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Expert System for Grade "A" Hexagonal Bolts and Nuts Design and Drafting for Manufacturing Industry Production

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***Abstract*-**Hexagonal bolts and nuts are the most important and common fasteners used for various mechanical devices. Their production either by machining, casting or forging process required selection of accurate technical parameters and precisioned equipment for their effective and quality production. The world is going out of paper documentation towards a computer data-based system to increase productivity, reduced space and quick management of stored data. This research identified nominal size, thread pitch, thread length(R); washer face thickness(W); fillet transition diameter(T); under head fillet maximum(U); minimum washer face diameter(E); the maximum and minimum head height(H); maximum and minimum width across the flat(F); minimum width across the corner(G); and minimum wrenching height(K) of hexagonal bolts found in designed manual, journals and textbook and create a data-based for all these parameters using Grade "A" Hexagonal bolts and nut only as a case study due to variance and complexity of different bolts and nuts. A software model Expert System was developed for decision making by providing all the required parameter for Grade "A" Hexagonal bolts and nuts production the moment the nominal size required is supplied. This software (HexES) used this data to generate graphic picture of the hexagonal bolts and nuts with their specification and the hard copy printed out for the production department of the manufacturing industry for the production of the required nominal size of the bolt and nut.

Keywords- *Bolts and Nuts, Grade "A" Size, Manufacturing Industry, Parameter, Production, Software Development*

I. INTRODUCTION

An expert system is a computer programme capable of using knowledge base embedded system to solve problems, making decision or gives an advice like a human expert in situations where need be.

"Fasteners are mechanical devices used to join two parts together for easy disassembling and reassembling". [1] A Bolt is a strong fastener with external threading designed to go through holes in assembly parts. A nut is a type of fastener with an internal threading (hole), often used with a mating bolt to join assembly parts together.

The choice of type of fastenings and its location are very important. The fastenings should be located in such a way so that they will be subjected to tensile and or shear loads and bending of the fastening should be reduced to minimum [2].

The bending of the fastening due to misalignments, tightening up loads, or external loads is responsible for many failures. [3] In order to relieve fastenings of bending stress, the use of clearance spaces, spherical seat washers, or other devices may be used [4].

Landgraf (1998) listed stresses in screw fastening due to static loading as: internal stress due to screwing up forces; stresses external forces and stresses due to the combination of the aforementioned stresses and expressed the initial tension in a bolt, based on experiments [5]. Landgraf expression may be found by the relation:

$$P_i = 2840\ dN \quad (1)$$

Where P_i=Initial tension in a bolt, and d=Nominal diameter of bolts in mm.

He added that above relation are used for making a joint fluid tight like steam engine cylinder joints**.** When the joint is not required as tight as fluid-tights joint, then the initial tension in a bolt may be reduced to half of the above value.

$$P_i = 1420\ dN \quad (2)$$

The small diameter bolts may fail during tightening, therefore bolts of smaller diameter (less than M16 or M18) are not permitted in making fluid tight joints [6].

Blake and Kurtz (2007) said the stress could be obtained using the relation: [7]

$$\text{Stress area } [\delta_a] = \frac{\pi}{4}\left(\frac{d_p+d_c}{2}\right)^2 \quad (3)$$

Where d_p=Pitch diameter, and d_c=Core or minor diameter

Many other parameters than these are to be design for in bolts and nuts production. But all these have been factored into design chart made available in production manual which this model used as data-based for supplying production details required for the Hexagonal Bolts and Nuts Grade "A".

According to America Society of Mechanical Engineers (ASME) the bolt threads and those of the matting nut are designed to be complementary [8]. Turning the mating nut normally tightens or releases the bolt. Apart from difference in height; hexagonal bolt and nut are of the same dimensions.

Importance of bolts and nuts as fasteners in hardware production cannot be over emphasis and there is market always for its production all over the world. Many manufacturing companies are yet to be involved in application of software or expert system capable of design and drafting a Hexagonal Bolts and Nuts [9]

Since hexagonal bolts and nuts are most common and important fasteners, their economic value and importance to the production sector of the economy cannot be overemphasis. Therefore, this study focused on the development of an expert system called "HexES" which is the acronym for Hexagonal Expert System that uses adopted acceptable design data as artificial intelligence support system for design and drafting of Grade-A hexagonal bolts and nuts.

