Spreadsheets: The Ideal Tool for Distance Learning in Engineering Education

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ABSTRACT: Formal Engineering Education has traditionally been delivered using the low technology—high touch lecturing method, in which the lecturer and student meet face to face. Distance education in this field has been quite slow to develop primarily because of difficulty in delivery of practical based instructions and problems on integrity of assessments. Developments in information technology and the increased demand for further education by people already in employment have however changed this even in developing countries. It puts extra demand on Lecturers to guide distance learners in handling numerical computations so prevalent in Engineering. At the campuses, computer based methods are available in the high touch—high tech lecture method. High level and efficient computer software is used to help the student to simulate and solve some problems. However, such software is expensive—and therefore—not readily available to the distant learner. Spreadsheets on the other hand are almost universal on today's computers and they bridge the gap between hand calculations and high level programme computations. This paper therefore makes a case for the use of spreadsheets in Distance Engineering Education. An example in Spring Design, Selection and Adaptation is used to illustrate the simplification and other advantages of their use by practicing distance learners. © 2009 Wiley Periodicals, Inc. Comput Appl Eng Educ; Published online in Wiley InterScience (www.interscience.wiley.com); DOI 10.1002/cae.20235

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INTRODUCTION

Distance learning education has evolved over time to encompass many areas. Beginning in the 1840s with Pitman short hand courses in Great Britain, it soon rolled out to the rest of the world, thanks to the development of the Postal services [1]. Between 1873 and 1897 in the United States, correspondence instruction was given to 10,000 members—mostly women—by a low profile society founded by Anna Ticknor to enable them study at home [2]. This education system has since grown to include deliveries in humanities, pure and applied sciences, business and post-graduate courses. At first, there

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might have been concern about the effectiveness of teaching Sciences and Engineering by correspondence; but with the advent of the computer, the internet and the digital camera, the fears are being overcome. Hence it is becoming possible to offer distance learning courses in Engineering. On the African continent for example, the University of South Africa is the oldest and largest Open University, having received a royal charter in 1877 and started offering correspondence education in 1946 [2]. Today its college of Science, Engineering and Technology has over 17,000 registered students [3].

Development of spread sheet applications since 1979 [4] has simplified many tedious calculations without loss of understanding of the underlying physics of the problems. Computers are increasingly becoming available at low prices—and the spread sheet programme—especially, Microsoft Excel—is almost universally available on these machines. This paper examines the need for distance learning in engineering and shows that spread sheets can be used to meet this need.

DISTANCE EDUCATION

In the most general case, Distance Education may be defined as a system of learner—teacher interaction in which the two are separated by space. There are two extreme possibilities: same time, different place—called synchronous—and different time, different place, the asynchronous type. In the former, the teacher delivers the course material and the student immediately gets it through, say audio visual broadcasts or teleconferences. In the latter, material may be delivered in print form or on line or on a CD-ROM. It often happens that a practical programme lies somewhere in between these extremes. This is the case in situations where exams, laboratory experiments or workshop practices and seminars may have to be done on one appropriately equipped site. It is then a hybrid programme.

One other distinction is made between distance learning and its close cousin, Open Learning. The latter allows the learner to determine his/her time and place and therefore, decides the material absorption rate [2].

Need for Engineering Distance Education

Many countries especially in the developing world have very few well equipped engineering institutions for full time instruction. Even then, the labs and workshops on these campuses are not utilized throughout the year. Yet the demand for engineering education far outweighs the available full time spaces in these institutions. For example, in Uganda, of the 854 Students who completed Advanced level in 2006 and could have qualified for a BSc Eng admission (i.e., had at least a C in each of Physics and Mathematics), only 243 were admitted the rest going for other courses in Science and Statistics. The previous academic year's numbers were 244 out of 696 [5,6].

In situations of limited good job opportunities, many practicing Technicians and Technologists would wish to upgrade to graduate level without having to resign their jobs. This helps both the technician and the organization for which (s)he works because skilled and appropriately experienced people are often difficult to come by. Experience over a 15-year period with 14 technicians and 8 engineering graduates in two factories in Uganda revealed that while all technicians wished to continue to graduate level, only 3 could manage to seek admission to university. Yet of the three out of eight graduate engineers who wished, all managed to register for either a full time or a distance Masters programme.

