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Development Of Software For Riveted Joints Design

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***Abstract*—Accuracy, failure free, faultless and faster delivery of jobs call for computerization of most engineering designs. Hence, the need for the discussion of this article entitled Computer Aided Design of riveted joints. The design entails the development of software using Visual Basic 6.0 in designing for riveted joint of various types. The various design equations for rivet joints design and calculations were put together and sorted in classifying the input and output parameters for the coding aspect of the work. The software is flexible enough to accommodate variation of parameters as well as the partial view of any design of choice. The software was tested and found satisfactory when compared with manually solved designed problems. The produced CAD software is a student version meant to assist engineering students of the Federal University of Technology in learning rivet joints design and associated calculations.**

Keywords— riveted joint; computer aided design; visual basic 6.0;

I. INTRODUCTION

In engineering, fastenings/joints are processes employed in joining two or more similar or dissimilar solid materials/metals together for the intended purpose for which it is designed. Joints are classified into permanent and temporary joints. The former are joints which cannot be disassembled without breaking or destroying the material components. While the latter are those fastenings which can be disassembled without destroying the components. Soldering, brazing, welding and riveting joints are examples of permanent joints while nutting, bolting, screwing, cotter joining, pinning are examples of temporary joints [1].

Riveting is an operation by which a cold or red hot rivet pin is inserted into already drilled hole of both plates intended to be joined together. When a cold rivet is used, the process is known as cold riveting, and it becomes a hot riveting when a hot rivet is used. The cold and hot riveting process finds its applications in structural joints and leak proof joints respectively [1].

In view of the importance of riveted joints to engineering applications, there is need to give it a special consideration in order to ensure safe and reliable design of engineering facilities and structures.

Anatomically, a rivet pin has head, shank (body) and tail. Rivets are the main kind of fasteners in light frames and thin-sheet shells made of light alloys (especially in the aircraft industry). This is due to the fact that light alloys are difficult to weld.
The welded joints have a low vibration resistance, and the inevitable warping especially pronounced when long products are welded. Intricate forms and restricted overall dimension inherent in aircraft designs make it difficult to manipulate welding device and check the quality of weld. Corroboratively, reference [2] affirmed that riveting joint is the most efficient way to analyze and estimate the deformation of joints for performance evaluation and fatigue durability of aircraft structure building. Reference [3] opined that no two manufacturers of composites hardware can develop the same structural allowable for materials with same resins and fiber ingredient as the cure cycle, resin content, bagging techniques, storage condition and lay up environment will account for the different mean strengths and scatter factors. Hence, the need to have design template flexibilities that accommodates these variations in riveting joints design.

Reference [4] discussed on riveted assembly modeling in which study and numerical characterization of a riveting process was fully examined. Their work presents adjustment of a numerical model for the simulation of a rivet using different approaches resulting in knowledge improvement on the behavior of rivet links at varying loads. Strains and residual stresses effect under post riveting on the links were as well aimed at, thereby making the model to reduce model size and calculation time needed in its characterization module. Reference [5] worked on optimization of a reshaping rivet to reduce the protrusion height and increase the strength of clinched joints. Their work used the reshaping principle whereby the reshaping rivet needs to be embedded in the clinched joint, and then compressing the protruded part of the pin using a single stroke under a flat pair of dies. The optimization result on this reshaping process established that the protrusion height of riveted joints should be 1.0mm, while the average cross tension and tension shearing strengths were increased to 1154.9N and 2757.3N as against 957.9 and 1229.4N respectively.

The riveting process mathematics modeling and simulating to more accurately analyze deformation of thin walled sheet metal parts was discussed by [6]. Their proposition was based on the theory of ABAQUS, finite element system, mathematics and mechanics models for the elastic deformation, plastic deformation and spring back of the rivet pins. And their findings based on comparison of the three theories proved to be true from the modeling perspective.

Reference [7], [8], and [9] studied: the quality of drilled and milled rivet holes in carbon fiber reinforced plastics; vibration measurements of clinched joints and self-pierce riveting; and hybrid joining of boron steels in multi-material and multi-sheet joints respectively. Their contributions were on the applications of riveting joints for quality output in carbon fiber reinforced plastics and boron steels.

Despite the enormous work carried out by some of the aforementioned authors, there had not been any research work focusing on the rivet joints design aided by the use of dedicated software. Therefore this paper focuses on the design of rivet joint tailored towards teaching aid assistance for the learning of the design in fastening operations.

II. METHODOLOGY

The methods adopted for the work is simply by considering the design equations has laid out in texts, transform the various design steps into flowchart algorithm required for the development of the software, and then translate the algorithm into coding using the visual basic 6.0 programming language. Therefore, the subsequent sections of this paper shall be considered as spelt out in the aforementioned,

A. *Design Equations*

The design of riveted joint is an important job in modern design in the present age. A faulty design can lead to many complications, while designing a riveted joint for structural use; the following assumptions must be put in place: load on joints is equally sheared by all the rivets; plates are rigid; bearing stress is uniform; shearing stress in all the rivets is uniform; the bending of rivet is neglected; initial tensile stress or shearing stress in the rivet is neglected; and frictional forces between the plates are neglected.