A. Expert System (ES)

"Expert systems are designed to make available some of the skills of an expert to non-experts" [10]. In other words it is an artificial intelligent system that acts and functions like human expert. The history of Expert Systems has been one of the bright spots of artificial intelligence research; it had been one of the few areas in which the high expectations placed on the field were matched by successful and useful systems.

When properly built and well-focused; expert system can be used in solving unlimited problems that only specialist are left to answer. Applications of expert system include:

1. Weather analysis
2. Machine operations and performance monitoring
3. Forecasting due dates of activities
4. Maintenance of machinery as well as diagnosing their problems and proffer solutions
5. Allocating limited budget to equipment for their procurement just to mention few.

There is an expert system for diagnosing and proffering solutions to causes of overheating in Bulldozer Engine [11] and decision support system (DSS) for filter mechanics on Bulldozer power failure maintenance [12].

Over a century ago, expert systems have been developed for machine design and manufacturing. In 1998 Ernest Hall developed 'an expert system to design an automated guided vehicle' [13]. A system interfaced with CAD tool was used which generated a 3D solid model of the vehicle. Also Akinnuli and Babalola came up with software to determine industrial machinery optimal replacement period [14].

II. HEXAGONAL EXPERT SYSTEM

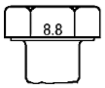
A. Grade-A Hexagonal Bolts and Nuts

The grade of a hexagonal bolt is determined by the strength of the material it is made of. In machine design; hexagonal bolts and nuts are made from steel because of it high strength, good durability, good machinability and formability.

Grade-A hexagonal bolts are class 8.8 metric bolts (ISO 4014) with metric thread pitch. They are made from carbon steel with other additive elements like Boron, Chromium or Manganese added in definite proportions. If medium steel is used it will undergo heat treatment process, quenched above transformation temperature in a liquid medium and tempered at 425^{o} C [15].

Their proof load and tensile strength vary according to their diameters. They have minimum proof load of $640N/mm^2$ and minimum tensile strength of $830N/mm^2$ [15]. Hence, Grade-A bolts have a preference for most applications and are often protected from corrosion by coating the surface. The details chemical composition of selected additive materials for Grade-A hexagonal bolts are as shown in table 1.

TABLE I. SELECTED ADDITIVES MATERIALS FOR GRADE-A HEXAGONAL BOLTS

	 Composition	
Material	Carbon Steel	Plain Carbon
Carbon	0.15-0.40%	0.25-0.55%
Phosphorus	0.035% maximum	0.035% maximum
Sulfur	0.035% maximum	0.035% maximum
Manganese	-	0.6% minimum
Elongation: 12% minimum		

Source: [5]

B. System Design and Development

Sequel to investigation results and the approval; is the design of the system named "Hexagonal Expert System". The team tactfully mapped out the procedures and resources needed to develop HexES successfully. The architectural design of the system is the design state that dictates precise operations and the necessary resources required for accomplishment of the desired result. A comprehensive and accurate documentation of various components of the system were spelt out with their functions and how these components integrate and interact with one another.

HexES Architecture design has a two-tier system consisting three major subsystems: the user interfaces through which the desired user gains access to input and retrieve records from the database. The database system; apart from housing the basic records, it contains in-built knowledge base and 'thinking' sub-systems known as the inference engine.

The design is for metric hexagonal bolts only and limited to bolts of metric types 'M1.6, M2, M2.5, M3, M4, M5, M6, M8, M10, M12, M14, M16, M20 and M24' [15].

HexES design comprises of the following major components:

i. User Interface System,
ii. Data Base System
   a) The knowledge base
   b) The interference engine

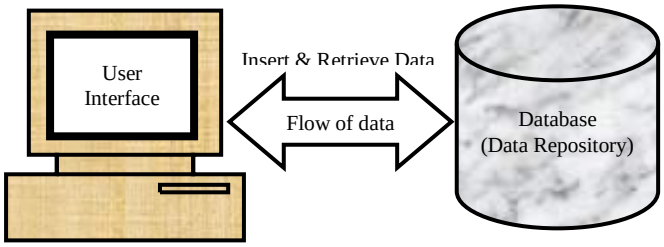


Figure 1. Architectural design of HexES

1) The User Interface Development:

