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Design, Analysis and Optimization of Oldhams Coupling based on 3D Printing Manufacturing Process

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Abstract: Oldham's couplings are widely used in many applications where power transmission is required even when the driver and driven shafts are in non collinear axis. The slider part is made of plastics or reinforced resins or aluminium bronze, they have good sliding effects but in the meantime they undergo plastic deformation during the application of transmission torque. When the applied load becomes against the design load (shock/impact), the slider part eventually ruptures in the direction of deformation. This causes to replacement of the slider material and in some cases, the entire assembly have to be replaced. This involves in additional cost to the unit. In this project, to reduce the failures in Oldhams coupling and to make sure the availability of the spares of particular part, we have concentrated on the design and optimization of parts of Oldham's coupling considering the 3D printing process. For this, the Oldhams coupling used in lead screw of the 3D printing is taken for analysis.
Here we have used the triangle, hexagon and octagon as the cross sectional shapes. These shapes are analysed and the best effective shape is incorporated in the coupling design. This new design is again analysed under the same boundary conditions and the results are compared and the effective design for 3D printing is suggested. Hence utilising the application of ANSYS Workbench for the effective design of a component
Keywords: Oldhams coupling – design optimization – 3D printing – shape optimization – FEA – static analysis

I. INTRODUCTION

Couplings are used in power transmission in rotary devices. In some cased couplings are used also for the stability of the devices. In most cases, the power transmission is carried out by the precise axial collinearity. In few cases, the axial collinearity is not possible to achieve. In these cases, the Oldhams couplings or flexible couplings are used. These couplings adjust their rotational parts according to the axis of the shafts.

The Oldhams couplings are widely used in the cases of axis non-linearity. These couplings are made of three parts – the hubs and a slider. The hubs are made of steel and the slider is made of various materials based on the application and nature of the works. These sliders are easily wearable and replacement if bit difficult as the spares are not available and they have to be purchased as a whole assembly. To avoid these issues and to reduce the failure rate and increase the life of the slider and considering various aspects, this project deals with the design, analysis and shape optimization of the Oldhams coupling.

A. Coupling

A link is a tool used for the transfer of energy by linking two shafts at their ends. Connections normally do not allow shafts to disconnect while operating, but when the torque limit has been exceeded, connections that slip or disconnect can exist. The primary purpose of the connections is to connect two rotating equipment and enable a certain distortion or ending movement. By choosing, installing and maintaining couplings attentively, considerable savings can be obtained in decreased maintenance costs and downtime.

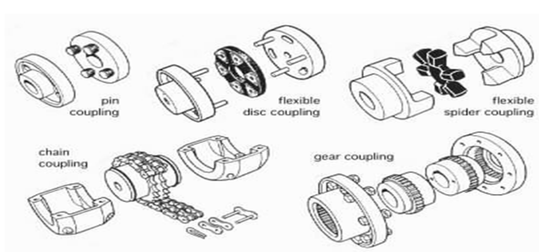

Figure 1.1. Mechanical Couplings

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B. Oldham

A couple of Oldhams has three disks, 1 with the input, one with the output and 1 middle disk with tongue and groove connected with the first two disks. On the one hand, the tongue and groove are perpendicular to the ear. At the same speed as the input and output shafts, the central disk rotates around their centre. Its core follows a circular orbit around the middle point between input and output shafts, twice by rotation. Springs are also used to decrease the mechanism 's reaction. Compared with two universal joints, the compact size is an advantage for this form of contact. The connection is named after John Oldham, in 1821 inventing a paddle in Ireland positioning problem in design of paddle steamer.

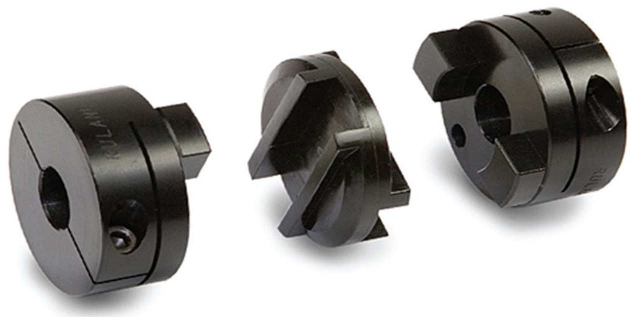

Figure 1.2.1 Oldhams Coupling

An Oldham coupler is a way of moving the torque between two parallel shafts but not between them. It comprises three disks, one linked to the input, one to the output, and a middle disk which is tongue and groove connected to the first two. On the one hand, the tongue and groove are perpendicular to the ear. Springs are also used to decrease the mechanism 's reaction. For example , two universal joints are much more compact than the connector.