1) Rivet Design Analysis

The rivet design comprises the following elements: diameter of the rivet; number of rivets; pitch of the rivet; and thickness of the cover plate. And these are as calculated as follows

i. Diameter of rivet

The diameter of the rivet in mm is obtained by the relation

$$d = 6\sqrt{t} \quad (1)$$

Where t is the thickness of the main plate in mm,

ii. Number of rivets

The number of rivets is usually calculated when the length of the joint is small. But when the joint is a continuous one (as in case of boilers), the number of rivets is not calculated. In a small joint the number of rivets is given as;

$$N = \frac{P}{R_v} \quad (2)$$

Where P is the thickness of the main plate in (mm); R_v is least rivet value for shearing and bearing.

iii. Pitch of rivet

The pitch should be between 2.5 to 4 times the diameter of the rivet from practical considerations, the pitch should not be less than 2d + 12mm. where d is the diameter of the rivet in mm, a little consideration will show that the strength of the joint in such a case will be tearing strength of the plate that is P_t (because the value of P_t is taken lesser than the rivet values in shearing and tearing)

$$\text{Efficiency, } \eta = \frac{P_t}{P} = \frac{\sigma_t(P-d)t}{\sigma_t Pt} = \frac{(P-d)}{\mathrm{P}} \quad (3)$$

iv. Thickness of cover plate

The two cover plates are provided each of thickness 0.625t where t is the thickness of the main plate in mm [1].

2) Rivet Joint Design Analysis

The rivet joint is designed for using the following parameters:

i. Tension failure mode,

$$p = (w - nd)t\delta t \quad (4)$$

ii. Bearing failure mode,

$$p = \delta_b ndt \quad (5)$$

iii. Shearing failure mode

$$p = \frac{\pi d^2 \delta_3 n}{4} \quad (6)$$

Where: n is number of rivets; P is allowance load; w is main plate width; t is plate thickness; d is nominal rivet diameter; D is diameter of the hole on the plate (D – d + some clearance) $\delta, \delta_{b,} \delta_3$ are permissible tensile, bearing and shearing stresses respectively. The shearing pressure, Ps; bearing pressure and plate strength design calculation is as listed in equations (7), (8) and (9).

$$P_s = \frac{\pi d^2 t}{4} \quad (7)$$

$$P_b = \sigma_b t d \quad (8)$$

$$P_t = \sigma_t (P - d) t \quad (9)$$

iv. Diameter of rivets, d, is still same with that of equation (1) $d = 6\sqrt{t}$

Where t is thickness of the main plate in mm (*d must be greater than t)*

v. Number of rivets:

This is considered when the length of the joint is small.

$$N = \frac{P}{R_v} \; or \; \frac{P_t}{P_s \; or \; B_b} \quad (10)$$

[the lesser value is used]

vi. Pitch of rivets = 2d + 12mm (11)

vii. Joint Efficiency,

$$\eta = \frac{P_t}{P} = \frac{\sigma_t (P - d) t}{\sigma_t P t}$$

$$= \frac{(P-d)}{\mathrm{P}} = \frac{\text{least of Ps, } \mathrm{P_b} \text{ and } \mathrm{P_t}}{\mathrm{P}} \quad (12)$$

Where: P is thickness of the main plate in (mm); R_v is rivet value (that is the least of the rivet values for shearing and bearing pressure); σ_t is permissible stress in tearing; t is thickness of the plate; d is diameter of rivet; and P is pitch.

viii. Plate thickness, t_s = 0.625t (13)

ix. Shearing of rivet,

$$P_s = n_r \times J_T \times \tau \times \frac{\pi}{4} \times d^2 \quad (14)$$

Where: n_r is number of rivet; J_T = joint type if single, then, $J_T = 1$, if double then $J_T = 2$, if multiple then $J_T = ?$; τ is permissible shear stress in rivets; d is diameter of rivets

x. Bearing strength of rivets,

$$P_b = n_r \times \sigma_b \times t \times d \quad (15)$$

It should be noted that If $P_b > P_s$ the strength of the rivet = $\frac{P_s}{n_r}$, else strength of the rivet = $\frac{P_b}{n_r}$

xi. Tearing of the main plate:

$$P_{ts} = \sigma_t [b - (s - d)] t \quad (16)$$

Where s is the number of sections s, {1, 2, 3, 4… x}

xii. Strength of the main plate: this is the value of P_{ts} at a section where the value is minimum plus the preceding strength of rivet,

P_{ts} Minimum + [nr X strength of one rivet] (17)

Where n_r is the number of rivets preceding the section.

xiii. Tearing of cover plate:

$$P_{tc} = \sigma_t [b - (S_n \times d)] 2t \quad (18)$$

Where: b is width of plate; S_n is section number; P_{ts} is minimum; and t_c is cover thickness

B. Flowchart Algorithm for Rivet Design Software

The algorithm of the design is as stated in Fig.1 to Fig. 4.