The HexES user interface system contains sub-interfaces. Visual Basic (VB), a high level object-oriented program, it is a rapid application development environment for Windows platform and used in the development of the user interfaces. Each interface and its appropriate code form a module meant to proffer specific solution. The interfaces include menu generators and presentation components. VB is a common language providing Windows applications access to a database on a network, is very simple (user-friendly) and effective programming language with the ability to create beautiful user interfaces, write result-oriented codes, and to connect several database management systems. It runs on Microsoft Windows operating system platform, it performs well on Microsoft Windows 7 and higher versions.

2) Development of the Data Base System:

HexES has a database attached to it with in-built domain knowledge. Microsoft Access Database was adopted as the back-end database for the system. Visual Basic has a direct link to access database functionality; hence it serves as the front-engine and Microsoft Access as the back-engine.

Figure 2. A screen shot of HexES Interface Design Environment –IDE

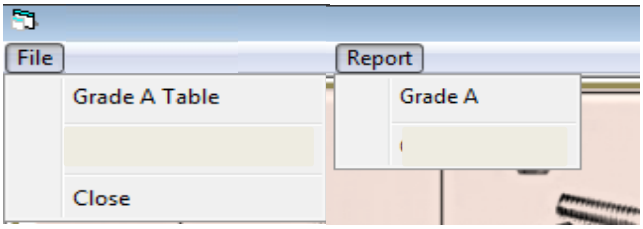


Figure 3. A screen shot of HexES menu bar

TABLE II. DETAILS OF ADOPTED ACCEPTABLE DESIGN DATA FOR HEXAGONAL BOLTS GRADE-A ISO 4014

Nominal Size	Thread Pitch	R		W		T	U	E	H		F		G	K
		Threaded Length		Washer Face Thickness		Fillet Transition Diameter			Head Height		Width Across Flat		Width Across Corners	Wrenching Height
		L < = 125 mm	L>125mm <= 200mm	Max	Min	Max	Max	Min	Max	Min	Max	Min	Min	Min
M1.6	0.35	9	-	0.25	0.1	2	0.6	2.27	1.225	0.975	3.2	3.02	3.41	0.68
M2	0.4	10	-	0.25	0.1	2.6	0.8	3.07	1.525	1.275	4	3.82	4.32	0.89
M2.5	0.45	11	-	0.25	0.1	3.1	1	4.07	1.825	1.575	5	4.82	5.45	1.1
M3	0.5	12	-	0.4	0.15	3.6	1	4.57	2.125	1.875	5.5	5.32	6.01	1.31
M4	0.7	14	-	0.4	0.15	4.7	102	5.88	2.925	2.675	7	6.78	7.66	1.87
M5	0.8	16	-	0.5	0.15	5.7	102	6.88	3.65	3.35	8	7.78	8.79	2.35
M6	1	18	-	0.5	0.15	6.8	104	8.88	3.85	3.85	10	9.78	11.05	2.7
M8	1.25	22	-	0.6	0.15	9.2	2	11.63	5.15	5.15	13	12.73	14.38	3.61
M10	1.5	26	-	0.6	0.15	11.2	2	14.63	6.58	6.22	16	15.73	17.77	4.35
M12	1.75	30	-	0.6	0.15	13.7	3	16.63	7.68	7.32	18	17.73	20.03	5.12
M14	2	34	40	0.6	0.15	15.7	3	19.37	8.98	8.62	21	20.67	23.36	6.03
M16	2	38	44	0.8	0.2	17.7	3	22.49	10.18	9.82	24	23.67	26.75	6.87
M20	2.5	46	52	0.8	0.2	22.4	4	28.19	12.715	12.285	30	29.67	33.53	8.6
M24	3	54	60	0.8	0.2	26.4	4	33.16	15.215	14.785	36	35.38	39.98	10.35
Tolerance on Length		12-16mm 0.15 0.35				20-30mm ± 0.42			35-50mm ± 0.5			55-80mm ± 0.6		
		9-120: ±0.7							130-150mm ± 0.8					

Source: Industrial Threaded Products Inc.

