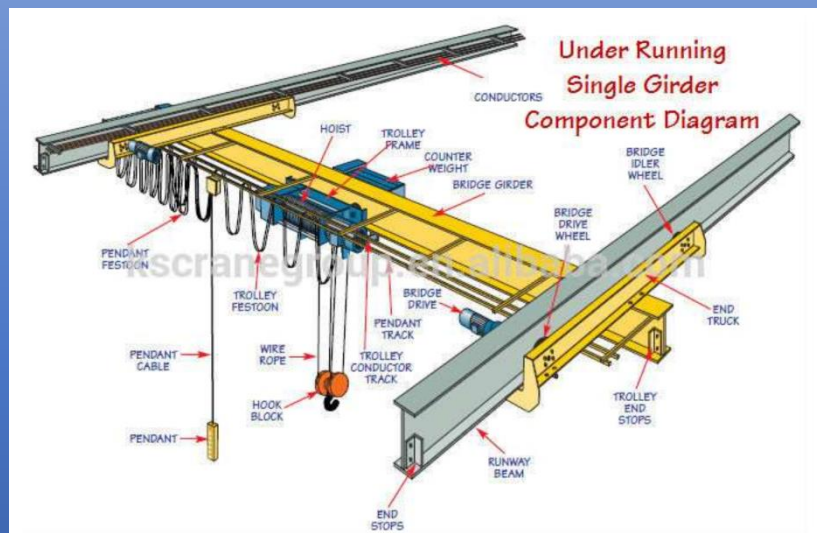




Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

DESIGNING AN OVERHEAD GANTRY CRANE

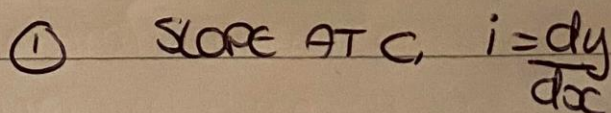


Owen David Bayliss (1708437) Word Count - 2704

ACMA5010 Stress Analysis and Dynamics

"DESIGNING AN OVERHEAD GANTRY"

- FIRSTLY WORK OUT THE BASIC DIFFERENTIAL EQUATION FOR THE DEFLECTION OF BEAMS:-



③ SINCE $i = \frac{dy}{dx}$ $\frac{1}{R} = \frac{di}{dx} = \frac{d}{dx} \left(\frac{dy}{dx} \right)$

$$\therefore \frac{d^2y}{dx^2} = \frac{1}{R}$$

④ INTRODUCING THE SIMPLE BENDING THEORY

$$\frac{M}{I} = \frac{E}{R}$$

$$\therefore \frac{1}{R} = \frac{M}{EI} \quad \therefore M = \frac{EI}{R}$$

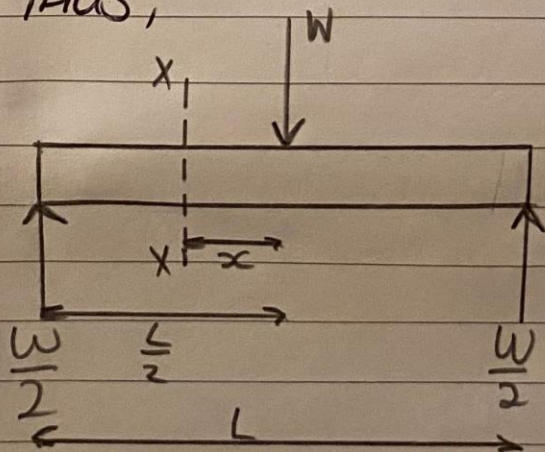
(WE PREVIOUSLY WORKED OUT, $\frac{1}{R} = \frac{d^2y}{dx^2}$)

$$\therefore EI \frac{d^2y}{dx^2} = M$$

THIS IS THE BASIC DIFFERENTIAL EQUATION FOR DEFORMATION OF BEAMS THAT WE WILL USE TO WORK OUT THE SECOND MOMENT OF AREA FOR THE BRIDGE GURDGE.

THE FIRST ASSUMPTION I WILL MAKE IN ORDER TO COMPLETE MY TASK IS THAT THE BRIDGE GURDGE IS A SIMPLY SUPPORTED BEAM WITH A CENTRAL CONCENTRATED LOAD.

