Optimal feeder design of Oldham’s coupling by using Casting simulation Technology

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Abstract – Oldham’s coupling accommodates both lateral and angular misalignment to some extent when compared to few other couplings such as muff couplings. Proper design and manufacturing is necessary for effective power transmission and longer durability of any coupling. The defects caused in manufacturing are more due to faulty design of feeders and gating system than defects caused due to other manufacturing problems. In this project a model of Oldham’s coupling is designed in 3D modeling module of AutoCAD software further this model is simulated to find defects which can occur while solidification in casting process in E-foundry. E-foundry developed by IIT-B mainly aims for removal of hot spots by iterating simulations considering design parameters. All the hotspots in the component are removed and optimum yield has been achieved by designing feeders with appropriate calculations.

Keywords: AutoCAD, E-foundry, simulation, feeder, hotspots.

I. INTRODUCTION TO OLDHAM’S COUPLING

A **coupling** is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings don't regularly permit disengagement of shafts amid operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded.

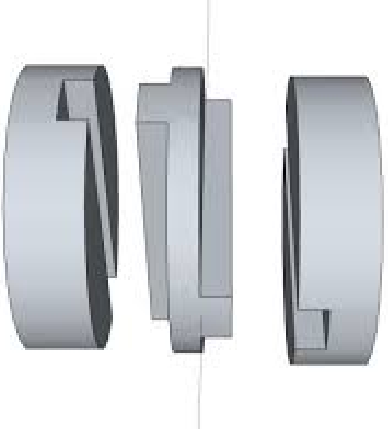

Fig 1.1 Oldham coupling

Oldham couplings are a three piece design comprised of two metal hubs press fit onto a centre disk. The coupler is named for John Oldham who invented it in Ireland, in 1820, to solve a paddle placement problem in a paddle steamer design.

Torque transmission is accomplished by mating the slots on the center disk to the drive tenons on the hubs. During operation the center disk slides on the tenons of each hub (which are orientated 90° apart) to transmit torque. While the couplings accommodate a small amount of angular and axial misalignment, they are particularly helpful in applications with parallel misalignment.

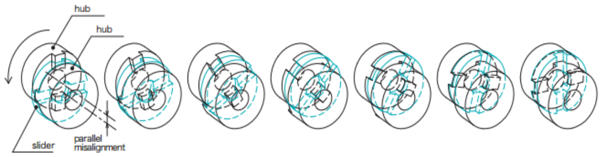

Fig 1.2 showing Oldham’s coupling overcome the parallel misalignment of shafts

Ideal for many light duty industrial and motion control applications, Oldham couplings have the ability to protect more expensive machinery components.

Dimensions of Oldham’s coupling:

Ideal for many light duty industrial and motion control applications, Oldham couplings have the ability to protect more expensive machinery components. For example the Oldham coupling acts as a torque limiter during overload. When the disk fails, it breaks cleanly and does not allow any transmission of power. Oldham couplings also have the advantage of electrical isolation due to the non-conductive nature of the center disk. This prevents electrical currents from being passed to delicate instruments which can cause inaccurate data readings or damage.

Advantages:

- Protects driven component by serving as a mechanical "fuse" - an inexpensive replaceable plastic midsection shears under excess load

- Protects support bearings by exerting consistently low reactive forces, even under large misalignments
- Homokinetic transmission - driving and driven shafts rotate at exactly the same speed at all times
- Zero backlash and high torsional stiffness
- Electrical insulation
- Accommodates large radial misalignment in a short length
- Easy installation in blind or difficult installations when through-bores are used
- Economically priced compared to other couplings with similar performance characteristics
- Inexpensive replaceable wear element
- Low moment of inertia