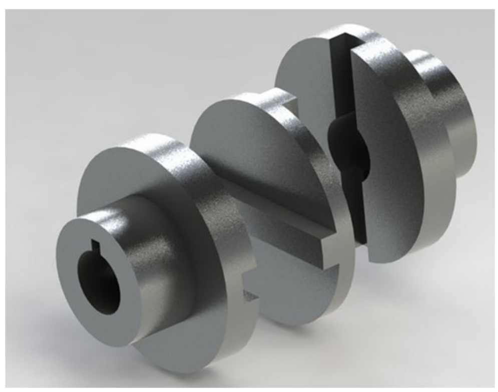

Figure 1.2.1 Peculiar Oldhams Coupling

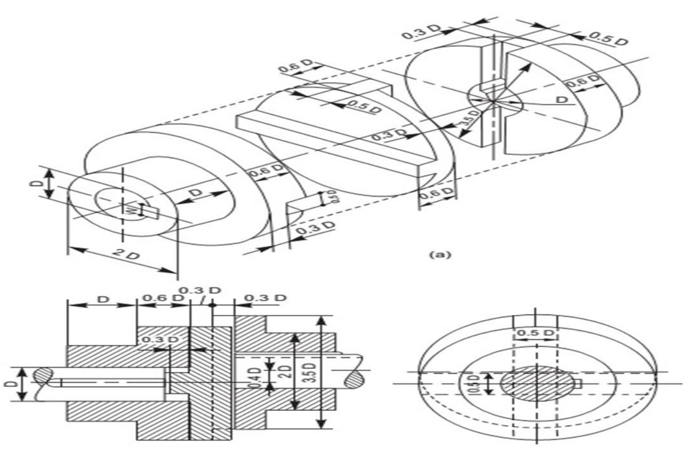

Figure 1.2.2 Schematic View Of Oldhams Coupling

C. Requirements Of Good Shaft Alignment / Good Coupling Setup

1) Connecting or disconnecting the connection should be simple.
2) There are discrepancies between the two parallel rotation axes of the shaft.
3) The goal should be to reduce remaining misalignment in service, optimizing power transmission and optimizing system run-time (coupling, bearing and screening).
4) No projection parts should be given. The manufacturer's target alignment values should be used in order to set the machine train to a given non-zero alignment because the alignment conditions are later ideal when the system is in operation at the temperature.

D. Coupling Maintenance And Failure

1) Maintenance of connections is generally a simple matter, requiring regular inspections of each connection. It's made up of check for wear or fatigues signs and clean couplings, visual checks and daily washing. Periodically test and adjust lubricant for lubrication of the coupling. For most couplings and also for couplings in harsh environments or in challenging operating conditions this maintenance is required annually. The maintenance documents conducted with the date on every link. However, couplings can fail even with adequate maintenance.
2) Except for repair, the underlying reasons for failure include:
3) Setup wrong • Limited number of couples • Process without the opportunity to design.

The only way to improve connection life is to understand and correct the failure before installing a new connection. Several external signs suggesting potential failure of coupling include: • Abnormal noise like chirping, chattering, or screaming • Excessive wobbling or vibration • Lubricant leakage or contamination-related broken seals.

E. Typical Errors In Selecting Couplings

Too late in the design process, pick the connection: Movement control connectors are too frequently chosen very late and without meeting the specific specifications of the device in the application design process. Connections are a crucial element to assess and achieve system efficiency overall. Early selection should reduce mistakes and the chance of premature coupling failure. Coupling selection includes: application, torque, misalignment, rigidity, inertia, RPM, shaft mounting, environmental factors, limitation of space, service factors, and other design criteria. In order to ensure that couples function properly without premature failure, all requirements must be considered and discussed in the process of selection. This is important in the initial selection of the coupling and if the application changes over time. Connections are also defined if torque in the application is not carefully considered. In addition to the steady torque in the state, the design selection must consider the maximum instantaneous torque, particularly when the torque is different from the start and stops. In some cases, a degree of torsional conformity can be considered to dampen torque shock loads and peaks.

