A Project Report on

Optimization of Design of Robotic Scoop Arm Mechanism by using ADT and Selection of Material, Shape and Process for components

Submitted by

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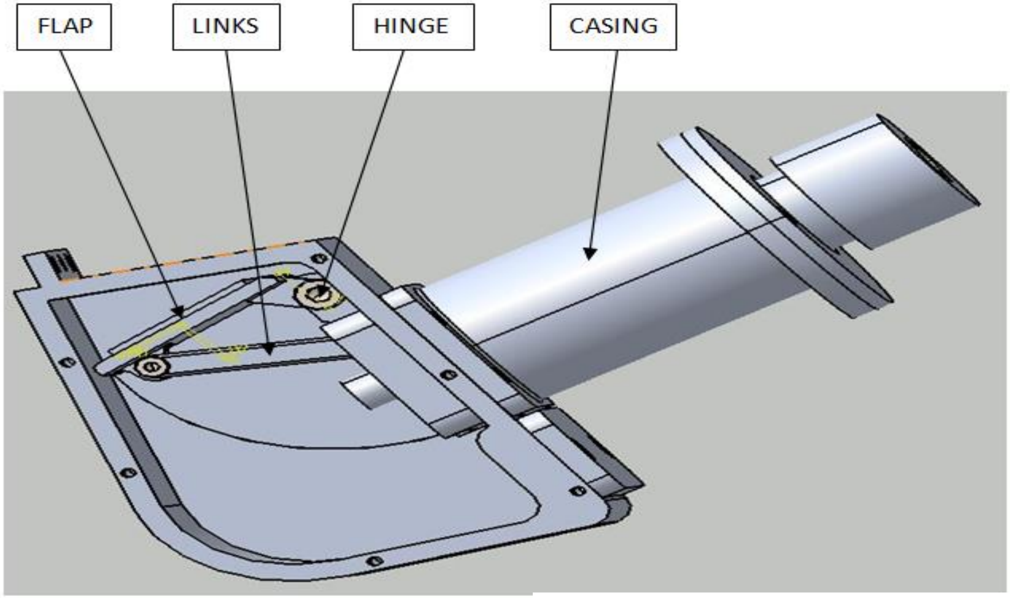
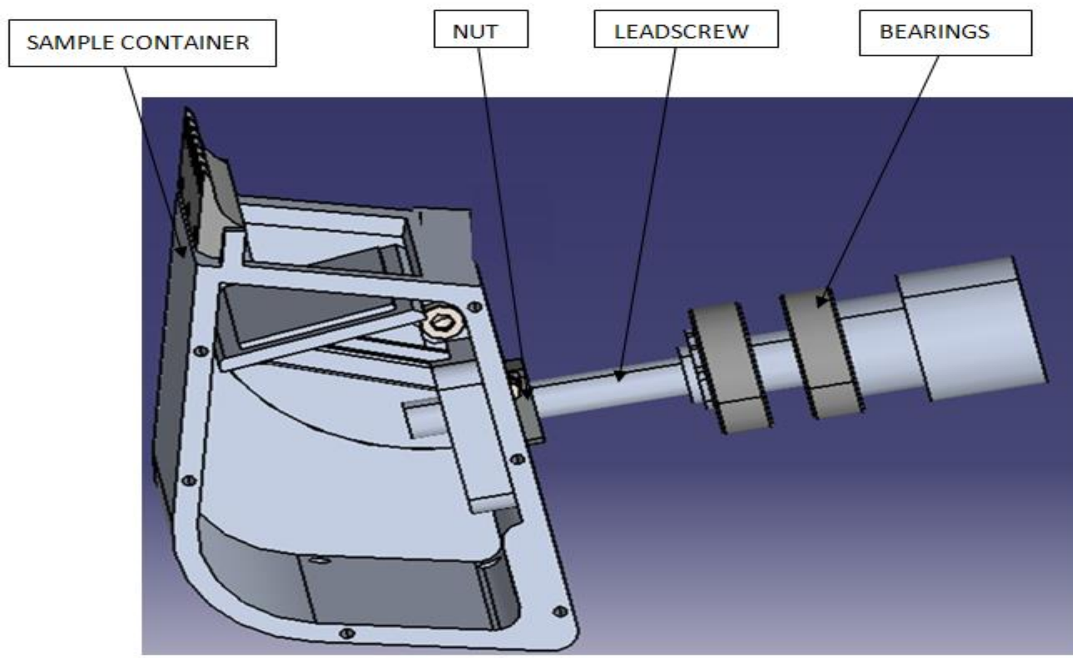
Problem Definition

- Optimize Design of Robotic Scoop Arm Mechanism by using Axiomatic Design Theory.
- Co-selection of material, shape and process for components of robotic scoop arm – Flap and Links

Application of Axiomatic Design Theory





DESIGN 1

FUNCTIONAL REQUIREMENTS

- FR1 : Sample should not be contaminated and Proper collecting Space
- FR2 : Less consumption of power while closing the flap
- FR3 : Flap should be locked in its position when drive iscut off
- FR4 : Nut should not be tilted
- FR 5: More opening of flap.
- FR 6 : Bearings should be properly insulated.

