BARREL ALIGNMENT- A CRITICAL FACTOR IN REDUCING EXTRUDER WEAR

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Abstract

As processors increase the demand on the extruder for increased rate and product quality it is essential that the barrel, feed throat and drive are maintained properly for maximum service life. It is a common misconception that as long as the feedscrew and barrel are straight the machine will be in alignment. However, if the barrel is misaligned it can cause excessive wear and tear on the barrel and screw as well as the internal bearings and mechanisms within the gearbox which will reduce the service life. Excessive wear to the radial bearings can cause the screw to seize in the barrel. The scope of this paper is to investigate the factors that influence the extruder alignment and the proper procedure to measure and align an extruder.

Introduction

In most single screw extruders the machine has four major components which make up the extruder; Gearbox, Feed throat, Barrel, and Feedscrew as shown in Figure 1. The gearbox, thrust bearing and shaft assembly is normally supplied as one unit as shown in Figure 2. The thrust shaft holds and turns the screw which is the centerline of the axis of rotation. The feedscrew, which is the heart of all extruders, is used to convey, melt and pump the molten resin into a desired form (1). In order to achieve and maintain optimum machine efficiency, the clearance between the screw and barrel must be kept at a minimum. The typical radial clearance C_r between the screw and barrel I.D. is shown in Figure 3 and is calculated by equation 1 (2).

$$C_r = .001 * D_b \qquad (1)$$

Where D_b is the nominal inside diameter of the barrel. If any of these components are not aligned from the centerline of the thrust shaft there will be contact between the screw and barrel which will cause excessive wear and ultimately an increase in clearance. This clearance will reduce the efficiency of the extruder. In addition to reduced efficiency, if the clearance between the screw and barrel becomes too great it can cause the screw to flex each revolution. After enough flex cycles, the metal fatigues and could cause the screw to break (3).

There are number of factors that can lead to extruder alignment issues with some being more obvious than others. It is a common misconception that as long as the extruder is level the components must be properly aligned. It is always good practice to level a machine but it does not insure that the components will be in proper alignment. Most machine builders and screw and barrel suppliers go through many painstaking procedures to make sure the components are straight in accordance to the Society of Plastics Industry's machinery specifications (2). However, once the machine is shipped or moved the alignment can change. The only way to insure that the extruder is in alignment is by using the proper equipment. Figure 4 illustrates how a typical extruder is setup to check alignment. A bore scope is mounted to the output shaft of the extruder gearbox. The scope is centered to the gearbox through-hole and adjusted to the true center line of the gearbox. A target is then placed in the center of the barrel at the discharge end. Depending on the device used and the accuracy of the equipment a reading is taken on the misalignment of the discharge end of the barrel to the gearbox axis of rotation.

Optical Vs. Laser Alignment Systems

The two primary methods for measuring the extruder alignment are by either optical or by lasers systems. Historically, optical systems have dominated the extrusion industry primarily due to the low cost of the equipment and its ease of use. Optical systems use a precision telescope (Bore scope) that establishes a precise reference line of sight. Inside the scope, at the focus of the eyepiece is a cross hair that is projected to infinity, enabling the operator to note the position of a target relative to the cross hair. A horizontal and vertical optical micrometer is used to bring the center of the target into the cross hair. The operator reads the change in elevation from the axis of the cylinder. Most optical alignment telescopes have a magnification of 4x at zero focus to 46x at infinity. Depending on the type of equipment and the experience of the operator, the typical accuracy of an optical system is .25 mm in 30 m. Figure 5 shows a typical optical telescope used for extruder alignment.

Over the last 10 years laser alignment systems have steadily replaced optical systems. The success of laser systems for alignment has been in the increased accuracy and time to fully align a machine. In addition, most lasers systems have the capabilities of generating computer readouts which reduce human error typically associated with the optical systems. As with the optical systems, a laser is positioned on the gearbox shaft and adjusted so it is coincident with the axis of rotation. A light-sensitive target that detects the laser beam is moved through the length of the barrel and the misalignment is displayed on a digital readout. The accuracy of a laser system is typical in the range of .025 mm in 30 m. Laser systems are very accurate in short distances but tend to lose accuracy as the distance increases due to the quality of the laser beam. Figure 6 shows a typical laser system.

