Alignment of Engine and Gear Box Using Laser System in LCH & ALH

[1]Akhilesh Kumar Chauhan, [2]Adrian Rodrigues, [3]Sanath K, [4]Akash Anand, [5]Shanawaz Patil

[1,2,3,4] UG Students, School of Mechanical Engineering, REVA University

[5]Assistant Professor School of Mechanical Engineering, REVA University

[1]REVA University, Bengaluru, Karnataka

Abstract: A laser shaft alignment tool based on spot viewing method is designed in this thesis. All the parts of tool are designed and fabricated as per the requirement of the method. The tool has two different approaches for testing. The first one is a manual method, where the deviation of spot is measured manually whereas in the other method a digital receiver end is designed to get more precise location of the laser spot on the disc. The designed laser alignment tool can compensate soft ground effect and temperature effect. Therefore, it will do alignment activity beneath varied conditions. It will meet the necessity of coaxiality measurement in shafting. The tool can also be calibrated using a V-notch block manually.

***Index Terms* – Manual method, electronic method, coaxiality, spot, laser, shaft alignment**

1. INTRODUCTION

Laser shaft alignment became popular in the mid-1980s when a company named Prueftechnik introduced OPTALIGN, The world's first commercially available computer aided laser shaft alignment tool. Despite its then relatively high price, the system quickly gained market popularity with mechanics and companies across a wide spectrum of process industries in the world. This system offered many significant advantages in affecting quick and accurate alignment of coupled rotating machines [1].

Since the introduction of the first systems and tools, developments in laser and microprocessor technology have allowed new generations of laser systems to be developed which offer the user simple to understand, easy to use and menu led systems that can be used for virtually any shaft alignment task irrespective of complexity or size [1].

As we have seen in the mechanical method of shaft alignment there are a number of important considerations that should be take into account when using mechanical methods of shaft alignment, additionally calculations of shaft alignment corrections can be complicated and very error prone. None of the considerations apply to the laser shaft alignment method. Access to precision shaft alignment and the benefited that this brings is readily available when laser shaft alignment is used on site [1].

Machine jointed by coupling would generate vibration when running because of shaft misalignment and the vibration affects the using life of machine and damages the parts. As we know almost 50% of the rotating machinery fault is caused by the shaft misalignment. Hence shaft alignment is an important process in power machinery assembly and operation.

The advanced laser technology is the key technology in measuring and adjusting shaft misalignment. The newly designed laser shaft alignment tool is used as alignment tools and the deviation value is given by manual calculation. The tool can also be developed such that the deviation can be given displayed digitally on a screen. It can't take the advantage of the laser shaft alignment efficiently, and foreign products are very expensive. Therefore laser shaft alignment tool based on spot viewing technique is designed in this thesis. In the actual measurement, the relative position of the two shafts can be calculated by locating the spot on the receivers end on eight different locations each at an angle of 45˚. The alignment purpose can be realized by adjusting shaft position according to the calculated result. Furthermore, prototype is designed and used to detect the actual engineering measurement.

2. SHAFT ALIGNMENT AND MISALIGNMENT

Shaft alignment is the process of aligning two or more shafts with each other within a tolerated margin. It is one of the most important requirements for machinery before the machinery is put in service [2].

When a driver shaft like of an electric motor or a turbine is coupled to a pump, generator, or any other piece of equipment, it is important that the shafts of the two pieces are aligned properly. Any misalignment between the two shafts increases the stress on the shafts and will almost certainly result in excessive wear and tear, premature breakdown of the equipment. This can be very costly for any industry or any machinery. When the equipment's performance is down, production might be less too. Also bearings or mechanical seals could also have been damaged and are needed to be replaced. Flexible couplings are designed to allow a driver (electric motor, engine, and turbine, hydraulic motor) to be connected to the driven equipment with a given tolerance limit [3].

Tools used to achieve alignment may be mechanical or optical, like the Laser shaft alignment method, or they are gyroscope based. The gyroscope based systems are very time efficient while operating and can also be used if the shafts are at greater distance (e.g. on marine vessels).

Before such a shaft alignment is to be done, it is also important that the foundations for the driver shaft and the driven shaft are designed and installed correctly. If both the shafts are installed properly, then shaft alignment can be started. The resulting deviation i.e. if alignment is not achieved within the demanded limits is termed as shaft misalignment, which may be parallel, angular, or both. Misalignment can have adverse effects like, increased vibration and loads on the machine parts. These external unrequited forces can lead to wear and tear of the parts (i.e. improper operation).