Constraints to Engineering Distance Education

The biggest constraint to distance engineering and science education has been the problem of delivery of laboratory exercises and other hands—on activities. Problems of assessment and hence reliability of the grades have also been pointed out [7,8]. At the higher levels, the use of expensive specific software in some courses—which are not universally available—compounds the situation. In Engineering for example, a combination of any of: CAD, MATLAB, MathCAD, Fluent software may be required but each of these is likely to be out of reach in terms of cost, for an individual.

In developing countries even reduced cost of limited student versions of software packages is beyond most students' financial means. For example, in Uganda, the better paid practicing Technician would on average be earning about US$2,800 annually. This is hardly enough to support the average 5.1 dependents [9] in a household, leave some for own further education and purchase of the required software. In Tanzania, Nyichomba, and Mrema reported that "the low salary levels – make it very difficult for Engineers and Technicians to sponsor themselves for continuing engineering education" [10].

Modes of delivery have in the past presented other constraints on their own. For a long time, printed material used to be the main mode of knowledge transfer in distance education. But the postal services in many developing countries are inefficient—and in some—ridden with theft of postal parcels. The recent proliferation of FM radio stations in newly liberalizing economies and the availability of cheap AM/FM radio sets—some going for under US$5 a piece—are opening opportunities of expansion of the distance learning programmes. But these, on their own, will tend to benefit the Humanities and Arts courses more than the practical oriented courses such as engineering.

It is the advent of the computer and the Information Technology revolution that is to bring practical—biased courses fully into the distance education arena. Professors can now set up websites, and students and non-students can access them via the internet. Student chat rooms can be arranged on the net, and a virtual university environment created where they exchange and share experiences, views and even solutions!

However, the digital divide in third world countries is still big. According to Balakrishnun [11], Internet users in Africa and Asia were 52.26 and 324.5 compared to 1504.49 and 1264.32 in North America and Europe per 10,000 of population respectively. And the numbers of personal computers per 100 of population stood at 0.94, 2.88, 24.26, and 19.81 respectively. The report however recognizes the intra regional and intra country divide within the developing countries' figures—which means, the digital density in some pockets of these countries was much higher. For a start, it is in such pockets that Computer Aided Instruction is most helpful. And since these pockets are generally urban, the problems of assessment and laboratory work are easier to handle.

A successful attempt at delivering real labs in Sciences is described by Maureen O'Halloran and Kitty LaBounty of the University of Alaska South East [12]. Hands—on laboratory work was used to complement interactive simulations and video presentations in Chemistry, Biology, and Physics. One of the keys to success in this attempt seems to have been the relationship of the labs to the experiences of the students. For example Electricity and Magnetism were investigated "by building a small electric motor rather than studying more abstract circuits".

A similar observation—in one of the least developed countries - was made in a Science popularization programme to rural schools and communities in Western Uganda [13]. In 2004–2005, 1 h local FM Radio broadcasts were used to teach and illustrate basic science and technical principles to the communities in their local languages. Simple and targeted questions were set for four groups of people—General public; Primary schools; Ordinary level Secondary schools and Advanced level Science classes. Weekly prizes were availed by the sponsoring Company to the best answers in each group. It was found that the general public category was the most enthusiastic and most honest in answering the questions. It was also noted that the semi skilled groups—that is local butchers, motor mechanics, carpenters, masons, local herbalists etc. were really keen to follow and report back on practical instructions in the quizzes. This illustrated the fact that long distance practical work is most enthusiastically received and most beneficial in cases where the learners are already practicing the particular trade.