DESIGN PARAMETERS

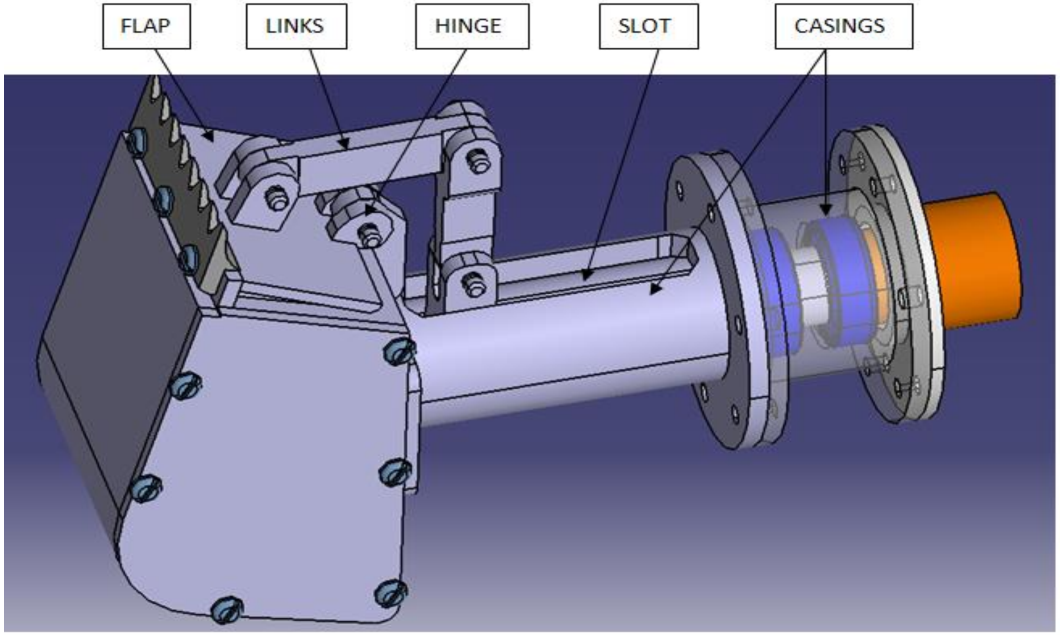
- DP1: Sample container
- DP2 : Links and Hinge position
- DP3 : Leadscrew
- DP5 : Two links are used.
- DP5 : Mechanism and linkages(Inside the sample container).
- DP6 : One Casing is used for Leadscrew-Nut and Bearings.