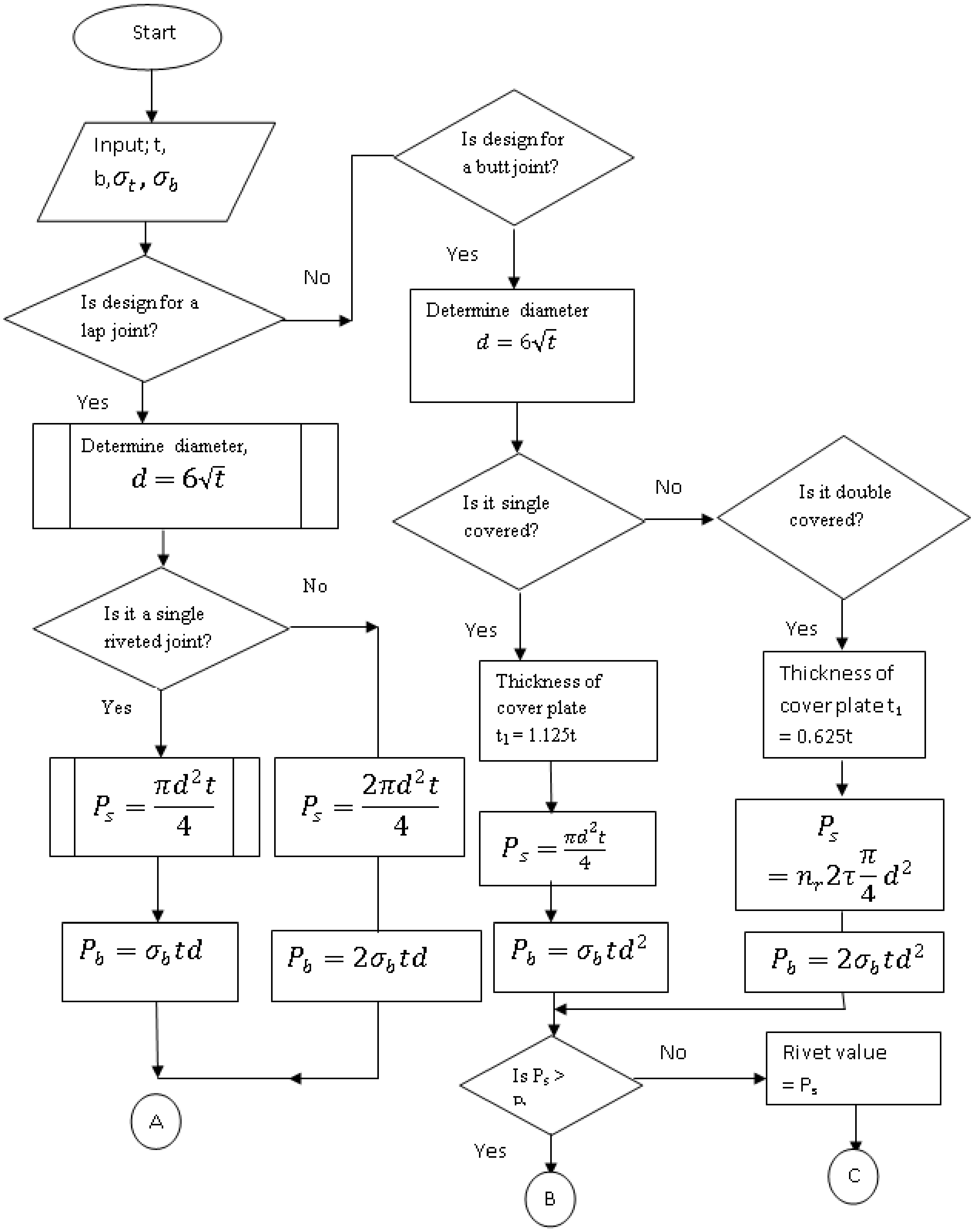

Fig. 1: Flowchart depicting the algorithm for rivets joint design.