1) *Choose The Wrong Form Of Connection For The Application:* The selection of couplings requires a range of design parameters, such as application, dynamometry, misalignment, rigidity, inertia, RPM, shaft mounting, environmental considerations, space constraints, duty factors, costs ... In order to ensure that couples function properly without premature failure, all requirements must be considered and discussed in the process of selection. This is critical both when choosing the initial connection and when circumstances change over time in the application.
2) *Use the Wrong Combination For The Misalignment Conditions Of Application:* In the selection of the template, it is important to match the appropriate linkage to the misalignment or combination of conditions present to avoid premature coupling failures. Shaft malalignment can be circular, parallel or axial with additional complications if combined (complex misalignment). Flexible links are usually intended to mitigate particular misalignment requirements for use. An oldham coupling is good for handling large quantities of parallel misalignment, and it is not capable of offsetting angular and axial motion.
3) *Unless Unnecessary Misallocation Has Been Corrected:* Excessive misalignment between joined shafts is one of the most common reasons for failing to attach as charges exceed coupling requirements are produced. All flexible shaft connections are built to malalign one or more styles and to varying degrees of flexibility. It is important to understand the flex that is required for the coupling. Besides potential premature coupling failures, bear in mind that all couplings that are built to curve during misalignment produce loads for the bearing.
4) *Choose The Wrong Relation In The Application For The Torque:* Connections are also defined if torque in the application is not carefully considered. In addition to the steady torque in the state, the design selection must consider the maximum instantaneous torque, particularly when the torque is different from the start and stops. Based on the design form, flexible

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connectors have specific static torque levels. For example, if all other application design variables are within rating of two alternatives, a double disco coupled usually offers the same size oldham coupling 15–20 percent static torque rating higher than static rating torque over oldham cup of the same size and acetal disks.

5) *Windup Consideration:* Both couplings are torsionally compliant or torsional rigid. Windup is the rotation of the driver's (i.e. motor) and load deflection. Consider it as a spring winding the coupling. The most important issue with windup in a servo application is preserving the exact position, since the angle movement of one end of the connection to the other is different. Windup may also carry a resonance into the device and make the servo unstable if it is poorly tuned.
6) *Consideration for Backlash:* Backlash is for playing in couplings and is mostly lost movement. The backlash effect is a power interference or uncoupling when the driver (e.g., the motor) transfers power to load. In movement control applications, Backlash is not acceptable, the main consequences of which are lack of control in placement precise and difficulty in tuning the system. Backlash creates timing issues in a motion-centric application such as a servo that can cause the link to be pushed too far forward and backward, thus causing tension that can lead a premature failure. Because of these reasons, zero-backlash connections are ideal for servo applications.
7) *Selecting A Link With The Incorrect Absorption And Humidification Of The Shock:* The device damping means reducing the propagation of shock and vibration in a mechanical power transfer. Damping is especially important to reducing unwanted vibration which wastes energy and causes harmful stresses on system components in application for motion control and power transmission. Shock damping helps to reduce the effect on the motor and other sensitive devices of pulse loads, minimizing shocks. Couplements can not lead to vibration of the device, and can be selected according to desired damping effects.
8) *Consideration for Inertia:* Inertia is an organic resistant to angular velocity change and controls the connection tendency to remain at constant velocity in response to external forces applied (e.g. torque). In a power transmission system, mass and axis distribution decide the inertia, which determines the required drive torque. Choosing a servo drive system connection in which links start and end intermittently, in addition to zero reaction and torsional rigidity requires inertia consideration. Selection also needs an understanding of the inertia values of the guided systems and their effect on the relation.\

II. EXPERIMENTAL DETAILS

A. Geometry Specifications

The diameter of the lead screw used in the 3D printing machine is 20mm. based on this, using the calculations described in the text books and using a handbooks, the CAD model is prepared accordingly

