COMPUTER-AIDED DESIGN OF BLANKING AND PIERCING OPERATIONS

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Abstract
The research prescribes a computer - aided approach to the design of blanking and piercing operations using washer, which is typical of presswork as a case study. This makes the design to be fast without being laborious. An effective procedure for the design involves the compilation of well-known equations. This was in turn used to develop model CAD software for dies and punches; washer begin used to validate the CAD, incorporating the detailed engineering drawings of parts to be pressed. Visual Basic Language was used for the software, which also does the drafting of the blanking and piercing operations detailed drawings. The developed CAD software will greatly reduce the repetitive and cumbersome nature of designing for the operations in manufacturing industries. It will enable practitioners to quickly design and produce similar configurations of the design with relative ease. **Key words:** Blanking, piercing, software, operations, washer and manufacturing industries

Introduction
Preambles

Presswork process is the application of large forces by press tools for a short time interval which results in the cutting (shearing) or deformation of the work material (Wilson, 1990). A presswork operation, generally completed by a single application of pressure often results in the production of a finished part. Presswork forces are set up, guided and controlled in a machine referred to as a press. There are varieties of this.

Stamping is the general term for presswork operations such as punching, blanking, piercing, bending and forming that are performed on a press with the use of dies (Lindgerg, 1990). Of all these operations, this paper addresses only two: blanking and piercing. Stamping dies consist of punches, usually held in the upper half of the die, and matching dies, which are normally located in the lower half. (Amstead et al, 1979).

The punch refers to that part of the assembly, which is attached to the ram of the press and is forced into the die cavity; the die is usually stationary and rests on the press bed. It has an opening to receive the punch and the two must be in perfect alignment for proper operation (Amstead et al, 1979). Punches and dies are not interchangeable. This research addresses the design of blanking and piercing using die and punch for presswork through computer-aid. For every job of presswork, a design engineer must design for die and punch suitable for the production of that job.

A component called washer was identified. For the production of this component, computer is used to design die and punch. Only two operations are required for the production of the washer. They are piercing and blanking. Piercing refers to cutting openings such as holes by the use of die and punch but the slug produced is scrap. Blanking refers to a situation when the punch cuts through unprocessed material and the slug that results is the workpiece (Niebel, 1989). In general, the results of a blanking operation are blank, which is the workpiece; whereas the results of a piercing operation are usually scrap (Anon, 2002). The cutting operation that takes place when a punch cuts through a piece of material has three components. They are plastic deformation, shear and break (Pollack, 1990). The washer allows close fitting in roofing, generator plants, machinery, automobiles and so on. In the design of blanking and piercing for the production of washer, Computer-Aided Design (CAD) was employed. Groover (1987), defined CAD as any design activity that involves the effective use of computer to create, modify, or document an engineering design. CAD is most commonly associated with the use of an iterative computer graphics system, referred to as a CAD system. Iterative computer graphics denotes a user-oriented system in which the computer is employed to create, transform, and display data in the form of pictures or symbols (Emory et al 1984). The development of CAD has provided designers with a powerful and flexible tool. A designer can now prepare and evaluate in hours a design that would have taken days or even weeks using traditional manual methods, A CAD system not only increases the productivity of the designer but also improves the quality of the design (Wu, 1994).

1. With the capability by CAD, more complete design analysis can be carried out resulting in less risk and uncertainty.
2. With the ability quickly to store and retrieve design data, the amount of efforts involved in various stages of the design process is significantly reduced. More attention can thus be paid to the quality aspect of the design so that there are fewer opportunities for errors to occur.
3. With the flexibility provided, design changes can be more readily incorporated, allowing design errors to be more easily rectified and modification requests more easily accommodated, resulting in a much more rapid response.
4. CAD gives a much more accurate and professional presentation of a design, resulting in better documentation and communication.

Design equations parameters and constants were involved in this research. A lot of calculations go into the design of punch and die. There are two operations involved; piercing and blanking. The punches sizes and dies' sizes were calculated.

Justification for the Research

For the production of any component of presswork, suitable dies and punches must be available. They do not come in standards neither are they set when used. It is therefore essential that for every job of presswork, a design engineer must design for die and punch suitable for the production of that job. The compilation of well-known equations for die and punch design were used to determine clearance, piercing punch size, piercing die opening, blanking punch size and blanking die opening, these are in turn used to determine piercing and blanking forces for the piercing and blanking.

