MODELLING AND ANALYSIS OF BALL VALVE HANDLE USING CAD SIMULATION

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Abstract—The ball valve being one way valve used to control the flow of fluids through it. Ball valve is made up of different components such as ball, stem, seat, body, and handle. Ball valve handle being the element undergoing failure most frequently requires further studywith respect to forces acting on it and material considerations. In this study different materials for ball valve handle are considered and their effect on stress, strain and displacement are analyzed. In conclusion the optimum material for ball valve handle is recommended based on stress, strain, displacement, and cost.

Index Terms—Ball valve handle, Modelling and FEA analysis, Material considerations.

I. INTRODUCTION

A valve is a mechanical device which regulates either the flow or the pressure of the fluid. Its function can be stopping or starting the flow, controlling flow rate, diverting flow, preventing back flow, controlling pressure, or relieving pressure.Ball valve is a one-way valve with a spherical disc, which controls the flow through it. Torque is the main factor for operating ball valves. It is a one-way valve that is operated and closed by pressure on a ball which fits into a cup shaped opening. A ball valve is a rotational motion valve that uses a ball-shaped disk to start or stop flow of fluid. When the valve handle is rotated to open the valve, the ball turns to a point where the hole through the ball is in line with the valve body outlet and inlet. When the valve is shut, the ball is turned so that the hole is perpendicular to the flow openings of the valve body and the flow is stopped. Ball valves are used in various power plants and it has extensive scope.

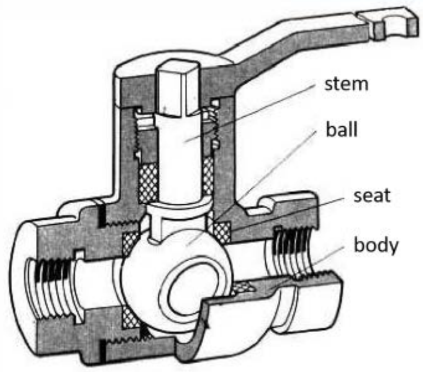


Fig-1. Schematic Diagram of Ball Valve

Important components of ball vale includes:

a) *Body:* The body of the butterfly valve is made up of the cast iron, stainless steel, and carbon steel. The cast iron is the material that is highly used in the body of the valve. The body of the valve is mounted between the two pipes of the flow. One-piece bodies are ribbed to assure high strength and minimum weight.
b) *Ball:* The function of the ball is to regulate the flow of the material or fluid within the conveying line. The ball is controlled by the handle. ball material should need to be chosen carefully as the valve is always in contact with fluid. Stainless steel, ductile iron, carbon steel are common materials used for the ball of the valvedue to their resistance to corrosion.
c) *Stem:* The stem is the component that attaches the centre of the valve and the handle. As the handle turns the stem moves along which the ball also moves. Depending on the application of the valve and size of the valve the stem may be one piece or two piece construction.
d) *Seal or Washer:* In the closed position, the

disc rim and stem seal lands form an uninterrupted line of sealing contact with the resilient seat, to assure drop tight sealing at rated shutoff pressure. Seats are offered in a wide range of materials.

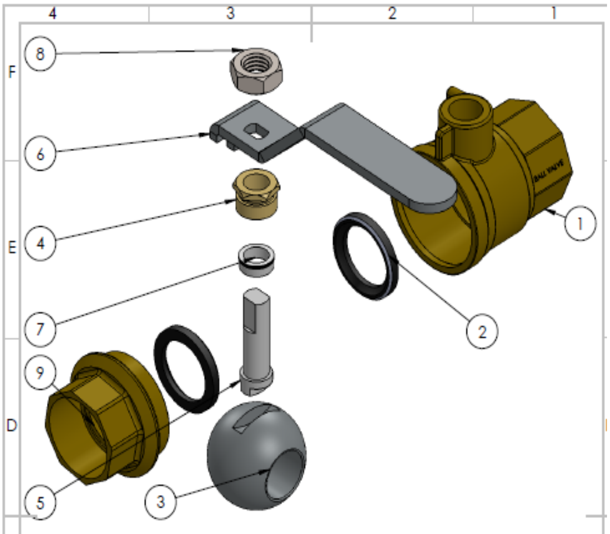
e) Handle: Handle is the type of component that mounted over the body of the valve. Different types of actuators are present in butterfly valves. The different types are: manual handle, gear, pneumatic, electric and electro-hydraulic. Handle may be enclosing by separate Housings for underground applications.