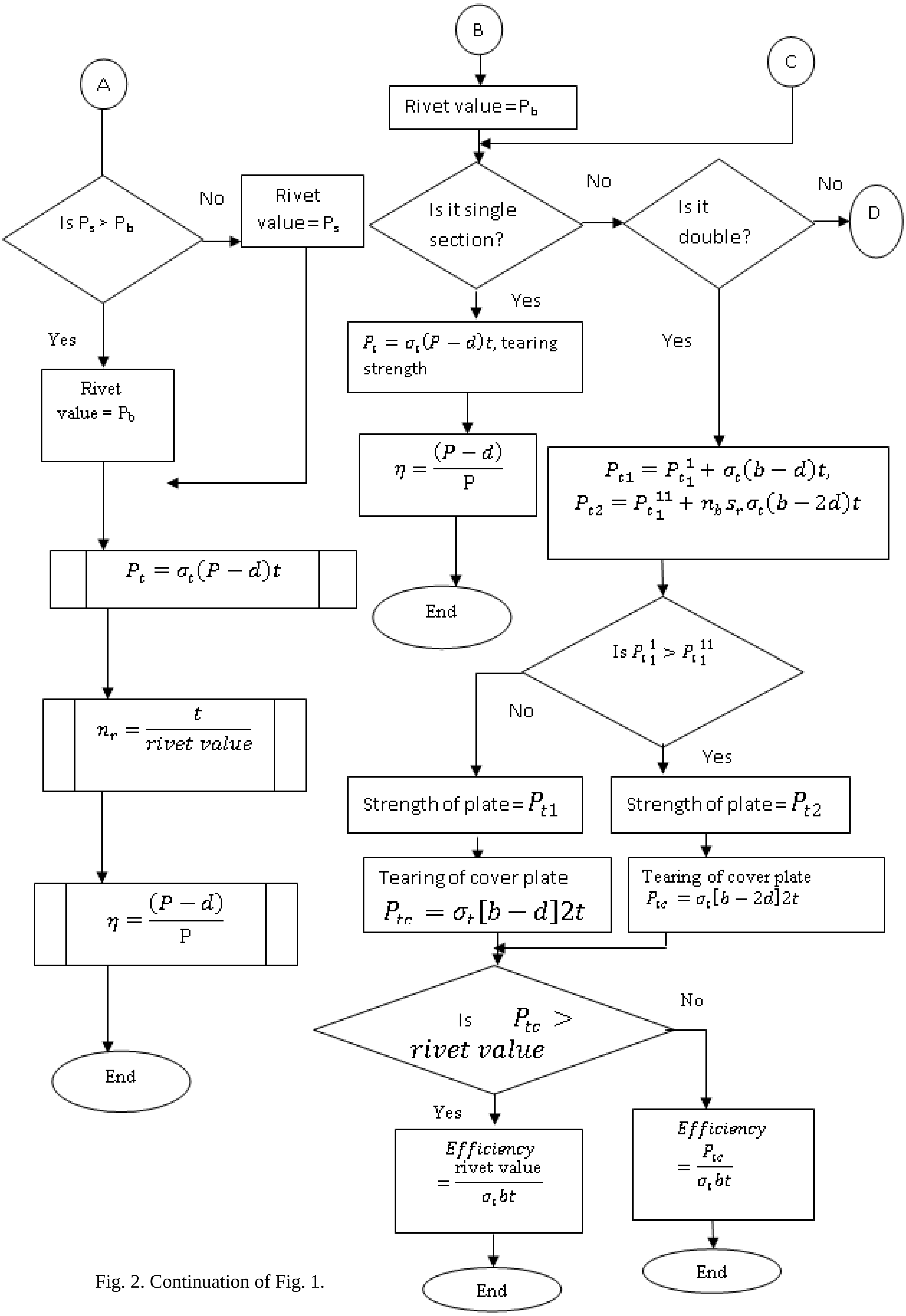

Fig. 2. Continuation of Fig. 1.

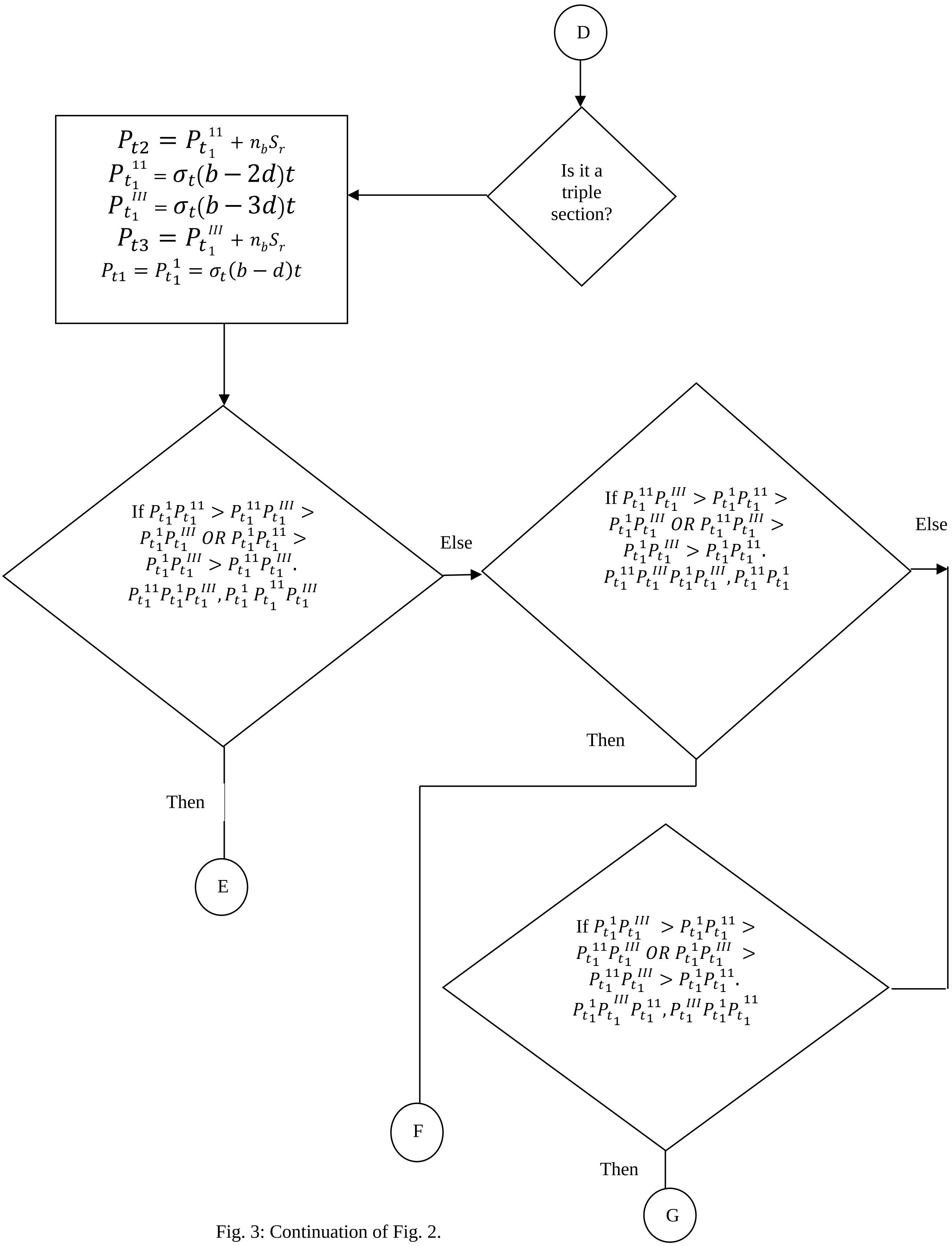

Fig. 3: Continuation of Fig. 2.