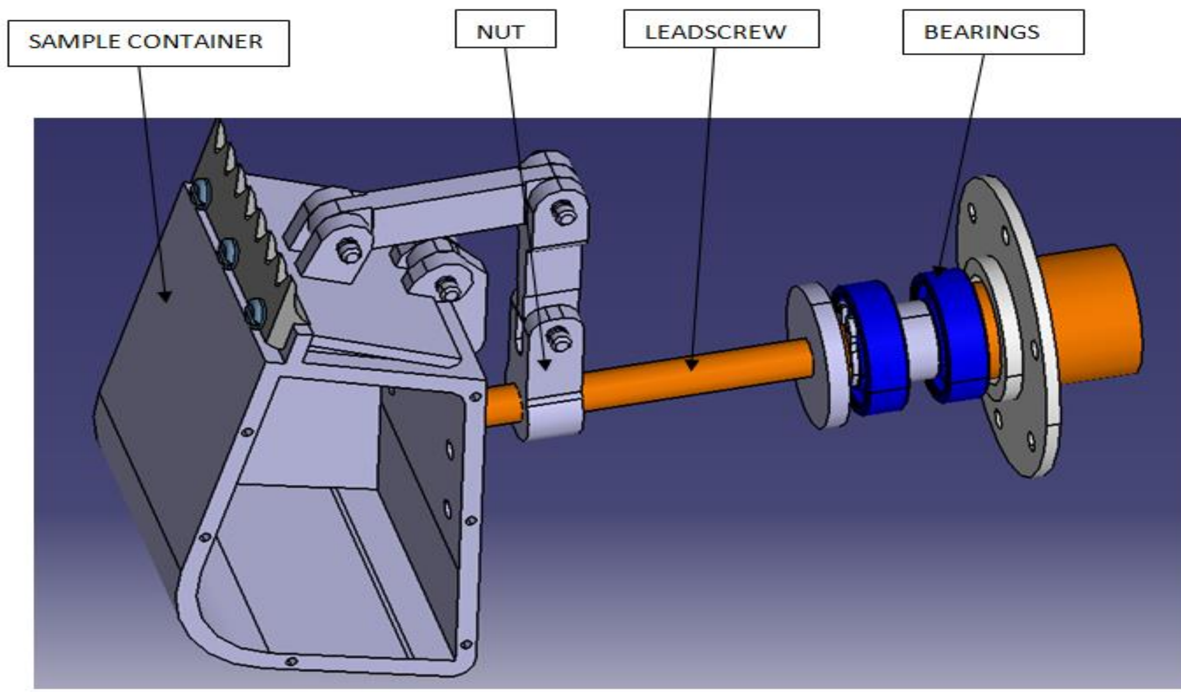
DESIGN MATRIX

{FR}=[A]{DP}

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \\ FR5 \\ FR6 \end{Bmatrix} = \begin{bmatrix} X & X & X & X & X & 0 \\ 0 & X & 0 & 0 & X & 0 \\ 0 & 0 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 \\ 0 & X & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \\ DP5 \\ DP6 \end{Bmatrix}$$

Coupled Design.
Not a proper design.


FLAP
LINKS
HINGE
SLOT
CASINGS


SAMPLE CONTAINER
NUT
LEADSCREW
BEARINGS

DESIGN 2

FUNCTIONAL REQUIREMENTS

- FR1 : Sample should not be contaminated and Proper collecting Space
- FR2 : Less consumption of power while closing the flap
- FR3 : Flap should be locked in its position when drive is cut off
- FR4 : Nut should not be tilted
- FR 5: More opening of flap.
- FR 6 : Bearings should be properly insulated.

DESIGN PARAMETERS

- DP1: Sample container
- DP2 : Hinge position.
- DP3 : Leadscrew
- DP5 : Slot in casing.
- DP5 : Mechanism and linkages (Outside the sample container)
- DP6 : Separate Casings are used for Leadscrew-Nut and Bearings

DESIGN MATRIX

{FR}=[A]{DP}

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \\ FR5 \\ FR6 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 & 0 \\ 0 & X & 0 & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \\ DP5 \\ DP6 \end{Bmatrix}$$

Uncoupled Design.
Proper design.

Co-selection of Material, Shape and process for Flap and Links.

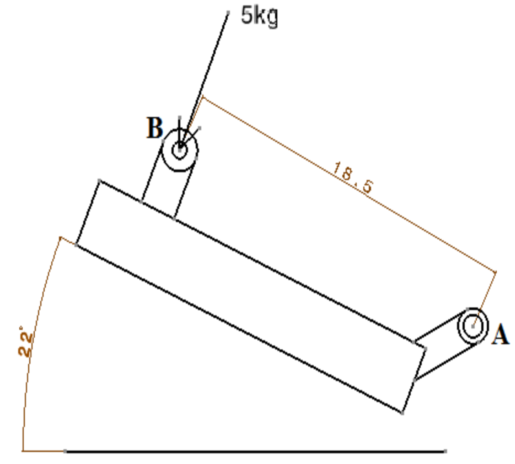
Co-selection of Material, Shape and process for Flap

- **Function** : Flap of Robotic scoop arm mechanism
- **Constraints** : 1. Must not fail under design loads – strength constraint.