SHOWN THUS,



THE ORIGIN IS IN THE CENTER OF THE BEAM.

CONTINUING

$$\textcircled{1} M_{xx} = \frac{W}{2} \left(\frac{L}{2} - x \right) = \frac{WL}{4} - \frac{Wx}{2} = EI \frac{d^2y}{dx^2}$$

FIRST DERIVATIVE

$$EI \frac{dy}{dx} = \frac{WLx}{4} - \frac{Wx^2}{4} + A \quad \textcircled{1}$$

SECOND DERIVATIVE

$$EI y = \frac{WLx^2}{8} - \frac{Wx^3}{12} + Ax + B \quad \textcircled{2}$$

~~FROM~~ FROM EXAMINING OUR BEAM SECTION
WE CAN DETERMINE OUR BOUNDARY
CONDITIONS.

$$\textcircled{1} \text{ WHEN } x=0 \quad \frac{dy}{dx} = 0$$

$$\textcircled{2} \text{ WHEN } x = \frac{L}{2} \quad y = 0$$

$$\textcircled{3} \text{ WHEN } x = -\frac{L}{2} \quad y = 0$$

SUBSTITUTING OUR FIRST BOUNDARY
CONDITION INTO OUR FIRST DERIVATIVE.

$$x=0 \quad \frac{dy}{dx} = 0 \therefore \underline{A=0}$$

SUBSTITUTING OUR SECOND BOUNDARY
CONDITION INTO OUR SECOND DERIVATIVE.

$$\text{WHEN } x = \frac{L}{2} \quad y = 0.$$

$$\therefore 0 = \frac{WL}{8} \left(\frac{L}{2} \right)^2 - \frac{WL}{12} \left(\frac{L}{2} \right)^3 + B$$

$$\therefore B = \frac{WL^3}{96} - \frac{WL^3}{32}$$

$$\therefore B = -\frac{WL^3}{48}$$

INTRODUCE 'B' INTO DERIVATIVE ~~NUMBER~~
~~THE~~ NUMBER (2).

$$y = \frac{1}{EI} \left[\frac{WLx^2}{8} - \frac{WLx^3}{12} - \frac{WL^3}{48} \right]$$

FOR $y_{\max}$ $x=0$.

$$\therefore y_{\max} = -\frac{WL^3}{48EI}.$$

WE WILL USE THIS EQUATION TO WORK OUT
THE MINIMUM SECOND MOMENT OF AREA REQUIRED
FOR THE BRIDGE GIRDER.

REARRANGING THIS EQUATION TO WORK OUT "EI", THIS WOULD THEREFORE BE,

$$y_{\max} = -\frac{WL^3}{48EI}$$

$$\therefore EI = -\frac{WL^3}{48y}$$

$$\therefore I = \frac{\left(-\frac{WL^3}{48y}\right)}{E}$$

INTRODUCING OUR FACTORS.

$$I = \frac{\left(\frac{(-49 \times 10^3 \times 20^3)}{48 \times -10 \times 10^{-3}}\right)}{210}$$

$$= 3888888.889 \text{ mm}^4$$

$$\therefore \underline{I = 3888.888 \text{ m}^4}$$

2. Discuss any Assumptions that you have made in Task 1.

In order to complete task 1, firstly I would have to make some assumptions in order to organise and build a suitable equation using the 'slope and deflection of beams' theory. Firstly, upon assessing what information was already presented to me in the task description, it was clear that there was no specified length for the Bridge girder. Therefore, in order to complete my equation this was something that I would make a researched assumption for early on in my process. Upon beginning my research,

I look for existing examples of pre existing under running cranes that are being produced and sold for large warehouses and factories. The first company I found was The Taval Cranes Group, a Chinese crane manufacturer which specialized in underhung cranes. On their website they give a specification for their underhung cranes. From this specification shown above, they state that their under running cranes capable of lifting 5 ton (as our task description specifies) will have a span greater than 16m (Overhead Crane Manufacturer. 2021).