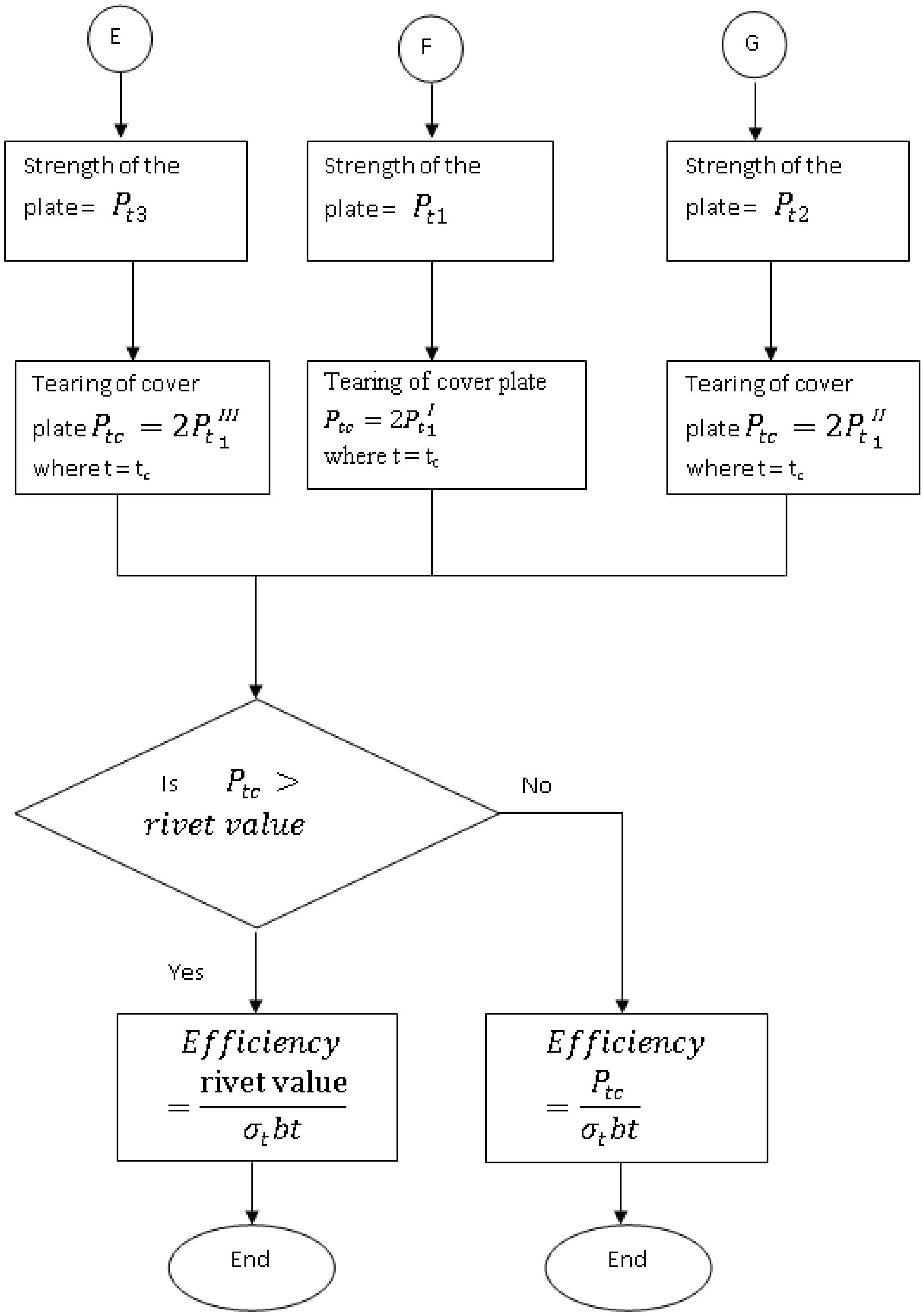

Fig. 4: Continuation of Fig. 3.

C. Software Development

The flowchart of Fig.1 to Fig. 4 is coded using visual basic 6.0 programming approach The built up or deployed programs resulting from these are as discussed in Fig. 5 to Fig. 9. Fig. 5 displays the main menu of the system.

Fig. 5: Application main-menus

While Fig. 6 gives graphical user interface that provides shortcut to the major components and functions of the software package; it is accompanied with good navigation technique.
On accessing the type of joint as displayed in Fig. 6 will display the submenu interface for lap joints as shown in Fig. 7.

