PARAMETRIC DESIGN OF A FLYWHEEL FOR AN ELECTRIC PUNCH PRESS

By

Prashant Dhakal

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Approved By

Advisor: Dr. Tejas Pandya

Reader: Dr. Taiho Yeom

Reader: Dr. Wen Wu

DEDICATION

This thesis is dedicated to everyone who guided and encouraged me throughout the year. Thank you.

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ABSTRACT

Almost all designs start with a design requirement. These may be weight, volume, clearance, and even custom calculations. To find a solution that meet these requirements often involve tedious and time-consuming iterations. Once the solution has been found, the design must be optimized to find the best possible solution. Finding the ‘best possible design’ requires substantial time and effort dedicated iterating and analyzing the potential model solutions. This is where Parametric design comes in play. The parametric design aids in specifying the key parameters of the design and makes changes interactively, with the model updating automatically. The purpose of this project was to implement parameters to the design of flywheel, which powers a punch press. A punch press is a machine that is used to punch a hole on a piece of material by applying pressure to a die in which the workplace is held. The design of flywheel varies with its application. Depending on its application, a flywheel’s design must be optimized. The project employs flywheel with a punch press, so the flywheel needs to be matched according to the work expected, the amount of energy needed at a given rate to accomplish the machining operation, and the size and the number of holes punched by the press. The designing was performed with the help of 3D Solid Modeling software CREO Parametric 7.0. More specifically, the behavioral modeling feature was used. An Excel sheet containing all the parameters was linked with CREO and changing the input values in Excel updated the model. Thus, with the help of CREO, a feasible design of the flywheel was drafted. Along with this, several shapes of flywheel were studied and compared to find the best shape for the press.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

BMX	Behavioral modeling extension
CAD	Computer-aided Design
3D	Three dimensions
2D	Two dimensions
tp	Thickness of the plate
dh	Hole diameter
df	Diameter of flywheel
n	Efficiency
c	Coefficient of fluctuation of speed
Fs	Shearing force

Introduction

This report investigates the application of design automation using 3D Solid Modeling software CREO 7.0 to engineering design process. Traditionally, almost all designs start with a design requirement. These may be weight, volume, clearance, and even custom calculations. To find a solution that meet these requirements often involve tedious and time-consuming iterations. Once the solution has been found, the design must be optimized to find the best possible solution. Design optimization requires substantial time and effort dedicated iterating and analyzing the potential model solutions. Hence, automation is a huge opportunity to speed up and make the design process dynamic. From re-using design data to create new models to writing Macros and saving processes to reduce modelling time, the benefit to a company or design team is huge. The purpose of this project was to implement parameters to the design of flywheel, which powered the punch press. The design of flywheel varies with its application. Depending on where its used, a flywheel's design must be optimized. The project employed flywheel with a punch press, so the flywheel had to be modified according to the size and the number of holes punched by the press. The design of the flywheel was done with the help of CREO Parametric 7.0. More specifically, the behavioral modeling feature was used. An Excel sheet containing all the parameters was linked with CREO and changing the input values in Excel updated the model. Thus, with the help of CREO, a feasible design of the flywheel was drafted. Along with this, several shapes of flywheel were studied and compared to find the best shape for the press. The flywheel designed here was used for an electric punch press. A Punch press is a machine that changes the size or shape of a piece of material, usually sheet metal, by applying pressure to a die in which the workpiece is held. The form and construction of the die determine the shape produced on the workpiece [1]. The flywheel used in the press acts as an energy bank between the source of power & the driven machinery. In a punching machine, maximum power is required only during a small part of the cycle, when actual punching or shearing takes place. During the remaining part of the cycle, negligible power is required to overcome the friction. If the press is directly driven by an electric motor, a higher capacity motor corresponding to maximum power requirement during actual punching will be required. Such a motor will run almost idle during the remaining part of the cycle. It is obviously wasteful to provide such a large motor when its full capacity is needed but a small fraction of the time. Providing a flywheel to the press will allow a much smaller motor to be used. During the actual punching or shearing operations, energy will be taken from the flywheel, slowing it down. During the relatively long period between two punching operations, the motor will accelerate the flywheel back to its original speed. Thus, the flywheel stores the kinetic energy during the idle portion of the work cycle by increasing its speed & delivers this kinetic energy during the peak-load period of punching or shearing [2]. The project aims to study the application of automation in design process and see how feasible it is to apply automation to a design process.

