Online Identification for the Automated Threaded Fastening Using GUI Format

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1. Introduction

Screw insertions are a common joining process and are especially popular in assemblies that need to be disassembled for repair, maintenance or relocation.

A human performing screw fastening will typically use four stages (L.D. Seneviratne et al., 1992):

1) Alignment: the holes in the mated parts are aligned and firmly held together.

2) Positioning: the screw is globally positioned with respect to the aligned holes.

3) Orientation: the screw is oriented until its axis coincides with the axis of the aligned holes.

4) Turning: the screw is turned with the appropriate torque until fastening is achieved.

In manual screw insertions, the torque exerted by the screwdriver depends mainly on the applied operator force. Human operators are particularly good at on-line monitoring of the operation. However, with power tools, the increased insertion speed reduces the human ability to monitor the insertions on-line. Thus on-line automated monitoring strategies for the screw fastening process are highly desirable. One such approach is based on the "Torque Vs. Insertion Depth" signal measured in real time; if this signal is within a pre-defined bound of the correct insertion signal, then the insertion is considered to be satisfactory. The torque signature signal for a correct insertion is either taught as predicted using an analytical model (Klingajay & Seneviratne, 2002). Industrial applications of automated screw insertions have been implemented in several forms. These achieved forms are applied in different objectives. With the development of electrically powered screwdrivers the attempts at automating the screw insertion process with emphasis on the torque signature signal vs. angle signal and become to the primary mathematical model. In 1997, this analytical model was implemented by (Ngemoh, 1997). The Neural Network techniques have been applied by using the ability of Weightless to monitor the screw insertion processes in difference insertion cases (Visuwan, 1999). Bruno has distinguished between successful and unsuccessful insertion based on Radial Basic function (Bruno, 2000). Both monitoring performs are to apply Artificial Neural Network in view points of classifications. "A distinction without a difference has been introduced by certain writers who distinguish 'Point estimation', meaning some process of arriving at an estimate without regard to its precision, from 'Interval estimation' in which the precision of the estimate is to some extent taken into account" (Fisher, 1959). Fisher founded the Probability theory as logic agree, which gives us automatically both point and interval estimates from a single calculation. The distinction commonly made between hypothesis

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testing and parameter estimations are considerably greater than that which concerned Fisher. In this point of view, it may be not a real difference. The screw fastening processes have carried out insertion on eight different materials of plate and the general self-tapping screws with using mainly screw AB sizes 4, 6, and 8. These self-tapping screw sizes are the most common sizes in manufacturing. The corresponding theoretical profiles of a curve of the torque signature signal and rotation angle for each set of insertions have been also generated using the mathematical model by (Seneviratne et al., 2001). The mechanical properties of the plate materials have used the theoretical model that was obtained from (Ngemoh,1997). The average properties have used the provided data sheets that were the published texts and materials standards specifications (ASM V.1, 1990); (ASM V.2 ,1990); (Verlag, 1993); (Walsh, 1993); and (Bashford, 1997).

2. The Experimental Test Rig Setup

The Implementation of Screw Insertion System model (ISIS) has been integrated with three main factors. The first one is the screwdriver with the pilot materials for attempt to insertion screw. The second one is the instruments and sensor controller. This controller consists of the Rotary transducer or Torque sensor for capture a torque signature signal and the Optical Encoder for measurement the rotation angle during the on-line process. This controller is including the torque meter and manipulator equipments. The third one is the monitoring system based-on the parameter estimation has employed for prediction of the required parameters of the threaded fastening process. These factors have interfaced and implemented by the Graphical User Interface technique (GUI) using Matlab programming. More details on these equipments have described in next.

2.1 Tools and Manipulations

The tools and manipulations are necessary as input devices, which brought the input signal to the process. An electrically powered screwdriver has used with a torque range varying between 0.4 and 3.2 Nm to drive the screw into the hole for this experimental testing. An illustration this screwdriver present in Fig.1.

Figure 1. The illustration of screwdriver

2.2 The Instrument and Sensor Controller

The controller is main function to command the process that aims to control the instruments and sensors for the on-line operation. The integrated fastening process with GUI system has been employed and interfaced with the Data Acquisition (DAQ) card. The details of these devices are following.

2.2.1 Instrument and Sensor Controller

In Fig. 2, the rotary torque transducer has used in this experiment, which has attached to the shaft of the screwdriver between the end of screwdriver and the nut settings. This torque sensor is in position that can reduce the effects of inactive and friction associated of the gear and the drive motor and gears. This torque sensor is a measurement based on strain gauges with capable in measuring torque is in the range between 0 and 10 Nm with accuracy of 1% of full scale deflection.

Figure 2. Torque Sensor

The Torque sensor was electronically interfaced with a digital torque meter that is produced and used of a strain gauge amplifier.
The voltage output of torque reading from the torque meter is proportional to the measured torque during screw insertion into the hole. Each output voltage has corresponded to the maximum transducer capacity of torque at 10 Nm.

2.2.2 Optical Encoder

An optical encoder has used to measure the rotation angle of the screw. This optical encoder consists of an optical switch and a measured disc.
The optical switch has functioned with a light sensitive device with a built-in amplifier, the shape and wiring diagram are presented in Fig. 3. It was mounted on the torque sensor casing.
The optical switch used in this test to be model of UZJ272. Its performance is to fix on the focus reflective/u-shaped type of the micro-photosensors low-cost.

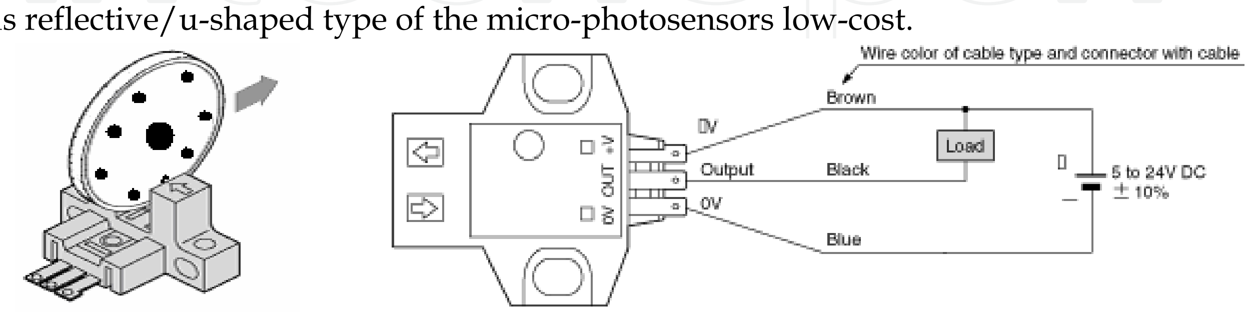


Figure 3.1 Optical Encoder   Figure 3.2 Typical wiring diagram

Figure 3. The application of Optical Encoder

A measurement disc has attached to the Torque sensor, which fixed at the shaft of the driver bit see Figs 2 and 8. This disc is perforated every 45° allowing 8 readings per revolution. Every time a hole in the plate is detected the opto-switch produces a voltage pulse by measurement strategy in Fig. 4.