Another way of overcoming the problem of practical work is the use of videos/movies which enhance the experience of a distance learner. However, nothing will replace a laboratory experience so important in engineering education. Some educators dealt with this problem by providing such students with internet access to campus laboratory equipment creating remote on-line or computer aided laboratories In majority of cases it involves the use of National Instrument's LabView software or MatLab (Watson et al. [14], Consonni et al. [15], Henry [16]). It may also involve use of software specifically prepared at a university (Nedic [17], del Alamo et al. [18]). Although systems based on commercial software, offer realistic data for analysis, it is hard to perceive them as anything different from a simulation environment. They all acquire data through the reading of inputs in text fields. However, those created specifically for on-line laboratories usually offer students real hands-on practical experience. They require the student to carry out each step as it would be done in a physical laboratory.

The problem of assessments in Distance education has been described by several educators. Palloff and Pratt [7] point out the problems of student assessment and explanation to the students on the modus operandi of the assessment. They highlight seven principles to guide the on line assessment but perhaps the most important underlying theme in these principles is the involvement of the learner. They advise that assessment should involve self reflection on part of the student and Peer or Student to student assessment. It is also argued that the students should have an input on how they can be assessed. These are quite revolutionary when compared to the traditional face-to-face classroom assessments.

Chapman of Creighton University [8] discusses the issues of impersonification during examinations, reliable delivery of assessments, technical support during assessments and timely feedback to students. These are overcome by use of Proctors in examinations—and use of question banks, adaptive testing, mastery exams and timed papers for un-proctored assessments. A toll free telephone line to a trained examination manager helps address issues of technical support during the exams.

COMPUTING IN ENGINEERING EDUCATION

Broadly, there are four levels of use of computing in engineering. At the highest level, is the use of high level programming languages like FORTRAN, BASIC, C++, Pascal, etc. Here, the student learns how to write programmes for numerical solution of equations. The student must be able to know how to write the code, how to set up the equations and how to solve them so that (s)he gives the computer the algorithms to follow in availing him/her the solution. Normally, many engineering students detest this and as Wankat and Oreovicz [19] point out, "Some students will do almost anything to avoid programming."

At the mid level, are equation solving programmes such as MathCAD, MATLAB, TK! Solver, etc. Here the student writes the equations and the programme lists the variables. On assignment of values to the variables by the student, the computer gives a solution or iterates to give a final one if the student has given an initial trial solution. These programmes are easier and quicker to learn, have already inbuilt algorithms, and the student need not therefore know how to solve the equations. But they lack logic capability, can not do branching and each programme must be learnt on its own merit.

At an extreme end, are problem specific commercial software such as CAD programmes, ADAMS, SPICE, FLUENT etc. These are powerful, and realistic—as they are written for the practicing engineer. However, they are extremely costly and each is unique in its application. Not everyone finds them user friendly and they have been reported to encourage the "black box" and the "not invented here" syndromes [19,21].

Most of the problems associated with the above programmes are addressed by the use of generic software especially in form of spreadsheets.

SPREADSHEETS APPLICATIONS

Spreadsheets are application packages that ease calculations in tabular form. They were originally developed for applications in Finance and Accounting [20] but soon entered the engineering education arena. Developed first as VisiCalc by Daniel Bricklin with assistance from Bob Frankstan in the United States in 1978/79, spreadsheets have transformed to include charting, graphical interfaces, pull down menus and point and click capabilities. Today, Excel spreadsheets are almost universal in the engineering education world. Others include Sun Star Office as used by G Tabor [22] in examples on Computational Fluid Dynamics.

Spreadsheets are characterized by arrays of cells in which data is input either as numbers or text or as formulae. Comments on data in the cells can also be input and hidden if desirable. Because of the mathematical nature of engineering studies the use in which spreadsheet allows for numerical computations and for creation of good charts makes it the favorite tool for Engineers [23]. It is therefore not surprising that it has become useful and inevitable tool in engineering education.