Chapter I

Identification of Need

Companies offering custom products are often putting their engineers under pressure. They are squeezed to create proposal documents and drawings as fast as possible. This leads to best guess costings, for orders that are not guaranteed. Engineering departments are wasted on tasks that could be automated. They have less time to re-engineer existing designs, update drawings and carefully check every detail. Jobs are then left open to errors, rework, backlogs, and delays [3]. All of this can affect profit margins and damage reputation. By automating time-sensitive and often repetitive upfront activities, the company will reap the benefits. The company have more time to innovate and add value to their products, improving their position in the market. One survey indicated that the typical company re-creates an item's geometry five or more times in such areas as customer proposals or marketing specifications; conceptual design; detail design; finite element analysis; other engineering analysis; detail drafting; fabrication or assembly sketches; work cell device programming; tooling and fixture design; and training and service manuals. Each time part geometry or product design information is independently maintained in a separate system or independently created on paper, another source of redundant design information is created that needs to be managed [4]. Hence, the answer to this conundrum is automation. Automation is a huge opportunity to speed up and make the design process dynamic. From re-using design data to create new models to writing Macros and saving processes to reduce modelling time, the benefit to a company or design team is huge. Some more benefits of automating the design process are, it helps to capture and re-use the design knowledge to save time and money, incorporate design rules to minimize errors and cost from manual mistakes, free design engineers from doing repetitive tasks and concentrate on new and special designs, and generate variations quickly and easily based on the rules created [5].

Chapter II

Background Research

The review consists of two things, the study of the evolution of design process in Engineering, and the application of flywheel in an electric press. Modern engineering has been one of the most in-demand services that technology had great impact on. Modern engineering design and drafting can be traced back to the development of descriptive geometry in the 16th and 17th centuries. Drafting methods improved with the introduction of drafting machines, but the creation of engineering drawings changed very little until after World War II. Patrick Hanratty and Ivan Sutherland contributed significantly on today's well-known Computer-aided Design (CAD), as they consider it as a faster and more accurate tool compared to previous drafting methods. Computer-aided design (CAD) is the use of computer systems or workstations to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. Starting around the mid-1970s, as computer-aided design systems began to provide more capability than just an ability to reproduce manual drafting with electronic drafting, the cost benefit for companies to switch to CAD became apparent. The benefits of CAD systems over manual drafting are the capabilities one often takes for granted from computer systems today; automated generation of Bill of Material, auto layout in integrated circuits, interference checking, and many others. Eventually, CAD provided the designer with the ability to perform engineering calculations. During this transition, calculations were still performed either by hand or by those individuals who could run computer programs. CAD was a revolutionary change in the engineering industry, where draftsmen, designers and engineering roles begin to merge. Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modelers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematical modeling, in which case it may be marketed as CAD. CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects with advanced rendering and animation capabilities so engineers can better visualize their product designs [6]. Furthermore, the automation feature is a huge opportunity to speed up and make the design process dynamic. From re-using design data to create new models to writing Macros and saving processes to reduce modelling time, the benefit to a company or design team is huge. Some more benefits of automating the design process are, it helps to capture and re-use the design knowledge to save time and money, incorporate design rules to minimize errors and cost from manual mistakes, free design engineers from doing repetitive tasks and concentrate on new and special designs, and generate variations quickly and easily based on the rules created [5].

For this project, flywheel was designed for an electric punch press. The flywheel used in the press acts as an energy bank between the source of power & the driven machinery. In a punching machine, maximum power is required only during a small part of the cycle, when actual punching or shearing takes place. During the remaining part of the cycle, negligible power is required to overcome the friction. If the press is directly driven by an electric motor, a higher capacity motor corresponding to maximum power requirement during actual punching will be required. Such a motor will run almost idle during the remaining part of the cycle. It is obviously wasteful to provide such a large motor when its full capacity is needed but a small fraction of the time. Providing a flywheel to the press will allow a much smaller motor to be used. During the actual punching or shearing operations, energy will be taken from the flywheel, slowing it down. During the relatively long period between two punching operations, the motor will accelerate the flywheel back to its original speed. Thus, the flywheel stores the kinetic energy during the idle portion of the work cycle by increasing its speed & delivers this kinetic energy during the peak-load period of punching or shearing [2].

Chapter III

Design Calculation

Before proceeding with the design, some calculations had to be made. The flywheel is used in an electric punch press. So, the requirement of the press had to be considered to design the flywheel. The press in this project is a miniature press. For calculation purposes, the press had to punch 12 holes/min with a hole diameter of 20mm, and the thickness of the plate was 15mm. The plate was an aluminum alloy with a shear stress of 70MPa. More detailed calculation is shown below:

Calculation

Here,

Thickness of the plate (t_p) = 15mm

Hole diameter (d_h) = 20mm

Shear stress of the plate (τ) = 70MPa

No of holes/min = 12

Diameter of flywheel (d_f) = 1000mm

Efficiency (n) = 80%

Coefficient of fluctuation of speed (c) = 0.1

Energy to punch a hole = $\frac{1}{2} * (Shearing\ force * Thickness\ of\ plate)$

$$= \frac{1}{2} * \left(F_s * t_p\right) = \frac{1}{2} * 65973.45 * 0.015 = 494.80\ J$$