Underhung Bridge Crane Specification

NO	ITEM	SPECIFICATION
1.	Product Name	Underhung Bridge Crane
2.	Capacity	0.5 tons, 1 ton, 2 tons, 3 tons, 5 tons, 10 tons
3.	Span	> 16 meters
4.	Lifting Height	> 10 meters
5.	Working Class	A5/A6/A7/A8/A9
6.	Lifting Mechanism	Electric motor or hydraulic motor
7.	Control System	Remote control, manual control
8.	Electrical Parts	CEC or Schneider
9.	Wheels	Hardened steel
10.	Brakes	Hardened steel
11.	Frame	Forged steel with anti-rust
12.	Lifting Speed	< 10m/min
13.	Travel Speed	< 20m/min
14.	Crane Traveling Speed	< 20m/min
15.	Service	On-site installation, maintenance
16.	Warranty	12 months, 24 months, 36 months

Furthering my research, I came across Engineered Material Handling, an American company which also specialise in the production of under running

cranes. In their specification for an underrunning crane with the capability of lifting 5 ton, they state the Span of the single bridge girder is 18m (EMH, Inc. 2021). Finally, I came across AICRANE again a Chinese company that specialises in crane packs and under running crane their specification specified a max span of 22.5m for a 5 ton under running crane designed and manufactured to European standards (AICRANE. 2021). Compiling all this basic research on max span under running cranes I made the decision to make the Bridge girder 20m in my equation and design. The next assumption that I made is to base my equation on a simply supported beam with a



concentrated central load. By coming to this decision this allowed me to make several more assumptions based on this equation alone. For example, as it is a simply supported beam with a central concentrated load the origin is now in the middle of the beam unlike a simply supported beam with a universally distributed load which has an origin on a single end of the beam. Also, in order to complete my equation using this theory I assumed that the crane is always stationary whilst it is lifting the load. I had to assume from the task description that the beam was a complete isotropic material which means that the material has the same mechanical properties throughout the beam and in all directions (Staab, G., 2015). If the beam is being manufactured from an isotropic material, then I can assume from this and from sections clearly shown in my research that the Beam is going to have a constant cross section throughout, so therefore my second moment of area is not required to change moving along the bridge girder. Finally, the last assumptions that I can make whilst completing my equation are the three boundary conditions which I have outlined in my notes. These are as follows,

When $X=0$ then $dy/dx=0$

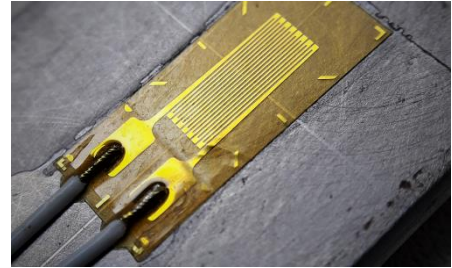
When $X=L/2$ then $Y=0$

When $x=-L/2$ then $Y=0$

These three boundaries allowed me to accurately work out my equation and come to a suitable answer.

3. Discuss the types of strain gauges available, how and why these have been developed historically and how these may develop in the future.

Strain Gauges are used in all aspects of an engineering and manufacturing process from research, development and testing all the way to manufacturing and installation. They are primarily used to measure the stresses put on an object or component to measure the components durability and to sometimes measure exactly how much of an impetus force a component or material can take before actually breaching its limits and breaking or deforming. The first recognisable Strain Gauge was produced by Charles Kearns in the 1930's he used this bonded resistance gauge to measure the vibration strains in a propellor blade (Sensorland.com. 2021). This resistance gauge was produced using carbon composite resistors and the cemented onto the component. However, these strain gauges were not very accurate and could only give limited results and were not very reliable. The next notable progression in Strain gauges came in 1938 when Arthur Claude Ruge an American Mechanical engineer (Matthews, M., 2013) who produced what we would recognise today as a modern wire resistance strain gauge shown above. Ruge's discovery was especially ground breaking as he was the first to implement electrical resistant alloys for the strain wire that could also be bonded directly to the surface that would be under strain (Matthews,M.2013). The introduction of printed circuit boards in 1954 allowed the strain gauge to once again progress, by printing the pattern for a gauge on thin foil of a printed circuit this meant that strain gauges could now be produced at a fraction of the size and a fraction of the cost.