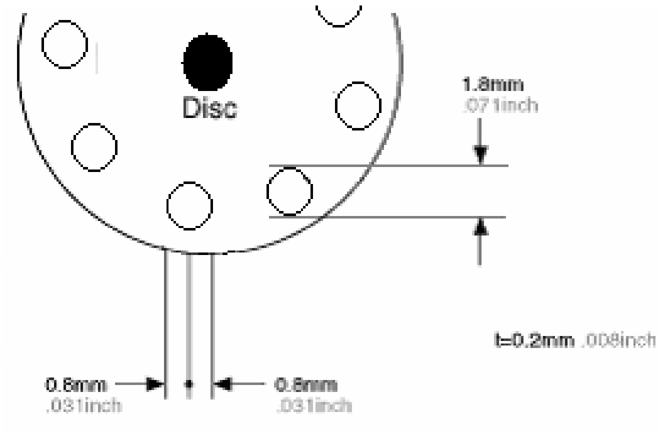


Figure 4. A measurement disc

The Optical encoder has a measurement resolution of 45°. This digital signal of a pulse voltage has been converted to the rotation angle (radial) during screw insertion. This application for reading signal on 8 holes as angle has present in Fig. 5.

Figure 5. Optical Encoder (Opto switch and Disc)

2.2.3 The Reference Label Box or Connector Box

This reference label box is used to select the channel, port number, and type of signal for system to identify during on-line process. This box has connected with the SH68-68 cable to the Multifunction DAQ card see Figs. 6 and 7. The details of the Multifunction DAQ card has described in next.

Figure 6. The wiring circuit in the Connector box

2.2.4 A Multifunction DAQ Card.

The multifunction DAQ 12 Bit Analog-Digital I/O card has used in this experimental test is product of National Instrument and Sensor (NI) with model “NI PCI 6024E”. This is required as PCI bus, which is the low-cost E Series multifunction data acquisition device. It provides the full functionality of I/O 68-pin male 0.050 D-type with voltage output range of ± 10 volts.

Figure 7 (a). A DAQ PCI card

Figure 7(b). A DAQ card with cable

Figure 7. Multifunction NI DAQ PCI 6024E card with application

In Fig. 7 has presented a multifunction DAQ that connected to the SH68-68 cable for install into a PCI slot on computer board. This card has used to archieved the signal from the sensors via the Connector box. The screwdriver attached the instruments with sensor controllers for this experimental test, shown in Fig. 8. The integrated component system (hardware) has applied for this experimental test of screw fastening system, which shown in Fig. 9.

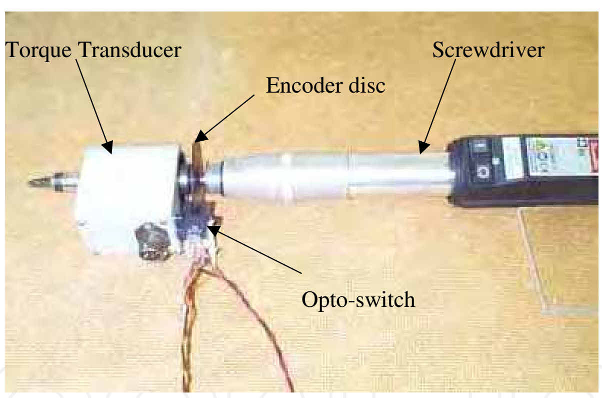


Figure 8. A screwdriver attached transducer and encoder

Figure 9. The screw fastening setup

3. Strategy for the On-Line Experimental Test

The experimental equipments are required to connect as the applied screw fastening software has implemented as the appropriated efficiency system with this integrated system has written using Graphic User Interface format (GUI) and Data Acquisition Toolbox of Matlab program to get signal from the torque sensor and optical encoder for Torque signature signal and rotation angle during the screw insertion. The captured signal has been applied the curve fitting and curve management techniques to identify the curve. The parameter estimation method has used the unknown parameters at this insertions. The details have presented the flowchart in Fig. 10.

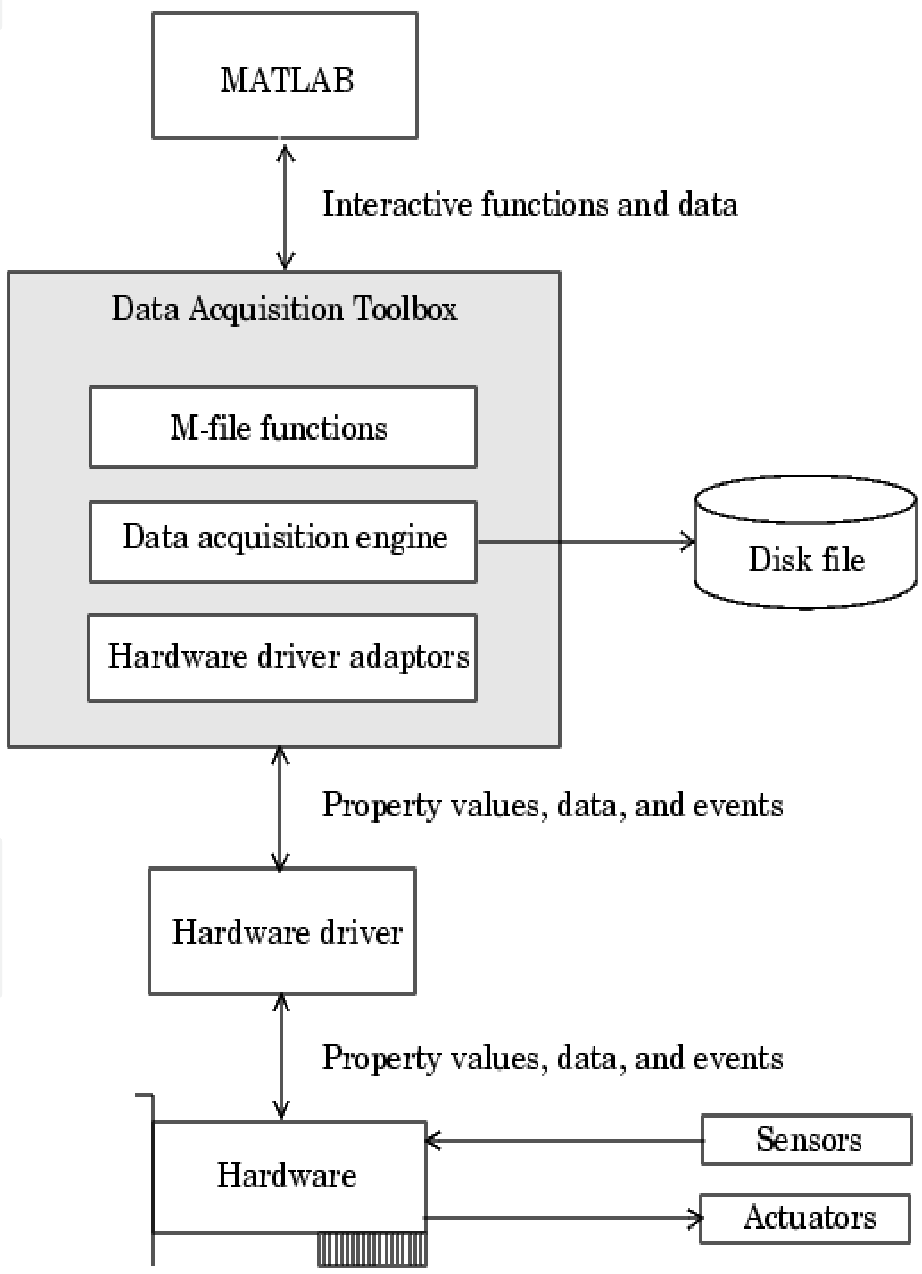


Figure 10. Flowchart of the on-line procedures

A flowchart in Fig. 10 presents the implemented procedure that applied the DAQ module to communicate between the screwdriver and the instruments and sensors.

The performance of the screw insertion identification tasks, the NRM technique is fed with torque-insertion depth signature signals. The screw insertions were performed with the use of a screwdriver. A torque sensor mounted at the tip of the screwdriver provides torque readings, and an optical encoder provides pulses, which are related to the screw rotation angle. The stream of pulses was integrated to determine the corresponding insertion depth. Model was developed and using the curve fitting technique to filter the signal. The experimental test rig prior to presentation to the on-line screw fastening process for the parameter identification has been described in next.