Specific Objectives of Research

The specific objectives are to:

a) Establish an effective procedure for the design of piercing and blanking. This involves the compilation of well-known equations for design.
b) Develop model CAD software for piercing and blanking.
c) Use washer as a case study to validate the computer-aided design of piercing and blanking, incorporating the detailed engineering of parts to be pressed.

Research Method

Theories of presswork and design of dies and punches were analyzed. Reliable design equations for piercing and blanking requiring specifications of clearance, piercing punch size, piercing die opening, blanking die opening size and blanking punch size, were used to determine the required piercing and blanking forces as well as die and punch sizes.

These design equations were programmed in a Visual Basic software language to automatically design and provide detailed engineering drawings of dies and punches. Only minimum input specification i.e. materials type, hole diameter, blank diameter and material thickness are to be supplied to produce various drawings as might be required.

Expected Contribution to Knowledge

The developed software will greatly reduce the repetitive and cumbersome nature of designing for piercing and blanking in manufacturing industries. This is a reflection of most current developments in the field.

Presswork is a non-standardized manufacturing process; its design had always been repetitive depending on each job being processed.

The software developed will enable practitioners to quickly design and produce similar configurations with relative ease.

Literature Review

Presses

The various types of machines manufactured to apply forces, repeatedly, to workpieces so that the metal may be cut, shaped or caused to flow into a desired pattern are called presses. These forces may be applied through the use of mechanical or hydraulic systems. The most commonly used press is the inclined press, sometimes referred to as the open-back inclined press (Pollack, 1990). The presses are the machines primarily used for the operations of blanking and piercing.

Press Capacity

The capacity of a power press may be considered as the maximum pressure exerted. It is usual to allow 25% pressure in addition to that required. For a press capacity of 50 tons, 25% of 50 must be added; therefore a power press of about 62.5 tons is needed.

The actual calculation of the theoretical pressure required to produce a given blank makes use of the following equation: Shear stress = pressure/area of shear, And hence, **pressure = (shear stress)(area of shear)**

For practical purposes, the shear strength is taken as equivalent to 80% of the tensile strength. (Niebel, etal 1989).

Blanking

This is the cutting of flat metal sheet or strip stock into the required size and shape. Here, tooling consists of a punch, die and a set of guides and stripper. Typically, the entire periphery, which may include rounded corners and irregular shapes, is cut in one stroke of the press (Anon: 2002).

Designers who are in the testing stage of products that will ultimately run at high volume in tooling might consider the use of simple push through dies for blanking of prototype parts. In contract, quantities up in the thousands or more merit production units that feed strip or coil to limit handling and keep blanking operations as economical as possible.

In practice, different types of blanks are used, depending on the next operation in the manufacturing sequence, such as drawing or forming. Tool development for a drawn part may involve the building of the draw die before the blanking die to establish the final blank size.

Piecing

Piecing generally refers to cutting openings such as holes and slots in sheet stock strip material or a part. This operation is similar to blanking, but here slug produced by piecing is scrap (Anon: 2002). Where possible, all holes and openings in a part are pierced in one stroke. This results in a much more consistent part than punching features in separate strokes of the press. Since all punches are permanently mounted in the same master dies and enter the work piece at the same time, once they are checked and located correctly, dimensional repeatability of all features is high.

Other types of piercing operations require special punches, among them: pierce-and-extrude (for an extrude hole), lance and form (for a small feature from the body of the part), slotting, countersinking and cutting of tabs. Additionally, just about any operation - blanking, drawing, forming - can be combined with piecing (Anon: 2002).

Design Considerations

Clearance

Clearance, by definition, applies to the space between the punch and the die (Pollack, 1990).

Clearance C = at Where a = allowance t = material thickness

The general rule for application of clearance is as follows:

(a) The size of the punch determines the size of the pierced hole.

(b) The size of the die opening determines the size of the blanked part. In the application of these rules, a condition must be taken into account. This is the condition of recovery that takes place within the structure of the material (Pollack, 1990)

It is always observed that the material being worked will cling to the piercing punch. Once this material is stripped off the punch, the material recovers and the hole size decreases so that the hole is actually smaller than the punch, which produced it. The same thing happens when a part is blanked in a press. The blanked part is larger than the die opening, which produced it.