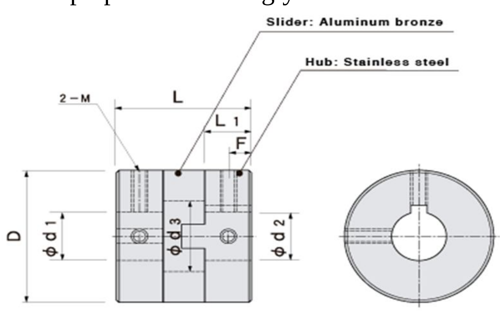
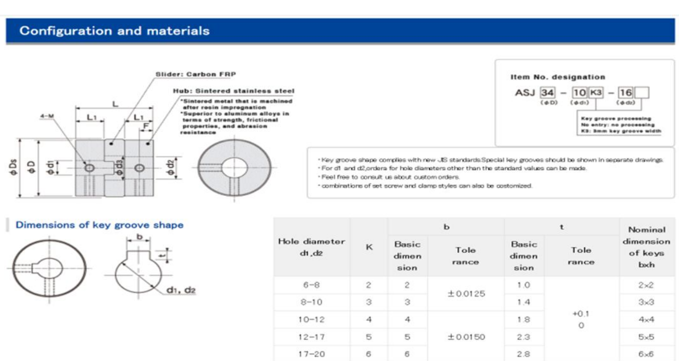
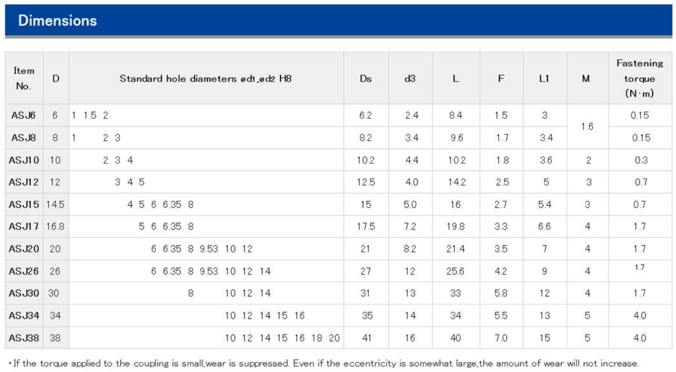


Figure 2.1.1 Specification Of Standard Coupling



Hole diameter d1,d2	K	b		t		Nominal dimension of keys bxh
		Basic dimension	Tolerance	Basic dimension	Tolerance	
6–8	2	2	±0.0125	1.0	+0.1 0	2×2
8–10	3	3		1.4		3×3
10–12	4	4	±0.0150	1.8		4×4
12–17	5	5		2.3		5×5
17–20	6	6		2.8		6×6

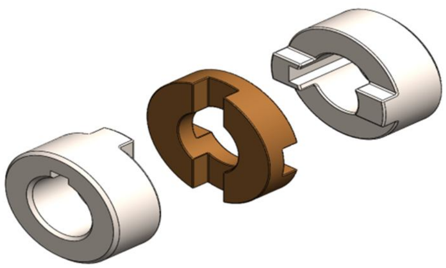
Figure 2.1.2 Industrial Design Specification Chart 1


Dimensions

Item No.	D	Standard hole diameters ød1,ød2 H8	Ds	d3	L	F	L1	M	Fastening torque (N·m)
ASJ6	6	1 1.5 2	6.2	2.4	8.4	1.5	3	1.6	0.15
ASJ8	8	1 2 3	8.2	3.4	9.6	1.7	3.4		0.15
ASJ10	10	2 3 4	10.2	4.4	10.2	1.8	3.6	2	0.3
ASJ12	12	3 4 5	12.5	4.0	14.2	2.5	5	3	0.7
ASJ15	14.5	4 5 6 6.35 8	15	5.0	16	2.7	5.4	3	0.7
ASJ17	16.8	5 6 6.35 8	17.5	7.2	19.8	3.3	6.6	4	1.7
ASJ20	20	6 6.35 8 9.53 10 12	21	8.2	21.4	3.5	7	4	1.7
ASJ26	26	6 6.35 8 9.53 10 12 14	27	12	25.6	4.2	9	4	1.7
ASJ30	30	8 10 12 14	31	13	33	5.8	12	4	1.7
ASJ34	34	10 12 14 15 16	35	14	34	5.5	13	5	4.0
ASJ38	38	10 12 14 15 16 18 20	41	16	40	7.0	15	5	4.0

• If the torque applied to the coupling is small,wear is suppressed. Even if the eccentricity is somewhat large,the amount of wear will not increase.