Based on the relevant literature it is evident that lot of research relating to different parts of ball valve has been carried outexcept ball valve handle. In addition, ball valve handle is the part subjected to non-uniform loading conditions and combination of stresses resulting in frequent failure. Considering this, the focus of this study is on ball valve handle and stress analysis of it is carried out using SOLIDWORKS SIMULATION. To be specific the objectives of this study are as follows:

1) Create a CAD model of an existing ball valve handle using SOLIDWORKS.
2) Analyze the ball valve handle to study stress and strainand accordingly modify design parameters.
3) Analyze the ball valve handle for different material and choose the optimum material.

II. MODELLING AND ANALYSIS

As mentioned in previous section the tool used for modelling and further analysis of ball valve handle is SOLIDWORKS Simulation. At first a 3-D model of ball valve is created with real world data. Individual parts of the assembly and assembled view of the ball valve are shown in Fig.-2 and 3 respectively.



ITEM NO.	PART NUMBER	QTY.
1	BODY	1
2	SEAT RING	2
3	BALL	1
4	PACKING GLAND	1
5	STEM	1
6	HANDLE	1
7	STEM PACKING	1
8	HJNUT 0.3750-16-D-S	1
9	BODY VALVE END	1

Fig. 2- exploded view of ball valve

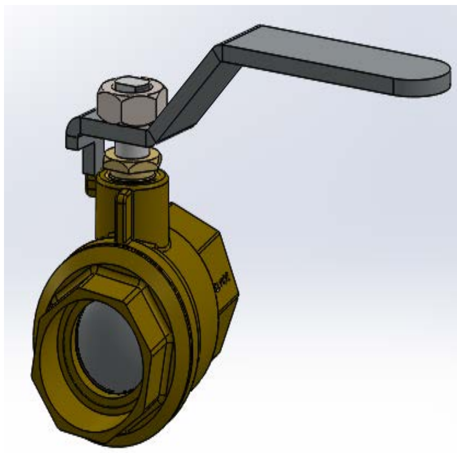


Fig. 3- Ball valve assembly

The model of the ball valve handle is developed in sheetmetal feature with following diemnsions.
Width = 17.145mm
Thickness = 3.30mm
Bend radius = 0.60mm

In this study, for analysis purpose four different materials for ball valve handle are considered as cast carbon steel,ductile iron, grey cast iron, and malleable cast iron.The material properties of the ball valve handle for four considered materials are shown in Table 1, 2, 3, and 4 respectively.

Table 1. Material properties for handle of cast carbon steel

Name:	**Cast Carbon Steel**
Model type:	**Linear Elastic Isotropic**
Default failure criterion:	**Max von Mises Stress**
Yield strength:	**2.48168e+008 N/m^2**
Tensile strength:	**4.82549e+008 N/m^2**
Elastic modulus:	**2e+011 N/m^2**
Poisson's ratio:	**0.32**
Mass density:	**7800 kg/m^3**
Shear modulus:	**7.6e+010 N/m^2**
Thermal expansion coefficient:	**1.2e-005 /Kelvin**

Table 2. Material properties for handle of ductile iron

Name:	**Ductile Iron**
Model type:	**Linear Elastic Isotropic**
Default failure criterion:	**Max von Mises Stress**
Yield strength:	**5.51485e+008 N/m^2**
Tensile strength:	**8.61695e+008 N/m^2**
Elastic modulus:	**1.2e+011 N/m^2**
Poisson's ratio:	**0.31**
Mass density:	**7100 kg/m^3**
Shear modulus:	**7.7e+010 N/m^2**
Thermal expansion coefficient:	**1.1e-005 /Kelvin**

Table 3. Material properties for handle of grey cast iron

Name:	**Gray Cast Iron**
Model type:	**Linear Elastic Isotropic**
Default failure criterion:	**Mohr-Coulomb Stress**
Tensile strength:	**1.51658e+008 N/m^2**
Compressive strength:	**5.72165e+008 N/m^2**
Elastic modulus:	**6.61781e+010 N/m^2**
Poisson's ratio:	**0.27**
Mass density:	**7200 kg/m^3**
Shear modulus:	**5e+010 N/m^2**
Thermal expansion coefficient:	**1.2e-005 /Kelvin**