Shearing force= $Shear\ stress * Cross\ section\ area\ of\ flywheel$

$$= \tau * \pi * t_p * d_h = 70 * pi * 0.015 * 0.020 = \ \ 65973.45\ N$$

Power of Motor= $Energy\ to\ punch\ a\ hole * No\ of\ holes\ per\ minute = 494.80 * 12 =$

$$= 98.96 KW$$

Mean speed of flywheel = $9 * No. of\ holes\ per\ minute = 9 * 12 = 108\ RPM$

Angular velocity = $\frac{\pi * (Mean\ speed\ of\ flywheel)}{30} = \frac{1}{30} * pi * 108 = 11.31\ rad/s$

Actual energy to punch a hole= $\frac{Energy\ to\ punch\ a\ hole * 100}{Efficency} = \frac{1}{0.8} * 494.80 = 618.50\ J$

Fluctuation of energy= $0.9 * Actual\ energy\ req. to\ punch\ a\ hole = 0.9 * 618.50 = 556.65\ J$

Mass of flywheel= $\frac{(Fluctuation\ of\ energy)}{(Radius\ of\ flywheel)^2 * (Angular\ velocity)^2 * (Coeff. of\ fluctuation\ of\ speed)} =$

$$= \frac{556.65}{(0.5)^2 * (11.31)^2 * (0.1)} = 174.08\ kg$$

The calculation here is a steppingstone to the next step. Now, since all the parameters of the design is identified, the next step is the actual design process.

Chapter IV

Modelling of flywheel

The modeling of the flywheel was carried out using CREO 7.0. Creo, the shorthand name for Creo Parametric, (formerly known as Pro Engineer) is a powerful and intuitive 3D CAD software optimized to address the challenges organizations face as they design, analyze, and share information with downstream partners [7]. Creo Parametric is a robust modeling tool whose focus is on providing modularity and instant feedback for design changes. Its surfacing capabilities allow users to turn their 2D sketches into full 3D models by either parametrically building or organically shaping complex surfaces. Creo Parametric's "Unite" toolset even features support for importing geometries from competing applications. Creo Parametric also supports 2D drafting in addition to its 3D modelling capabilities, meaning that a designer can easily switch between the 3D model and its corresponding 2D draft, with either view reflecting changes made on the other. The Creo suite's emphasis towards real, manufactured products is demonstrated by many of Creo Parametric's features [8].

There are many designs of flywheel, the most popular ones are web type flywheel, straight elliptical arm flywheel, and tapper arm flywheel. For the purpose of this project, all the three designs are modeled here. The flywheel design is shown below:

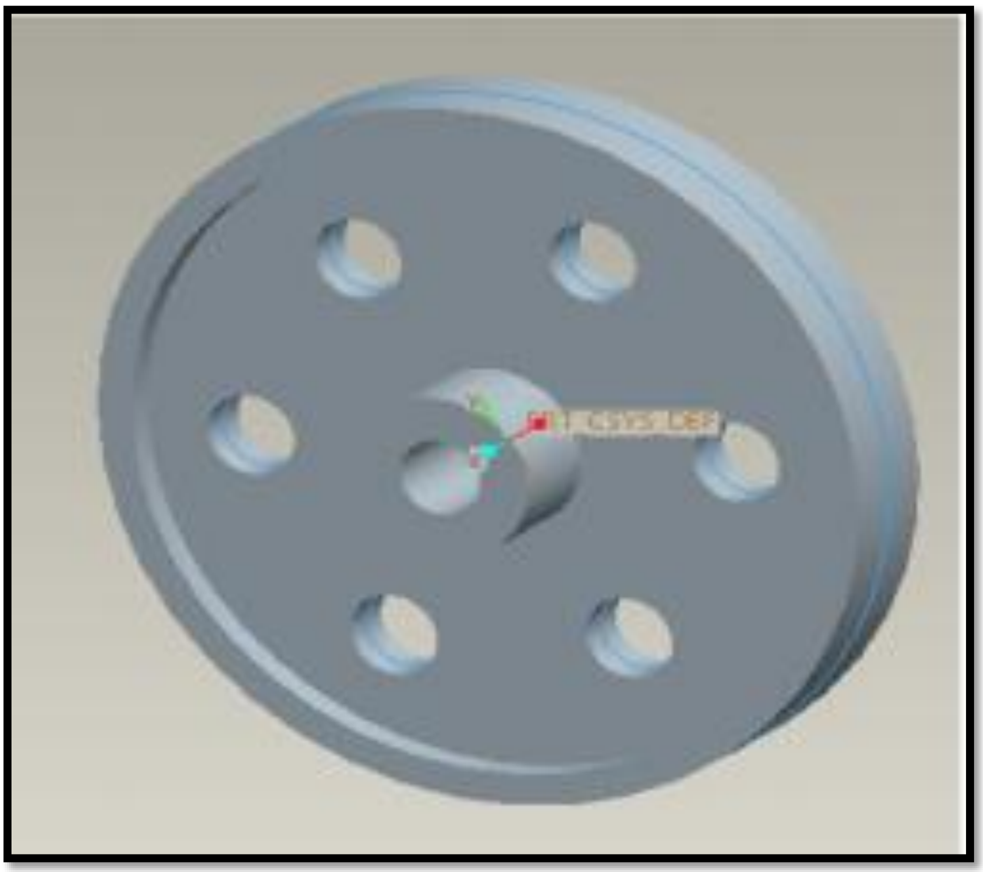

Figure 1:Web type flywheel

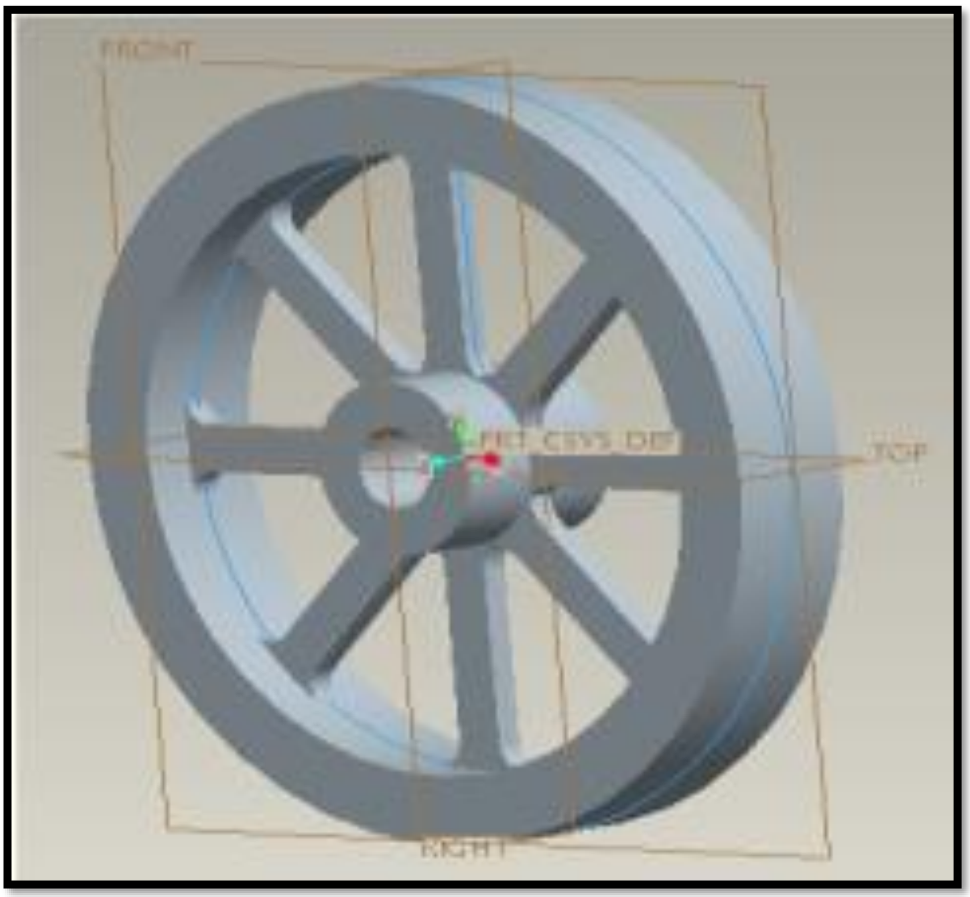

Figure 2:Straight elliptical arm flywheel

Figure 3:Tapper arm flywheel

The optimal flywheel design will be a flywheel having minimum weight, to provide a particular moment of inertia and to control the fluctuating energy with safe stresses in all parts of the flywheel. An optimum design of flywheel is the one that has more inertia and can handle fluctuations in energy of the shaft. The moment of inertia of a rim is more than that of a disc of the same mass as the mass is distributed farther away from the center in a rim. Hence a rim is preferred over a disc for a flywheel.

Chapter V

Parametric design of flywheel

Now after all the calculations and modeling is done. The final step is the parametric design of the flywheel. Here, the excel sheet containing all the parameters is linked with the CREO 7.0 application with the help of Creo Behavioral Modeling Extension (BMX). BMX is the ultimate in feature based parametric modeling through which a new feature is created that ensure changes to geometry and update the rest of the model [9]. The pictorial representation of this is shown below.