The question is: how smaller is a pierced hole than the punch that produced it or how much larger is the blanked part than the die opening that produced it? The answer is determined majorly by the clearance in between the die and punch.

Land

This is the name given to the paddle part of the die. Grinding the surface of die and punch is achieved no more than about 0.05mm removed during surface grinding operation. The purpose of the blank is to ensure that the profile of the blanked component remains unchanged (Pollack, 1990). The depth of the land is about one-third of the metal thickness. Therefore, a die made for the blanking and piercing of the washer requires a depth of land one-third of the material thickness.

If a die requires re-grinding for every ten thousand components made and that 0.05mm is removed, then the useful life of the die is one-third of material thickness divided by 0.05. This gives the exact number of regrinds required.

Theory of Cutting in Press-Working

The cutting operation that takes place when a punch cuts through a piece of material has three components as follows:

Plastic Deformation

After the punch has contacted the work, the continued downward movement of the punch exerts forces on the work material. Once the elastic limit of the material has been exceeded, plastic deformation takes place (Pollack, 1990).

Shear

The slug is pushed farther into the die opening by the punch, but at this point in the operation, the material has begun to separate as a result of being cut. The material is able to resist fracture at the cutting edges of the punch and the die, and therefore, the punch cuts (shears) the materials at the cutting edges of the punch. At the same time the slug is pushed farther into the die opening. Again, the material resists fracture and is sheared at the cutting edge of the die opening (Pollack, 1990)

Break

The cutting operation is completed when the material can no longer resist the force of cutting. It fractures as the punch pushes farther into the material (Pollack 1990).

Economy of Metal Cutting

Economics may be achieved by correct strip layouts of the material. Because of the capability of high production, the major portion of the cost for producing a stamping is the material. The layout of the scrap strip is therefore, of utmost importance from the standpoint. In addition, the scrap strip layout is a good place to start when designing a die (Niebel et al 1989).

Computer-Aided Design (CAD)

Computer-Aided Design (CAD can be defined as any design activity that involves the effective use of the computer to create; modify, or document an engineering design (Groover, 1987). CAD is most commonly associated with the use of an interactive computer graphics system, referred to as CAD system. CAD has grown from a narrow activity and concept to a methodology of design activities that include computer or group of computers used to assist in the analysis, development and drawing of product components (Niebel et al, 1989).

The original CAD systems developed and used in industry could more realistically be classified as computer-aided drafting systems. However, the benefits of using basic geometric information for structural analysis and planning for manufacturing were quickly recognized and included in many CAD systems. Today, as in the past, the basic for CAD is still the drafting features or interactive computer graphics that these systems were originally design to perform. However, the scope of these systems has taken on a new meaning.

Important Reasons for Using CAD System

Computers are utilized extensively by engineering designers, ingenerating design configurations, drawings and graphic display. Although this is the area with which CAD is most commonly associated, in fact CAD incorporates all the design activities that involve the use of a computer, including modeling, analysis and evaluation as well as design documentation and communication (Wu, 1994).

The development of CAD has provided designers with a powerful and flexible tool. A designer can now prepare and evaluate in hours a preliminary design that would have taken days or even weeks using traditional manual methods. There are several important reasons for using a computer-aided design system to support the engineering functions (Emory et al 1984).

- To increase the productivity of the designer. This is accomplished by helping the designer to conceptualize the product and its components. In turn this helps to reduce the time required by the designer to synthesize, analyze and document the design.
- To improve the quality of the design. The use of a CAD system with appropriate hardware and software capabilities permits the designer to do a more complete engineering analysis and to consider a larger number and variety of design alternatives. The quality of the resulting design is thereby improved.
- To improve design documentation. The graphical output of a CAD system results in better documentation of the design than what is practical with manual drafting. The engineering drawings are superior, and there is more standardization among the drawings, fewer drafting errors and greater legibility.
- To create a manufacturing data base. In the process of creating the documentation for the product design (geometric specification of the product, dimensions of the components, material specifications etc), much of the required database to manufacture the product is also created.

If the general process of product design can be summarized by the three design functions-preliminary design, product development and final design- then a true CAD system should assist the full range of activities involved.