Many studies and papers have been written to show the applications of Spreadsheets in engineering. A special issue of the International Journal of Engineering Education was published in 2004 dedicated fully to different forms of application of spreadsheets in engineering education. A comprehensive and instructive review was done by Oke of the University of Lagos in 2004 [4]. He credits Electrical Engineers for pioneering use of spread sheets in engineering education. Examples of researchers and practitioners in electromagnetism, logic networks, antenna design, microprocessor systems, Fourier series for harmonics analysis etc. are given. In general engineering, numerical analysis, differentiation, integration and solution of partial differential equations are highlighted. While in mechanical engineering, research on heat transfer and finite element equations was highlighted. In chemical engineering, work by Rives and Lacks on supplementing analytical methods with numerical methods using spreadsheets applications in teaching process control is cited. A review of spreadsheet applications in electrical engineering is presented by Chehab et al. [24]. There are other examples of the use of spreadsheets in different areas of engineering education; electrical engineering [25], environmental engineering education [26], chemical engineering [27,28], energy, thermodynamics and fluid mechanics [29−31]. G Tabor [22] discussed the solution of the Navier Stokes equations in Computational Fluid Dynamics for incompressible fluid flow.

At the University of Botswana, spreadsheets have been successfully used by the Mechanisms and

Control Engineering lecturers in solving simple vibrations problems [32], calculating the Routh-Hurwitz coefficients and making the Nyquist and Bode plots for systems with up to five poles [33]. The lecturers described the layout of a well designed spreadsheet which enhances student understanding of the physics and mathematics behind the programmed equations.

All of the investigations convincingly make an argument that spreadsheets are an ideal tool for engineers and therefore should be used, taught and applied in the process of educating future engineers. The arguments are based on the following points which can be considered as attributes of commonly used spreadsheets.

- The basics of spreadsheets are easy to learn—typically within 1–2 h—much unlike any other computational programme.
- The tedium of iterative calculations is easily removed letting the student to concentrate on scenario building and motivating discovery learning at virtually no cost.
- Spreadsheets encourage structured thinking—thus leading to better thought out solutions to physical problems.
- They are easy to document and debug. Hence, it is much easier to follow the logic of the computations and the solutions.
- Through their charting feature, quality presentations are easily distilled from the mass of numbers that they generate so quickly. Hence they are a favourite among scientific and business executives.
- They are generic and available almost on every personal computer. Experience in one is adequate to enable a student easily adapt to any other.
- Most important for the student, competency in use of spreadsheets builds confidence and prepares him/her to learn higher level software and programming.

Because of these facts, some investigators [4] have actually recommended that spreadsheets literacy should be one of the criteria for admission to an engineering degree course.

The main disadvantages of spreadsheets have been reported to be the low speed in cases of very large problems and the difficulty in large scale branching [34]. In fact almost all the above investigators agree that spreadsheets should not completely substitute the higher level software like MATLAB and discipline specific software used in industry. In a 2006 Mathsoft white paper—that could easily be mistaken for a spreadsheets decampaign in industry—Joung [35] cites concrete and costly examples of errors in their applications. The propensity to errors stems from the way the equations are entered in the cells. The syntax buries the physics of the problem in parentheses, and for long complex equations, it is very difficult to discover one's own mistake. Studies have also shown that a second checker will miss over 50% of such mistakes [35]. Thus, the argument is for use of spreadsheets in less mission critical calculations in industry and/or where one user develops it for his/her own use—not to be shared with others over big engineering projects.

In undergraduate engineering education and below, problems are not always as complex as in the real world in industry. Besides, at that level, in absence of spreadsheets, the choice is between manual and high level programming calculations—neither of which is ideal for a start up learner. The distance learner practicing in industry therefore has an opportunity to work on his own and test—use spreadsheets on some less critical but live problems in industry. Below, an illustration on how such a learner might be able to use an Excel spreadsheet to study Compression Spring design while at the same time solving a practical problem at his place of work is given. It is also shown how such an approach can contribute to reducing the problems of assessments and some practical work mentioned earlier in connection with distance learning.