Input Values			**Output results**	
Thickness of the plate(t)(m)	0.015		Energy to punch a hole(J)	494.80
Hole diametrer(m)	0.02		Power of motor(W)	98.96
Material property(Mpa)	70	Alum alloy	Shearing force(N)	65973.45
Radius of the flywheel(m)	0.5			
Diameter of flywheel(m)	1		Mean speed of flywheel(RPM)	108
No of holes/min	12		Angular velocity(rad/s)	11.31
Efficency	80		Actual Energy required to puncha ho	618.50
Coefficient of fluctuation of speed	0.1		Fluctation of Energy	556.65
Flwheel hole	0.05		Mass of the flywheel(kg)	174.08

Figure 4: A representative screenshot of excel spreadsheet with list of parameters to be inputted by the user, and the Output values.

The figure4 above shows all the parameters involved in this design process. For a flywheel design, the main parameters are, diameter of flywheel and flywheel hole. These two parameters need to be changed based on the requirement of the press. Before the use of the BMX feature of CREO, the design had to be manually edited when the requirement of the punch was altered. However, with the application of the BMX feature, the manual editing ceases. This is demonstrated below:

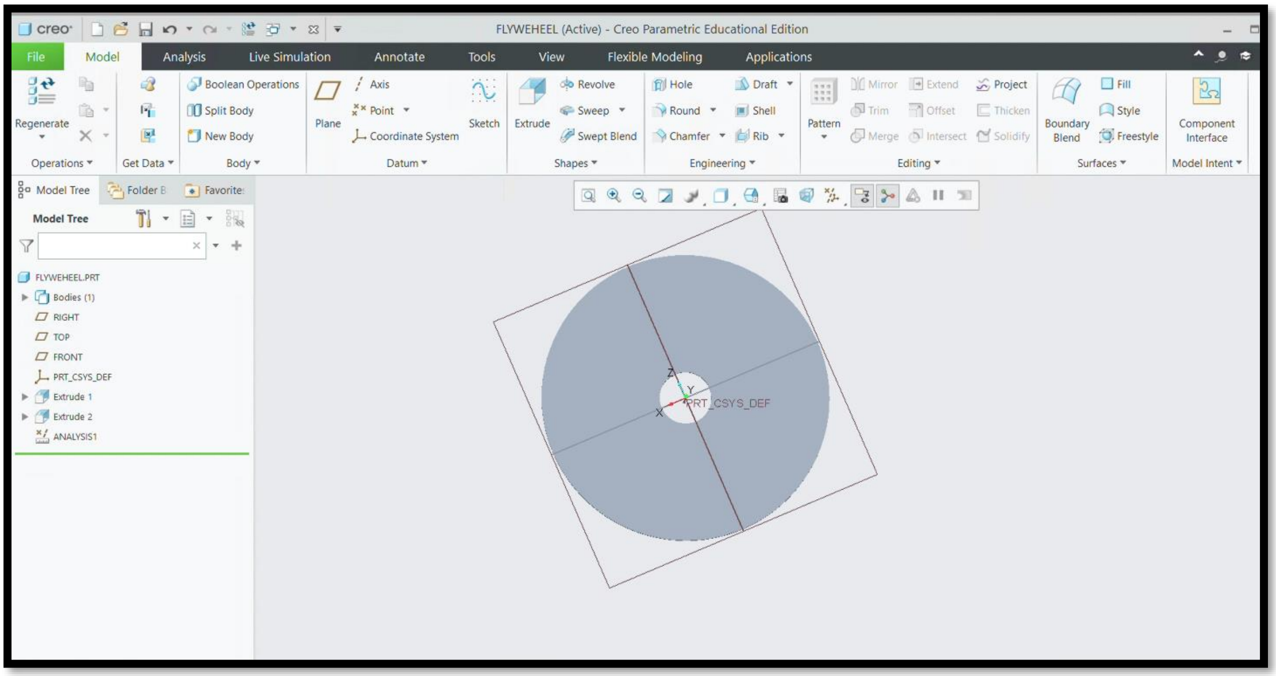

Figure 5:Original design

Here, the figure5 shows a basic disc type flywheel with its diameter being 5 m and the diameter of the flywheel being 0.05m. Now, the task is to create a flywheel of 1 m diameter. Traditionally, this can be achieved my manually altering the design. However, here it is done by the BMX feature of CREO by simply changing the diameter in the excel. So now, the new diameter of the flywheel is 1 m and the hole diameter is 0.03 m. The new excel sheet is shown in figure 6 below,