Both systems will perform well and will accurately measure the misalignment of the gearbox and barrel. Both optical and laser systems require that the extruder barrel be clean and at room temperature before measuring the bore. Both systems can be adapted to measure the thermal growth of the barrel by installing targets on the exterior of the barrel.

Barrel Supports

Most extruders have at least one barrel support to hold the barrel in place and prevent it from deflecting or sagging due to the weight of the barrel. Barrel supports also contain a form of adjustment which is used during the alignment process to compensate for any misalignment. The barrel supports must be robust in order to support the barrel but also allow some form of adjustability. A properly designed and maintained barrel support will allow the barrel to move freely during the heat up and cooling cycles. An improperly designed or maintained support will restrict the barrel in the diametrical and or horizontal plane which can result in increased barrel and screw wear. Excessive misalignment conditions caused by a poorly designed support can also lead to a catastrophic failure of the critical components.

Example

The following example is a typical alignment that was performed on a 114.3mm diameter extruder with a length-to-diameter (L/D) ratio of 30 (4). The outside diameter (OD) of the screw and the inside diameter (ID) of the barrel were manufactured to the Society of Plastics Industry's machinery specifications with a radial clearance of .114 to .127mm per side. The goal of this work was two fold. First, to determine the alignment of the extruder bore in the vertical and horizontal position in relation to the gearbox in the "cold" condition. Second, to determine the effects of the alignment when the extruder was brought up to processing temperatures. The equipment used was a Line of Sight (LOS) Optical telescope. In order to determine the thermal growth and avoid any influence caused by heat, targets were positioned on the exterior of the barrel. Six targets were positioned on the top of the extruder and six targets were positioned on the side of the extruder at 90^0 from the top. Cold inspection was performed at the twelve points and recorded. The barrel was then heated up to processing conditions and the same twelve inspection points were recorded.

Results

A LSO was established coincident to the center of the gearbox and discharge end of the barrel. Readings were taken at 305 mm intervals for both vertical and horizontal positions in the cold condition inside the barrel. Figure 7 shows the deviation from the centerline in the vertical condition. The readings show a +.31mm rise in the middle of the barrel upstream from the barrel support. This deviation is more than two times than the radial clearance which will cause the screw OD to make contact with the barrel ID. Figure 8 represents the deviation from the center line in the horizontal position. The reading show a max offset of .08 mm. This is well within the acceptable range.

The targets were then positioned on the outside of the barrel and a reference point was established at the gearbox end. Figure 9 shows the vertical deviation of the barrel in the cold and hot conditions. The effects of thermal growth are consistent over the entire length of the barrel in the vertical direction. Figure 10 represents the deviation of the barrel in the horizontal direction. The readings show a maximum thermo growth of .49 mm to occur at the center of the barrel. The thermal growth appears to be consistent over the entire length of the barrel except at the discharge end where the reading indicated a .13 mm movement in the opposite direction.

Discussion

The example clearly shows that the alignment in the vertical direction exceeds the radial clearance of the screw and barrel. If this is not corrected, the screw OD and barrel ID will make contact, which will lead to excessive wear. The change in alignment when the extruder is heated further compounds the issue. The data in Figure 9 and Figure 10 suggests that the barrel support may be restricting the barrel in both the vertical and horizontal position by not allowing the barrel to expand when heated. To reduce bending or buckling of the barrel, the barrel must be allowed to move in the horizontal direction within the barrel support and the vertical movement of the barrel must not be restricted. In addition, the barrel support should be adjusted in the vertical and horizontal position until the maximum deviation is less than the total radial clearance.

