researchers inspection process for different applications, and many practical systems have been made and put into practice. In this paper, the designed mechanical device is expected to improve the inspection efficiency if integrated with the vision inspection system. In order to ensure the device capability in improving the measuring efficiency, the obtained results were compared with similar work obtained from literature. Several methods and techniques of automated inspection systems in the field of surface inspection have been investigated. The obtained results and conclusions were evaluated and appreciated. A review on the surface inspection techniques using active vision systems was made Tian ,Gledhill (2007) and Golnabi (2007). Surface measurements techniques were developed and applied in the industrial field to determine the physical and geometrical properties of the objects Zhang and Krewet (2006). Methods for checking the object for correct shape, position, and detection of parts for possible defects or irregularities were developed Tsai (1999). On line and non contact dimensional measurement has been evaluated Rosati et al.(2009). Surface defects identification and classification were reviewed Zhang, Krewet, and Kuhlenkotter (2006). Metal finishing and machine parts processing were studied. Finally, the mechanical device was operated to inspect the surface quality for two different objects with different shapes (cylindrical and prismatic objects) was made. The captured images during the testing procedure are presented. The pits, scratches, cracks, textures, and finishing shown in the images are used to demonstrate the device robustness. With certain adjustments, the device has been used in dimensional control tasks to check the shape, orientation, alignment, roundness, etc. It worth noting that the device location must be at the beginning of the assembly or production line, in order to verify the objects prior to start the assembly process.

2. IMPORTANT CONSIDERATIONS

2.1 Classification of the machine vision applications

The main concern of using a vision based inspection system is to recognize that the inspected object is within the specified characteristics in terms of dimensions, tolerances, and shape. Most applications are related to at least one type of inspection

The industrial applications can be classified into four main categories, namely:

1. Dimensional quality including: dimensions, shape, position, orientation, alignment, roughness, roundness, straightness.
2. Structural quality for correct and complete assembly (holes, slots, screws, nuts, clamps, .etc.)
3. Surface quality: Pits, cracks, scratches, finishing, texture.
4. Operational quality: For incompatibility and non-conforming to standards

2.2 Important design and operational considerations

The successfully designed machine vision system starts with basic understanding of the required feedback information, application domain, requirements, and constraints. The developed system must be able to differentiate between the acceptable and unacceptable variations. Accurate feedback information is highly dependent on the performance of integrated subsystems in the machine vision system, such as: the scene consideration, image acquisition, and processing. Image acquisition is an important process for the performance of a machine vision system. The high quality image results in faster and easier analysis. The acquisition subsystem is used to convert the optical data from the captured image into numerical data in order to be efficiently manipulated and processed by the computer. The recognition subsystem has a significant role to identify the objects and determine their position. The recognition process compares the geometrical properties of the inspected region to those stored in the database. Image processing is used to modify and prepare the pixel values of a digital image to produce more suitable form for subsequent operation. Inspection strategy plays a significant role in determining the main parameters of the inspected object. The quality of needed feedback information is highly dependent on the size of the inspected object that must be representative of the entire surface. Proper selection and uniform distribution of the inspection points is essential, the number of selected points must be sufficiently enough to provide accepted information regarding the inspected object. British Standard (B.S.7172) recommends that the number 5 to 15 selected points along the inspected surface gives sufficient feedback information Zhang et al. (1996). The nature of inspected surfaces must be highly considered. Rough surfaces require greater number of sampled points to get sufficient feedback).