EXAMPLE OF SPREADSHEET APPLICATIONS FOR DISTANCE LEARNERS: COMPRESSION SPRING STATIC DESIGN

The spreadsheet presented as the case study is to enhance the collaborative component of education with the focus on the learning process. The students should not treat it as a "black-box" as they should be aware of the calculations done. The students can follow easily the equations which are entered in a simple form. On the contrary, in a high level language a significant proportion of student effort is expended in trying to make sense of coding issues rather than understanding the calculations. In addition, in writing high-level code it is necessary to cope with issues of data storage and manipulation that are more relevant to computing courses than to understanding of a design process of a spring. The use of the spreadsheet allows for an iteration process necessary in the spring calculations to be done almost intuitively.

It also eliminates the tedious and repetitive manual calculations and the students can concentrate on the analysis of the problem and on the results on the final results due to changes of different parameters.

The spring calculation spreadsheet addressed all learning objectives from lowest to the highest level: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. In particular the spreadsheet was to increase student understanding and interest in the design by presenting problems of springs calculations in a familiar context. The objectives were to allow them analyse the system; teach them the calculations of spring compressions; and show them the influence of material and design parameters on the calculation results. The additional objectives were to improve the student's ability to use spreadsheets as an engineering analysis tool, and to provide experience in dealing with the open-ended, real engineering problems.

By way of learning outcomes, students should be able to:

- indicate the importance of the spring calculation
- understand the spring design procedure and the iterative processes involved
- calculate the key characteristics of a given off the shelf spring
- appreciate the effects of manufacturing tolerances on overall spring interchangeable use
- summarise the different effects of material and geometry selection on spring performance
- build confidence to tackle the more difficult cases of dynamic and impact loading

The spreadsheets were discussed with a group of about 100 practicing Engineers from different fields (Mechanical, Civil, Mining, and Electrical) at a professional meeting [36]. It was unanimously agreed that the first spreadsheet would enable first time learners to quickly understand issues of spring design. In fact, non-Mechanical engineers commented that they felt more confident to tackle spring design on their own and to apply a similar approach in some of their areas. The Mechanical and Mining Engineers in the group on the other hand, requested for a version that deals with dynamic and impact loading—meaning they were appreciative of the approach.

At university, to arouse interest, teaching starts with pointing out how compression springs are important in industry. From critical applications like in weigh scales and internal combustion engine valve mechanisms—through medium ones like shock and vibration isolation in machinery mountings—to simple ones like providing a quick spring back as in some pens. Two practical approaches to understanding spring design are then used. In one, overall design requirements such as: type and nature of application, available space, working forces, and/or deflections are known or can be determined. The designer then proceeds to determine the spring characteristics de novo: that is, derive: material, wire and coil diameters, number of coils, free length and ends design—see Figure 1. Based on information from normal recommended Machine Design texts (such as Refs. [34,37]) spreadsheet 1 in Figure 3a is presented. In the second approach, given the requirements for the spring, the designer scans available ready made springs which match the space and end conditions constraints then computes the design decision parameters to check whether any of the design window constraints are violated. Optimization in this case is effected through selection of the least costly springs with in the design window. The latter approach is the commonest and the most popular in industry. But unless sourced from spring makers or their representatives, the wire material properties may not easily be known. For the practicing learner, there are practical ways to overcome such problems. In one, the modulus of rigidity G is estimated from simple force—deflection experiments; the derived value is then compared with those in catalogues and design tables. A conservative guess of the material is then made. This is a kind of *component reverse engineering*. In situations where the spring is being re used from some other machinery (cannibalization) or from an old disused or scrapped machine (recycling), the idea would be to assume the original design was done in accordance with the "book rules"—and then again make a conservative guess of the material from tables. Spreadsheet 2 in Figure 3b represents the case for reverse engineering.