Figure 2.1.3 Industrial design specification chart 2



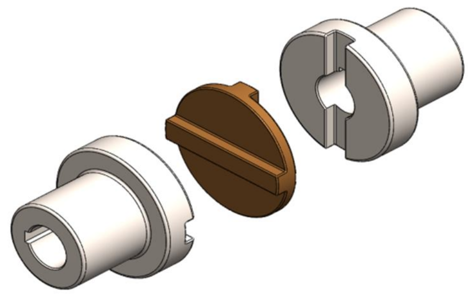


Figure 2.1.4 CAD model of Industrial design

Figure 2.1.5 CAD model of proposed design as per text book

B. Material Specifications

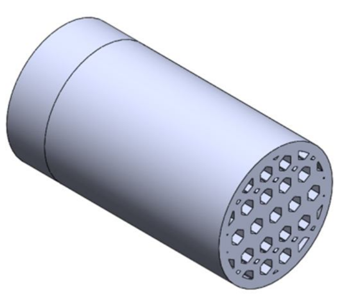
The material used for the 3D printing is ABS plastic. The below are the properties of the ABS available in the ANSYS material library.

Table 2.2.1 Material properties of ABS plastics

PROPERTY	VALUE	UNIT
Density	1040	Kg/m3
Young's Modulus	2390	MPa
Poisson's Ratio	0.399	
Tensile Strength – Yield	41.4	MPa
Tensile Strength – Ultimate	44.3	MPa

C. Design For Optimization

Based on the material reduction and 3D printing guidelines, the below are the proposed shell model. These models are analysed first and then the best one used for actual design of coupling.



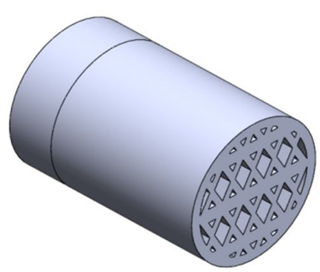


Figure 2.3.1 Shell pattern 1 – Hexagon

Figure 2.3.2 Shell pattern 3 – Triangle

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D. Analysis

The analysis is carried out using the ANSYS workbench FEA tools. Here the static structural method is used for the analysis of the strengths. The analysis is carried out in 3 phases.

1) *Pre Processing:* This involves the geometry importing, meshing and applying the boundary conditions. The below are the step by step process in the pre-processing phase.