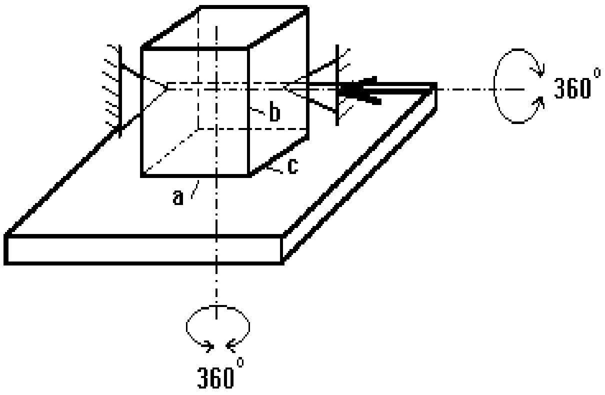
3. MATERIAL AND METHODS

3.1 Design and operation of the suggested device.

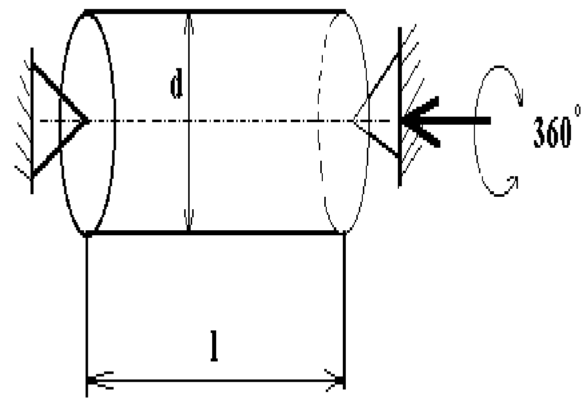
Today's machine vision inspection systems are composed of different components, each component has its specific role in the inspection process. The operational and design consideration mentioned in section 2.2 were highly appreciated and considered in this work.

This paper focuses on the key aspects of the designed system aiming to provide more flexible and practical technique of inspection as well to increase the inspection efficiency. The device is used to provide correct positioning, fixation, alignment, and proper orientation of the inspected objects. These important tasks must be achieved prior to start the inspection process. Therefore, the device is placed at the beginning of the production or assembly lines, in order to prevent the non-conforming of a final product that could be produced. In order to achieve the main target of increasing the inspection efficiency, the mechanical device was designed and operated to facilitate the inspection process. The developed system is integrated and interconnected with the recognition and image acquisition systems in the vision inspection station. In order to achieve high accuracy of feedback information and efficient inspection, it is necessary to provide correct synchronization between these systems (the device, recognition, and image acquisition).

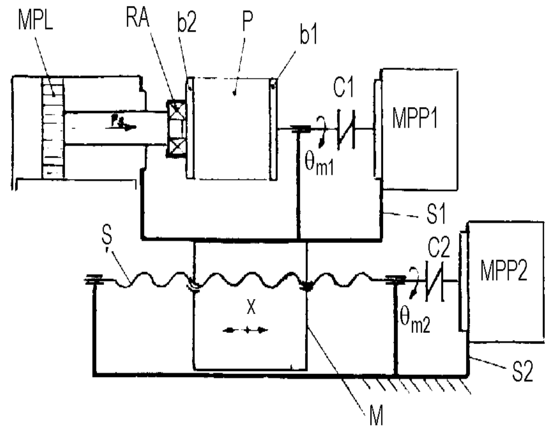
The developed device is used to present the prismatic as well as the cylindrical object to apply the point-by-point inspection strategy. The same procedure of presentation can be used for both objects with small adjustments to use the suitable mandrels for each shape. One or more CCD cameras are used to provide high accuracy of feedback information regarding the inspected object. The proper positioning and orientation is recognized by the first camera, while the second camera captures adequate images to be used in the measurement process. The recognition process is based on the comparison between the real inspected properties with those stored in the database. The decision of acceptance or rejection is taken by the recognition system. Improper positions or properties result in rejection the object before starting the assembly process. The designed system provides two types of rotary and linear motions, these motions are used to present the inspected object to the image acquisition system in vertical and horizontal plans. The significant contribution of using these motions is observed on the higher accuracy of the obtained feedback information. Both motions are performed by using two step-by-step electrical stepper motors. The stepper motors are synchronized in such away to drive the inspected object in linear motion with constant speed and to be rotated one full rotation for each 2 cm along the inspected surface. The linear driver drives the inspected object along its measuring direction in order to present the object to the front view of the acquisition system. Main while, the rotary motion is necessary to provide a 3-D scanning for the entire inspected surfaces. This arrangement is achieved by using two cameras placed in both vertical and horizontal plans, in order to capture several images. In each rotation, the image acquisition system is synchronized to capture 6 images from different points and surfaces of the inspected object for every single rotation resulting in improving the inspection efficiency. The suggested device is employed in certain inspection applications, namely for dimensional and surface quality inspection, it facilitates the inspection of external surfaces for possible defects, pits, cracks, scratches, finishing, and texture.