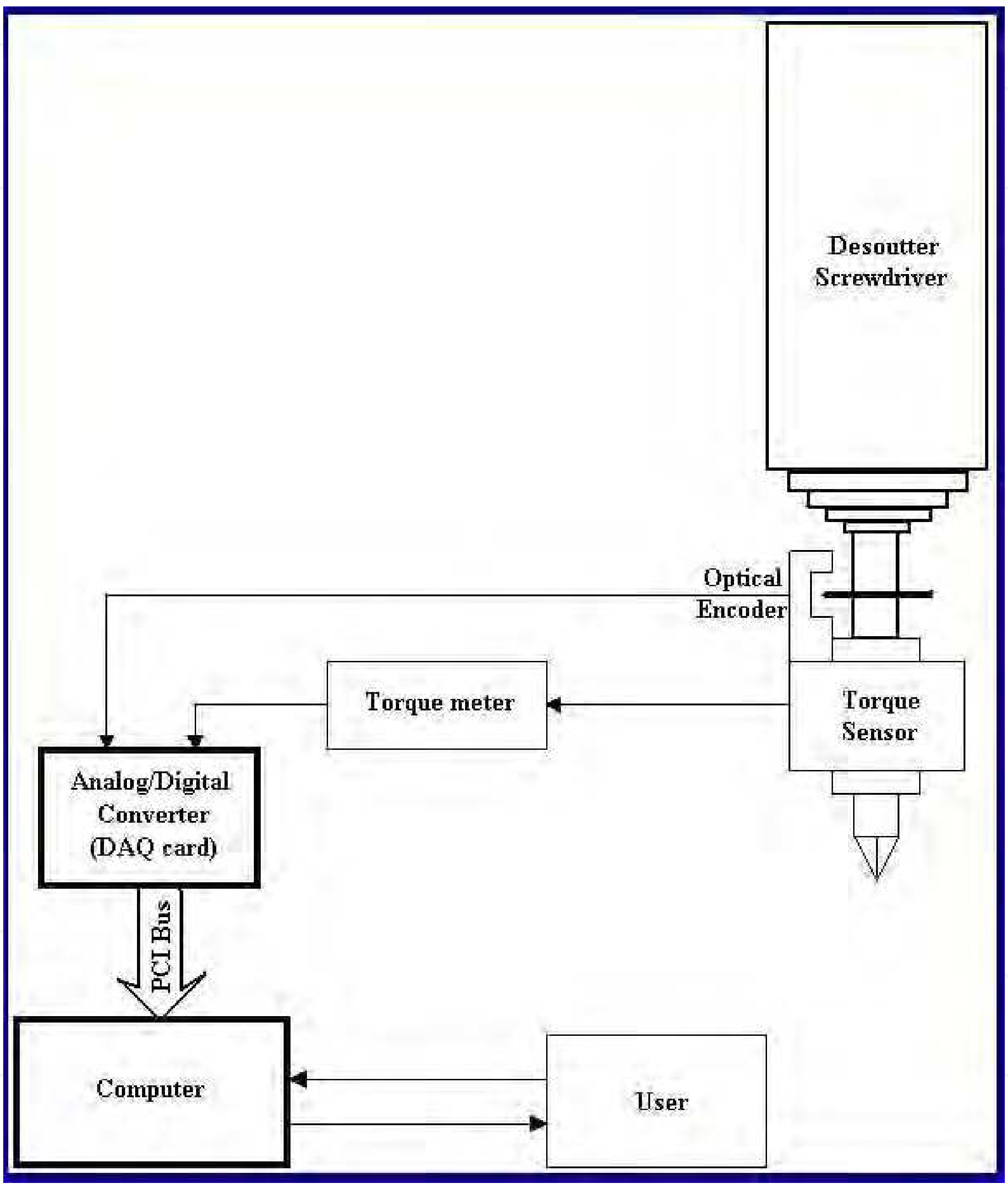


Figure 11. The overview of the experimental test rig

An online screw fastening process software has used to manage all instruments and sensors for the input task and interfacing with the screwdriver and linking with the monitoring based-on parameters estimation. The main functions of this control system have been implemented as GUI format. Reading the torque vs. time data from the torque transducer and the rotation angle vs. time data from the optical encoder. These online results can be presented the signal data in Fig. 12.

In this paper has used the monitoring technique based on parameter estimation to validate the experimental tests with simulation tests (theoretical model). The parameter estimation based on Newton Raphson Method has used to identify the unknown parameters. This estimation algorithm has applied to the torque signature signal after fitting the smooth curve by the curve fitting technique. This curve fitting technique has described more details in next.

3.1 Curve Fitting Technique on the Experiment

The smooth curve can be fitted and applied to the experimental signal. Using the interpolating polynomial of nth degree then we can obtain a piecewise use of polynomials, this technique is to fit the original data with the polynomial of degree through subsets of the data points.

This result is quite suitable approach as a least square fit algorithm. That has applied these fitting on points with the exactly points so close to actual curve when has been validated with theoretical curve.

Curve fitting to measure the signal data is a frequently occurring problem. These signals are two vectors x and y of equal size. The situation is aims to fit the data because being a dependency of y on x in form of a polynomial. The method of least squares can be used to solve the over constrained linear system which gives the coefficients of the fitting polynomial. Therefore, the higher degree polynomial has represented the dependency for this fitting technique.

For a given data set (x; y) - where x and y are vectors of the same size. The least square technique can be used to compute a polynomial for that best fits these data has used a polyfit function at the degree of the fitted polynomial (Klingajay & Giannoccaro, 2004).

An illustration problem on this technique has applied on experimentally with the relationship between two variables x and y that have recorded in a laboratory experiment in Fig. 12 (a). However, this captured curve has been fitted for a new validated smooth curve with the curve fitting algorithm has described in next.

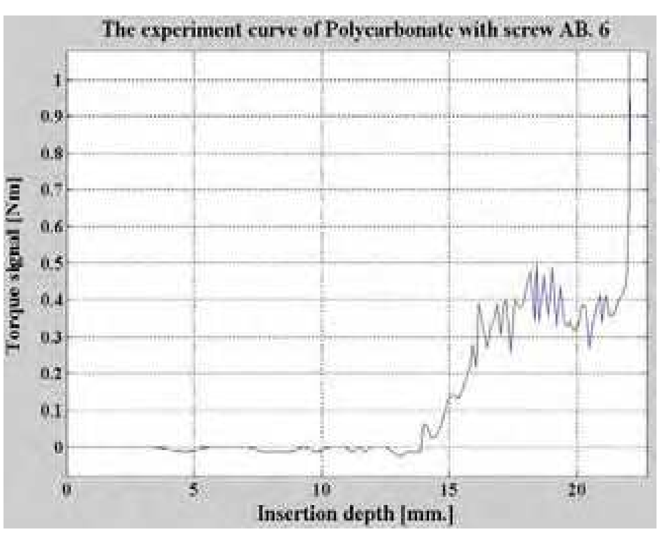


Figure 12 (a). An On-line signal.