Using CAD for Manufacturing Component Design

Although CAD represents the integrated use of a computer in the design process, the use of CAD does not change the design process requirements.

As in the past, the designer is still responsible for:

- Developing the necessary analysis on the design.
- Reviewing and altering the design on the basis of functional and economic characteristic.
- Communicating the design via an understandable drafting system.
- Independent of whether a CAD system was employed in the design or whether the designer used a standard drafting table, each of these design steps must be addressed either formally or informally.

Design Using CAD System

The basic tasks that are performed automatically using CAD system include:

- Geometric modeling
- Engineering analysis
- Data storage and retrieval
- Automated drafting.

The functions performed by the CAD system are those functions that are normally employed in the design of any product, independently of whether a CAD system is used. Again, these design

functions might be employed formally or might be employed as part of an informal design and manufacturing system.

Computer Software

Brebbia and Ferrante (1986), were of the opinion that a programme is written according to certain rules that are part of so-called computer language. The software developer will write his programme using a language, which he selects from several languages that the computer might accept. The data for the programme will be written in the corresponding information support according to the rule set by the developer. When writing the programme, programme and data are not in general read simultaneously or intermixed. The programme is normally read first. Then the computer operates according to the instructions included in the programme which, among things, indicate to the computer when and how to read the data. The programme is usually packaged and stored in the computer. Any software developed for assisting design activities is referred to as CAD system.

The CAD system allows the automation of engineering design. Goestch (1992), implies that the automation of engineering design activities will help in increasing the speed of operation and improving the quality of product at reduced cost. Ray (1987), reported that the use of computers and the development of computer aided design techniques have resulted insignificant reductions in design project cost, working hours, inconsistencies and mistake and further stated that major technological advance in computer "power" indicate that the user of CAD will continue to increase. This then makes CAD to be economical as Hardisy (1994), reported that economists are now suggesting that once a product gets ahead of its rivals in price and quality then it will continue to get even ahead.

Material Requirements and Design Equations

Material Requirements for Washer

Some engineering materials were identified for the production of washer. These materials have varying shear strengths, percentages of allowances and some material characteristics. The materials are tabulated below.

Material	Shear Strength (N/mm^{A}2)	Allowance (%)
Mild Steel	**380**	**5**
Medium Carbon Steel	**580**	**6**
Soft Brass	**240**	**4**
Copper	**200**	**3**
Aluminum	**160**	**3**

Table 3.1 Table of Materials (Pollack, 1990)

Design Equations of Washer

Assume a washer of the following dimensions. All dimensions are in millimeters and the material is mild steel.

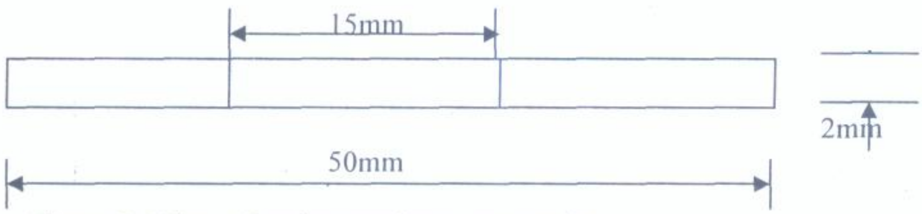


Figure 3.1 Plan of washer used as a case study

Determination of Punch and Die Dimensions and forces for Blanking and Piercing (i) Mild Steel (5% allowance)

Allowance = 5% Material thickness = 2mm Clearance = at 5% x 2 = O.lmm

= 49.82mm

Blank force required is

F_b = **S7I0t**

= 200 x 22/7 x 50 x 2 = 62857.14N

(v) **Aluminum (3% allowance)**

Allowance = 3%

Material thickness = 2mm

Shear strength = 160N/mm^2

Clearance = at = 3% x 2 = 0.06

The piercing punch size required is

Pp = (15 + 0.06)mm

= 15.06mm

The piercing die opening is

$D_b = P_p + 2c$

= 15.06 + 2(0.06)

= 15.06+0.12

= 15.18mm

The piercing force required;