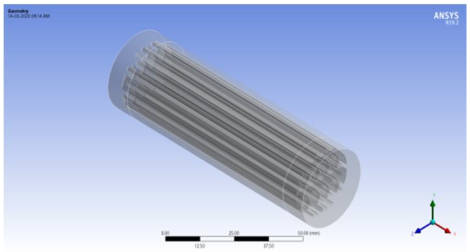


Figure 2.4.1. Importing the shell model

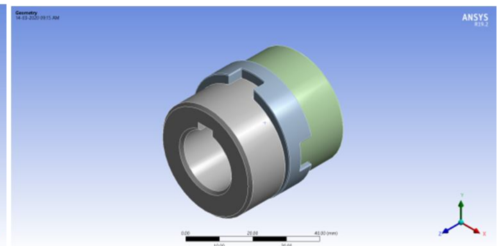


Figure 2.4.2. Importing the Existing design model

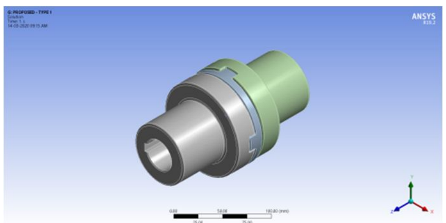


Figure 2.4.3. Importing the proposed design model

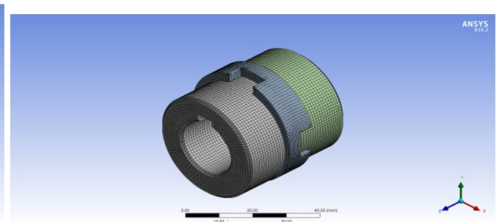


Figure 2.4.4 Meshing of the Existing design model

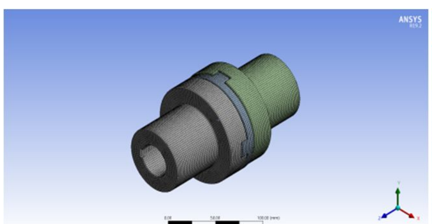


Figure 2.4.5. Meshing of the proposed design model

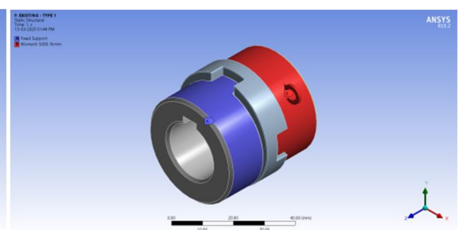
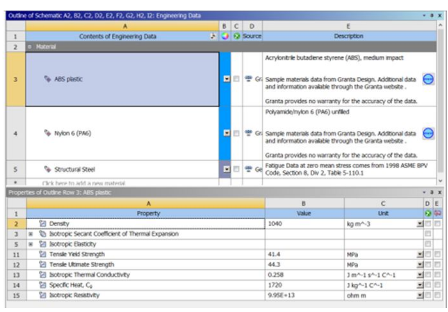


Figure.2.4.6 Boundary conditions for the actual product



Outline of Schematic A2, B2, C2, D2, E2, F2, G2, H2, I2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	ABS plastic			Gr	Acrylonitrile butadiene styrene (ABS), medium impact. Sample materials data from Granta Design. Additional data and information available through the Granta website . Granta provides no warranty for the accuracy of the data.
4	Nylon 6 (PA6)			Gr	Polyamide/nylon 6 (PA6) unfilled. Sample materials data from Granta Design. Additional data and information available through the Granta website . Granta provides no warranty for the accuracy of the data.
5	Structural Steel			Ge	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

Properties of Outline Row 3: ABS plastic

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	1040	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
5	Isotropic Elasticity				
11	Tensile Yield Strength	41.4	MPa		
12	Tensile Ultimate Strength	44.3	MPa		
13	Isotropic Thermal Conductivity	0.258	J m^-1 s^-1 C^-1		
14	Specific Heat, C_p	1720	J kg^-1 C^-1		
15	Isotropic Resistivity	9.95E+13	ohm m		

Figure 2.4.7 Material data in ANSYS Workbench

The above are the pre-processing steps in ANSYS and in general FEA concept.

Here the geometry is analysed and optimised based on the below process. The shell models are first analysed under the boundary conditions. The shell models consists of 4 models. Solid, Hexagon, Octagon and Triangle shaped cross sections. Based on the analysis results of these shell models, the effective shape is used in the Oldhams coupling. The existing and proposed models of the couplings are of solid model.

2) *Solution:* The solution phase of this project is setting up of the analysis settings. In general the settings are kept at programme controlled. This helps in the determining the effective governing equations based on the model and boundary conditions.

3) *Post Processing:* The post processing is retrieving of the results in the form of coloured data and it is explained in the next chapter under results and discussions.

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III. PROBLEM IDENTIFICATION

The Oldhams couplings used in 3D printing lead screw is made of metal parts. This involves the increased price and increased load capacity. The replacement of the damaged part is also costly. So the problem is defined to design a simplified form of Oldhams coupling that can withstand the loads applied by the lead screw and doesn't compromise in the strength. The main objective is to design an Oldhams coupling to replace the existing metal coupling. This new coupling have to withstand the loads as like the metal coupling. Also the weight of the coupling have to be reduced to minimise the printing cost and material cost. The strength of the new design have to be checked using the ANSYS Workbench thus effectively using the FEA tools to reduce the risks of failures.

IV. METHODOLOGY

Methodology of this project includes the start to end of the design and fabrication process. This includes the problem definition, defining the objectives, creating the models, material selections, analysis, optimizations and observations and discussions. Below is the flow chart of the methodology process used in this project.