Basically there are two deviations in shaft misalignment. First one is the parallel deviation. It means that the two joined shafts are parallel, but not collinear. The other one is the angle deviation. It means that the two jointed shafts are not parallel and has formed an angle. When measuring, usually the two-axis spatial location are decomposed into two mutually perpendicular planes, then the acquired deviation can be calculated using the spatial relationship of the two axis, at last adjusting the shaft alignment according to the calculation result by eliminating the deviation can produce a successful shaft alignment[3].

3. MECHANICAL TOOL DESCRIPTION AND PROCEDURE

Currently a mechanical tool is used for the shaft alignment process by HAL in ALH & LCH. This tool has a cylinder piston type arrangement where the cylinder with smaller diameter is placed concentrically within the cylinder with larger diameter. During the process shims are used to adjust the alignment. Each shim is of 1 mm in thickness. When the outer surface of the inner cylinder does not touch with the inner surface of the bigger cylinder the engine and the MGB is said to be in aligned position.

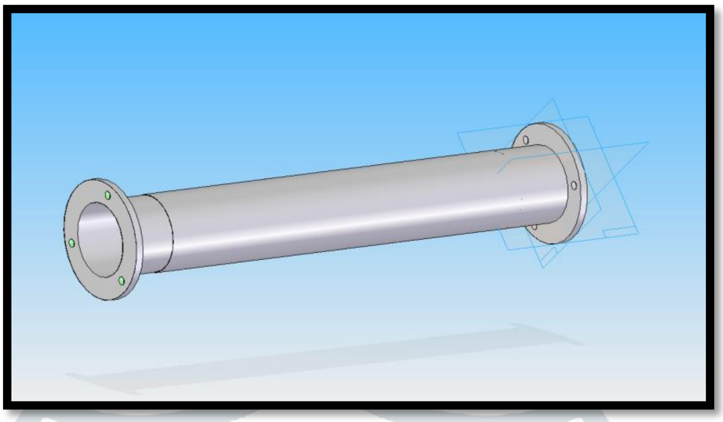

Figure 1: Isometric view of Assembly of Mechanical tool

4. LASER SPECIFICATIONS REQUIRED

For the purpose of shaft alignment a "Semiconductor Diode" laser is used in this thesis. Semiconductor diode laser is used as it is readily available and also semiconductor diode is very affordable when compared to other types of laser. The means of generating optical gain in a diode laser pointer, the recombination of injected holes and electrons (and consequent emission of photons) in a forward-biased semiconductor pn junction represents the direct conversion of electricity to light. This is a very efficient process, and practical diode laser devices reach at least 50-percent electrical-to-optical power conversion rate. This can be achieved at an order of magnitude larger than most other lasers. Over the past 20 years, the trend has been one of a gradual replacement of other laser types by diode laser based–solutions, as the considerable challenges referring to engineering with diode lasers have been met. At the same time the compactness and the low power consumption of these diode lasers have enabled important new applications such as storing information in different ways in compact discs and DVDs, and the practical high-speed, broadband transmission of information over optical fibers, a central component of the Internet [4] .

Since the laser used in this thesis is used for shaft alignment, the spot diameter of the required laser diode has to be less than 3mm. As the tolerance limit for the given laser alignment is 2.5 mm at a distance of 365.5 mm, hence a laser diode of spot diameter less than 3 mm is used in this thesis. The semiconductor laser diode used for this project has a spot diameter approximately equal to 1.2 mm at a distance of 365.5 mm. For the TDS alignment the tolerance limit is 6.5 mm at a distance of 4 meters. The spot size of the laser diode used at a distance of 4m is found to be less than 3mm, hence the laser diode used for the project suitable for the alignment of shaft by spot viewing technique.

The wavelength of the laser light should be between 630 nm to 650 nm. As we know that energy of an electromagnetic radiation increases with reduction in wavelength (i.e. Energy is inversely proportional to wavelength). This can be proved by equation (1) where "E" is Energy, "h" is Planck's Constant, "C" is speed of Light and "λ" is Wavelength of light.

$$E = {}^{hC}/_{\lambda} \quad \ldots\ldots\ldots (1)$$

For a given laser divergence increases with increases in wavelength of the laser. Though for the purpose of shaft alignment a laser with a little higher wavelength is commonly used but it is between 600nm to 700nm only as a laser with more than 700nm wavelength will have more divergence. This can be proved using the Gaussian equation (2).

$$\Theta = \frac{\lambda}{\pi w} \quad \ldots\ldots\ldots (2)$$

Where λ is the laser wavelength and "w" is the radius of the beam at its narrowest point, which is known as the "beam waist". This type of beam divergence is observed in optimized laser cavities. Information on the diffraction-limited divergence of a coherent beam is inherently given by the equation proposed by N-slit interferometric theory.