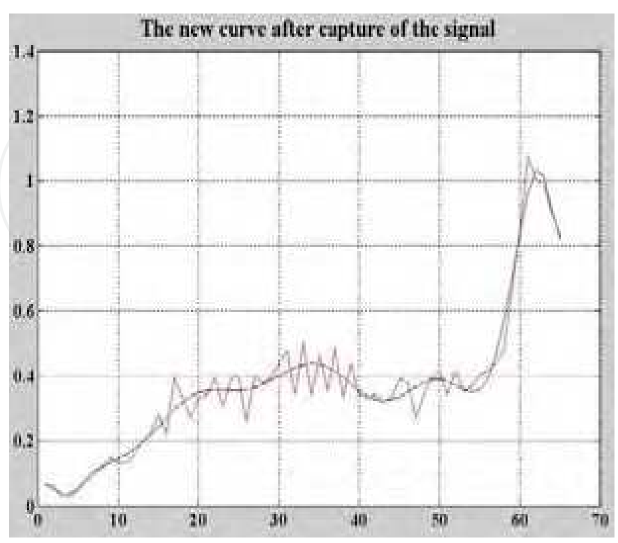


Figure 12 (b).A curve of fitted signal.

Figure 12. The noise reduction using curve fitting strategy.

In Fig. 12 (a) shows a captured curve from the experimental test during on-line insertion. The curve fitting strategy based-on Least Square technique has been applied to fit on this captured curve.

This a new smooth curve after fitting process has presented in Fig. 12(b). The on-line curve has been adjusted for the actual starting point of insertion then the new smooth fitted curve has presented the experiment torque signature signal that can be compared with the theoretical curve in Fig. 13.

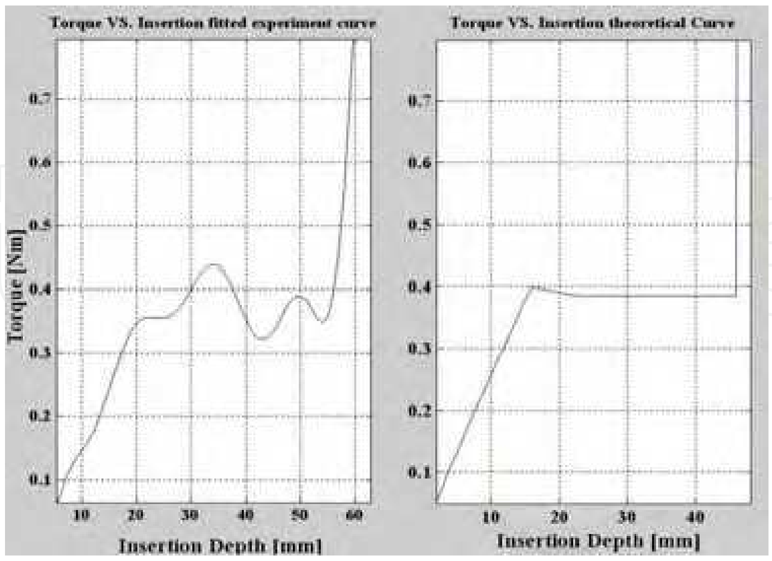


Figure 13. The theoretical and experimental curves.

3.2 The Experiment Curve Identification

The screw insertion process has been described on the required parameters depend on the each equation in the five different stages of insertion. Therefore, this NRM algorithm has applied with screw insertion process that required the exactly Displacement of depth, which has applied for those curves in each stage. Thus, the curve identification technique has become the important technique to employ for recognition the curves of the torque signature signal and displacement of depth of insertion.

Basically, the actual curve of the torque signature signal and rotation angle is the non-linear curve as being discontinue in each stage of insertions. These stages have divided the nature curves that could be generated from simulation tests or captured during experiment tests.

	Experiment Properties	
Material and Plate Properties	Material type	Polycarbonate
	Tap Hole Diameter (D_h)	2.0 mm (0.0020 Meters)
	Tensile Strength (σ_{UTS})	45Mpa
	Yield Strength (σ_Y)	45Mpa
	Elastic Modulus (E)	2.35Gpa
	Coefficient of Friction (μ)	0.19
	Tap (far) plate thickness (T_2)	3 mm (0.003 Meters)
Screw Properties	Screw type	AB No. 6
	Screw major diameter (D_s)	3.42mm (0.00342 Meters)
	Screw head diameter (D_{sh})	6.52mm (0.00652 Meters)
	Screw thread pitch (P)	1.19mm (0.00119 Meters)
	Screw taper-length (L_t)	2.94mm (0.00294 Meters)
	Screw total threaded-length (L_s)	9.67mm (0.00967 Meters)

Table 1. Parameters for insertion of Polycarbonate and screw AB 6

The screw, material, and plate properties in Table 1 have been used to produce the simulation screw insertion curve in Fig. 14(a).
This insertion curve has been identified the insertion stages of stages 2, 4, and 5, shown in Figs. (14 (b) - 14 (d)).

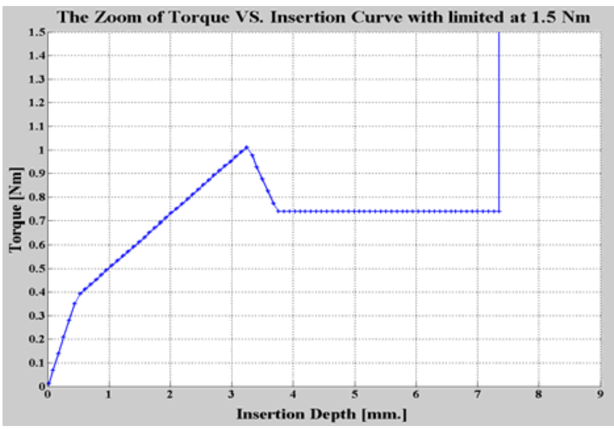


Figure 14(a). The torque as fastening process

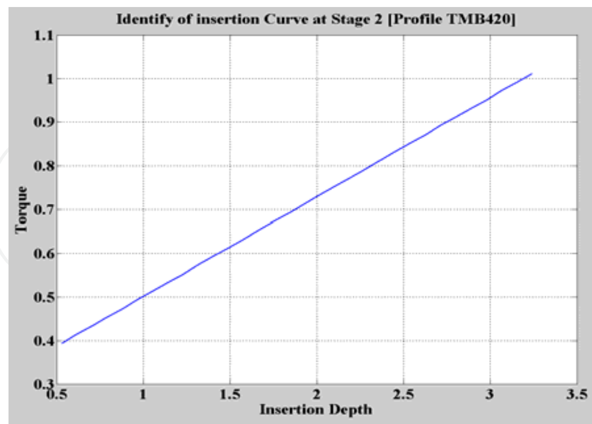


Figure 14(b). The identified torque at stage 2

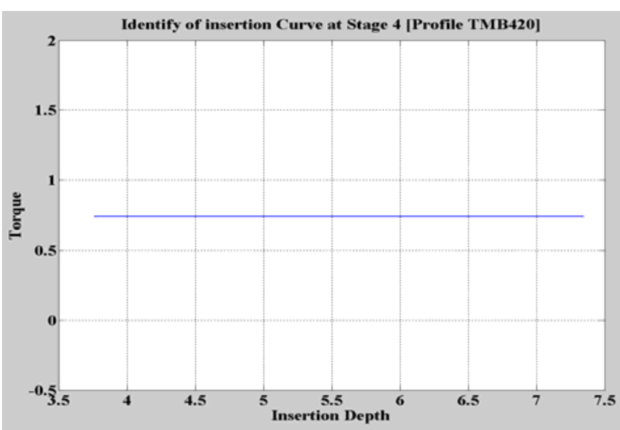


Figure 14(b). The identified torque at stage 4

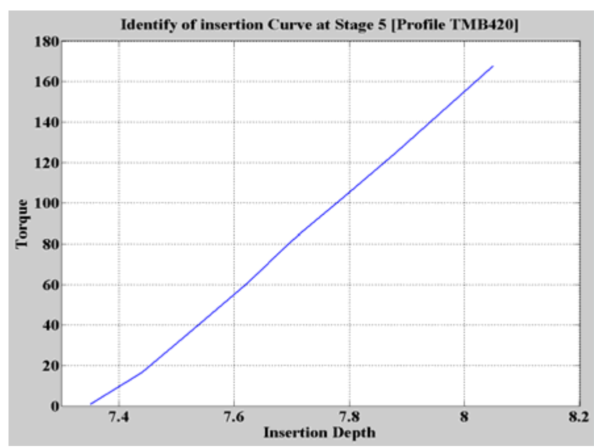


Figure 14(b). The identified torque at stage 5

Fig. 14. The curve torque signature signal for screw AB6 with Polycarbonate.