  2. Length specified.
- **Objective** : Minimize mass
- **Free variables** : 1.Cross section area of flap

  2.Choice of material

  3.Section shape



MATERIAL SELECTION

FLEXURAL FORMULA

$$\sigma_f = \frac{M}{Z}$$

$$Z = \frac{A^{3/2}}{6}$$

$$m = Al\rho$$

$$m \geq (6M)^{2/3}(l)\left(\frac{\rho}{\sigma_f^{2/3}}\right)$$

MATERIAL INDEX

$$\boxed{M = \frac{\sigma_f^{2/3}}{\rho}}$$

For minimizing the mass, maximize above value

SHAPE SELECTION

$$\phi_B^f = \frac{Z}{Z_0}$$

$$Z_0 = \frac{A^{3/2}}{6}$$

$$\phi_B^f = \frac{6Z}{A^{3/2}}$$

$$\sigma_f = \frac{M}{Z}$$

$$m = Al\rho$$

$$m \geq (6M)^{2/3}(l)\left(\frac{\rho}{(\phi_B^f \sigma_f)^{2/3}}\right)$$

SHAPE INDEX

$$\boxed{M = \frac{\left(\phi_B^f \sigma_f\right)^{2/3}}{\rho}}$$

For minimizing the mass, maximize above value

MATERIAL	Strength σ_f (MPa)	Density ρ (Mg/m^3)	Shape Factor φ_B^f	Material Index $\frac{\sigma_f^{2/3}}{\rho}$	Shape Index $\frac{(\varphi_B^f . \sigma_f)^{2/3}}{\rho}$
Steel	770-990	7.82	7-8	12	44-48
Aluminium (6061 T6)	240-260	2.70	5.5-6.3	15	47-51

Based on the values, select material Aluminium (6061 T6) for flap

PROCESS SELECTION

Design Requirements of Flap

- **Function** : Flap
- **Constraints** : Material : Aluminium – 6061 T6
- **Shape** : Noncircular Prismatic
- **Mass** : 0.1- 0.2 kg
- **Minimum Section** : 2.5 mm
- **Precision** : ± 0.1 mm
- **Roughness** : < 1 µm
- **Objective** : Minimize Cost
- **Free Variables** : Choice of Process
- **Process Selected** : Conventional Machining

Charts Shows selection of process on the basis of given constraints.

Co-selection of Material, Shape and process for Link

- **Function** : Link of Robotic scoop arm mechanism
- **Constraints** : 1.Must not buckle under design loads – strength constraint.

  2.Length specified.
- **Objective** : Minimize mass
- **Free variables** : 1.Cross section area of link

  2.Choice of material

  3.Section shape

MATERIAL SELECTION

Euler's Buckling Load

$$P = \frac{\pi^2 EI}{l^2}$$

$$m = Al\rho$$

$$I = \frac{A^2}{12}$$

$$m \geq \left(\frac{12P}{\pi^2}\right)^{1/2} (l^2)\left(\frac{\rho}{E^{1/2}}\right)$$

Material Index

$$\boxed{M = \frac{E^{1/2}}{\rho}}$$

For minimizing the mass, maximize above value.

SHAPE SELECTION

$$\phi_B^e = \frac{I}{I_0}$$

$$I_0 = \frac{A^2}{12}$$

$$\phi_B^e = \frac{12I}{A^2}$$

$$P = \frac{\pi^2 EI}{l^2}$$

$$m = Al\rho$$

$$m \geq \left(\frac{12P}{\pi^2}\right)^{1/2} (l^2) \left(\frac{\rho}{(\phi_B^e E)^{1/2}}\right)$$

Shape Index

$$\boxed{M = \frac{\left(\phi_B^e E\right)^{1/2}}{\rho}}$$

For minimizing the mass, maximize above value

MATERIAL	Young's Modulus E (GPA)	Density ρ kg/m^3	Shape Factor ϕ_B^e	Material Index $\frac{E^{1/2}}{\rho}$	Shape Index $\frac{\left(\phi_B^e E\right)^{1/2}}{\rho}$
Aluminium (6061 T6)	71	2700	4-14	3.12x 10^{-3}	6.2-11.7
Steel	7900	7900	10-21	1.83-10^{-3}	5.8-8.2
Copper Alloy	8900	8900	10-13	1.23-10^{-3}	3.9-4.4

Based on the values, select material Aluminium (6061 T6) for Link.