The divergence angle of the laser beam used in this thesis is less than ~1 mrad. With a greater divergence angle the spot size will increase with increase in distance from the source. As for our project work the spot size has to be less than 3mm at 4m, If the divergence angle is 2mrad and power of the laser is ~5mW and the exit beam diameter at the aperture is 1.1mm then at 4m the spot size of the beam will be 9mm. This is way more than the requirement. On the other hand, if beam divergence is less than 1mad say around 0.5mrad and power of the laser is ~5mW, exit beam diameter at the aperture is 1.1mm then at 4m the spot size of the beam will be 3mm.

The divergence of a given laser beam can be calculated if the beam diameter d_1 and d_2 at two separate distances are known by the operator. Let z_1 and z_2 are the distances along the laser axis, from the end of the laser to points '1' and '2'. Usually, divergence angle is taken as the full angle of opening of the beam. Then,

$$\Theta = \frac{d_2 - d_1}{z_2 - z_1} \quad \text{........... (3)}$$

Half of the divergence angle can be calculated using the equation (4)

$$\theta = \frac{w_2 - w_1}{z_2 - z_1} \quad \text{............. (4)}$$

Where w_1 and w_2 are the radii of the beam at z_1 and z_2.

Like all electromagnetic beams, lasers are subject to divergence, which is measured in mil radians (mrad) or degrees. For many applications, a lower-divergence beam is preferable.

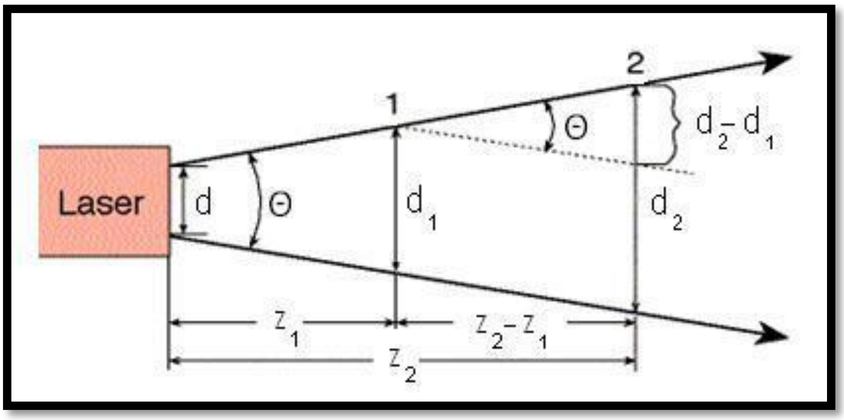

Figure 2: Method used to calculate beam divergence for a given laser

The output power of the laser beam used in this thesis is less than 5 mW. The reason behind using low power laser is that with a high power laser pointer it is difficult to do shaft alignment process. With increase in power of the laser the range increases and also the divergence angle of the laser beam reduces but it also produces a very bright spot which is not suitable as it is very difficult to see the center bright spot of the laser or the half angle divergence part of the laser. This "Half Angle Divergence" part is used for the calculation of the divergence angle hence a very bright spot would make it difficult to calculate the divergence angle. Usually the price of the laser pointer increases with increase in power hence a laser pointer with output power near to ~5mW is affordable and suitable for the project. As for our project we have to locate the spot size on the receiving end, a laser pointer with high power would burn the retina of an eye if seen or pointed at an eye. Hence, a laser with 5mW is best suited for the project work.

The preferable color of laser shaft alignment is usually red. Red color is used because we know that red color scatters the least. This property of red color helps in identifying the spot precisely while viewing the laser spot on the receiver's end of the designed tool.

As we know that in this method of alignment, we are viewing the laser spot directly, hence as per the guidelines provided by the government any laser till class IIIA is safe and can be used by wearing safety glasses. In this thesis we use a laser of class IIIa which can be operated easily when using safety goggles.