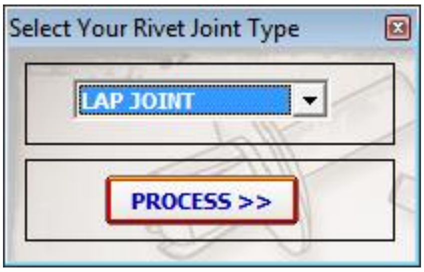

Fig. 6: Type of rivet joint

Fig. 7: Lap joint submenu interface

Once any type of the lap joint is clicked, it displays the input parameters design templates. This is as shown in the displayed template of Fig. 8. While Fig. 9 shows the output template of the developed software.

Fig. 8: Lap joint input menu interface

III. DEVELOPED SOFTWARE TESTING AND EVALUATION

Performance test of the developed software was carried out using two case studies of manually solved calculation from Machine design textbook by [1], and the resulting answers from the developed software were compared with the values obtained from the aforementioned text.

A. Case Study One

Question:

A double riveted lap joint is made between 15mm thick plates. The rivet diameter and the pitch are 25mm and 75mm respectively. If the ultimate stresses are 400MPa in tension, 320MPa in shear and 640MPa in crushing, find the minimum force per pitch which will rupture bent? If the above joint is subjected to a load such that the factor of safely is 4, find out the actual stresses developed in the plates and rivets [1].

Manual Solution Approach**:**

Given t = 15mm; d = 225mm; p = 75mm; and

σ_{nt} = 400mpa = 400N/mm^2: τ =320MPa = 320 N/mm^2: σ_{cu} = 640MPa =640 N/mm^2

To calculate the minimum force per pitch which will rupture the joint?

Since the ultimate stresses are given, therefore there is need to find the ultimate values of the resistances of the joint.

The ultimate tearing resistances of the plate per pitch,

$$P = (P - d)t \times \sigma_{tu}$$

$$P = (75 - 25)15 \times 400 = 300000N$$

The ultimate shearing resistance of the rivet per pitch is thus calculated as:

$$P_{su} = n \times \frac{\pi}{4} \times d^2 \times \tau_u$$

$$P_{su} = 2 \times \frac{\pi}{4} \times 25^2 \times 320 = 314200N$$

And the ultimate crushing resistance of the rivets per pitch is derived as:

$$P_{cu} = ndt\sigma_{cu} = 2 \times 25 \times 15 \times 640 = 480000N$$

The minimum force per pitch which will rupture the joint is 300000N or 300KN [1].

Actual stresses produced in the plates and rivets

Since factor of safety is 4, therefore a safe load per pitch length of the joint is thus calculated to be $300000/_4 = 75000N$

If σ_{ta}, τ_a, and σ_{ca} be the actual tearing, shearing and crushing stresses produced respectively with a safe load of 75,000N in tearing, shearing and crushing, then the actual tearing resistance of the plates (P_{ta}) will be:

$$75000 = (P - d)t \times \sigma_{ta}$$

$$= (75 - 25)15 \times \sigma_{ta} = 750\sigma_{ta}$$

$$750\sigma_{ta} = 7500$$

$$\sigma_{ta} = \frac{100N}{mm^2} = 100MPa$$

Actual shearing resistance of the rivets (P_{sa}), is thus calculated as:

$$7500 = n \times \frac{\pi}{4} \times d^2 \times \tau_a$$

$$7500 = 2 \times \frac{\pi}{4} \times 25^2 \times \tau_a$$

$$7500 = 982\tau_a$$

$$\tau_a = 76.4MPa$$

And actual crushing resistance of the rivets (P_{sa}),

$$75000 = n \times d \times t \times \sigma_{ca}$$

$$= 2 \times 25 \times 15 \times \sigma_{ca} = 750\sigma_{ca}$$

$$= 100MPa$$ [1].

Software solution to Case study 1

The given data were input into the developed system as picked from case study sample problem 1, and the resulting solution is as shown in Fig. 9.

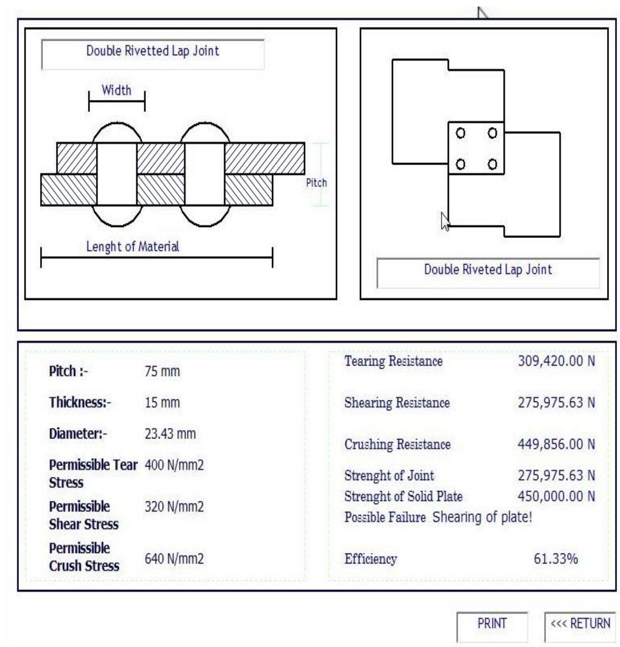

Fig. 9. Software solution to case study 1.