F_p = STC0t

= 160x22/7x15x2

= 15085.71N

Blanking die size is

D_b=50-0.06

= 49.94mm

Blanking punch size is

$P_p = D_b - 2c$

= 49.94 - 2 x 0.06

=49.94-0.12

= 49.82mm

Blank force required is

F_b = S7t0t

= 160x22/7x50x2

= 50285.71N

Table of Hand Calculated Results

Material	C(mm)	P_P(mm)	D_p(mm)	Pb (mm)	D_b (mm)	F_P(N)	F_b(N)	a
Mild steel	0.1	15.10	15.30	49.70	49.90	35828.57	119482.57	0.05
Medium carbon steel	0.12	15.12	15.36	49.64	49.88	54685.71	182285.71	0.06
Soft Brass	0.08	15.08	15.24	49.76	49.92	22628.57	75428.57	0.04
Copper	0.06	15.06	15.18	49.82	49.94	18857.14	62857.14	0.03
Aluminum	0.06	15.06	15.18	49.82	49.94	15085.71	50285.71	0.03

Note: The thickness t for any material is constant; t = 2mm

Software Development

The above design procedure/calculations were used to develop the software used in the design of the blanking and piercing. This was made possible by transforming the required dimensions of die and punch, forces, clearance and thickness into a set of instructions/codes. The codes written could validate the user and respond by giving the user the necessary information.

System Design

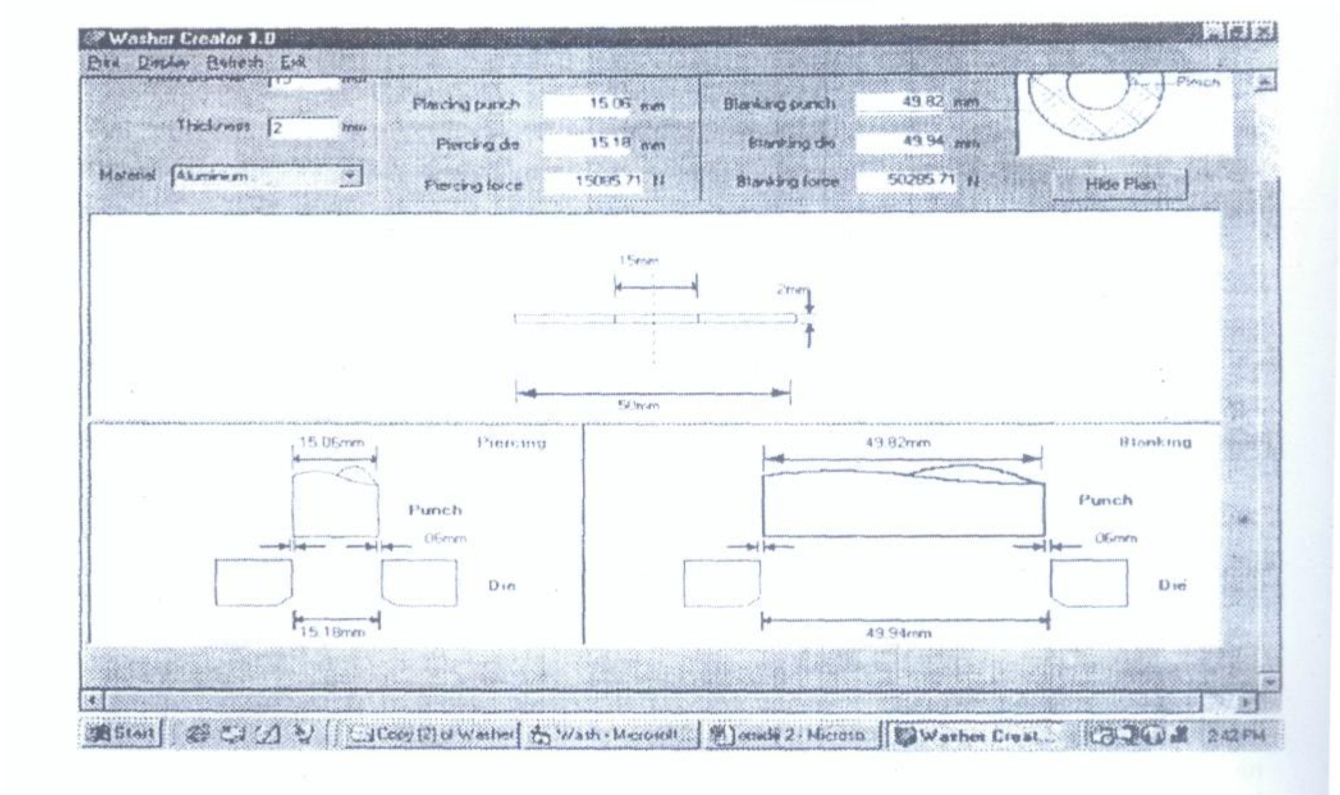
System design is defined, according to Cornel (1997), as the process of developing a plan for implementing the set of functional hardware and software systems. It is the creative ability of combining theoretical ideas with available resources to achieve a desired output; the objectives of the system developed. This was the idea employed in the software development of blanking and piercing.