For the purpose of shaft alignment a TEM 00 laser pointer is used in this thesis. TEM refers to the transverse mode of laser pointer. The transverse modes for a given stable resonator have different beam diameters and divergences. The lower the order of the mode is, the smaller the beam diameter, the narrower the far-field divergence, and the lower the M2 value.

For example, the TEM01* doughnut mode is approximately 1.5 times the diameter of the fundamental TEM00 mode, and the Laguerre TEM10 target mode is twice the diameter of the TEM00 mode. Different transverse modes of laser pointer are shown in figure 3[5].

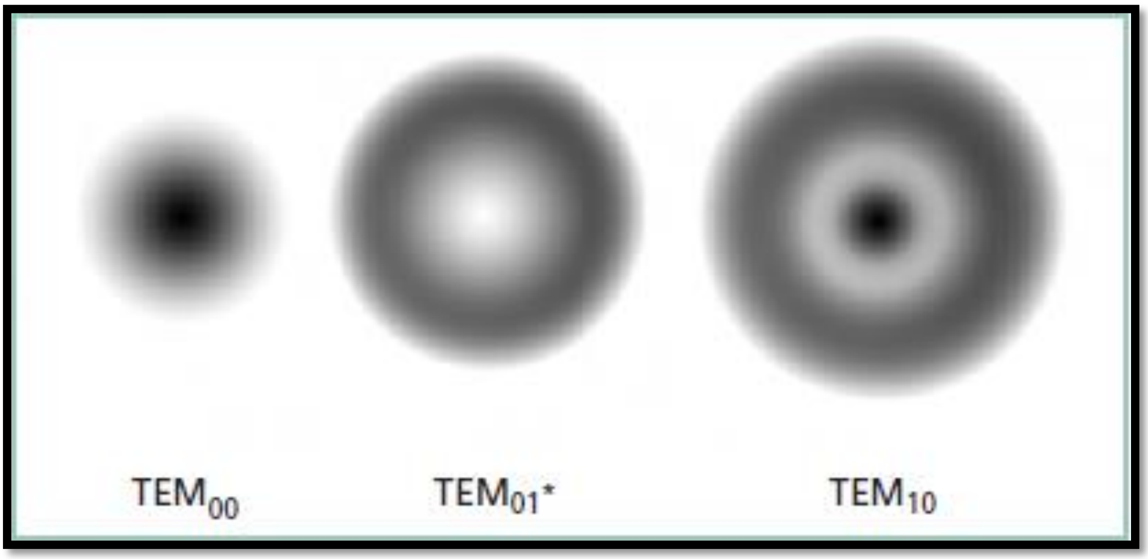

Figure 3: Different transverse mode laser beam.

5. FLEXIBLE DRIVE SHAFT (FDS) AND ITS LIMITATIONS

FDS is a device for transmitting rotary motion between two objects which are not fixed relative to one another. It may or may not have a covering, which also bends but does not rotate. It may transmit considerable power, or only motion, with negligible power [6].

In LCH (Light Combat Helicopter) and ALH (Advance Light Helicopter), FDS is placed between the MGB and the Engine. Since Engine and MGB are not placed on the same plane, FDS is used. Figure 4 shows a commonly used FDS in a Helicopter.

5.1. Some of the specifications of FDS are given below:

Tightening torque for fastener 28 to 30Nm
For balancing remove material from areas indicated limit value 70 gm.-mm, Maximum on each end.
Axial Stiffness (Tension and Compression) < 200 N/m
Torsional Stiffness > 398 N-m/degree
Bending Stiffness < 9.5 N-m/degree
Provide slippage marks on all nuts in Red.

5.2. Limitations of FDS:

The degree of misalignment between MGB and Engine should not exceed 6˚ in all directions.
A maximum of 6mm deviation is permitted in x, y and z directions.
Longitudinal displacement of 2-5mm is permissible.

Figure 4: A commonly used Flexible Drive Shaft in a Helicopter

6. EXPERIMENTAL SETUP

There are two different setup provisions are available on both the discs for two different alignment. The three holes at a Pitch Circle Diameter (PCD) of 92 mm is made for the alignment between engine and main gear box, whereas three holes at a PCD of 90 mm is made for the alignment between main gear box and intermediate gear box. There are two more holes present on the projecting discs. These two holes are used to mount the two laser diodes. One of the laser diode has its centre at the centre of the disc whereas the other has its centre at a diameter of 47.5 mm. The second laser can be mounted anywhere on a PCD of 47.5 mm. The projecting disc is mounted on the input of Engine flange and the receiving disc is mounted on the output side of the MGB flange. This setup is used for alignment between Engine and MGB. For TDS alignment the projecting disc is mounted on the IGB (Intermediate Gear Box) flange and the receiving disc is mounted on the output of Engine flange. Figure 5 shows the isometric view of experimental setup used for the alignment between engine and MGB. In a similar way the setup is arranged for the TDS alignment.