Conclusions

Extruder alignment performed as part of a regular preventive maintenance program can increase the service life of critical components. Both optical and laser systems can be used with varying degrees of accuracy to check the alignment. Once a base line is established on the current alignment condition of the barrel and gearbox, adjustments can be made to the barrel support to correct any deviation. Regular inspection and maintenance of the barrel supports to ensure they are working properly will reduce the chance of buckling the barrel. It is highly recommended that the extruder be checked for alignment each time the barrel is removed or when the extruder is relocated. Most machinery suppliers can supply the tolerance and maximum acceptable deviation for the different size extruders. However, as a general rule of thumb, the maximum misalignment should not exceed the total radial clearance between the screw OD and barrel ID.

References

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4. Data supplied by Alignment Services of North America Inc. Barrington, NH (2004)
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Key Words: Barrel alignment, Extruder wear

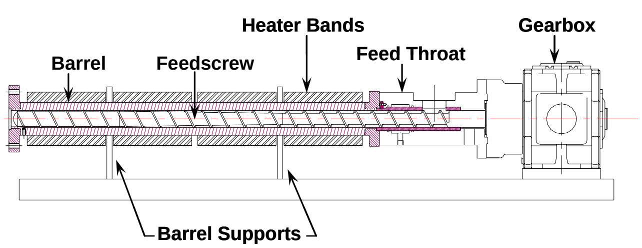

Figure 1. Typical extruder assembly.

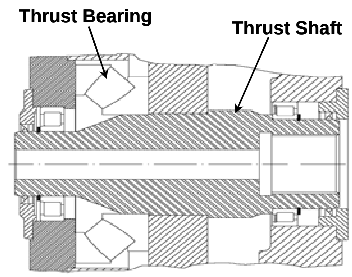

Figure 2. Typical Gearbox and Thrust Bearing assembly.

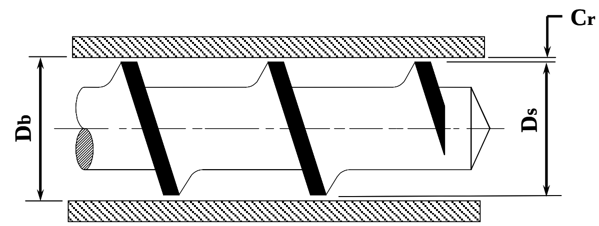

Figure 3. Typical Screw and Barrel clearance.

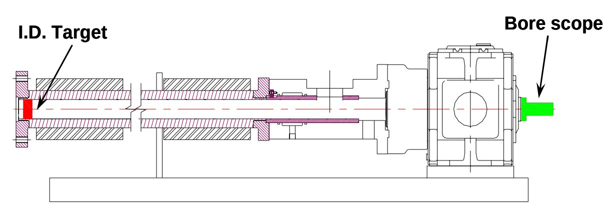

Figure 4. Extruder alignment setup.

Figure 5. Typical Optical Telescope.

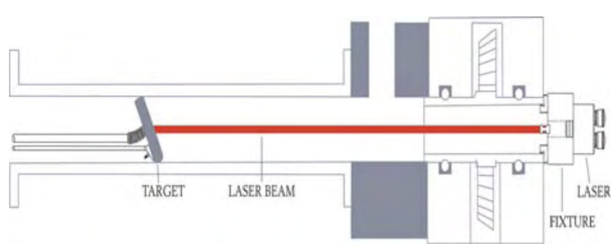

Figure 6. Typical Laser system (5)