The adopted design data in Table 2 were read into the database through the user interface by clicking on 'Grade A Table' under File menu. The input interface for Grade A Table is displayed, after computing the design parameters click on Save/Update button to save them into the data base.

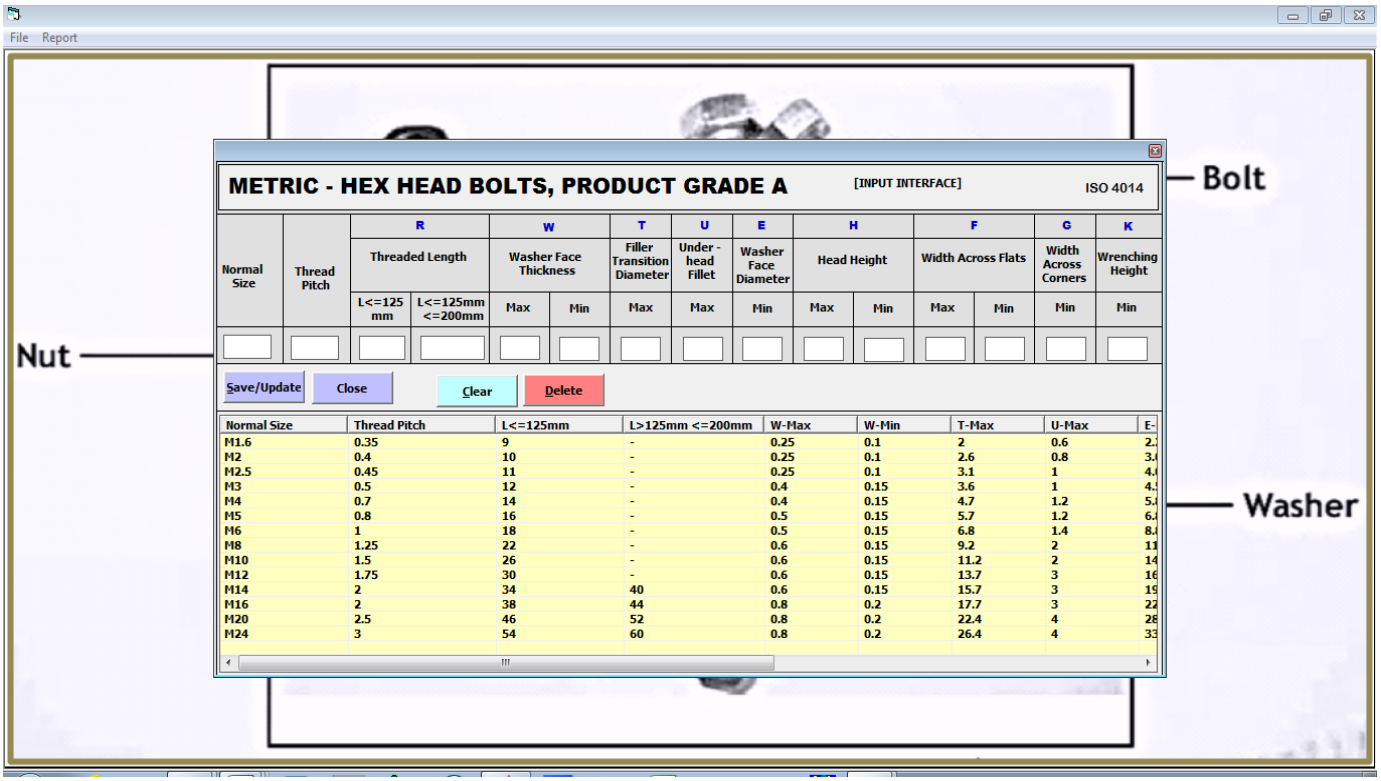


Figure 4. A screen shot of HexES input interface

The information acquired from our adopted design data is formatted into a structured knowledge that can be effectively act upon by HexES interference engine so that the software can select the exact bolt based on the decision or input of the user. The domain knowledge integrates various interactive knowledge and made them available for processing (when need be) to generate the required output.

C. Software Development and Implementation

Water fall model was adopted for the software development process of HexES because it is easier to implement. The description of the interfaces built and their functions are explained below:

1) Algorithm for the Development of HexES:

An algorithm is a distinct step by step computational procedure in procuring solution to a particular problem. It defines the sequence procedure for attaining input/output relationship needed to transmute input to output. Pseudo-code and flow charts are the most common notations used for expressing algorithm.