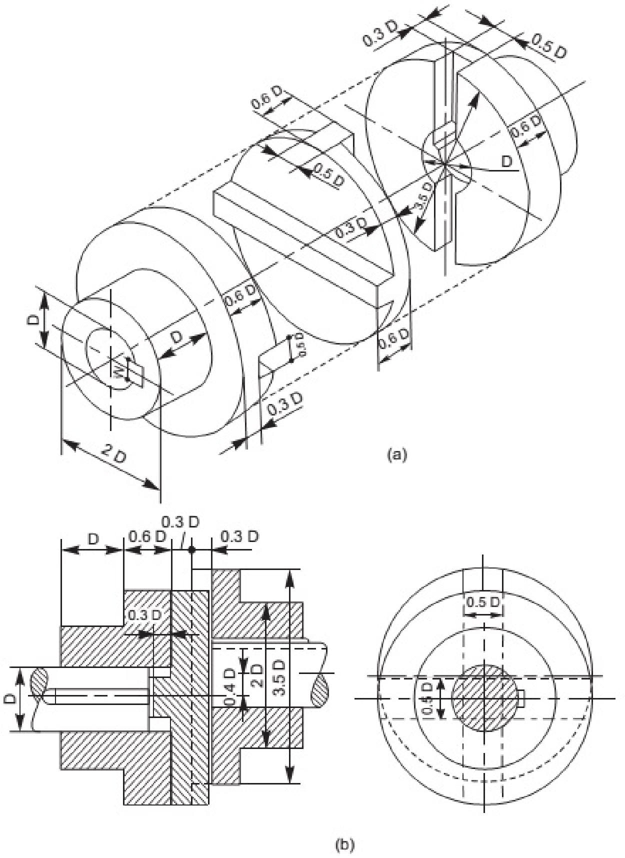

Fig 1.3 standard dimensions of Oldham’s coupling

Disadvantages:

- Accommodates a relatively small angular misalignment.
- Lower peak torque and torsional stiffness than standard Oldham coupling
- Slightly non- homokinetic transmission (that is, the driven and driving shafts don't move at exactly the same speed throughout one rotation) when angular misalignment is significant.
- Axial reactive loads exerted on support bearings when torque approaches maximum

. **Applications:**

- It was basically invented to connect two parallel non co axial shafts.
- It is a really good mechanism and transmits the same speed and same direction of rotation.
- It is not of much importance now as gears are being used.
- Printing and copying machines; robotics and servo applications.

II. CASTING AND ITS DEFECTS:

Oldham’s coupling is manufactured by the process of casting. Metal casting is one of the direct methods of manufacturing the desired geometry of component. The method is also called as near net shape process. It is one of the primary processes for several years and one of important process even today in the 21st century. Early applications of casting are in making jewellery items and golden idols. Today, casting applications include automotive components, spacecraft components and many industrial & domestic components, apart from the art and jewellery items. The principle of manufacturing a casting involves creating a cavity inside a sand mould and then pouring the molten metal directly into the mould. Casting is a very versatile process and capable of being used in mass production. The size of components is varied from very large to small, with intricate designs. Out of the several steps involved in the casting process, moulding and melting processes are the most important stages. Improper control at these stages results in defective castings, which reduces the productivity of a foundry industry.

During the process of casting solidification, liquid metal starts solidifying from the mould boundary till it reaches to certain point/points in the mould-cavity known as hot spot/spots. This hot spot region is a local temperature maxima, which effectively feeds adjacent regions in the casting. Since molten metal shrinks in volume during solidification (1-5% by volume) in the mould cavity, a portion of fresh molten metal should be fed or compensated to make up for the shrinkage at the hot spot region. However, the fresh molten metal cannot be fed to an isolated non-solidified metal completely surrounded by solidified metal, due to which porosity defects such as a cavity and other void regions are formed. The cavity thus formed is called a shrinkage cavity which is one of the most serious casting defects and accounts for maximum casting rejections.