PROCESS SELECTION

Design Requirements of Flap

- **Function** : Flap
- **Constraints** : Material : Aluminium – 6061 T6
- **Shape** : Noncircular Prismatic
- **Mass** : 0.1- 0.2 kg
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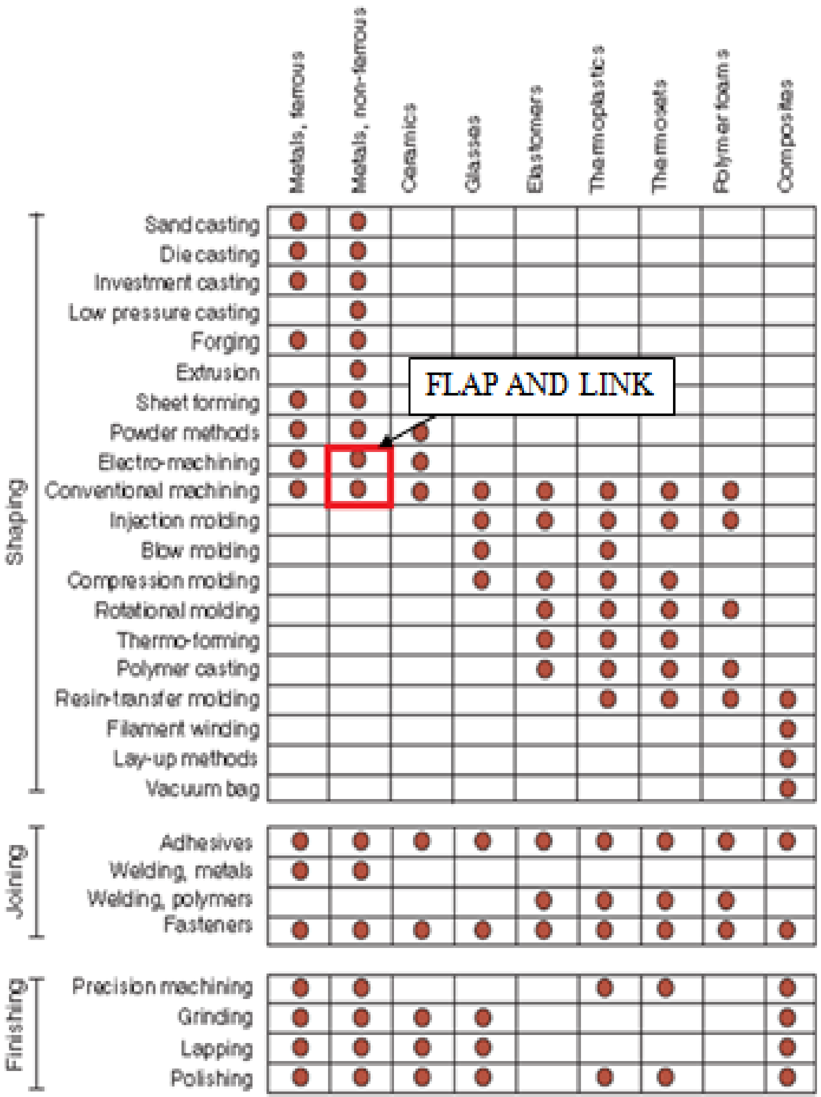
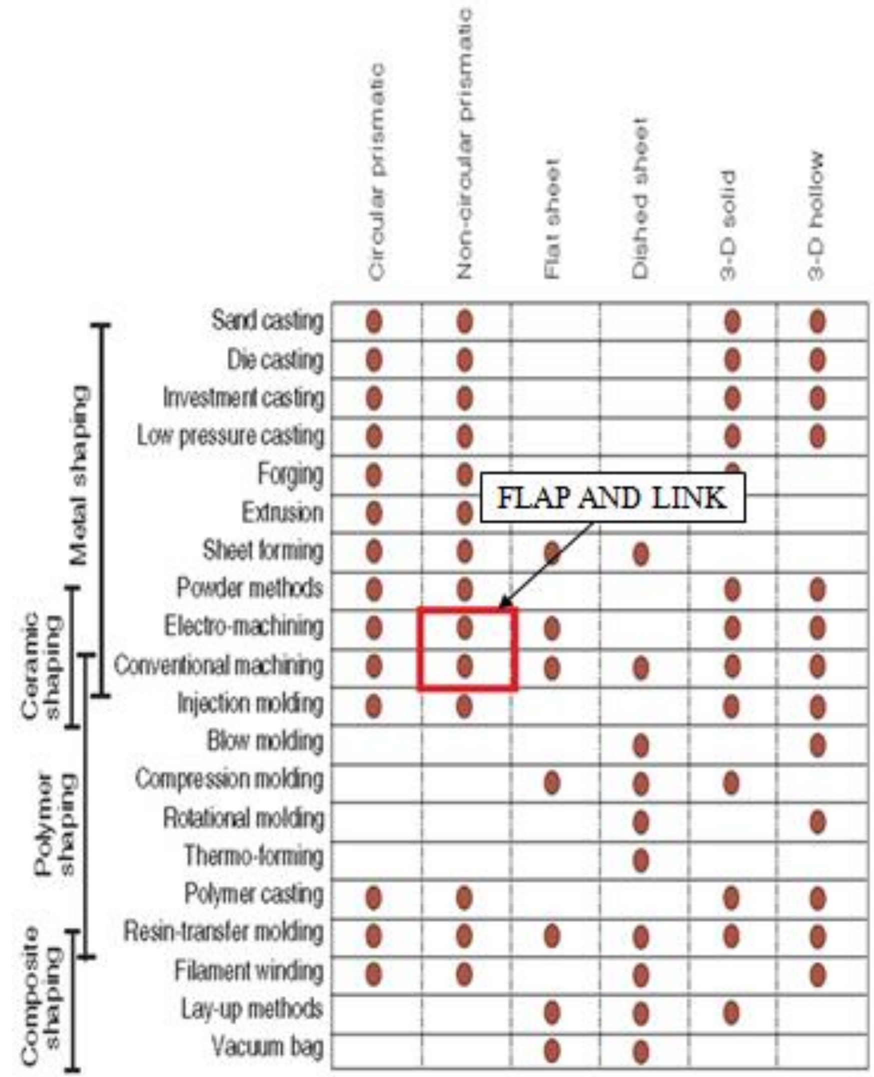
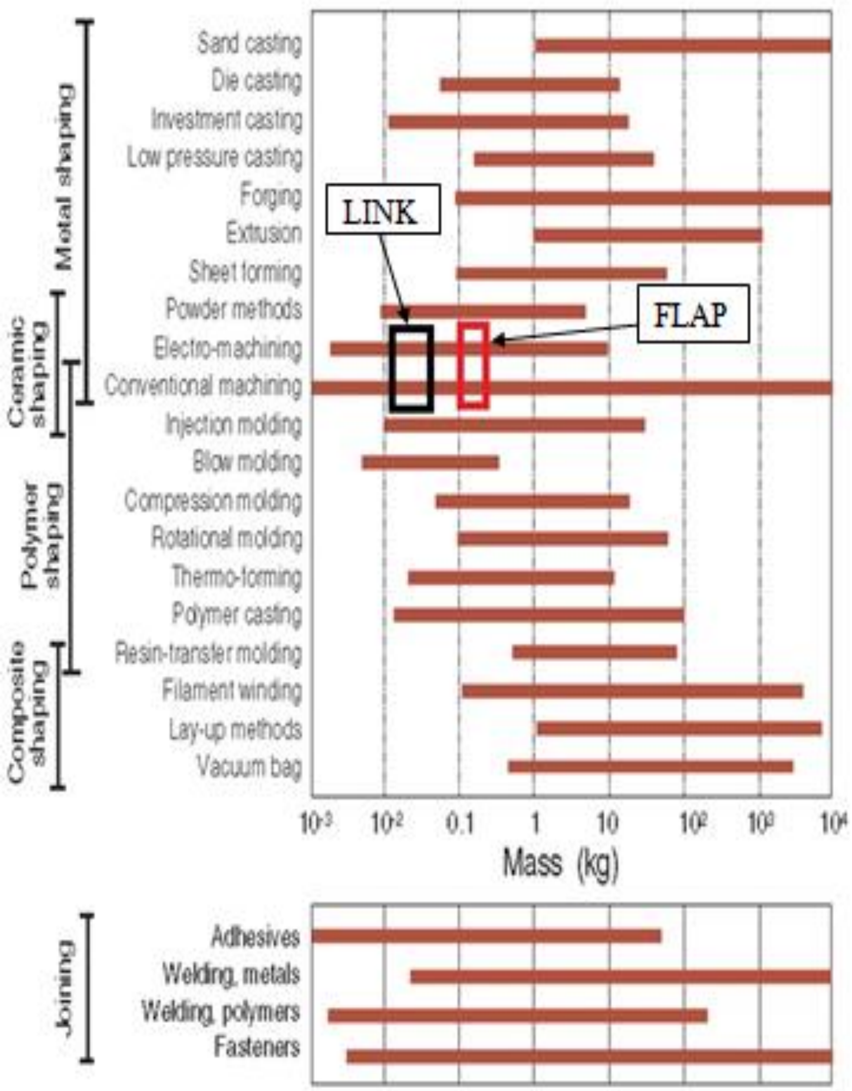
PROCESS SELECTION CHARTS