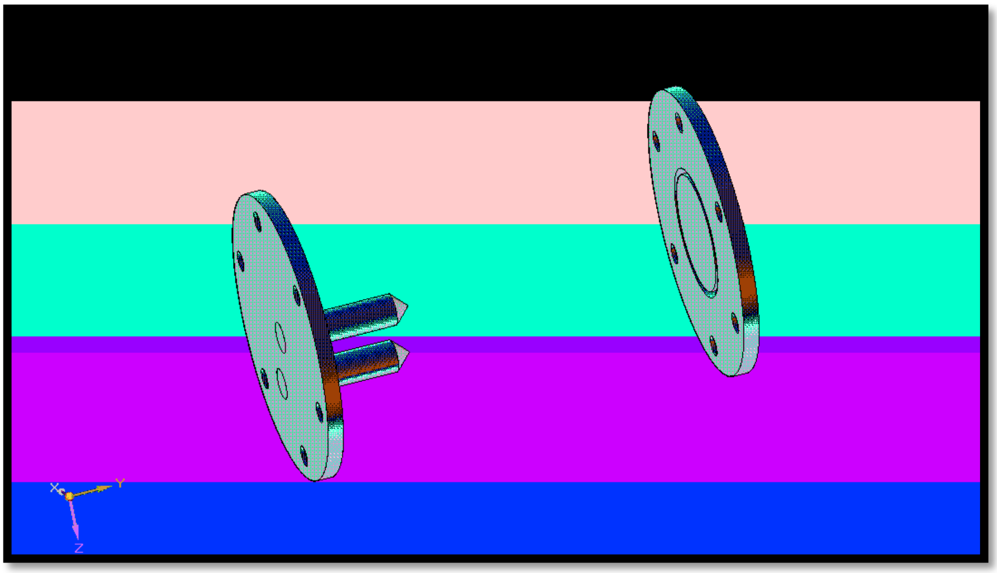

Figure 5: Isometric View of the Experimental Setup for Laser Shaft Alignment Procedure

7. ALIGNMENT PROCEDURE

In this method of shaft alignment the calculation of the deviation of laser light from the defined tolerance limit is calculated manually, hence it is defined as the manual method. Firstly the projecting disc is mounted on the engine flange using nuts and bolts. Similarly the receiving disc is mounted on the MGB flange using nuts and bolts.

Once the two discs are mounted on either side, the laser diode present on the 47.5 mm PCD is turned on. After turning on the laser diode the disc mounted on the engine is rotated. After every 45˚ of rotation a reading is taken.

Once the laser spot has been located on the receiving disc it is checked for the alignment. If the laser spot falls between a limit of 2.5 mm as defined, the two shafts are said to be aligned. If the spot is found to be outside the outer circle, the deviation is given a positive value and if the spot falls inside the inner circle the deviation is given a negative value.

If the laser spot falls on outer circle circumference it is denoted in the result sheet as OC and if it falls on the inner circle circumference it is denoted as IC on the result sheet.

After a full rotation of 360˚, eight numbers of readings are taken down each at an angle of 45˚. Any deviation found is adjusted by moving the engine side only because the MGB flange is fixed permanently onto the helicopter as it is the most dynamic part of the helicopter and consumes the highest percentage of energy produced by the output of the engine. Nearly 80% of the output energy produced by the engine is consumed by the MGB. Any vibration caused in the MGB can even result in the breakdown of helicopter.

Hence the engine shaft is adjusted using shims. Each shim is of 1 mm thickness. This is taken as the first trial for the alignment. Similarly 3 trials are taken for a successful alignment. Once all the three trials are taken and the deviation values are noted and the engine is adjusted, the engine shaft is said to be successfully aligned with the MGB shaft.

8. EXPERIMENTAL RESULTS

The actual measure of parallel deviation values between Engine and Main Gear Box at a distance of 365.5 mm is shown in table 8.1, table 8.2 & table 8.3 for 1st, 2nd & 3rd trials respectively. IC refers to 'Inner Circle' & OC refers to 'Outer Circle'. These values are noted when the laser spot falls on inner circle or on the outer circle.