III. OBJECTIVES OF THE PROJECT:

The objective of the project is, therefore, to design an Oldham's coupling and making it perfect for casting by removing the hotspots detected in the simulation performed with the aid of E-Foundry. This is achieved in three stages. In the first stage, a parametric model is designed by using 3D modelling module in AutoCAD Software. Later on solidification simulation and its thermal analysis is performed by using E- Foundry (IIT-Bombay) to predict the presence of casting defects, primarily hot spots i.e. the locations in a casting which solidifies last, which leads to shrinkage related defects and accounts for maximum casting rejections. In the last stage, appropriate feeders using standard dimensions are designed for each individual part of Oldham's coupling and simulated again. The results have shown the reduced hotspot which has made the product of casting more accurate and reliable. Also, the costs and the risks associated with the trial and error procedure of experimental castings are minimized.

IV. FEEDER AND ITS DESIGN

The design of casting feeders should be such that it must solidify at the same time as or later than the casting, which has to be satisfied by ensuring that the feeder has a modulus that is sufficiently larger than the casting. The volumetric contraction of the casting must be compensated by the feeder and thus should have volume greater than the shrinkage volume. At the same time, overdesigned feeders with large safety margins increase the cost and reduce yield (ratio of weight of casting to total weight with feeding system). So a fundamental problem foundries are facing is in developing feeder design, which fulfils the need for supplying additional molten metal to the solidifying region with the minimum volume of extra metal. Thus, there is a need to study optimal feeder design and its implementation. There are numerous optimization techniques but selecting and implementing the most efficient one is a challenge.

V. MODELLING OF OLDHAM'S COUPLING:

AutoCAD is a computer-aided design (CAD) program used for 2-D and 3-D design and drafting. AutoCAD is developed and marketed by Autodesk Inc. and was one of the initial CAD programs that could be executed on personal computers. In modern era, many modeling software are available in the commercial market. Three dimensional modeling can easily be generated in these kind of software for better imagination, visualization and better understanding; as well as to prepare manufacturing drawings and is more flexible as compared to two dimensional traditional drafting. Oldham's coupling is designed in the 3D Modeling workspace and drafted according to the standard dimensions (refer Fig 1.3) taking the value of diameter as 1cm.

Fig 5.1 model of Oldham's coupling in AutoCAD 3D

VI. THERMAL ANALYSIS WITH E- FOUNDRY SIMULATION

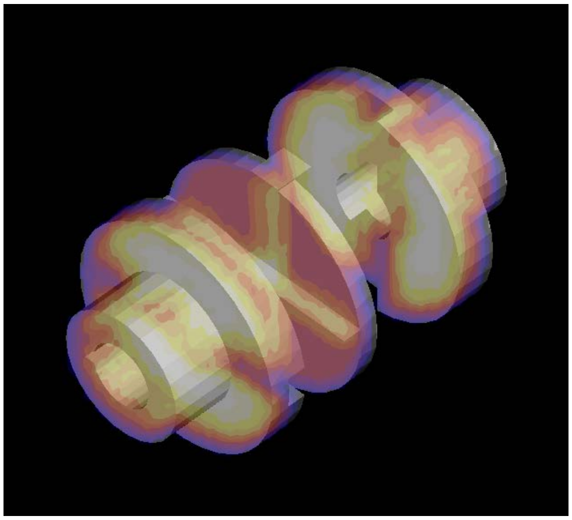

Fig 6.1 Simulation with Steel with coarse mesh temp-1493 C

E-Foundry is an Online learning resources in casting design and simulation. E-Foundry (http://efoundry.iitb.ac.in) provides teachers, students and casting industry professionals' free access to teaching content in casting design and simulation developed at IIT Bombay. Simulation lab accepts a 3D CAD model and generates solidification images. There is access to change the material as well as meshing of casting products. In this study we have used steel for simulation with coarse as well as fine meshes. The blue color indicates early freezing regions and white-yellow indicates the presence of hotspots. For a defect- free casting, it is important to have evenly solidifying casting with no hotspots. Thus, accomplishment of well- designed feeders allows a uniform cooling time and removes hotspots.