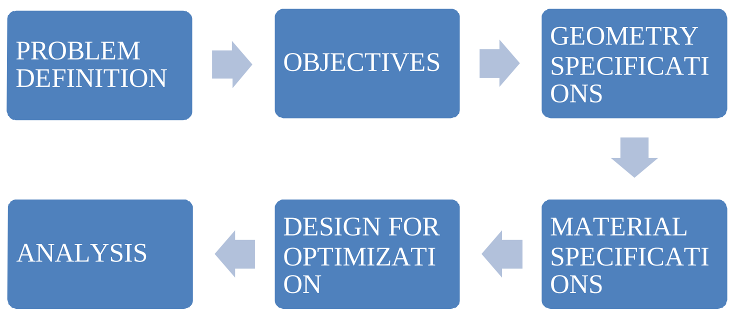

Fig 4.1. Methodology

V. RESULTS AND DISCUSSIONS

A. Results Of Shell Model

The below are the typical results of the shell models. The contour plots are for random model to show the forms of the results.

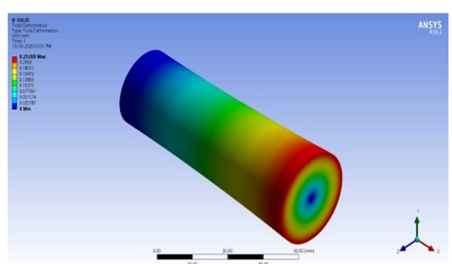

Figure 5.1 Deformation of Shell model

Table 5.1.1 Results of shell models

Results	Solid model	Hexagon	Octagon	Triangle
Deformation (mm)	0.23	0.2839	0.2825	0.274
Strain	0.0036	0.0047	0.0047	0.0047
Stress (MPa)	3.22	4.51	4.58	4.31
FOS	13.3	9.53	9.42	9.99

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B. Results Of Oldhams Coupling

The below are the results of the existing and proposed models. Also based on the above results, the hexagon is selected for the shell model of the coupling and that too is designed and analysed and plotted below accordingly.

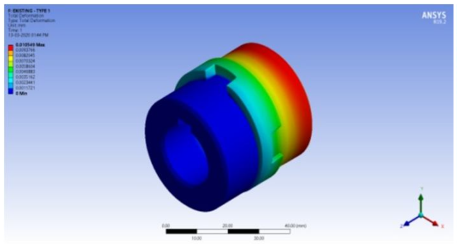

Figure 5.2.1 Deformation of existing design

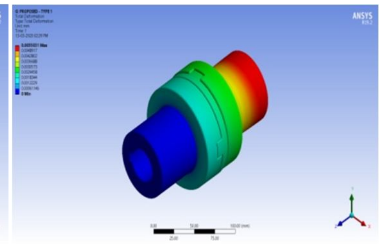

Figure 5.2.2 Deformation of proposed design

Table 5.1.2. Results of the Oldhams coupling FEA analysis

Results	Existing	Proposed	Existing – Shell	Proposed 2 - Shell
Deformation (mm)	0.015	0.0055	0.012	0.0016
Strain	0.0054	0.0002	0.005	0.0002
Stress (MPa)	12.3	0.57	13.06	0.3515
FOS	3.36	15	3.16	15

The triangle concept produces better results compared to the other two types when we look at the results of the shell model. Nevertheless, it is best to use the hexagon style when considering 3D printing guides. This hexagon configuration is used in the coupling system of Oldhams. The Oldhams coupling results indicate that the FOS is substantially higher than the current system for the proposed design. The replacement of a slot in the hub portion and the slider portion is due to this. The shell concept is that the design proposed is substantially better than the solid design proposed. Therefore, the production of the shell type process is suggested to have better effects and the reduction of material costs and production costs is recommended for light applications such as these.

VI. CONCLUSION

The design and analysis of Oldhams coupling was taken as the main scope of the project and carried out accordingly. Initially the application of the Oldhams coupling was identified and it was fixed to lead screw in 3D printer application. Then the design and modelling of the coupling was carried out using the industrial data and standard formulas. The modelled parts are assembled and analysed under standard boundary conditions.Then for the optimization of the design, the 3D printing guidelines was considered. Based on the available options for weight reduction, various shell patterns were designed and analysed. Out of it, hexagon was selected accordingly. This hexagon pattern is implemented in the coupling model and then the couplings are analysed again. On observing the results, the proposed designs are having better results than the available industrial design. The shell model of the proposed design is having considerably better results. Considering the weight aspect, the shell model of the proposed design is selected as the best design and replacement of existing design for the lead screw application. Thus, this project implies the application of softwares in modelling the designed product and application of FEA tools for analysing the products life by reducing the risks of failures.