Table 3. Material properties for handle of malleable cast iron

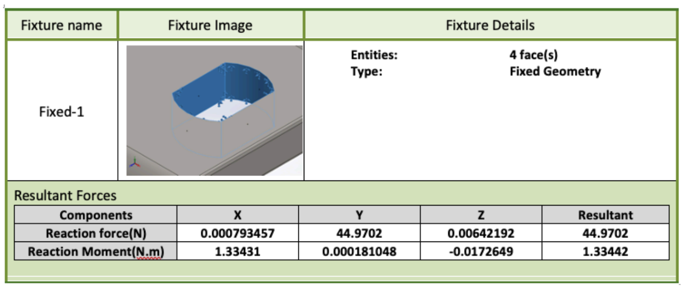
Name:	**Malleable Cast Iron**
Model type:	**Linear Elastic Isotropic**
Default failure criterion:	**Max von Mises Stress**
Tensile strength:	**2.75742e+008 N/m^2**
Compressive strength:	**4.13613e+008 N/m^2**
Elastic modulus:	**1.9e+011 N/m^2**
Poisson's ratio:	**0.27**
Mass density:	**7300 kg/m^3**
Shear modulus:	**8.6e+010 N/m^2**
Thermal expansion coefficient:	**1.2e-005 /Kelvin**

Next important step in this analysis was to mesh the developed models. For meshing total number of nodes used is 2218 and total elements used are 1032. Additional information related to meshing is shown in Table-5. Similar meshing properties are used for both the models of ball valve handles.

Table 5. Mesh Information

Mesh type	Shell Mesh Using Mid-surfaces
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	1.89476 mm
Tolerance	0.0947378 mm
Mesh Quality	High

The loads and fixtures considered for this study are as shown in Fig. 4 and 5 provided below



Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 4 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.000793457	44.9702	0.00642192	44.9702
Reaction Moment(N.m)	1.33431	0.000181048	-0.0172649	1.33442

Fig. 4- Fixture details

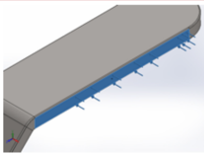
Load name	Load Image	Load Details
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 45 N

Fig. 5- Load details

III. RESULTS

Developed models with applied load is analyzed for stress, displacement and strain using SOLIDWORKS simulation. The results for both the models of ball valve handle are derived and further analyzed.

The results for von mises stress, resultant displacement, and equivalent strain at load 45 N for ball valve handle of cast carbon steel are shown in Fig. 6, 7 and 8 respectively. The results are summarized in Table 6.

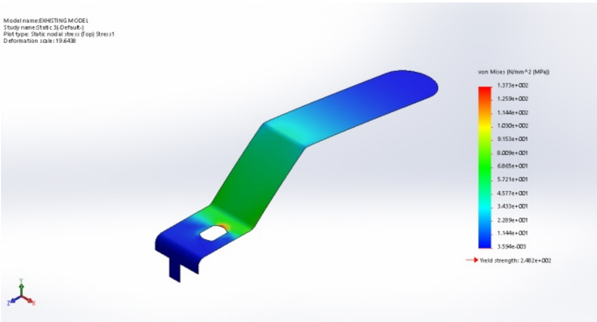


Fig. 6- Von mises stress for ball valve handle (cast carbon steel)

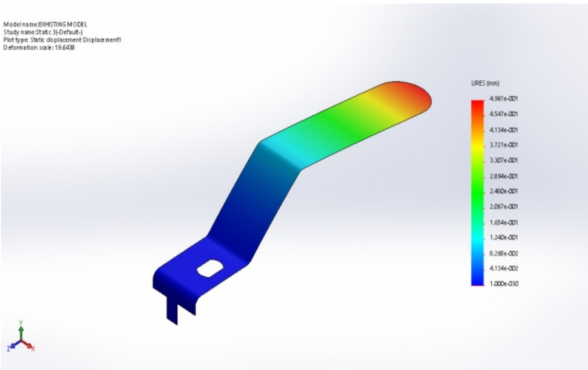


Fig. 7- Resultant displacement for ball valve handle (cast carbon steel)

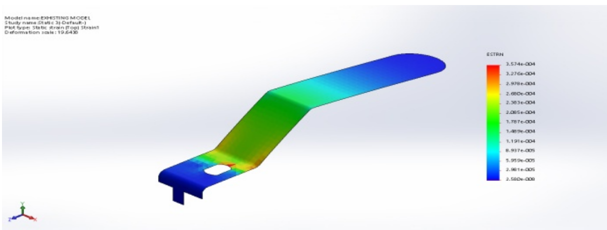


Fig. 8- Strain for ball valve handle (cast carbon steel)

Table 6. Summary of results for ball valve handle (cast carbon steel)

Material	Cast carbon steel
Stress	137.295 N/mm^2 (MPa)
Displacement	0.49609 mm
Strain	0.000357389
Cost per Kg	90/-

The results for von mises stress, resultant displacement, and equivalent strain at load 45 N for ball valve handle of ductile iron are shown in Fig. 9, 10 and 11 respectively. The results are summarized in Table 7.