The identified insertion curve at stages 2, 4, and 5 have shown in Figs. 14(b), 14(c), and 14(d) respectively. This behaviour presented to status of the screw that had turned from starting until the final of tightening been reached. These stage curves have used to estimate for the experiment of parameter identification. The methodology of parameter estimation has discribed in next.

4. Methodology of Parameter Estimation

In this paper present what is probably the most commonly used techniques for parameter estimation. The appropriable techniques for the particular attention in this paper devote to discussions about the Newton Raphson Methods is a choice of appropriate minimization criteria and the robustness of this application. The monitoring strategies have been applied the parameter estimation techniques to validate the screw insertion process in this experimental test.

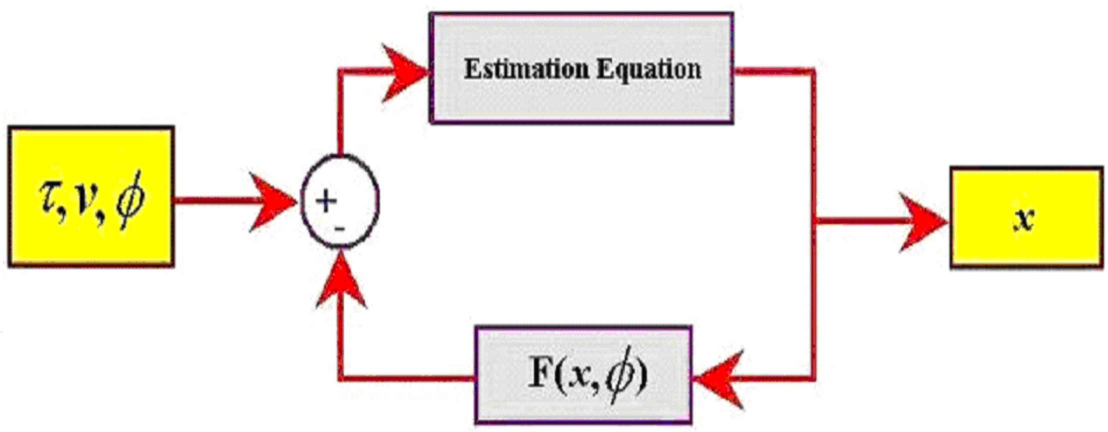


Figure 15. Estimation Parameters Scheme

Fig. 15, presents the scheme of the monitoring based on Parameter Estimation process. The main contribution of this paper is to apply the methodology for the estimated parameter application based on Newton Raphson Method (NRM) for screw fastening process with testing on the torque signature signal VS. insertion angle using the insertion stage 2. The model of monitoring has implemented with the estimation parameters Scheme in Fig. 15. In this Scheme, the required parameters have read the input data with contain both known and unknown parameters. A V vector consists of known parameters, the rotation angle (ϕ), a torque signature signal (τ), and the unknown parameter (vector xn) is an initialed value.

5. Analytical Model for Parameter Estimation

The focus on the experimental test parameter estimation based on NRM, which is the non-linear estimation parameter techniques that can solve problem over threaded fastening for screw insertion process. With parameters on the screw properties, plate properties, and material properties including friction and Ds, these techniques have been applied to predict two unknown parameters in this paper.
The two unknown parameters are required by the mathematical model can be estimated reliably on-line. experimental results without noise is presented to validate the estimation procedure in this paper. A self-tapping screw geometry and analytical model is mentioned in Ngemoh (Ngemoh, 1997), (Seneviratne et al., 1992), and (Klingajay & Seneviratne, 2002) that consist of five equations corresponding to each insertion stage:

$$\tau_1 = \frac{1}{\alpha} R_s A_c \sigma_{UTS} \cos\theta . \phi + \mu R_f K_f \sigma_f \cos\theta(\phi) \quad (1)$$

$$\tau_2 = R_s A_c \sigma_{UTS} \cos\theta + 2\mu R_f K_f \sigma_f \cos\theta(\phi - \alpha) \quad (2)$$

$$\tau_3 = \frac{1}{\alpha} R_s A_c \sigma_{UTS} \cos\theta + \mu R_f K_f \sigma_f \cos\theta (\phi_b + \phi) \quad (3)$$

$$\tau_4 = 2\mu R_f K_f \sigma_f \cos\theta (\phi_b) \quad (4)$$

$$\tau_5 = \left[\left(\frac{\mu\left(D_{sh}^3 + D_s^3\right)}{3\left(D_{sh}^2 - D_s^2\right)}\right) + \left(\frac{D_s + D_h}{4}\right) * \left(\frac{\pi\mu\left(D_s + D_h\right) + 2P}{\pi\left(D_s + D_h\right) - 2\mu P}\right)\right] * \left[\frac{K_{th} * K_{tb}}{K_{th} + K_{th}}\right] \quad (5)$$

Equations (1 – 5) can be written as

$$\tau = F(X, \phi), \quad (6)$$

Where ϕ is the screw angular rotation, X is the vector of system parameters:

$X = [D_h, D_r, D_s, D_{sh}, P, L_s, L_t, T_1, T_2, E, \mu, \sigma_Y, \sigma_{UTS}]$.

Where D_h = Tap Hole Diameter
- D_r = Screw root diameter
- D_s = Screw major diameter
- D_{sh} = Screw head diameter
- P = Screw thread pitch
- L_s = Screw total threaded-length
- L_t = Screw taper-length
- T_1 = Tap (near) plate thickness
- T_2 = Tap (far) plate thickness
- E = Elastic Modulus
- μ = Coefficient of Friction
- σ_Y = Yield Strength
- σ_{UTS} = Tensile Strength

Equations (1 -5) and the following variables $[\theta, \alpha, \beta, A_c, \phi_b, K_{th}, K_{tb}, R_s, R_f, K_f]$ are all a function of X, and are given and mentioned in (Seneviratne et al., 1992) and (Klingajay & Seneviratne, 2002). These equations have more details in Appendix. Thus given the system parameter vector ($D_h, D_r, D_s, D_{sh}, P, L_s, L_t, T_1, T_2, E, \mu, \sigma_Y, \sigma_{UTS}$), these parameters are important parameter that to be both variable and fixed parameters. These required parameters can be used to predict the torque signature signals. As the torque signature signal at stages 1 and stage 3 is very small value and too difficult to apply. Therefore, the torque signal at stages 2, 4, and 5 are used to investigate in this paper. An estimation parameter has been employed to predict the unknown parameters on the torque signature during screw insertion. As the torque signature signals are non-linear, therefore, the technique is applied with the multi-phase regression with all required parameters on the screw properties, plate properties, and material properties, including friction. The common methods often used is the Newton-Raphson Method. This methodology has been applied with the appropriate ability for this work on simulation tests and experimental tests (Klingajay et al., 2004).
This paper has used the mathematical model that is presented in (Seneviratne et al., 1992); (Seneviratne et al., 2001); (Klingajay et al., 2002). A model of the self-tapping screw fastening process has used the equation of five stages. Initially, the stage 2 equations, that is the torque required to drive the screw from screw engagement till initial breakthrough is used for parameter estimation in equation (2), can be rewritten as:

$$\tau_2 = f(\mu, \theta, \sigma_{UTS}, \beta, \phi, D_s, D_h, L_t, P) \quad (7)$$