Table8.1. Readings of 1st Trial for alignment between Engine & MGB using Laser System.

TRIAL 1		
Angle (˚)	Parallel Deviation (mm)	Limit (Y/N)
0˚	-0.5	N
45˚	-1.0	N
90˚	0	Y
135˚	0	Y
180˚	0.5	N
225˚	1	N

270˚	0	Y
315˚	-0.5	N

Table8.1. Readings of 2nd Trial for alignment between Engine & MGB using Laser System.

TRIAL 2		
Angle (˚)	Parallel deviation (mm)	Limit (Y/N)
0˚	IC	N
45˚	0	Y
90˚	0	Y
135˚	1	N
180˚	1	N
225˚	OC	N
270˚	0	Y
315˚	IC	N

Table8.2. Readings of 3rd Trial for alignment between Engine & MGB using Laser System.

TRIAL 3		
Angle (˚)	Parallel deviation (mm)	Limit (Y/N)
0˚	0	Y
45˚	0	Y
90˚	0	Y
135˚	0	Y
180˚	0	Y
225˚	0	Y
270˚	0	Y
315˚	0	Y

As we can see in Table8.3 that after 3rd trial there is no deviation and the laser spot is falling within the limits. This tells that the two shafts are aligned.

8.1. Tail Drive Shaft (TDS) Alignment Results

For TDS alignment the laser spot has to fall within the circle whose centre is at the centre of the disc and has a diameter of 12 mm. This 12 mm is the tolerance limit given for TDS alignment. The table 8.1.1 shows the first trail done using the designed tool. The misalignment between the two shafts (i.e. AGB (Auxiliary Gear Box) and IGB (Intermediate Gear Box)) is recorded and the shafts are then adjusted accordingly to eliminate these deviations. After eliminating the deviations found in the first trial we go for the second trial to eliminate any other deviation found in any direction.

Table8.1.1. 1st Trial for TDS alignment using Laser system in LCH TD4

TRIAL 1		
Angle (˚)	Parallel deviation (mm)	Limit (Y/N)
0˚	3	Y
45˚	4	Y
90˚	10	N
270˚	10	N

Table8.1.2. 2nd Trial for TDS alignment using Laser system in LCH TD4

TRIAL 2		
Angle (˚)	Parallel deviation (mm)	Limit (Y/N)
0˚	3	Y
45˚	3	Y
90˚	4	Y
270˚	8	N

Table8.1.3. 3rd Trial for TDS alignment using Laser system in LCH TD4

TRIAL 3		
Angle (˚)	Parallel deviation (mm)	Limit (Y/N)
0˚	0	Y
45˚	1	Y
90˚	1	Y
270˚	4	Y

As we can see that after the 3rd trial using the laser alignment tool, all kinds of misalignment is eliminated in all directions within the tolerance limits. Hence the Intermediate Gear Box and the Auxiliary Gear box is said to be successfully aligned.

9. Conclusion

The experimental system is simple and easy to use, and can be used by manual or digital measurement method. The scope of the designed tool is that it can be further developed in such a way that the tool would have automatic collection, transmission and storage data capabilities. It would calculate the data automatically and give the adjustment quantity by software. Image processing can be used for displaying the digital results. The designed tool has good repeatability and strong anti-jamming characteristics. Through several testing, the alignment effect is good, which facilitates adjustment and owns promoting value and many advantages compared with overseas similar products. There is also a provision for the calibration of the tool which can be done easily using a V-notch block and checking for the perpendicularity of the laser diode with respect to the disc plane. This technique is also a faster way of aligning two coaxial shafts when compared to the old mechanical tool used in the company.

10. References

1. Edition 44-03.007, © Copyright 2002, Prueftechnik Ltd, All rights reserved, Distributed in the US by LUDECA Inc.
2. Diagrams of parallel offset alignment, angular offset alignment and combination of both parallel and offset alignment
3. Lin Liu & Suri Ganeriwala Spectra Quest Inc. October, 01 2005
4. Fundamentals of Photonics Bahaa E. A. Saleh, Malvin Carl Teich Copyright © 1991 John Wiley & Sons, Inc. ISBNs: 0-471-83965-5 (Hardback); 0-471-2-1374-8 (Electronic).
5. www.mellesgriot.com
6. Peter Charles Bell (2 July 1971). Power Transmission. Palgrave Macmillan UK. pp. 112–. ISBN 978-1-349-01197-1.