HexES algorithm is expressed with flowcharts as shown in Figure 5. The program when executed runs from 'Start' which is the initial position, process the input and finally generate an output before terminating at 'Stop' the last finish position.

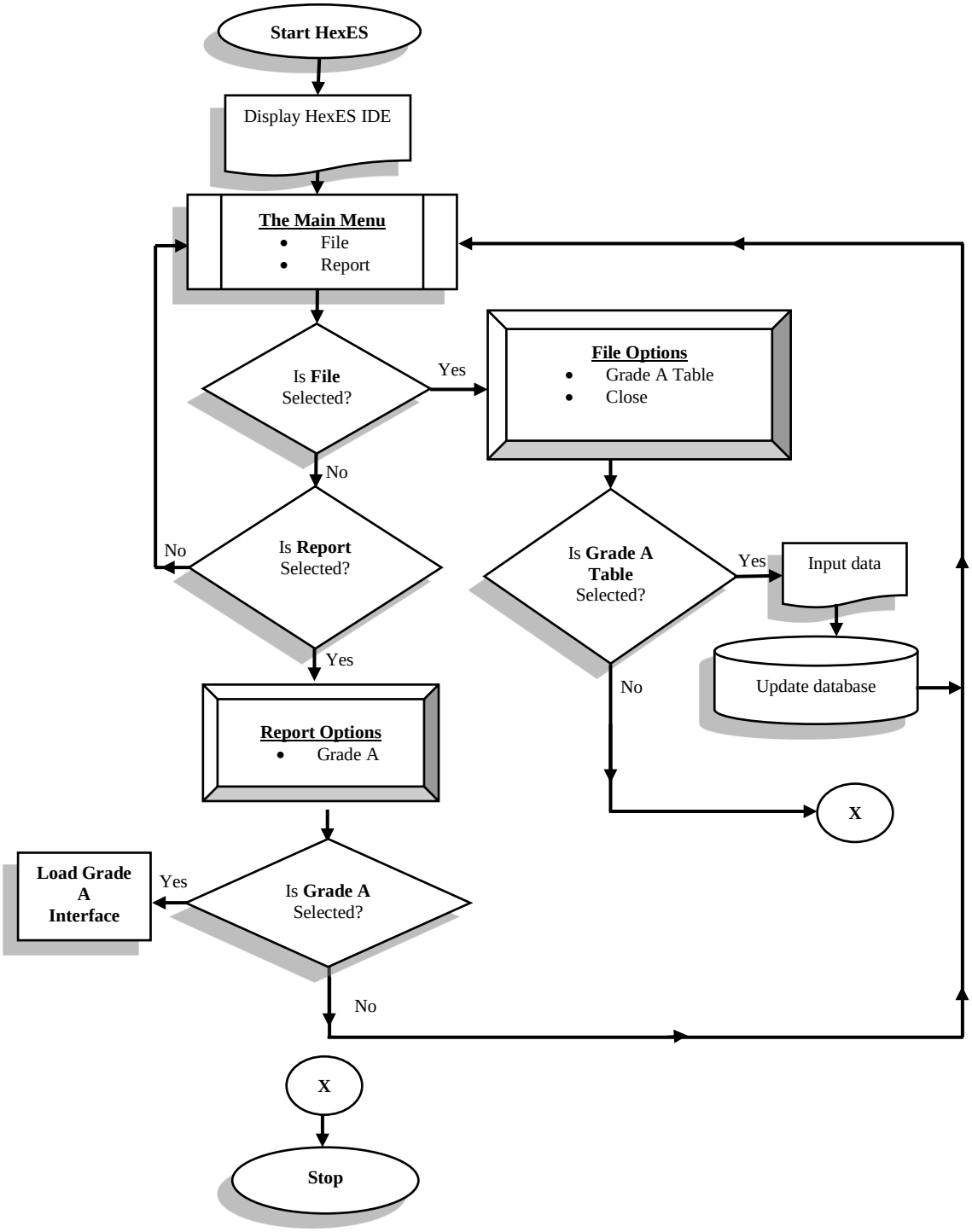


Figure 5. Algorithm (flow chart) for HexES

2) Glossary for the HexES Flow Chart:

Start: HexEs application start up and displays the splash screen

Ok: User decides to continue and load the Interface Design Environment (IDE)

Close or X button: The user clicks the X button to quit the application

IDE: It is a menu driven environment of the software that contains the main menus (File and Report).