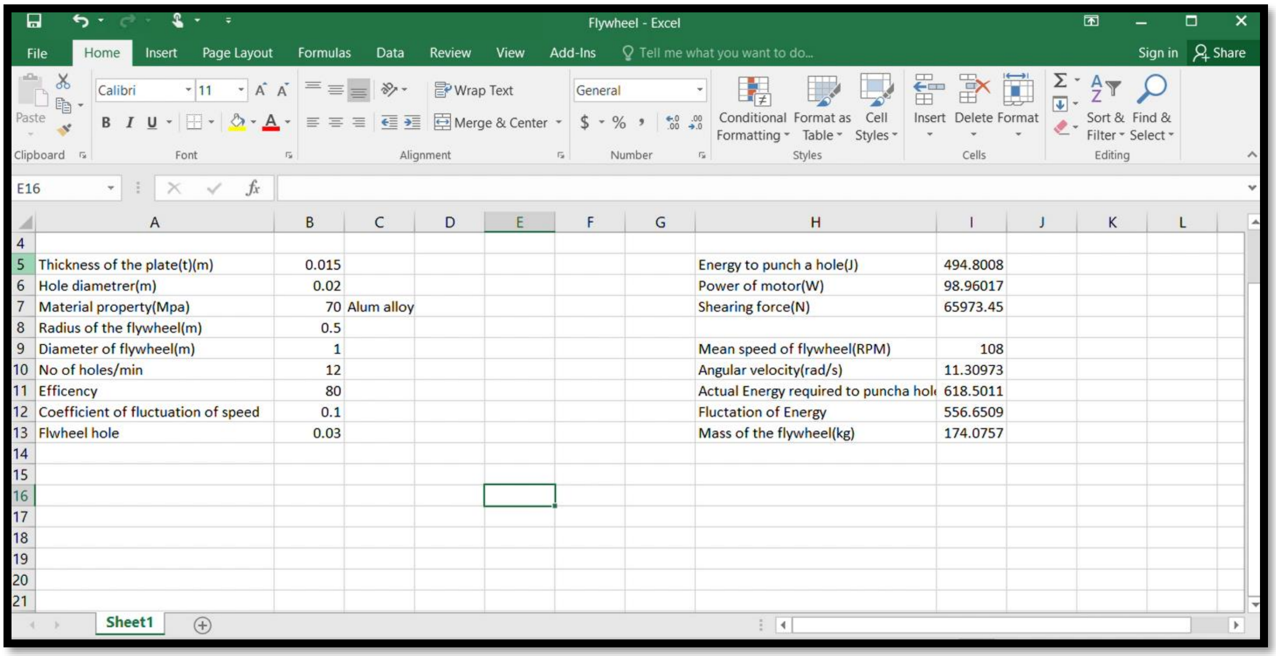

Figure 6:Updated excel sheet with new flywheel diameter

The figure6 above shows the updated excel sheet. Now, the diameter of the flywheel is changed to 1m. Figure7 below shows the BMX feature of the CREO. With the help of BMX, the next step is to simply regenerate the model.