B. *Case Study Two*

Question:

Find the efficiency of the following riveted joints:

i. Single riveted lap joint of 6mm plates with 20mm diameter rivets having a pitch of 50mm.

ii. Double riveted lap joint of 6mm plates with 20mm diameter rivets having a pitch of 65mm.

Assuming the given following values:
Permissible tensile stress in plate = 120MPa;
Permissible shearing stress in rivets = 90MPa; and
Permissible crushing stress in rivets = 180MPa [1].

Manual Solution Approach:

Given: t = 6mm; d = 20mm; σ_t = 120Mpa = 120N/mm^2; τ = 90Mpa = 90N/mm^2; $\sigma_c = 180MPa$

i. *Efficiency of the first joint*

Given pitch, P = 50mm
There is need to find the tearing resistance of the plate, shearing and crushing resistance of the rivets.

a. Tearing resistance of the plate

The tearing resistance of the plate per pitch length,

$$P_t = (p - d)t \times \sigma_t$$

$$= (50 - 20) \times 6 \times 120 = 21600N$$

b. Shearing resistance of the rivet

Since the joint is a single riveted lap joint, therefore the strength of one rivet in single shear is taken. Therefore, the shearing resistance of one rivet,

$$P_s = \frac{\pi}{4} \times d^2 \times \tau$$

$$P_s = \frac{\pi}{4} \times 20^2 \times 90 = 28278N$$

c. Crushing resistance of the rivet

Since the joint is a single riveted, therefore strength of one rivet is taken. And crushing resistance of one rivet,

$$P_t = d \times t \times \sigma_c$$

$$P_t = (20) \times 6 \times 180 = 21600N$$

Strength of the joint = least P_t, P_s and P_c = 21600N
Then strength of the unriveted solid plate,

$$P = p \times t \times \sigma_t$$

$$P = 50 \times 60 \times 120 = 36000N$$

Efficiency of the joint
N = least of:

$$\frac{Pt, Ps \text{ and } Pc}{P} = \frac{21600}{36000} = 0.6 \text{ or } 60\%$$

Software solution to Case study 2a

The given data were input into the developed system as picked from case study sample problem 2a, and the resulting solution is as shown in Fig. 10.

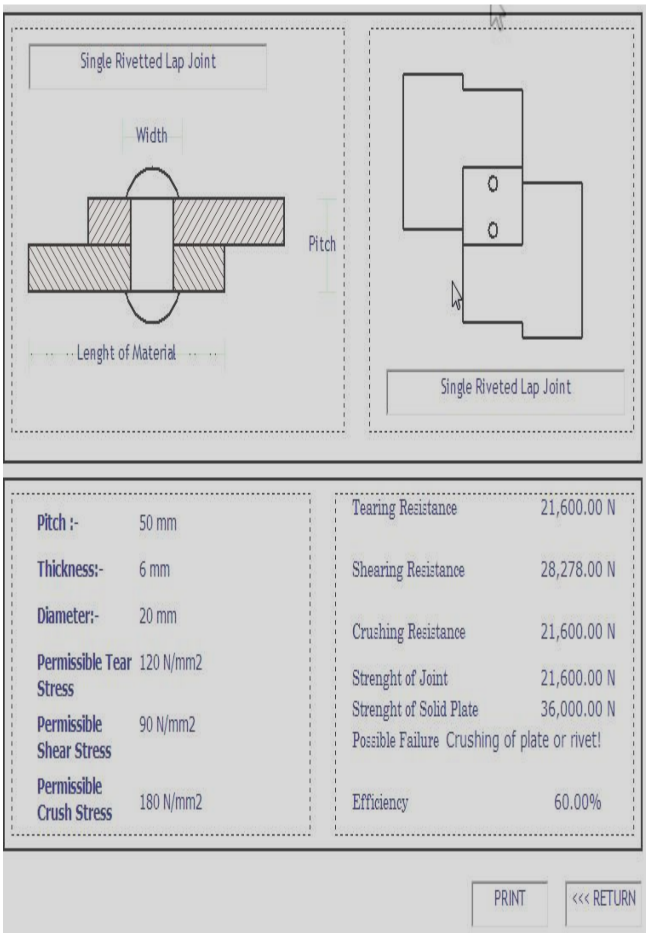

Fig. 10. Software solution to case study 2a.

ii. *Efficiency of the second joint*

a. Tearing resistance of the joint

The tearing resistance of the plate,

$$P_t = (p - d)t \times \sigma_t$$

$$= (65 - 20) \times 6 \times 120 = 32400N$$

b. Shearing resistance of the rivets

Since the joint is double riveted lap joint, therefore strength of two rivets in single shear is taken. Knowing that shearing resistance of the rivets is,

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau$$

$$P_s = 2 \times \frac{\pi}{4} \times 20^2 \times 90 = 56556N$$

c. Crushing resistance of the rivet

Since the joint is double riveted, therefore strength of two rivets is taken. Knowing that crush resistance of rivets,

$$P_t = n(d) \times t \times \sigma_c$$

$$P_t = 20 \times 20 \times 6 = 43200N$$

Therefore strength of the joint = least of P_t, P_s, and P_c = 32400N
But strength of the unriveted or solid plate,

$$P_t = p \times t \times \sigma_t$$

$$P_t = 65 \times 6 \times 120 = 46800N$$

∴ Efficiency of the joint,

$$\zeta = \frac{least\ of\ P_t, P_s, P_c}{P}$$

$$\zeta = \frac{32400}{46800} = 0.692$$

or 69.2%

Software solution to Case study 2b

The given data were input into the developed system as deduced from case study sample problem 2b, and the resulting solution is as shown in Fig. 11.