Report: Is the second main menu on the Interface Design Environment (IDE). 'Grade A' sub-menu drops down if the user clicks on it.

Grade A: It loads Grade A bolts interface if the user clicks on it

File Menu: If the user clicks on it; 'Grade A Table' and 'Close' sub-menu drops down

Grade A Table: It is a sub-menu under file; if selected by the user Grade A input interface will be loaded.

Input data: Add new data into the tables

Update database: Save the current change(s) made to the database. Changes on the database base include adding new data to the database, replace or delete data already stored into the database

Input Interface: The interface allows the user to input new data into the database; as well update (change or delete data already stored in) the database

Close: Quit the application

3) Software Coding

The coding of HexES became easier due to earlier proper analysis of planning and designing. During this process all unit of programs are written and combined together to meet the final requirements and functions of the software. In every cycle of the software project, documents are produced for the purpose of maintenance, end user, system analyst, system designer or for system review. At every stage of coding, a unit test and series of tests were conducted to verify the function of the system. System validation was carried out before final compilation of HexES by exposing the system to a methodical cohesive test.

Also, it is at this stage of the system that it is considered to be functioning according to the system specification and requirements. To ensure that the software will run to specification and avoid future malfunction each program unit (module) was evaluated during the coding of the software. It was observed that HexES performance is satisfactory and functions perfectly with at least 95% confidence interval, whereas the 5% is for unexpected bugs that have not been handled.

4) Software Installation

For convenience and simplicity purposes, the installation of HexES follows a window-based installation format. Hence, users will not find it difficult to install HexES into their computer system. The installation process is as follows:

- Boot your computer to start windows if you have not do so
- Insert the Compact Disk (CD) containing HexES
- The installation window appears as it often does
- Click next to run the software and follow the installation prompts.
- If the installation window did not appear after you insert the software CD, the Add or Remove Program should be opened following the steps below [7]:
- Choose Start button
- Control Panel will show up on the start menu and click on it
- Click the Add/Remove Program icon
- Click the Add New Programs button
- Browse the drive where the program resides (CD-ROM or any other storage device)
- Select HexES set up file
- Click on O.K

The rest of the installation proceeds and will guide the user until the final installation into the computer system [7].

D. Result and Discussion

The software was tested using illustrative examples as presented in Figure 4. After testing as shown by the illustrative example, the software was found to be accurate and reliable.

We analysed the efficiency of the software by given the same problem in the illustrative example to 5 competent Engineers and 5 Draftsmen to solve and draft the hexagonal bolts first with the aid of the necessary tables at their disposal, then with the aid of HexES. The ten of them were allowed to repeat the drawing process three times and the time that was spent each time was noted. The fastest time of the three time used to obtain the correct drawings were noted. This was found to be those drawings that was repeated last and is probably due to the fact that the people have got accustom to the software and drawing in the example.

Due to the fact that computer system process information with an amazing speed. A comparison of the time spent by the fastest Engineer to perform the designed drafting function for the illustrative example shows that HexES will draft in ten seconds that which a competent engineer will do in one thousand, three hundred and eighty seconds. Similarly, technical data sheet on the bolt dimensions is often time consuming and costly when using manual technical data sheet. But all these technical parameters have been programmed into HexES. Hence, making drafting process faster, save cost and enhance the productivity in area of design.