Scheme 1: The principle scheme of the indexing type table.



Scheme 2: The principal scheme of the catching and orienting the rotated object.



Scheme 3: The principal scheme of the designed device

A schematic illustration of the indexing table used to present the prismatic and cylindrical objects are shown in Schemes 1 and 2, respectively. An industrial robot with 5 DOF (Degrees Of Freedom) can be used for handling purposes only, it is used to carry the objects and put them on the mechanical device in order to perform the orientation and object presentation as needed in the inspection process. The main components of the designed system are illustrated in Scheme 3.

3.2 Important features and advantages

In comparison with the available systems in the local market, the developed system has some added values that should be considered, these values can be summarized as following:

- The point-by-point inspection with higher accuracy of feedback information from different points and surfaces can be easily achieved using the developed system resulting in multi-dimensional measurements. The rotary and linear motions are set to provide better scanning for the entire inspected surfaces. The available systems in the market are usually designed to provide only one motion (rotary or linear one).
- The developed system can be used to inspect different shapes and objects, while the available systems are designed to inspect only known objects and at fixed positions
- The higher accuracy of feedback from different points and surfaces is due to both rotary and linear motions. Some available systems provide inadequate quality of inspection and the results may be similar even for different positions.

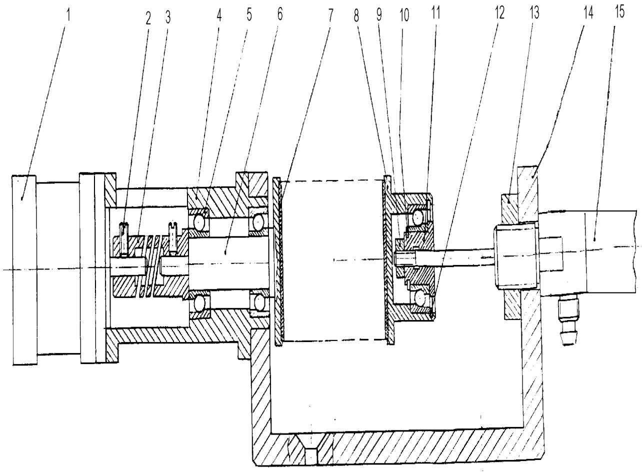
The orientation and positioning of the inspected objects in the available systems are usually performed by the industrial robots. The developed system has an economical aspect of stopping the robot to perform these activities, while the robot is used for handling purposes only.

3.3 Technical characteristics and components

The method of holding any workpiece depends on the size, shape, and weight. Holding devices are usually actuated hydraulically, pneumatically, or electrically. The common way of fixing and orienting the rotating objects can be made by means of bolts or clamps in a special holding device. The designed mechanical device can be used in certain inspection applications. The main components of the designed system are illustrated in Scheme 3. As shown in the Scheme, the device is composed by two major parts or subassemblies. The upper part is used to provide proper fixation, orientation, and to rotate the inspected object. The lower part drives the carrier that holds the upper part and the inspected object in a linear motion.