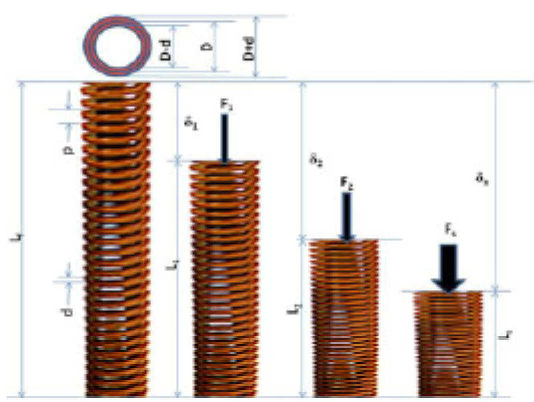

Figure 1 Compression spring design. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

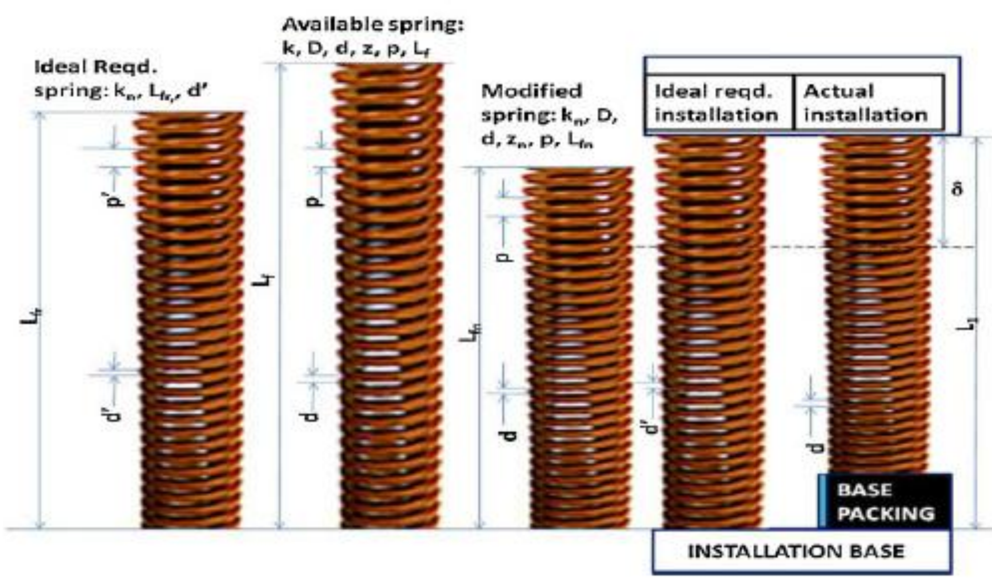

Figure 2 Spring selection and modification. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

In approach 2, it often happens that none of the available springs matches all the geometric and functional constraints—see Figure 2. If the problem on hand is urgent (as is most likely in industry), an intelligent modification of one of the available springs and/or its attachment to the machinery is resorted to. Spreadsheet 2 is extremely helpful in this. It helps overcome the difficulties one would have to face trying to adapt a spring to an application using manual computations. Without it, there is little wonder that many practitioners avoid the rigor of these calculations and simply use intuition to tackle the problem. The results are not always satisfactory in such cases.

In summary, the advantages of such spreadsheets to a distance practicing learner are as follows:

- Ease to use and apply to real life problems at no cost.
- Bridging the gap between abstract concepts (Engineering Science) and real life phenomena (Engineering practice)—hence helping develop a potential hands-on, "down to earth," engineer.
- Motivation to structured thinking and analysis in solving engineering problems
- Development of lateral thinking and simulations to increase possibility of new knowledge creation even at that level. Such learning can also prepare the student for future research based education.
- Self confidence building and recognition by work colleagues as some problems get correctly and accurately solved in reasonable time.
- Acquisition of a skill that can be used in areas outside engineering, and hence, enhancing life long learning. In a controlled experiment by Venkatasubramanian and Skromme of Arizona state University [38] for example, electrical engineering students who were exposed to Excel spreadsheets solutions in their course reported that they used the method on their own several times elsewhere outside class.

Overall assessment of the student can be made to heavily factor in problems that have been solved in such a practical way. While project work and Industrial Training/Attachment assessments may be normal in many engineering curricula, the problem solution simplification offered by spreadsheets should enable better cooperation between the instructor, the student and the employer/supervisor in setting more relevant and practical oriented problems. This clearly addresses two of the concerns on distance learning engineering education mentioned earlier in this paper.