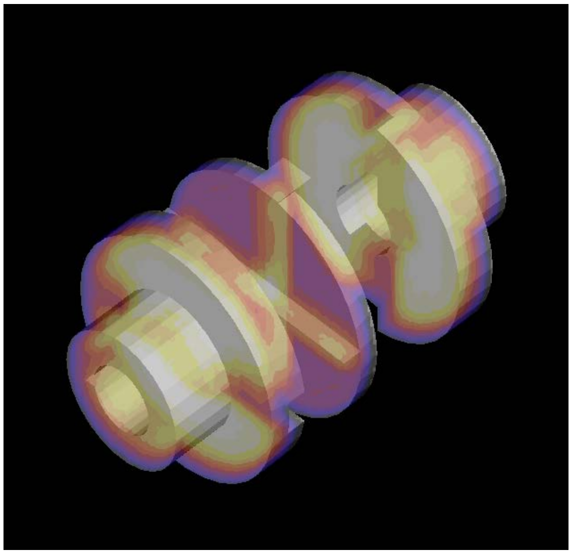

Fig 6.2 Simulation with Steel with fine mesh temp-1493 C

VII. RESULTS AND CALCULATIONS:

As the objective includes achieving a contrast between a faulty feeder and a well- designed feeder, in the first case a feeder is attached to the top hub with random dimensions which showed no effect in hotspot level as shown in Fig 7.1. In the next case all the dimensions of feeder are found based on their modulus values separately for the steel hub and the centre disk.

As the two hubs resemble in dimensions, only one is taken into consideration. The feeders are attached to their respective parts in AutoCAD 3D as shown in Fig 7.2 and 7.3. After they are simulated in E- Foundry, the level of hotspots is found to be greatly reduced as shown in Fig 7.4 and 7.5. The percentage of shrinkage also decreased with decrease in hotspots. Thus, Yield calculated is 82.33% for the center disk and 47.53% for the steel hub. The average yield of overall casting is 59.134%.

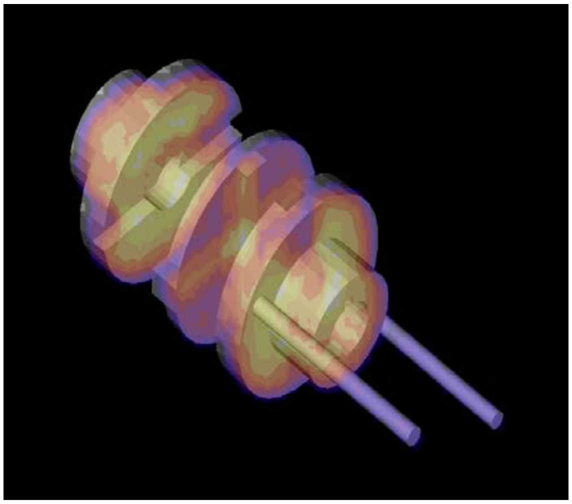

Fig 7.1 Simulation with faulty feeder

Calculations of dimensions of feeder and yield:

For centre disk:

Volume of casting=3.9363cm^3

Heat transfer area=27.3406cm^2

Modulus of casting $M_c = \frac{volume\ \ of\ casting}{Heat\ transfer\ \ area}$

$M_c = \frac{3.9363}{27.3406} = 0.143975$cm

Modulus of feeder $M_f = kM_c$

For steel k =1.3

M_f=1.3(0.14397) = 0.187161cm

For cylindrical feeder of diameter d and height H=1.5d,

from emiprical relations M_f=0.21d

here d is the diameter of the feeder.