In conventional estimation theory, these parameters of screw insertion are generally determined using the technique of numerical method with the initial value and number of independent samples. The field of optimisation is interdisciplinary in nature, and has made a significant impact on many areas of technology. As the result, optimisation is an indispensable tool for many practitioners in various fields. Usual optimisation techniques are well established and widely published in many excellent publishing, magazines, and textbooks depend on their applications. For all their complexity, the algorithms for optimising a multidimensional function are routine mathematical procedures. An algorithm of Newton-Raphson Method (NRM) has developed and used for inversion purposes is presented. It achieves convergence in about nth iterations and produces exact values of the parameters depends on the number of unknown parameter that is going to apply. The curves of torque signature and insertion angle signal are simulated using the successful data from Ngemoh (Ngemoh, 1997) to validate in different screw, material, and plate properties.
The Newton Raphson Method (NRM) is based on the generalitazion with considering for the j^{th} function f_j of n functions $\{f_1, f_2, . f_n\}$ that define our system. This is to calculate the total derivative as sum of partial derivatives respect to the n variables $\{x_1, x_2,\ldots x_n\}$ of the functions (Klingajay & Seneviratne, 2003).

However, this model requires various parameters as input, before the torque signals can be predicted and used to automate the operation. Both equations (2 and 7) can be revised for the two unknown parameters as:

$$\tau_2 = F(V, x, \phi)$$

Where V is the vector of known parameters ϕ is the screw rotation angle, and x is the vector of two unknown parameters in this identification for two unknown parameters of Friction (μ) and Ds that can be followed:

$$x = \begin{bmatrix} \mu \\ D_s \end{bmatrix}$$

The NRM works by modifying the unknown parameters in order to force an error function to approach zero:

$$\boldsymbol{f}(x, \phi)=\tau_2(\phi)-F(V,x,\phi). \tag{8}$$

Rotation angle ϕ is chosen here as the independent variable, and the remaining parameters are investigated as a function of ϕ. The error function f(x, ϕ) is sampled at two distinct instances of ϕ, providing two independent equations, which can be solved in an iterative manner to find the two unknown parameters by generate two equations by sampling at two angle locations (Klingajay et al., 2003):

$$\boldsymbol{f}_1(x, \phi_1) = 0 \text{ at } \phi_1$$

$$\boldsymbol{f}_2(x, \phi_2) = 0 \text{ at } \phi_2$$

Let $\bar{x}(k)$ be the kth estimate of the unknown parameters. Applying the NRM, x can be calculated iteratively:

$$\bar{x}(k+1)=\bar{x}(k)-J^{-1}\begin{bmatrix} f_1(x,\phi_1) \\ f_2(x,\phi_2) \end{bmatrix} \quad (9)$$

Applying Equation (9) iteratively until the error is reduced to a value close to zero will provide an estimate of the unknown parameters.

7. Test Results

The estimation algorithm is implemented and tested. The screw and material properties in Table 1 is used.

The integrated system has implemented in Graphic User Interface format (GUI) and linked-up with the Data Acquisition Toolbox in Matlab to get the signal from the torque sensor and optical encoder. The designed system has presented in Fig. 16, the estimated results have shown in Figs. 17.

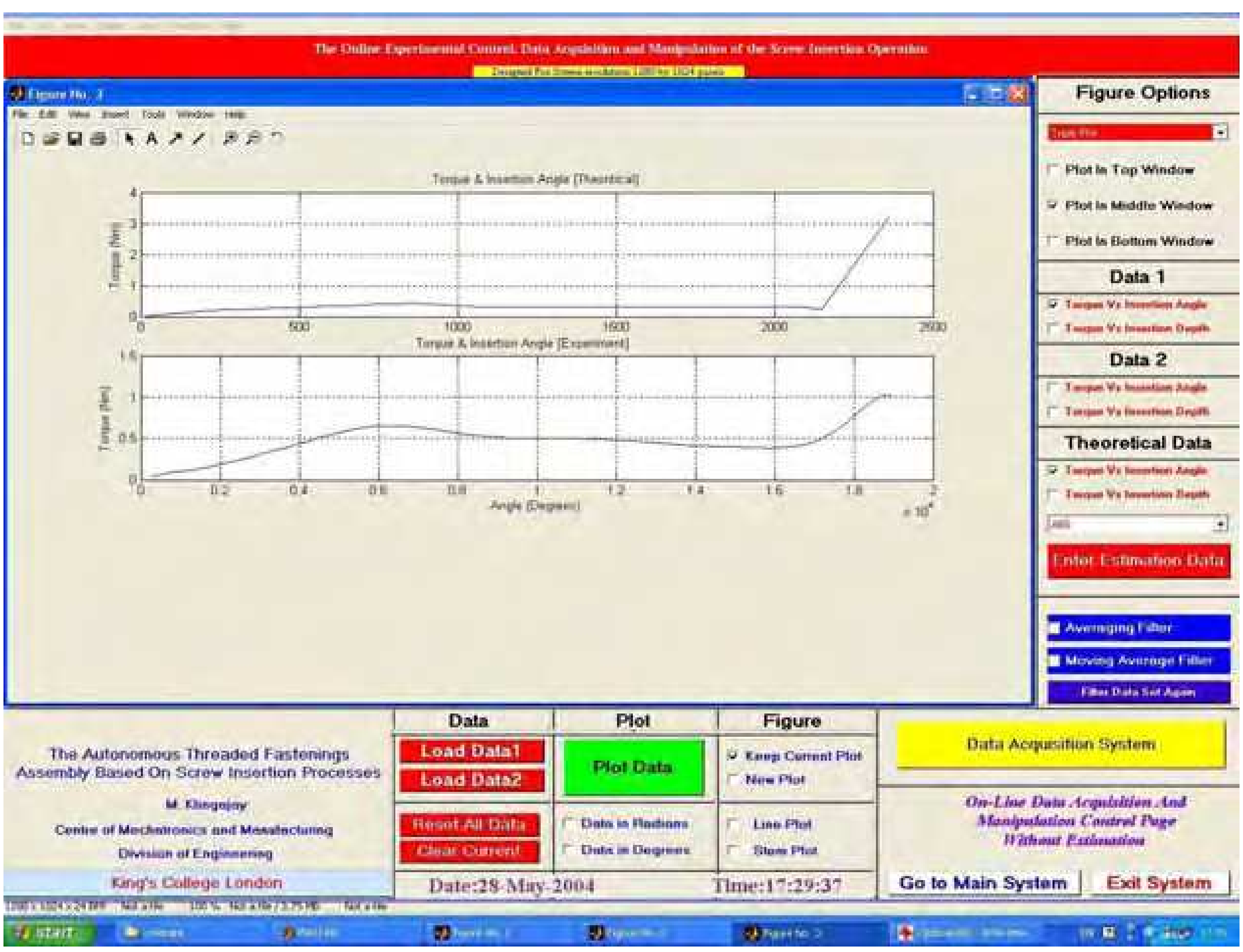


Figure 16. The online integrated system for threaded fastening (GUI)