3.3.1 The upper part:

As illustrated in Scheme 3. it can be seen that the proper positioning, orientation of the inspected object are performed by the designed system. The upper part of the device functions to correctly orient and expose the object to the acquisition system, The upper subassembly is also used to rotate the inspected object in the field view of the CCD cameras in order to provide better scanning of whole the surfaces. The positioning, alignment, and orientation tasks are achieved by using a simple micro-cylinder or a linear pneumatic motor (MPL). A pair of two grasp mandrels (b_1, and b_2 in Scheme 3) is used to fix the inspected object and to provide better conditions of alignment and orientation. The first mandrel (b_1) is actuated by the micro-cylinder (MPL). The micro-cylinder develops an operating pressure of (P = 4bar). The micro-cylinder has a diameter (d = 20 mm), and connected with the grasp mandrel (b_1) via the connecting rod with a diameter of ($d_{c.r}$ = 5mm) with an operating stroke of 110mm. The connecting rod is supported by an axial bearing (RA) used to facilitate the rotary motion. It should be mentioned that the micro-cylinder is capable to properly fix and orient different objects with variable length between 50 to 100mm. Detailed specifications and components of the upper part are illustrated in Scheme 4.



Scheme 4: The orientation and catching subasesmbly of the piece in the working post.

A step-by-step electrical stepper motor (MMP1) is used to actuate the second grasp mandrel (b_2). The choice for using the stepper motors is related to the fact that they provide accurate multiplication of the number of steps per revolution, resulting in smaller movements between steps. Two stepper motors (MMP1, and MMP2) are employed to provide both linear and rotary motions. The linear and rotary motions are synchronized to provide one full rotation for each 2 cm along the linear motion.
The technical characteristics of these motors are:

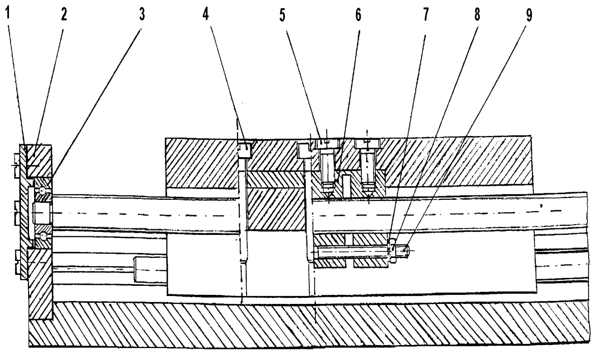
- Maximum torque 'M_{max}' is 0.2 N.m
- Maximum frequency '$F_{max.}$' is 800 Hz
- Step angle 'θ' =1.8º
- Electrical power 'U' is 5V
- Phase number 'p_{no}' is 4

The first stepper motor in the upper part is connected with the second grasp mandrel (b_2) via the shaft and one coupling point (C1).
As shown in Scheme 3, there are two elastic couplings

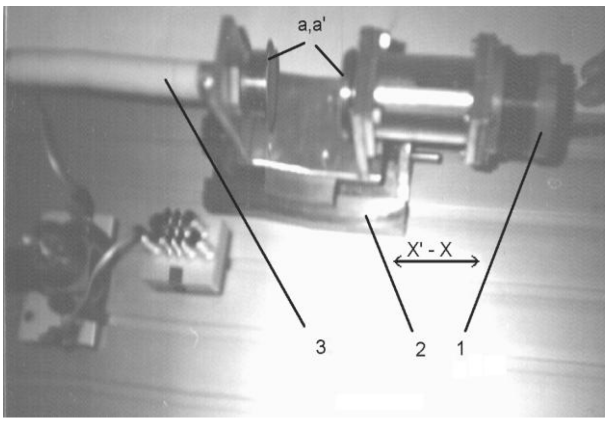
(C1, and C2), the elastic couplings are used in the upper and lower parts to compensate any expected deviation or miss-alignment between shafts (coaxility between shafts). In Scheme 4, the elasic and flexible coupling is placed between the pneumatic rod (position 1) and the intermediate shaft (position 6) and supportde by two axial bearings (position 5). The inspected object is to be placed in its proper location (P) between both jaws of mandrels. The grasp mandrels provide super conditions of holding, positioning, and accurate alignment under different turning speed. For each shape there is a special type of mandrels.