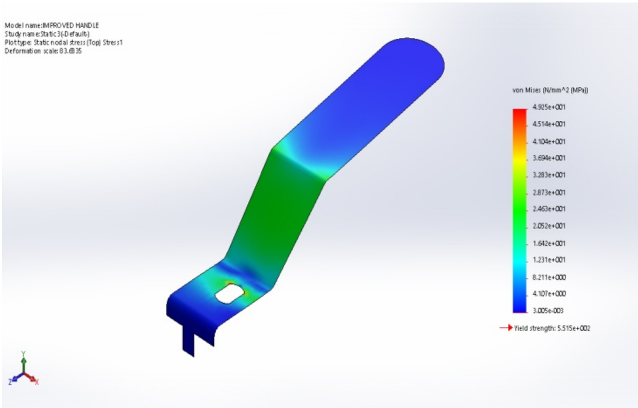


Fig. 9- Von mises stress for ball valve handle (ductile iron)

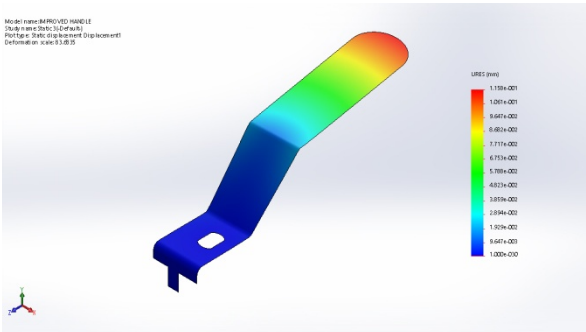


Fig. 10- Resultant displacement for ball valve handle (ductile iron)

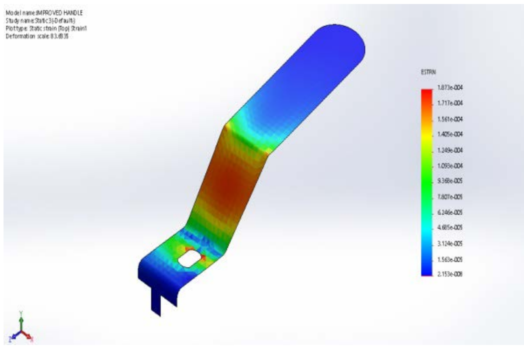


Fig. 11- Strain for ball valve handle (ductile iron)

Table 7. Summary of results for ball valve handle
(ductile iron)

Material	Ductile iron
Stress	49.2483 N/mm^2 (MPa)
Displacement	0.11576 mm
Strain	0.000141106
Cost per Kg	75/-

The results for von mises stress, resultant displacement, and equivalent strain at load 45 N for ball valve handle of grey cast iron are shown in Fig. 12, 13 and 14 respectively. The results are summarized in Table 8.

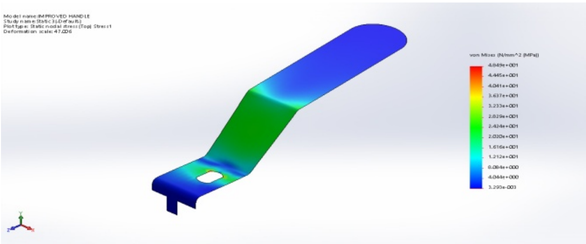


Fig. 12-Von mises stress for ball valve handle (grey cast iron)

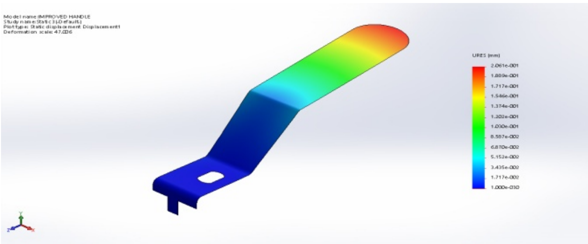


Fig. 13-Resultant displacement for ball valve handle
(grey cast iron)

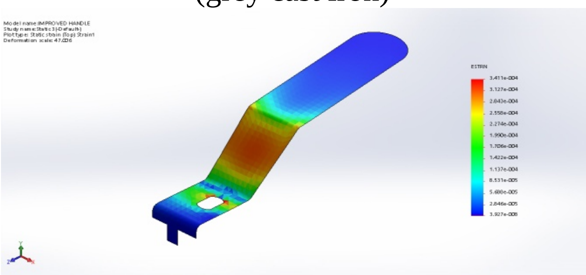


Fig. 14-Strain for ball valve handle (grey cast iron)

Table 8. Summary of results for ball valve handle
(grey cast iron)

Material	Grey cast iron
Stress	48.4867 N/mm^2 (MPa)
Displacement	0.206099 mm
Strain	0.00018734
Cost per Kg	65/-

The results for von mises stress, resultant displacement, and equivalent strain at load 45 N for ball valve handle of grey cast iron are shown in Fig. 15, 16 and 17 respectively. The results are summarized in Table 9.