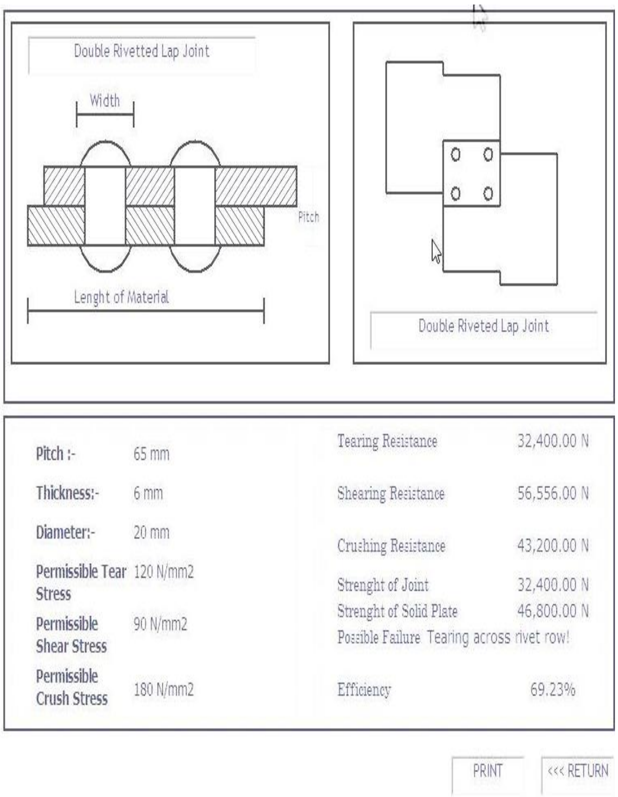

Fig. 11. Software solution to case study 2b.

From the two case studies considered, it is evidently cleared that the manually derived answers are same as the one given by the developed software. It is crystal cleared as that the solutions is not at variance to each other, which is an indication that the developed software is perfectly coded.

IV. CONCLUSION

The software package was successfully developed, branded and packaged on a recordable compact disc and it is installable on window's platform. This software will assist the riveting designer, frame work designer, structural engineers and many engineering industries who are into using riveting in construction as a means of connection. Having successfully taken into consideration the different loads carried by the joints, some other features were incorporated into the software which include the database for riveting joints and sample model of the expected type of rivet. Finally the software is user friendly and interactive.

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REFERENCES

[1] R. S. Khurmi and J.K. Gupta, "Riveted Joints, Machine Design," 14th ed., Eurasia Publishing house, 2009, pp. 281-340.

[2] K. Zhang, H. Cheng and Y. Li, "Riveting process modeling and simulating for deformation analysis of aircraft's thin-walled sheet metal parts," Chinese Journal of Aeronautics, vol24, issue 3 2011, pp.369-377, doi: 10.1016/S1000-9361(11)60044-7.

[3] L. J. Hart-Smith, "Design and analysis of bolted and riveted joints in fibrous composite structures," Recent advances in structural joints and repairs for composite materials, Springer Netherland, 2003, pp.211-254, DOI:10.1007/978-94-017-0329-1_7.

[4] V. Blanchot and A. Daide, "Riveting assembly modeling study and numerical characterization of a riveting process," Journal of Materials Processing Technology, Vol 180(1) 2006, pp.206-209 doi:10.1016/jmatprotec.2006.06.005

[5] C. Chen, S. Zhao, X. Han, M. Cui and S. Fan, "Optimization of a reshaping rivet to reduce the protrusion height and increase the strength of clinched joints," Journal of Materials Processing Technology, Vol 234, 2016, pp.1-9 doi:10.1016/jmatprotec.2016.03.006

[6] J.C Aurich, B. Kirsch, C. Muller and L. Heberger, "Quality of drilled and milled rivet holes in carbon fiber reinforced plastics," New production Technologies in Aerospace Industry 5th Machining innovation conference (MIC 2014), Procedia CIRP 24(2014) pp.56-61.

[7] X. He, Y. Zhanga, H. Cunb, S. Yuanb, Y. Dinga and K. Zenga, "Vibration measurements of clinched joints," 12th Global Conference on Sustainable Manufacturing, (2015)Procedia CIRP 26, 2015, pp.208-211.

[8] O. Han, G. Meschut, M. Bergau and M. Matzke, "Self-pierce riveting and hybrid joining of boron steels in multi-material and multi-sheet joints," (2015), International conference on manufacture of light weight components, Procedia CIRP

[9] C. A. Jan, K. Benjamin, M. Christopher and H. Lukas, "Quality of drilled and milled rivet holes in carbon fiber reinforced plastics," New Production Technologies in Aerospace Industry - 5th Machining Innovations Conference (MIC 2014), Procedia CIRP 24, 2014, pp.56 – 61.