- ⇨ 0.21d=0.18716
- ⇨ d = 0.89123cm

Height of feeder H=1.5X0.89123=1.3368cm
Volume of feeder=0.833942cm^3
Diameter of neck=0.3cm
Height of neck=0.15cm
Volume of neck=0.0106

$$\text{Yield}=\frac{part\ \ volume}{part\ \ volume\ +feeder\ \ volume\ +neck\ \ volume}$$

$$\text{Yield}=\frac{3.9363}{3.9363+0.833942+0.0106} = 0.8233$$

Yield =82.33%

For steel hub:

Volume of casting=7.2503cm^3

Heat transfer area=23.71cm^2

Modulus of casting $M_c = \frac{volume\ of\ casting}{Heat\ transfer\ area}$

$M_c = \frac{7.2503}{23.71}$=0.3050790cm

Modulus of feeder M_f =kM_c

For steel k =1.3

M_f=1.3(0.30570) =0.3975cm

For cylindrical feeder of diameter d and height H=1.5d,

from emiprical relations M_f=0.21d

M_f=0.21d

0.21d=0.3975

$\Rightarrow$ d = 1.8929907cm
Height of feeder H=1.5X1.8929907=2.8394cm
Volume of feeder=7.991cm^3
Diameter of neck=0.3cm
Height of neck=0.15cm
Volume of neck=0.0106cm
Yield=$\frac{part\ volume}{part\ volume + feeder\ volume + neck\ volume}$

Yield=$\frac{7.2503}{7.2503+7.991+0.0106} = 0.47537$

Yield =47.53%

Fig 7.2 AutoCAD model of steel hub with well designed feeder

Fig 7.3 AutoCAD model of centre disk with well designed feeder

Further these CAD models are simulated to find out its defects while casting.

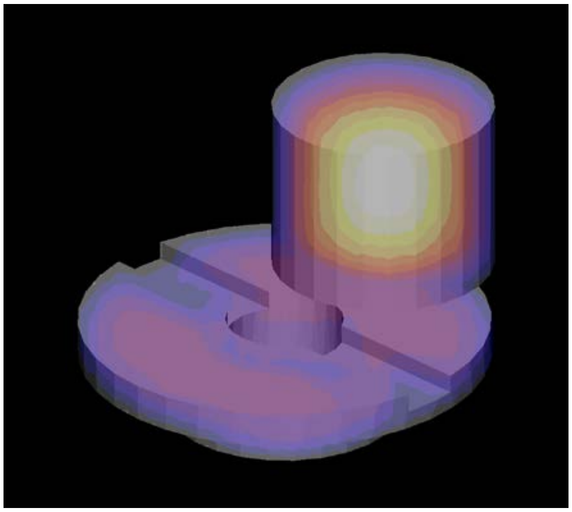

Fig 7.4 Simulation of steel hub with well designed feeder

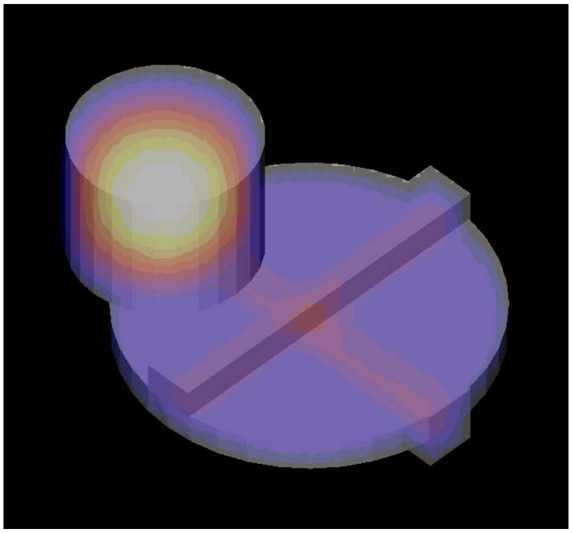

Fig 7.5 Simulation of centre disk with well designed feeder

All the hotspots in the casting are successfully removed by optimal design made to the feeder by calculations.

VIII. CONCLUSION

1) For the model with well designed feeder, hotspots are reduced which indicates less defects in the casted product and increased Quality of casting.

2) The overall yield of the casting obtained is 59.134% on an average, which indicates a good design to be casted.

IX. REFERENCES

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