The other important advantage of this approach—where many distance learners along with their employers participate in defining problems for the student—is the resultant closer cooperation between industry and the university.

INVARIANTS: i.e. Given or required conditions								
Space available:	Length or height:	L_1 (mm)	40	Diameter to fit D_H (mm)	20			
Spring Duty:	Forces:	F_1 (N)	0	F_2 (N)	100	Working displ. δ (mm)	10	
Spring to fit: (Enter 1 in only one & 0 elsewhere)		In hole	0	On rod	1	Free	0	
Ends design: (Enter 1 in only one & 0 elsewhere)		Plain	0	Plain & Ground (grd)	0	Squared (Sq) or Closed	0	Sq. & grd. 1
Ends support: (Enter 1 in only one & 0 elsewhere)		Fixed	1	Fixed & Hinged	0	Clamped & Free	0	hinged 0
CHECK VALIDITY BEFORE PROCEEDING:						CONTINUE BELOW		

a) Material Selection	
Material	
Allow. Str. factor q	
Computations:	
Trial diameter d (mm)	3.0
Ult. wire shear stress $\tau_u = A/d^x$: N/mm²	1447.1
Max. allow. shear str. $\tau_a = q\tau_u$: N/mm²	723.5
Stiffness $k = (F_2 - F_1)/\delta$: N/mm	10.0
Max. working length $= L_1$: mm	40.0
Min. working deflection $\delta_1 = F_1/k$: mm	0.0
Spring free length $L_f = L_1 + \delta_1$: mm	40.0
Spring to fit factor = s:	1.0
Mean coil diam. $D = D_H + 1.1sd$: mm	23.3
Diameters ratio $C = D/d$:	7.8
Good Eng. Practice? 4 < C < 13:	CONTINUE
Bergstrasser factor $K_B = (4C+2)/(4C-3)$:	1.2
Active coils $z = Gd^4/8D^3k$	5.4
Extra virtual coils at soliding = Q':	1.0
Number of inactive coils = Q:	2.0
Total number of coils $z_t = z + Q$:	7.4
Solid height of spring $L_s = d(Q'+z)$: mm	19.2
Defl. at Spring soliding $\delta_s = L_f - L_s$: mm	20.8
Max. working deflection $\delta_2 = F_2/k$: mm	10.0
Linearity limit? $\delta_2 < 0.85\delta_s$:	CONTINUE
Coil clear. Limit? $\delta_s - \delta_2 > 0.1dz$:	CONTINUE
Ends condition constant: υ	0.5
Material Constant $C_1 = 0.5E/(E-G)$	0.8
Matl. Constant $C_2 = 2\pi^2(E-G)/(2G+E)$	6.6
Crit. Defl. $\delta_{cr} = L_f C_1(1-(1-C_2D^2/\upsilon^2 L_f^2)^{1/2})$: mm	99.6
No Buckling before soliding: $\delta_s < \delta_{cr}$	CONTINUE
Shear stress: $\tau_2 = 8K_B F_2 D/\pi d^3$: N/mm²	258.90
Stress at soliding: $\tau_s = \tau_2\delta_s/\delta_2$: N/mm²	469.28
Factor of safety at soliding: $n_s = \tau_a/\tau_s$:	1.54
Good Eng. Practice? $n_s > 1.2$:	CONTINUE
Tol. on wire diam. Δd, +/-1%: (mm)	0.0
Tol. on coil diam. ΔD, +/-2.5%: (mm)	0.6
Tol. on No. of act. coils Δz, +/- 45° turn	0.1
Calculated Spring pitch p, (mm)	6.3
Tol. on installed deflection $\Delta\delta_i = \delta_i(\Delta F_i/F_i + 3\Delta D/D + \Delta z/z - 4\Delta d/d - \Delta G/G)$: (mm)	0.0
Tol. on pitch Δp, +/-1% pitch (mm)	0.1
Tol. on free length $\Delta L_f = p\Delta z + z\Delta p + z_t\Delta d$ (mm)	1.2
Interch. assembly? $\Delta L_f < \Delta L_{1,2} - \Delta\delta$; $s(D-d) > sD_H + \Delta D + \Delta d + \Delta D_H$;	CONTINUE
Tot. length of spr. wire: $l_w = \pi D z_t$ (mm)	570.531
Tot. spr. mass $M_t = 0.25\rho\pi d^2 l_w \cdot 10^{-9}$: (kg)	0.032
Relative cost of spring = cM_t	0.032