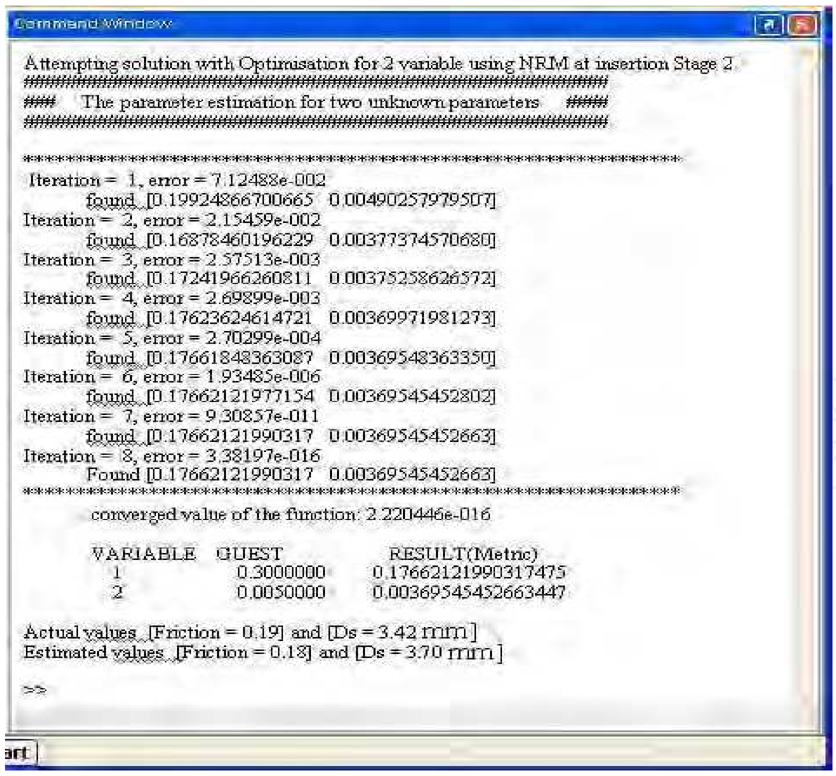


Figure 17. The experimental results estimating μ and Ds

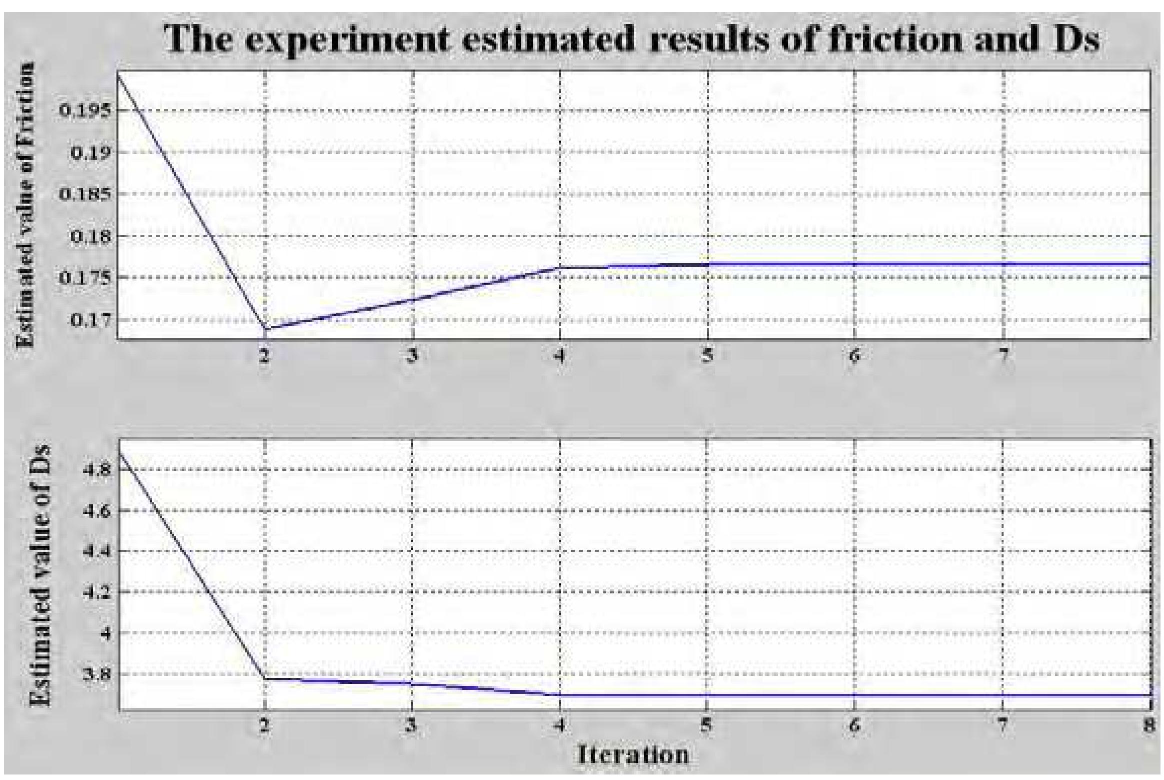


Figure 18. The estimated parameters without noise

Fig. 18, shows the estimated parameters of μ and Ds, the estimated values of these parameters are 0.18 mm. and 3.69 mm. However, these actual values of these parameters are 0.19 mm. and 3.42 mm. The percentage errors of these parameters of μ and Ds are 5.26% and 8.18% respectively, see Fig. 19 (Klingajay & Giannoccaro, 2004).

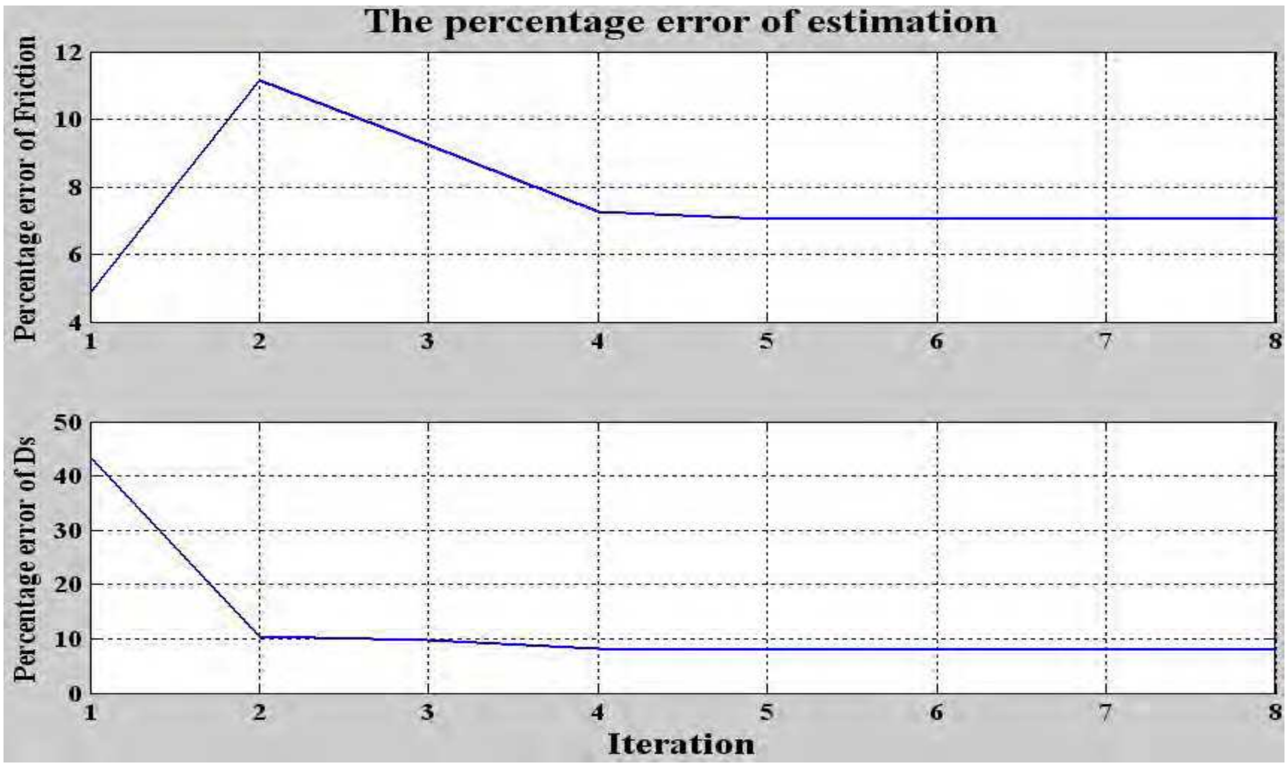


Figure 19. The percentage error of estimation without noise

8. Conclusion

The experimental tests have presented the validation of estimated parameters with the experiment data from [Ngemoh97] to validate. The test results has shown that the estimated parameters can be identified up-to four parameters for this experimental tests.