3.3.2 The lower part

The second major subassembly shown in Scheme 3, and illustrated in more details in Scheme 5 is used to drive the inspected object in a linear motion. As shown in both Schemes, the stepper motor (MMP2) is used to drive the mobile carrier (M) that holds the upper part as well as the inspected object. The carrier is clamped and connected and bolted with the upper part with two bolts. The linear motion is performed using the screw-nut mechanism, the nut is mounted in the body of the carrier, while the screw (S) is driven by the second stepper motor (MMP2). Scheme 5 illustrates more design specifications about the lower part



Scheme 5: The translation subansamble.



Scheme 6: The orientation and catching device

A clear image about the designed system is presented in Scheme 6, the developed device for fixing and orientation. The system components can be identified using the attached symbols and numbers, these are:

- o Number 1 represent the electrical stepper motor used to rotate the piece for inspection,
- o Number 2 represent the translational unit employed to move the object in the front view of a CCD camera
- o Number 3 represent the pneumatic cylinder used for fixing the inspected object
- o a and a' are the two mandrels used to hold and catch the inspected object

X-X'is the direction of sliding motion.

3.4. Operational procedure of the developed device

The proper step-by-step operational procedure is summerized as following:

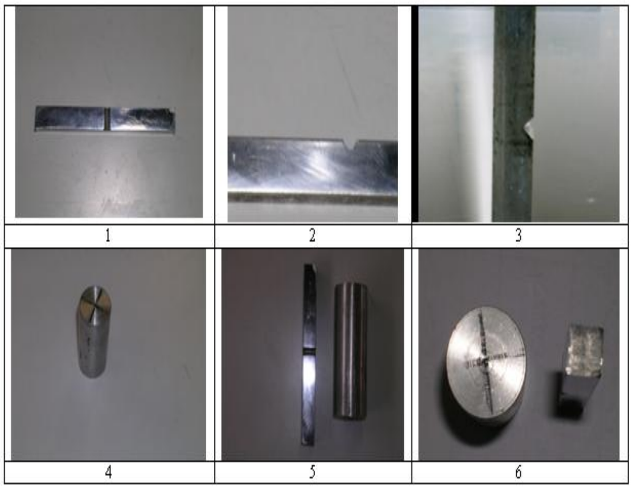
- o **Step. 1**: the industrial robot is engaged to bring the inspected object in order to be placed between the jaws of both mandrels. During this step the proper positioning, alignment and orientation should be performed prior starting the inspection process. The grasp mandrels are used to suit the shape of inspected object, the mandrels (a and a') are used for prismatic objects, and (b1,b2) for cylindrical objects.
- o **Step. 2:** The pneumatic micro-cylinder (MPL) in Scheme 3 is clearly indicated in Scheme 6 with number 3. The developed pressure of 4 bar by the pneumatic system is used to press the object between both mandrels. The mandrels have jaws used for catching purposes and providing better alignment even under higher rotary speed. The developed pressure is sufficintly enough to provide better positioning and orientation of the inspected object.
- o **Step. 3:** The obtained feedback information regarding the position and orientation of the inspected object is recognized by the recognition system. The received data is processed and converted into a suitable form. The obtained data will be compared with the stored set of information regarding the inspected object, and the decision of any orientation is needed will be made.
- o **Step.4:** The stepper motor (MMP1) is used to rotate the inspected object in order to provide better scanning of the inspected surfaces. The rotary motion allows the CCD cameras to acquire several images from different points of inspection.
- o **Step. 5:** As shown in Schemes 6 and 3, The stepper motor (MMP2) is used to drive the inspected object in a linear motion and at constant speed along the inspection direction X-X'. This arrangement allow the acquisition system to obtain more information from different points (accurately located and distributed.) on the inspected surfaces. Both motions are set to and synchronized in order to accurately present the inspected object to the acquisition system.