Mechanical Gauges or Extensometers

Mechanical gauges or extensometers are gauges used to measure a materials dimension or change in dimension whilst under stress. They can also be classed as dimensional gauges, they can also determine, yield strength, tensile strength, yield point elongation, strain-hardening exponent and strain ratio (Encardio Rite. 2021). Mechanical gauges can come in the form of DTI's (Dial test indicators) for example, dial test indicators can be used to test displacement in a component, they are primarily contact measurement gauges and can measure the deflection or bend on a component or part that is being subjected to forces in the x or y axis. Mechanical gauges can also be electronic, these electronic gauges are deemed as more reliable than their analog counterparts as human error when setting up the apparatus is less likely to be a contributing factor to the results that may read from the gauge. However digital gauges have their downfall due to their obvious need for batteries or an external power source (Thomasnet.com. 2021).



Pneumatic & Hydraulic Gauges

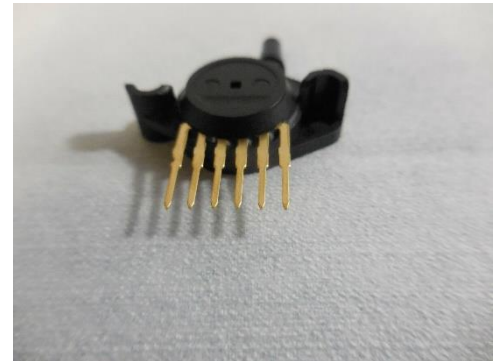
Pneumatic and hydraulic pressure are mounted on high pressure valve sets and pipes, they measure air pressure or oil and water pressure and are used in a wide variety of sectors. For example, pneumatic gauges in a large dry fire suppression system are key to the whole system working correctly, if there is a fire somewhere in the system then a sprinkler bulb will break allowing pressure in the system to drop, this change in pressure will be measured by the pneumatic gauge this will then trigger the system to release the control valve and allow the system to be flooded with water and extinguish the fire. A pneumatic or hydraulic gauge will measure the strain in 3 ways, Absolute, Gauge and vacuum. You will usually see a pneumatic gauge on a system either top mounted or mounted on a panel. A pneumatic gauge is extremely popular and accessible as they can be produced in any size, material and construction that you may require. These have been developed to measure the hydraulic or pneumatic stress that is



being applied to a system to ensure that a system is not overloaded or to measure the point in which a system will fail due to overloading.

Acoustic Gauges

An acoustic gauge is an instrument which is used to measure and detect frequency of vibrations in a component or wire. A wire is stretched between two-gauge points and the change in length is recorded as it alters the natural frequency of the wire. To alter the magnitude of frequency of change then you must decrease the length in the wire, this will then increase the magnitude of frequency of change (GT1169, G., 2021). Acoustic gauges are extremely accurate and very sensitive as they can pick up on the smallest frequencies of change within an object. They can be applied to objects on a nanoscale. However, this can make the very expensive as they are very specialist pieces of equipment and thus makes them very rare.



Semi-Conductor Gauges

A semiconductor gauge measures the Piezo-resistive affect in a component with a particular material such as silicon or Germanium (HITEC Sensors. 2021). The piezo-resistive effect is the change in a materials conductivity and resistance when a force is applied to a semiconductor. These gauges were the first micro electromechanical system, this is a component which is between 1 and 100 micrometres in size. These are extremely high in sensitivity and are also extremely reliable tools compared to a normal foil sensor (HITEC Sensors. 2021).

Inductance Gauges

Alike the other gauges an inductance gauge measures a specific strain output. In this case it is measure inductance. The most common inductance gauge which is used in many different industries is the LCR meter. The LCR meter measures the inductance of a circuit. Inductance (L) is caused when a current flowing through a circuit is changed then this will have a corresponding effect on the voltage and the conductors around it. This is defined as Inductance. This is especially the case when a current pass through a coil, the level of inductance will raise dramatically (Calculation, F. 2014). The LCR meter also, measures capacitance so this makes them very useful and reliable pieces of equipment.

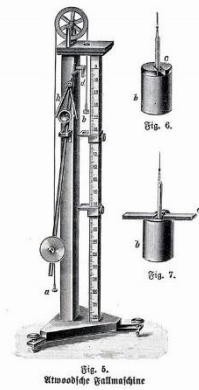


Accelerometers

Most people carry an accelerometer with them every day, they are in nearly all phones and sometimes can be found in many smart watches as they are now considered low costing and very durable. They allow the maps app in your phone to show you the correct direction and more simply it allows your screen orientation to change depending on how you are holding your phone, they are motion sensors which have a full 6 degrees of freedom. Like the semi-conductor gauge an accelerometer also uses piezo-resistive effect as well as a capacitance sensor. The piezoresistive effect is