b) TRIAL SPRING	
Free length L_f: mm	35.0
Coil outer Diameter D+d: mm	30.0
Wire diameter d: mm	3.0
Number of active coils z:	5.0
Total number of coils z_t:	7.0
Coil mean Diameter D: mm	27.0
Spring Diameters ratio C = D/d:	9.00
Spring pitch of active coils p: mm	5.80
Determine by experiment, spring rate k, and hence Rigidity Modulus G.	
Spring rate k: (N/mm)	7.00
Est. modulus $G = 8D^3zk/d^4$: (N/mm²)	68,040
Now investigate modification of Trial spring as follows:	
Reqd. spring stiffness $k_s = (F_2 - F_1)/\delta$: N/mm	10
New No. of active coils for trial spring: $z' = kz/k_s$:	3.5
New free length of trial spring: $L_{fs} = L_f - p(z - z')$: mm	26.3
Spring to fit factor = s:	1
Ideal required mean coil diameter $D_r = D_H + 1.5sd$: mm	24.5
Reqd. max. working length $= L_1$: mm	40.0
Minimum working deflection $\delta_1 = F_1/k_s$: mm	0.0
Required spring free length $L_{fr} = L_1 + \delta_1$: mm	40.0
Initial geom. & functional feasibility? $k \leq k_s$; $sD_H \leq sD_r$; $z' \geq 3$; $L_{fs} \leq L_{fr}$	CONTINUE
Using G value as guide, guess the material	
Material:	SS A313
Bergstrasser factor $K_B = (4C+2)/(4C-3)$	1.15
Additional virtual number of coils at soliding = Q':	1.0
Number of inactive coils = Q:	2
New total number of coils $z_{ts} = z' + Q$:	5.5
New solid height of spring $L_s = d(Q' + z')$: mm	13.5
Deflection at Spring soliding $\delta_s = L_{fs} - L_s$: mm	12.8
Maximum working deflection $\delta_2 = F_2/k_s$: mm	10.0
Check conditions at max. operating deflection: Linearity and coil clearance: $\delta_2 < 0.85\delta_s$; $\delta_s - \delta_2 > 0.1dz'$:	CONTINUE
Check for good eng. Practice ($n_s > 1.2$); Interchangeable assembly and cost as in a)	

Figure 3 (a) Spreadsheet 1: spring design. (b) Spreadsheet 2: selection and modification.

CONCLUSION

There is a need for distance engineering education especially in developing countries because of the limited number of institutions offering face to face instruction vis-à-vis the demand. But there have been concerns on the modes of delivery in the past and on the integrity of such education in respect of practical work and assessments. The unfolding technology revolution and the emerging high digital density pockets in these countries can help address the first concern.

Engineering work and education are highly mathematical and numerical. Broadly, there are two ways of solving numerical problems: manual and computer aided. The former is very tedious and would not easily motivate a distance learner. The latter—as used in industry—is expensive because of the specialized software. In between these extremes there are two methods. Spreadsheet solution and high level programming. Students are more comfortable with spreadsheets because they are generic and simple to learn and use. An illustration of the simplicity of this method has been demonstrated for otherwise difficult practical problems in spring static design and reverse engineering.

Practicing learners can use spreadsheets skills to solve some real world problems at their places of work. Cooperation between the university and industry to set realistic assessment problems for the learner addresses many issues at once. Integrity, practical work, course relevance and even further professional development of the instructor are all enhanced. While this could as well be done with other methods, the use of Spreadsheets would attract and retain more learners—and hence give a longer mileage. Therefore the use of spreadsheets in distance engineering education is strongly recommended.

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