The system developed has the input interface. The basic inputs in the system are the blank diameter, hole diameter material thickness and material type. The following dimensions; blank diameter 50mm, hole diameter 15mm and material thickness 2mm are basic to the washer used as the case study. The materials selected were mild steel, medium carbon steel, soft brass, copper and aluminum.

Another interface there in the system is the operation interface. The operations include piercing and blanking. Each of the operations has clearance, punch and die dimensions and force required. There is plan of washer used as a case study in the system and the interface beneath this houses the punch and die in each operation of blanking and piercing designed for the production of the washer.

User's Guide

The user's guide form appears below entitled **Washer Creator Version 1.0.** The password required should be supplied to give access. Once the access is given the software would be automatically loaded. Hence any information required can be supplied to aid the design of blanking and piercing with the dimensions and required forces. Inputs: blank diameter, hole diameter and material thickness for each of the materials: aluminum, mild steel, soft brass, copper and medium carbon steel are supplied and immediately the results and detailed drawings will be generated as shown below.



Detailed Engineering Drawing

Discussion of Results

The hand-calculated results were generated and tabulated. The results generated by the CAD software have been shown. Comparing the hard - calculated results with the CAD results, the following inferences are made.

(i) **Accuracy and Exactness in Calculations**

The same accurate, exact results were generated by both the hand calculations and the CAD software. There was no single variation in the number of places of decimal and figures.

(ii) **Time Management**

Hand calculations take a lot of time. Care must be taken in the calculations as they are subject to mistakes. The CAD calculations take only seconds to generate the results with sound accuracy; no mistakes of any sort. This ensures time management, which is an advantage over manual approach.

(iii) **A Reflection of Modern Technology**

CAD is preferred to manual approach as this is a modern technology. CAD is overtaking manual approach because of its advantages and every system is calling for computer usage. CAD calculations of the dimensions of the component washer and the forces required for the shearing and blanking were with relative ease. And also the design of the detailed engineering drawings required in the interface of the CAD system was with ease.

The CAD system is so user-friendly that there is no rigidity in it as it is not limited to the case study. Similar configurations of the blanking and piercing operations are designed by the required minimum input, blank diameter, hole diameter, material thickness and the material type.

The materials programmed in the CAD system are mild steel, medium carbon steel, soft brass, copper and aluminum. These have varying shear strengths and so the punching forces and blanking forces required for materials were different.

Recommendations

This software is recommended for adoption in industries. It can also be used as a training tool in our engineering institutions.

The research can be further developed to investigate the fracture mechanics of metal in stamping production.

Short courses can be arranged for lecturers, managers, and the likes to improve their skill in software development to appreciate CAD.

Conclusion

The research is able to design blanking and piercing. A Computer-Aided Design (CAD) was employed and washer was used to validate the CAD. There are established design equations for blanking and piercing. These were complied together to determine dimensions and forces used in the design. Four major inputs; hole diameter, blank diameter, material thickness and material type were used in calculations to generate the dimensions and forces. The material type gives the shear strength required.

In piercing operation to pierce the hole of the washer, clearance, piercing punch size, piercing die opening and piercing force were determined. In the blanking operation to blank out the periphery of the washer, clearance, blanking punch size, blanking die opening and blanking force were also determined. These dimensions and forces generated for the piercing and blanking operations were used to developed model CAD software for the design of blanking and piercing, which automatically does the drafting with the detailed engineering drawings of parts to be pressed. Visual Basic 6.0 was used for the CAD software developed.

Five materials with varying shear strengths and allowances were selected to validate the CAD to give different results to allow comparison of the hand-calculated results and the results generated by CAD. It is shown that there is no single variation when comparison was made.

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