9. APPENDIX : Equations for Torque Signature Signal

The mathematical model given in [1,2] is concluded below.
The torque signature curve is shown by five differences stages (Klingajay et al., 2003):

Stage 1 - Screw Engagement $\{ 0 \le \phi \le \alpha \}$
$\tau_1 = 1/\alpha \, R_s A_c \, \sigma_{UTS} \cos \theta . \phi + \mu R_f K_f \sigma_f \cos\theta(\phi)$

Stage 2 - ***Screw Breaks through*** $\{ \alpha \le \phi \le \phi_b \}$
$\tau_2 = R_s A_c \, \sigma_{UTS} \cos \theta + 2\mu R_f K_f \sigma_f \cos\theta(\phi - \alpha)$

Stage 3 - Screw Full-Breakthrough $\{\phi_b \le \phi \le \phi_{b} + \alpha \}$
$\tau_3 = 1/\alpha \, R_s A_c \sigma_{UTS} \cos\theta(\phi_b - \phi + \alpha) + \mu R_f K_f \sigma_f \cos\theta(\phi_b + \phi - \alpha)$

Stage 4 - Screw Sliding $\{\phi_b + \alpha \le \phi \le \phi_t \}$
$\tau_4 = 2\mu R_f K_f \sigma_f \cos\theta(\phi_b)$

Stage 5 - Screw Tightening $\{ \phi \ge \phi_t \}$

$$\tau_5 = \left[\left(\frac{\mu_h (D_{sh}^3 + D_s^3)}{3(D_{sh}^2 - D_s^2)} \right) + \left(\frac{D_s + D_h}{4} \right) \left(\frac{\pi\mu(D_s + D_h) + 2P}{\pi(D_s + D_h) - 2\mu P} \right) \right] \left[\frac{K_{th} K_{tb}}{K_{th} + K_{th}} \right] \left[\frac{P(\phi - \phi_t)}{2\pi} \right]$$

10. References

ASM V.1 (1990). Properties and Selection: Irons, Steels and High Performance Alloys, Metals Handbook Vol.1, ASM International, 1990.

ASM V.2 (1990). Properties and Selection: Non-ferrous alloys Special-purpose Materials, Metals Handbook Vol.2, ASM International, 1990.

Bashford, D. (1997). Thermoplastics Databook, Chapman and Hall, London, 1997.

Bruno, L. G. (2000). Intelligent Monitoring of Screw Insertions, Ph.D.Thesis, University of London, 2000.

Fisher, R. A. (1959). Statistical Methods and Scientific Inference, Oliver & Boyd, London, Second Revised Edition, Hafner Publishing Co., New York, 1959.

Klingajay, M. & Seneviratne L.D.(2002). Friction Estimation in Automated Screw Insertions, Proceedings of International Symposium on Robotics&Automation (ISRA2002), 2002, Vol.1, pp.682-688.

Klingajay, M.; Seneviratne, L. D. & Althoefer, K. (2002), Parameter estimation during automated screw insertions, Proceedings of 2002 IEEE International Conference on Industrial Technology (ICIT'02), 2002, Vol. II, pp.1019-1024.

Klingajay, M.;, Seneviratne, L.D. & Giannoccaro, N.I. (2003). Optimization of four estimated parameters for autonomous threaded fastenings, Proceedings of 12th International Workshop on Robotics in Alpe-Adria-Danube Region, RAAD2003, 2003, Italy.

Klingajay, M.; Seneviratne, L. D.; Althoefer, K. & Zweiri,Y. (2003). Parameter Estimations for threaded assembly based on the Newton Raphson method, Proceedings of 2003 IEEE the seventh International Conference on Automation and Technology(Automation2003), 2003, Vol.1, pp. 864-869.

Klingajay, M.; Seneviratne, L. D. & Althoefer, K.(2003). Identification of threaded fasteningparameters using the Newton Raphson Method, Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2003), 2003, Vol.1, pp.5055-2060.

Klingajay, M. & Giannoccaro, N. I. (2003). Parametric Estimation of Autonomous Threaded Fastenings Operation based on Non-linear Least Square Method, Proceedings of the ISCA 16th International Conference: Computer Application in Industry and Engineering (CAINE 2003), 2003, USA, Vol. 1, pp. 211-215.

Klingajay, M. & Giannoccaro N. I. (2003), Comparison between Least Square & Newton Raphson for Estimation Parameters of an Autonomous Threaded Fastenings, Proceedings of 2003 IEEE International Conference on Industrial Technology (ICIT'03), 2003, Vol. 1, pp.163-168.

Klingajay, M.; Seneviratne, L. D. & Althoefer, K.(2004). Model Based Automation Strategies for Threaded Assembly Systems, Proceedings of International Federation of Automatic Control (IFAC), Problems in Manufacturing (INCOM2004), 2004, Brazil.

Klingajay, M.; Giannoccaro, N.I. (2004). The Automated Threaded Fastening Based on On-line Identification, International Journal of Advanced Robotic Systems (IJARS), December, 2004, Vienna, Vol. 1, No. 4, pp. 263-272.

Ngemoh, F.A. (1997). Modelling the Automated Screw Insertion Process, Ph.D.Thesis, University of London. 1997.

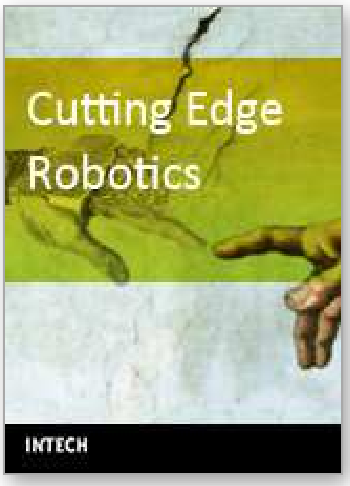
Seneviratne, L.D.; Ngemoh F.A. & Earles S.W.E. (1992). Theoretical Modeling of Screw Tightening Operations, Proceedings of ASME European Joint Conference on Systems, Design and Analysis, 1992, vol. 1, pp.189-195.

Seneviratne, L.D.; Ngemoh, F.A.; Earles, S.W.E. & K. Althoefer (2001). Theoretical modelling of the self-tapping screw fastening process, Journal of Mechanical Engineering Science (IMechE), Part C, Vol. 215:pp.135-154, 2001.

Verlag, C.H. (1993). Plastics for Engineers: Materials, Properties and Applications, Munich Germany, 1993.

Visuwan, P. (1999). Monitoring Strategies for Self- Tapping Screw Insertion Systems, Ph.D.Thesis, University of London, 1999.

Walsh, R. A. (1993). Machining and Metal working handbook. McGraw-Hill, 1994.



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