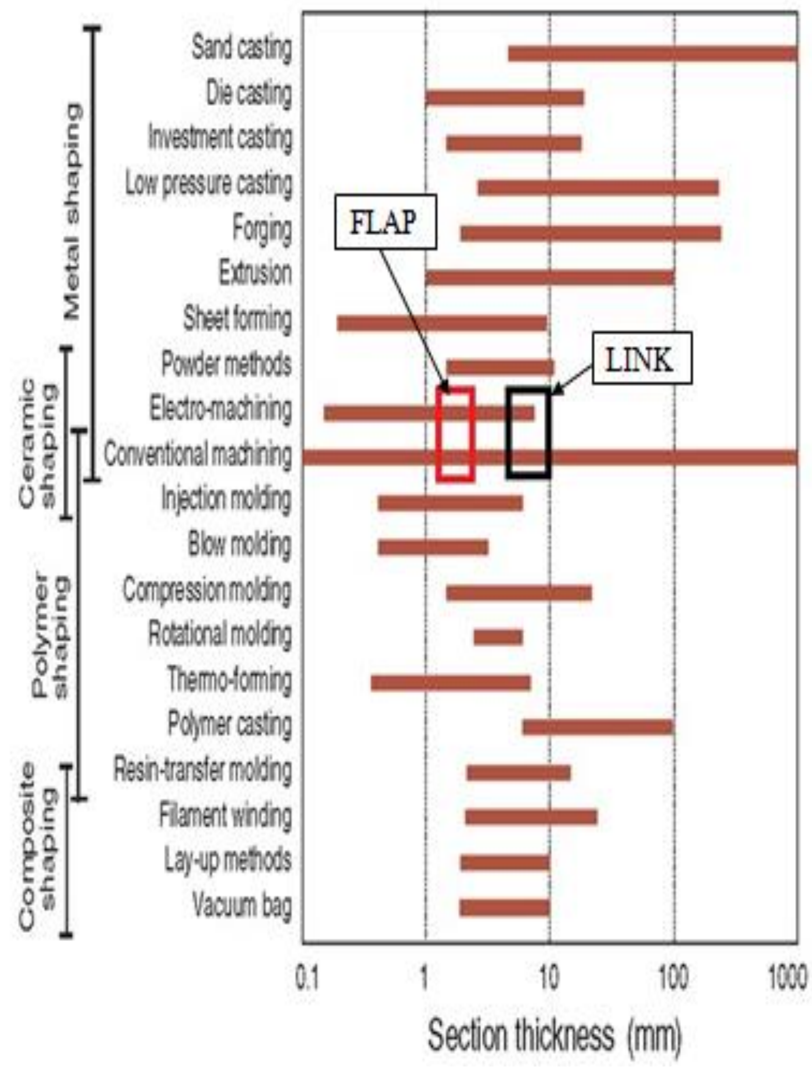
The process – material matrix



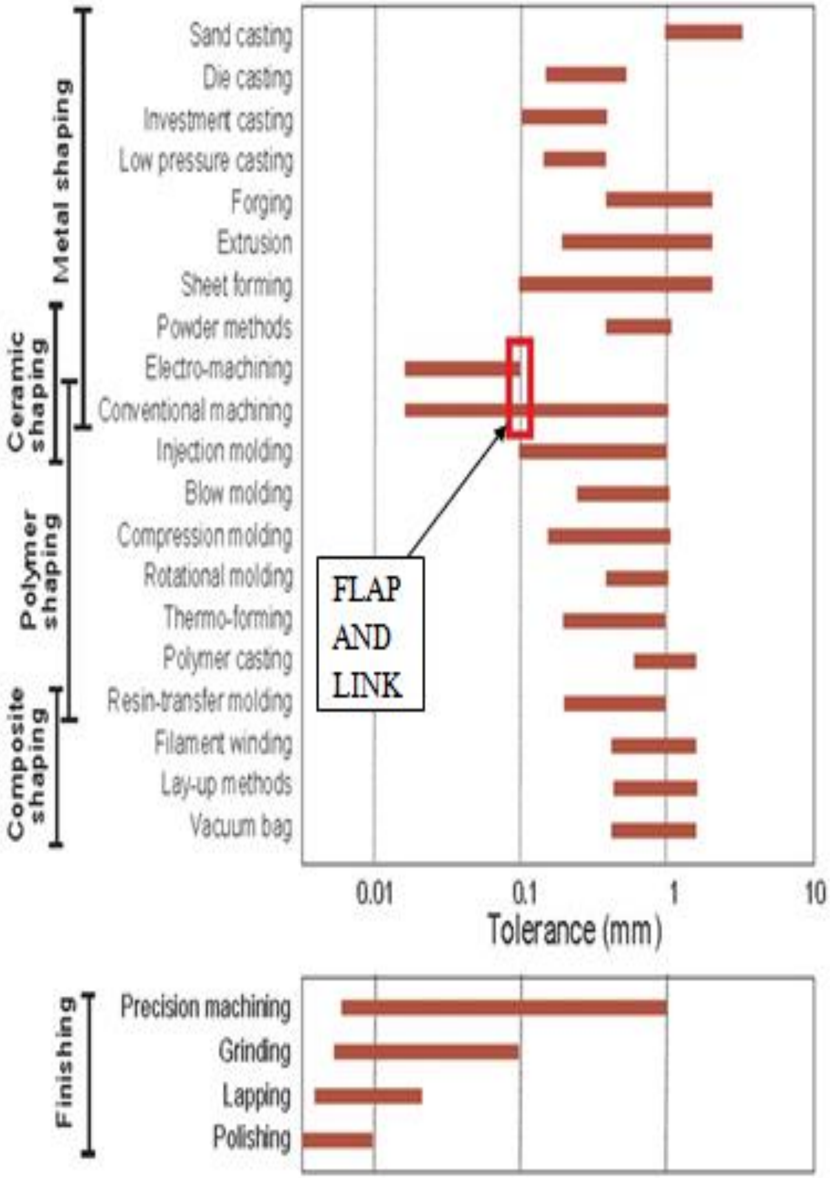
The process - shape matrix.