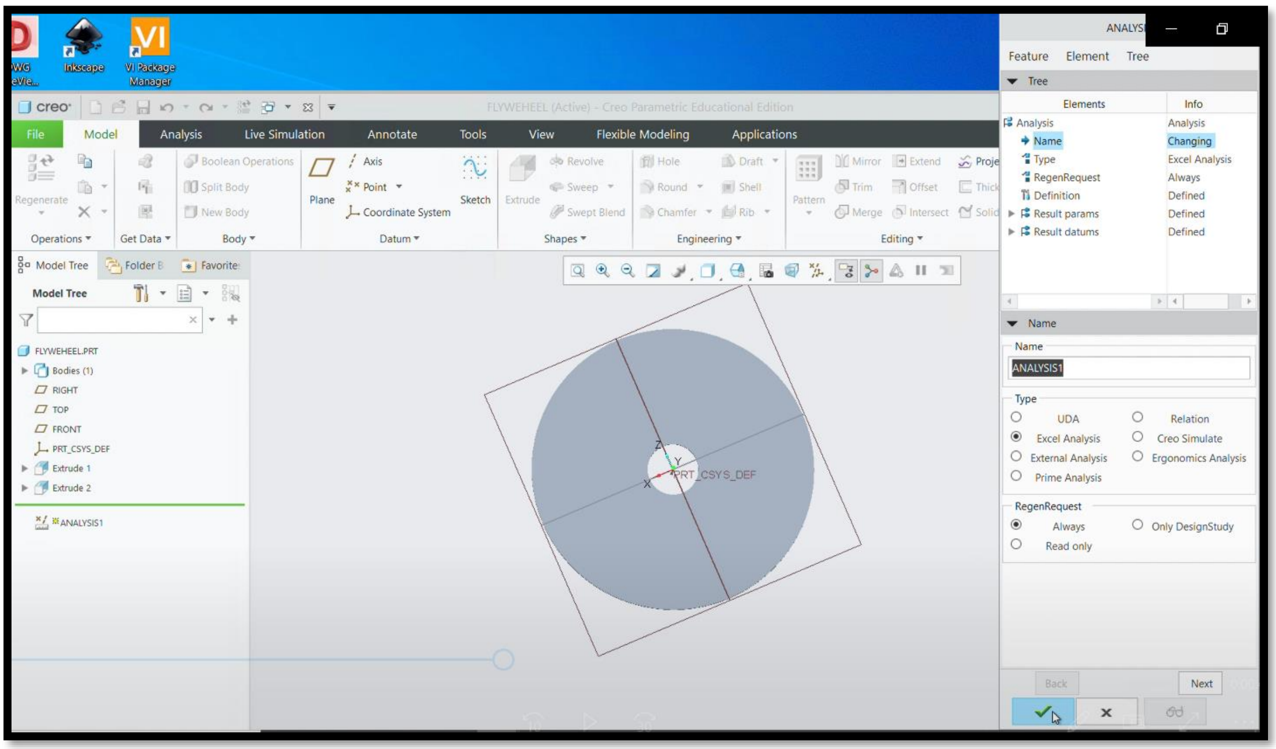

Figure 7:Regenerating the model by simply pressing a button

Now, this is where the magic happens. By simply hitting regenerate, a new model is drawn with the provided dimensions. Figure8-9 below demonstrates that,