5. RESULTS AND DISCUSSION

The developed system was operated, and sets of different experiments were made. The obtained results demonstrated its performance in providing high accuracy of feedback information regarding the inspected objects. The results confirm the device capability in improving the inspection efficiency for different shapes and objects. The first package of experiments was focused on providing correct adjustments and synchronization between the interconnected systems. The stepper motors (MMP1) and (MMP2) were calibrated to provide one full rotation for each 2cm distance along the direction of the linear motion. A proper synchronization was made between the device and the image acquisition system. The second package of experiment was concentrated on the dimensional and surface inspection for two different objects (prismatic and cylindrical shapes). The mechanical device was employed in certain inspection applications, namely for dimensional and surface quality inspection. The Surface measurements were applied to determine the physical and geometrical properties. More exactly, it was used to inspect the external surfaces for possible defects or irregularities such as: pits, cracks, scratches, finishing, and texture. The high accuracy of feedback information, and the improved efficiency were achieved by the means of the coupled rotary and linear motions provided by the device. Several images were acquired from different points and surfaces, while the rotary motion provided 3-D scanning for the inspected surfaces. Proper selection and uniform distribution of the inspection points is essential, the number of selected points must be sufficiently enough to provide accepted information regarding the inspected object**.** The point-by-point strategy inspection strategy was applied, the size, shape, and length of each inspected object were considered. Therefore, two metallic objects (cylindrical and prismatic) were tested and inspected. The inspected objects in this paper are illustrated in Scheme 7.

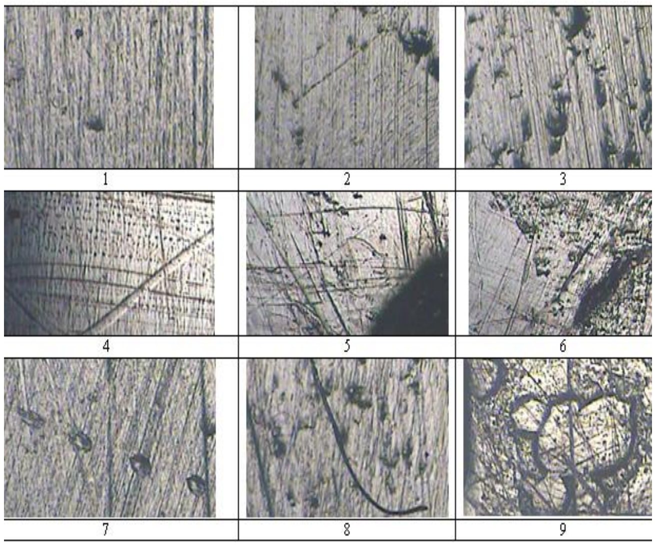
Scheme 7: The inspected cylindrical and multi surface objects

While Scheme 8, presents the inspected objects in more details and different views. The inspected objects are good representative samples, which cover different aspects of inspection. They have different sizes and shapes, and have the same length of 70mm. The cylindrical object has 7 cm length and 2 cm diameter. While the second object has different characteristics, it has 4 similar surfaces; each surface has 7 cm length and a width of 1 cm. The device can be used to inspect different objects with different lengths as between 50 to 100mm. The choice of using a length of 70mm was made to be within the operating range of the device. Different lengths between 50mm to 100 mm will be considered in our future work. The moderately large number (21) of the captured images in each experiment demonstrates the proper synchronization between the interconnected systems. Sex images were captured in each rotation and for each 2cm distance along the inspection direction.