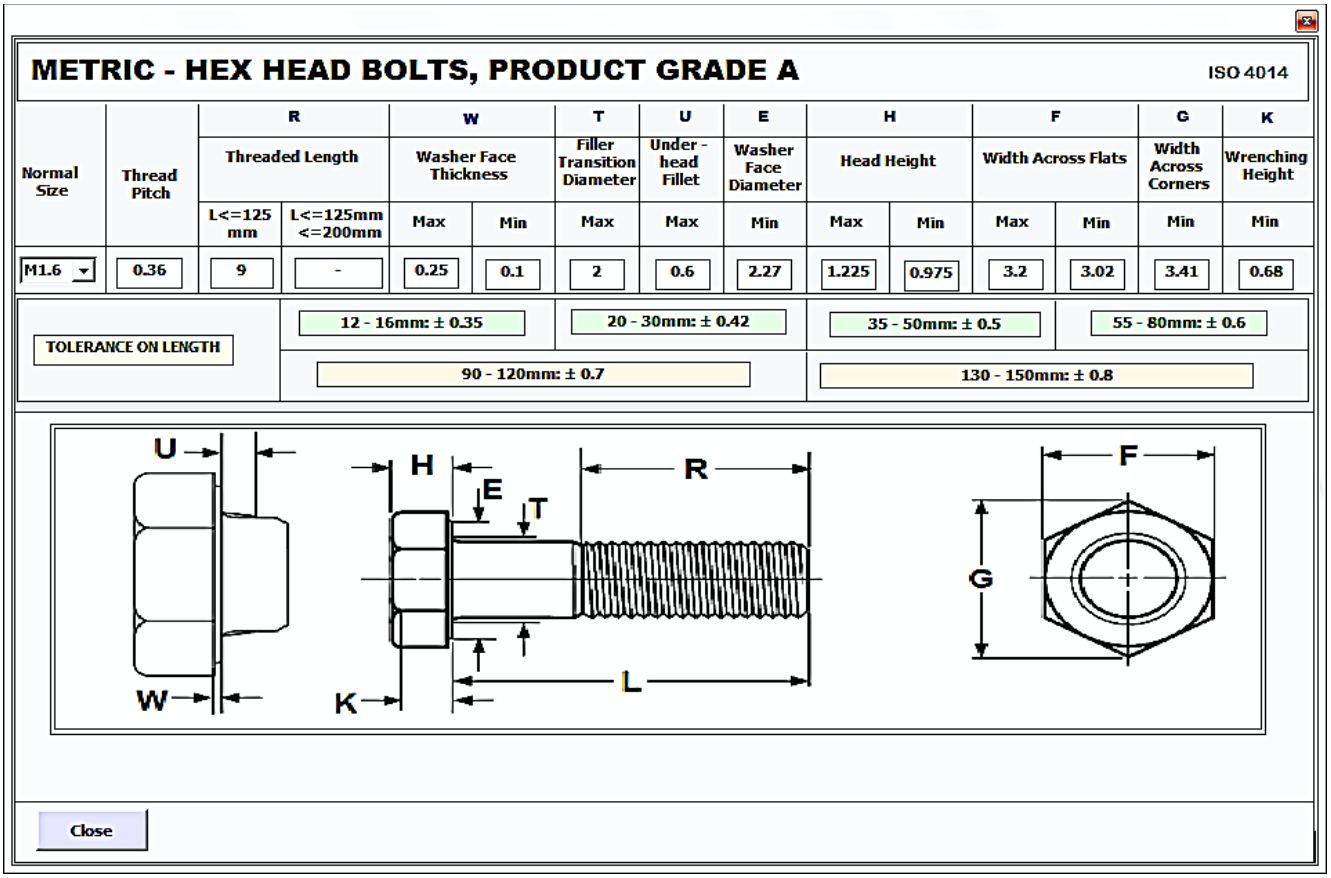


Figure 6. Illustrative example showing M1.6 hexagonal both in HexES main window

III. CONCLUSIONS

The purpose of this project, which is to assist the design of a hexagonal-metric bolt and nut Grade-A product with the use of computer was achieved. Algorithm was developed to assist the development of a reliable and accurate expert system. A standard table that captures all the parameters needed for drafting and design of Grade-A hexagonal bolts was adopted and translated to a logical set of programs (software).

The bolt was drafted neatly to dimension and tables produced by the computer are better than the manually prepared drawings. Hexes is user friendly, menu driven and runs on Microsoft windows operating system.

The software was found to be reliable and accurately select bolt types from the database attached to it. It is efficient, intelligent, maintainable, cost effective, time saving and supports the use of mouse as an additional input device. Above all, it is flexible and can be easily modified to meet future changes.

HexES is recommended for use in industries, as this will assist in the design and drafting of hexagonal bolts and nuts, thereby improve productivity of their design department.

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