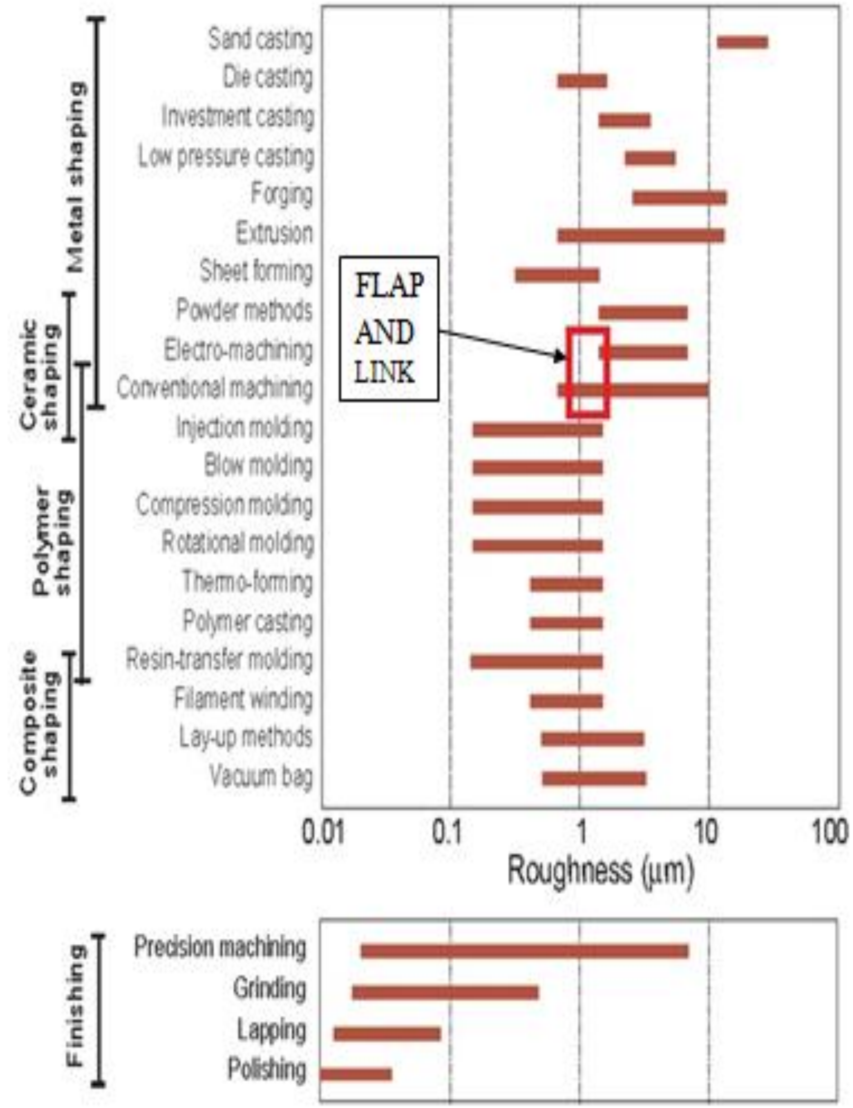
The process - mass-range chart



The process - section thickness chart



The process - tolerance chart



The process - surface roughness chart

Results and Conclusion

- By applying Axiomatic Design Theory, we improve the Design of Robotic Scoop Arm
- On the basis of material and shape index, material selected for Flap and Link – Al 6061 T6
- From given constraints, manufacturing process selected for Flap and Link – Conventional Machining

THANK

YOU