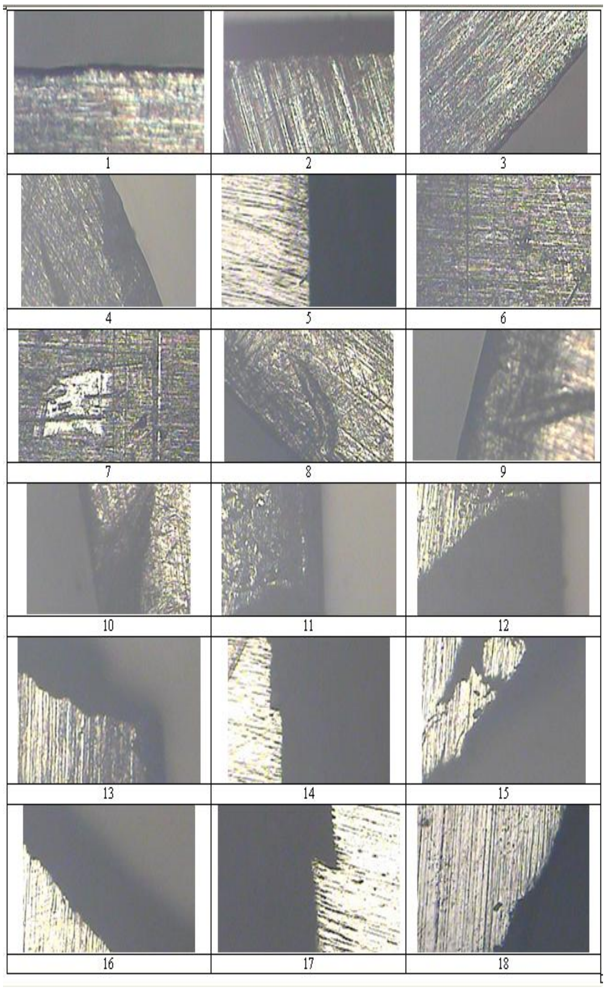
Scheme 8: Different views of the inspected objects

Table 1: Selected captured images from the cylindrical shape



This number can also be used as a good indicator of ensuring the number of rotations (3.5 rotations in each experiment). The obtained images from both objects were selected and classified in two separate Tables (Table 1 and 2). Surface measurements were made on the external surface of the cylindrical object. The captured images show different surface irregularities and defects as illustrated in Table 1 which presents 9 selected images with pits, scratches, texture, and poor finishing conditions. It can be clearly seen that the captured images demonstrate the device ability to provide accurate feedback information about the inspected objects. It should be mentioned that it is necessary to activate the zoom in the CCD cameras in order to show some invisible defects. The second shape (prismatic object) with four similar surfaces, was prepared in the workshop in such away to provide correct surfaces with proper finishing and without defect.

Table 2 Selected images from the multi surface object



The comparison between defected and un-defected zones was made in only one surface, where a special groove was deliberately created in the middle part of the prepared surface. This groove is considered as the defected zone, while the other zones on the same surface are free of any defects. The captured 18 images are tabulated in Table 2. These images show the detected defects including pits (As shown in image 7, Table 2), improper cutting that is shown in the images 10 to 18. These defects are obviously observed in the images 14 to 17. Additionally, scratch defects are clearly observed in the images 4, 6, 8, and 9. It should be mentioned that the device location must be at the beginning of the assembly pr production line, in order to verify the objects prior to start the assembly process. It can be used for different inspection application, such as in dimensional and control tasks of orientation, alignment, roundness, but it is necessary to perform certain adjustments and calibration.

7. CONCLUSIONS

The present work has presented the main aspects and design features of the developed system. The relation ship between the interconnected systems and parts was explained. The most important conclusion remarks can be summerized as follow:

- The developed system is capable to perform different tasks of inspection such as the orientation, positioning, and presentation different objects to the recognition and image acquisition systems. The economical aspect of using this system can be considered as it elamenates the use of industrial robots to perform the positioning and orientation tasks. Using this system the time consuming in the traditional inspection can be significantly reduced, and the production can be significantly increased.
- The developed device can be employed to inspect different shapes and objects, but some adjustments should be made to suit the requiered inspection application.
- The flexibility and simplicity are two important aspects that should be considered.
- The accurate feedback information of the inspected object, is due to the imposed rotary and linear motions provided by the designed system.
- The possibility of capturing several images from different surfaces, and the adequate scanning of the surfaces are additional values, which have significant contribution to the improved inspection efficiency. The captured vizible and invizible defects prove the device capability to be integrated in the vision inspection stations.

This work is directed toward obtaining a practical and flexible method of inspection, even for the small scale of manufacturing industry. Additional improvements will be made in the future work

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