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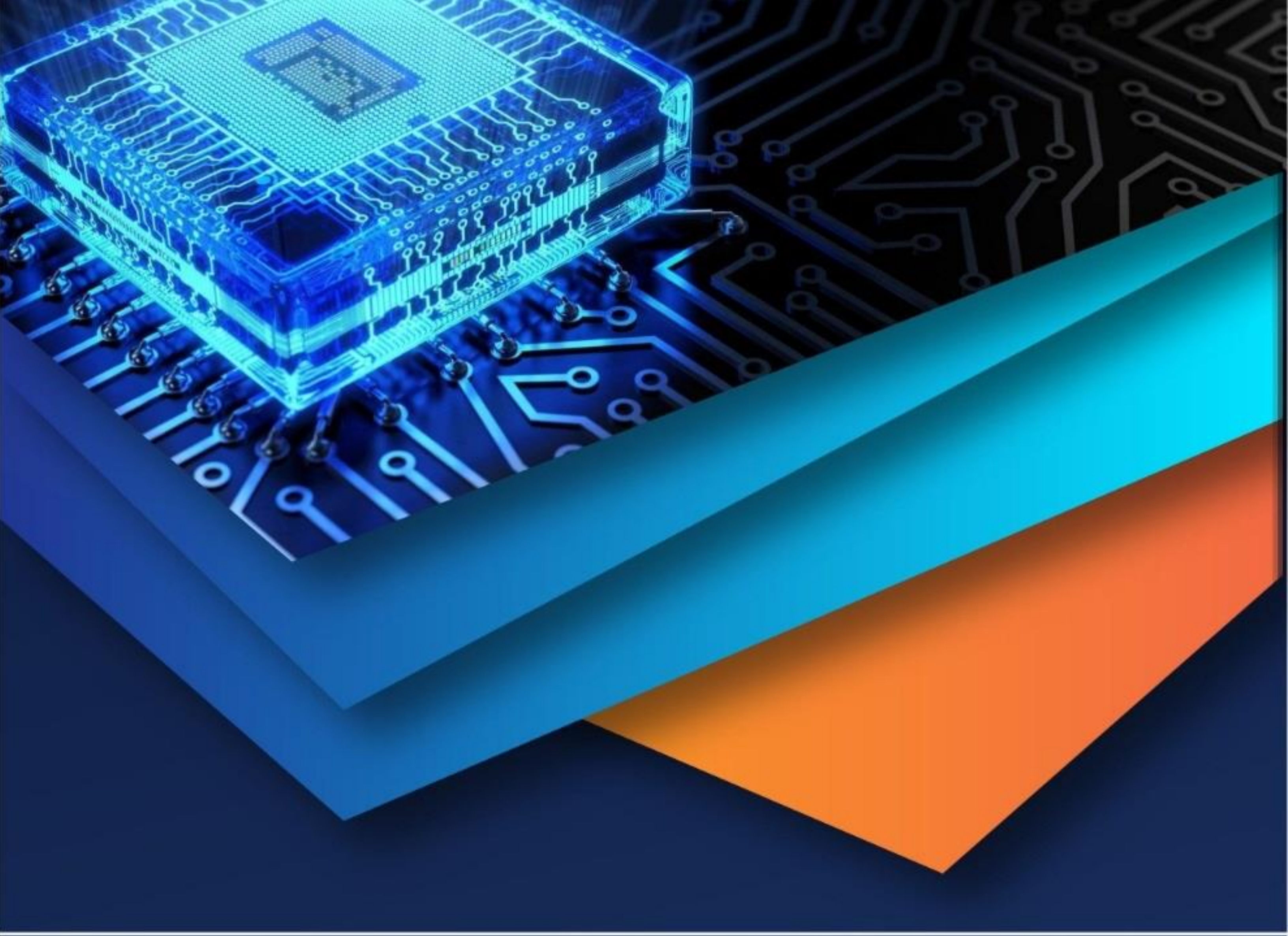

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