manipulated using microscopic crystals structures that when placed under a stress become fractured, this stress is acceleration and motion. From these fractures a sensor can determine the stress from the voltage produced this can then be converted in terms of motion and acceleration or deceleration (Goodrich, R., 2013). Now accelerometers are used in day-to-day life for very mundane tasks however their creation was for the purpose of “validating universal Gravity” (endeveco. 2017). The first accelerometer was created by a British physicist called George Atwood in 1738 and was aptly named the Atwood Machine. This machine works by upholding a mass on springs and whenever there is any form of acceleration and the mass is moved, the Atwood machine can then determine the velocity (endeveco. 2017). Accelerometers are used widely in many different industries now, and are a key part in the testing of vehicles and in testing how safe they are through the means of crash testing.



Future for Strain Gauges

Strain gauges have been used in nearly all fields from aerospace engineering and design all the way to construction and medicine. They are a key component to all stages of an engineering project from research and development through to design and manufacturing and then finally on to testing. The future of where strain gauges may progress in their respective fields are limited by only the requirements of the person who is using the strain gauges. As the requirements may progress then so will the strain gauges. For example, Tecat performance systems have begun to develop a 'Torque Measurement System'. This will consist of 8 'micro measurements' strain gauges configured on a flux plate and then fitted on to a vehicle (Dillman, L., 2016). Another case study which is being carried out with the progression of strain gauges at the heart of the study, again has been conducted using 'Micro-Measurements' strain gauges. The challenge the team faced was that they needed to understand the range of effects of wind currents have on devices such as aircrafts, helmets and wind turbines. Previously they would use smoke trails to give an understanding on wind currents in a wind tunnel, but this had its downsides as it would only give the engineers limited data on effects (Booth, D. and Johnson, J., 2015). They could not determine the forces exerted on the devices by the wind currents. This meant that their strain gauge needed to be small and reliable as well as very durable and strong when fitted to the device that was being tested. Due to these requirements and needs the usual protocol for testing is to use "6 Degrees of freedom Transducers", these transducers however come with a very large price tag of around \$40,000 each and are very delicate and difficult to set up and use (Booth, D. and Johnson, J., 2015). The solution for these engineers comes in the form of a particular "Micro measurement" advanced sensor, by using this advanced sensor it allowed the engineers to test their devices and not have to worry about having to calibrate a difficult piece of expensive equipment that is also very delicate, but most importantly it meant that they were able to gather reliable and important data on how the forces exerted by the wind current were having on the devices they were testing or may test in the future (Booth, D. and Johnson, J., 2015).

So, to summarise, the future of strain gauge development completely comes down to how people use them and what they require them for. To say they are developing in a certain direction is naïve as it truly comes down to what a person is needing the strain gauge for. In my few examples I have shown how engineers are taking strain gauge technology that already exists and apply them to projects and uses that were never originally intended for them and manipulating to suit their desired processes.

4. Using your discussion in task 3, suggest which strain gauges should be used as well as where and how they should be applied to the crane. Discuss how readings from these strain gauges should be interpreted.

For the testing of the underrunning crane and more specifically the bridge girder I suggest that a mechanical gauge is necessary for locating any deformities or irregularities that may occur during lifting and loading whilst the crane is in use. I suggest using multiple DTI (Dial test indicator) gauges situated on multiple areas along the bridge girder during testing, with a concentrated load applied to the bridge girder for a specific time period. Whilst this load is being applied, the readings from the multiple DTI gauges are taken. The load is then positioned at a new point on the bridge girder and the test is repeated. Once the test has been repeated enough times to ensure that the results are reliable the test should then be repeated with a greater weight and a different set time. The results should be taken the exact same number of times also. From these readings you can determine the max deflection in the beam and what slope is produced under different loads and at different load points. This test can also be altered by also repeating with a universally distributed load across the beam. Using the results of the multiple tests you can accurately work out the most appropriate cross-sectional area for the beam as well as its length and work out where is the strongest part of the beam. If set up correctly then the DTI method of testing will be very reliable and also very easy to understand and read. To summarise this method will be very easy to understand and will provide you with enough information and data to apply to many different pre-determined calculations, such as, finding the maximum deflection, slope and second moment of area.



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