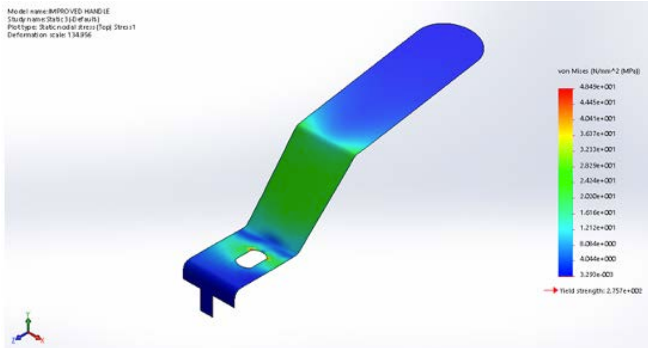


Fig. 15- Von mises stress for ball valve handle (malleable cast iron)

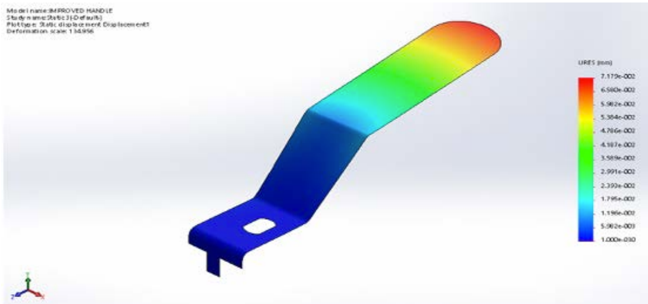


Fig. 16- Resultant displacement for ball valve handle
(malleable cast iron)

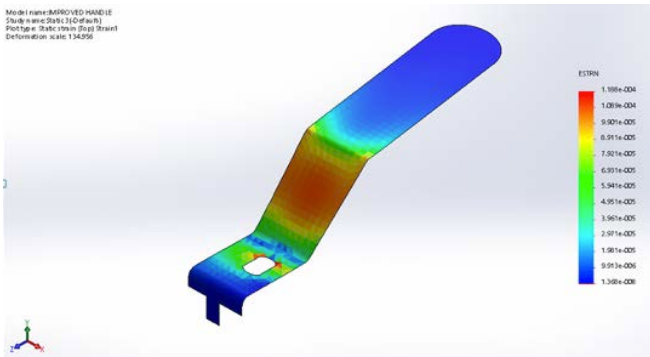


Fig. 17- Strain for ball valve handle (malleable cast iron)

Table 9. Summary of results for ball valve handle
(Malleable cast iron)

Material	Malleable cast iron
Stress	48.4867 N/mm^2 (MPa)
Displacement	0.0717856 mm
Strain	0.000118809
Cost per Kg	100/-

IV. CONCLUSION

CAD model of the ball valve handle is develped by considering four different materials as cast carbon steel, ductile iron, grey cast iron, and malleable cast iron. The ball valve handle considered in this study is subjected to non-uniform loading conditions and subjected to combination of stresses and hence undergoing failure with respect to desired durability. The results considering different materials are obtained using SOLIDWORKS simulation and are summarized in Table 10.

Table 10. Comparison of results for considered different materials

Sr. No	Material	Stress (N/mm^2 MPa)	Displacement (mm)	Strain	Cost per Kg
1	Cast carbon Steel	137.295	0.49609	0.0003573	90/-
2	Ductile iron	49.2483	0.11576	0.0003411	75/-
3	Gray Cast Iron	48.4867	0.206099	0.0001873	65/-
4	Malleable Cast Iron	48.4867	0.0717856	0.0001188	100/-

One can choose the best option considering stress, displacement, strain, and cost per kg. According to authors, considering all criteria the best option is of ductile iron ball vale handle for which stress value is 49.2483MPa, displacement value obtained is 0.11576 mm, strain value is 0.0003411 and cost per kg is 75/- which is economical.

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