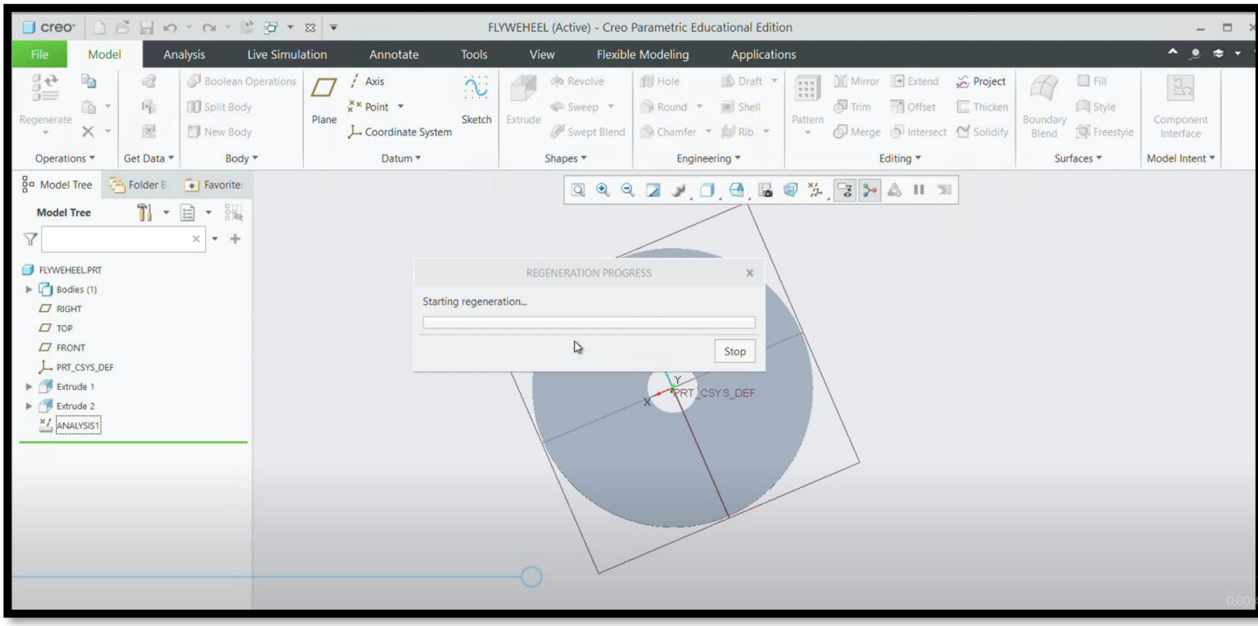

Figure 8:The new model being generated

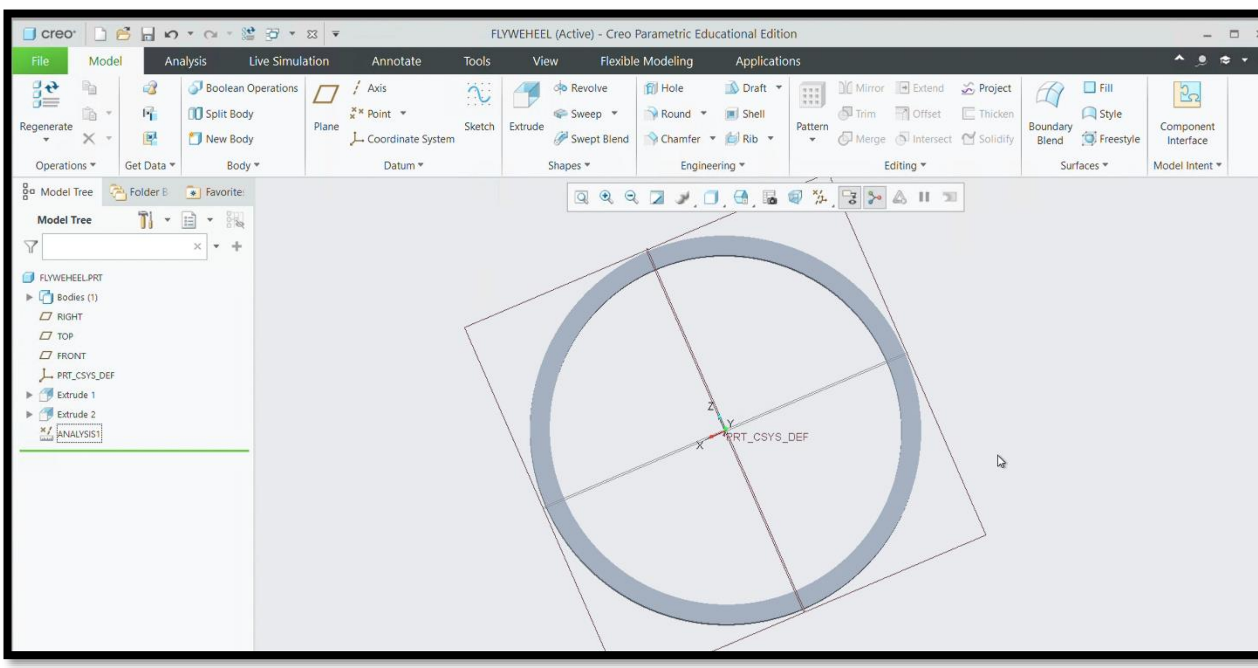

Figure 9:Updated model with new dimensions

Figure 9 above illustrates the new model of the flywheel. It does not quite look like one, but this was carried out for a demonstration purpose. Hence, a new model was made with just altering the parameter in the excel sheet and pressing the regenerate button in CREO. This CREO feature has a huge application. Thousands of hours can be saved by a manufacturing company by simply automating their design processes. Furthermore, the automation feature is a huge opportunity to speed up and make the design process dynamic. From re-using design data to create new models to writing Macros and saving processes to reduce modelling time, the benefit to a company or design team is huge. Some more benefits of automating the design process are, it helps to capture and re-use the design knowledge to save time and money, incorporate design rules to minimize errors and cost from manual mistakes, free design engineers from doing repetitive tasks and concentrate on new and special designs, and generate variations quickly and easily based on the rules created [5].

Conclusion

The work focused on demonstrating automation of an engineering process as a part of design of engineering components, using flywheel of a punch press as a representative exampl,. Traditional design process involved drafting machines and different drafting methods. The creation of engineering drawings changed very little until after World War II. Patrick Hanratty and Ivan Sutherland contributed significantly on today's well-known Computer-aided Design (CAD), as they consider it as a faster and more accurate tool compared to previous drafting methods. Since then, more companies began to use CAD software starting around mid-1970s. The computer-aided design systems began to provide more capability than just an ability to reproduce manual drafting with electronic drafting, the cost benefit for companies to switch to CAD became apparent [6]. Furthermore, the automation feature is a huge opportunity to speed up and make the design process dynamic. From re-using design data to create new models to writing Macros and saving processes to reduce modelling time, the benefit to a company or design team is huge. Some more benefits of automating the design process are, it helps to capture and re-use the design knowledge to save time and money, incorporate design rules to minimize errors and cost from manual mistakes, free design engineers from doing repetitive tasks and concentrate on new and special designs, and generate variations quickly and easily based on the rules created [10].

Here, a successful demonstration of the automation is shown with the design of flywheel by using the BMX extension feature of CREO. The flywheel designed with CREO was modified by simply altering the parameters in the excel sheet. This CREO feature has a huge application. Thousands of hours can be saved by a manufacturing company by simply automating their design processes. By automating time-sensitive and often repetitive upfront activities, the company will reap the benefits. The company have more time to innovate and add value to their products, improving their position in the market. One survey indicated that the typical company re-creates an item's geometry five or more times in such areas as customer proposals or marketing specifications; conceptual design; detail design; finite element analysis; other engineering analysis; detail drafting; fabrication or assembly sketches; work cell device programming; tooling and fixture design; and training and service manuals. Each time part geometry or product design information is independently maintained in a separate system or independently created on paper, another source of redundant design information is created that needs to be managed [11]. Hence, automation is a huge opportunity to speed up and make the design process dynamic.

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