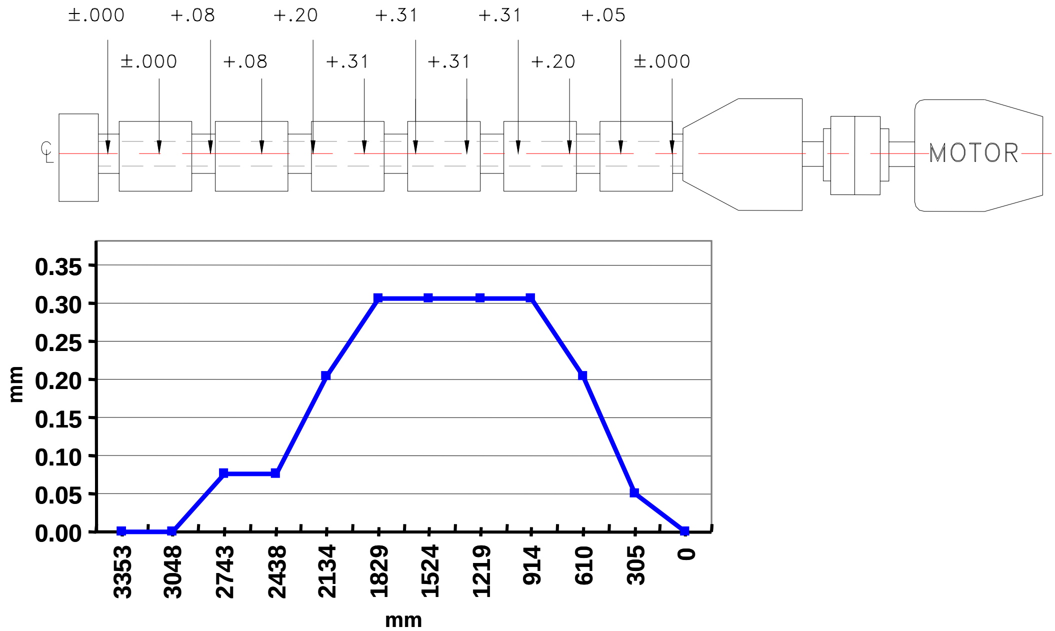

Figure 7. Side view, bore deviation in the vertical direction.

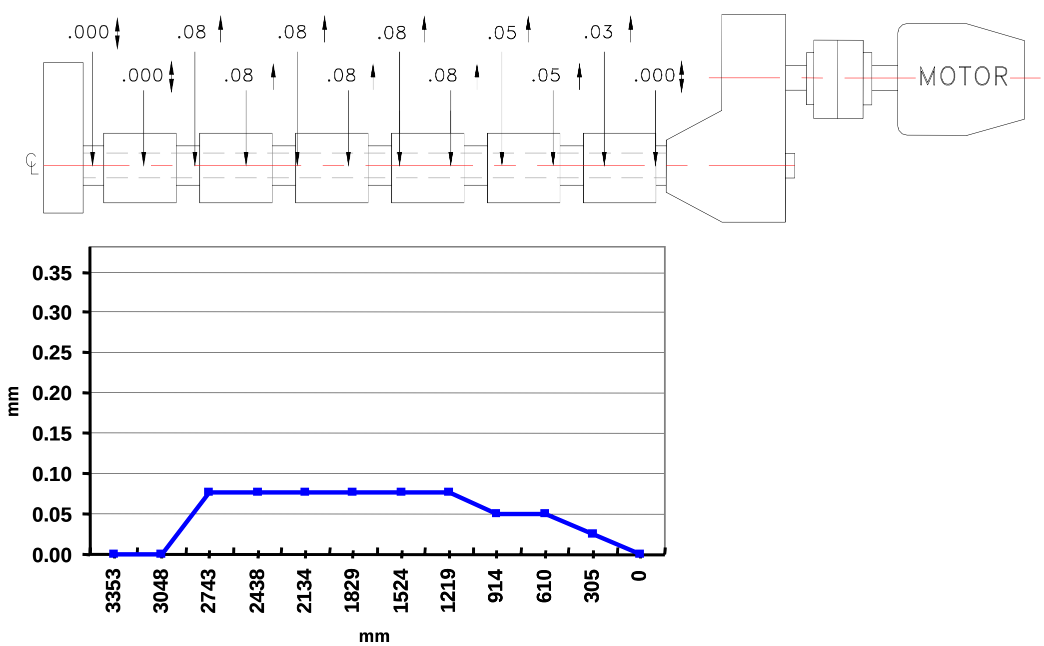

Figure 8. Top view, bore deviation in the horizontal direction.

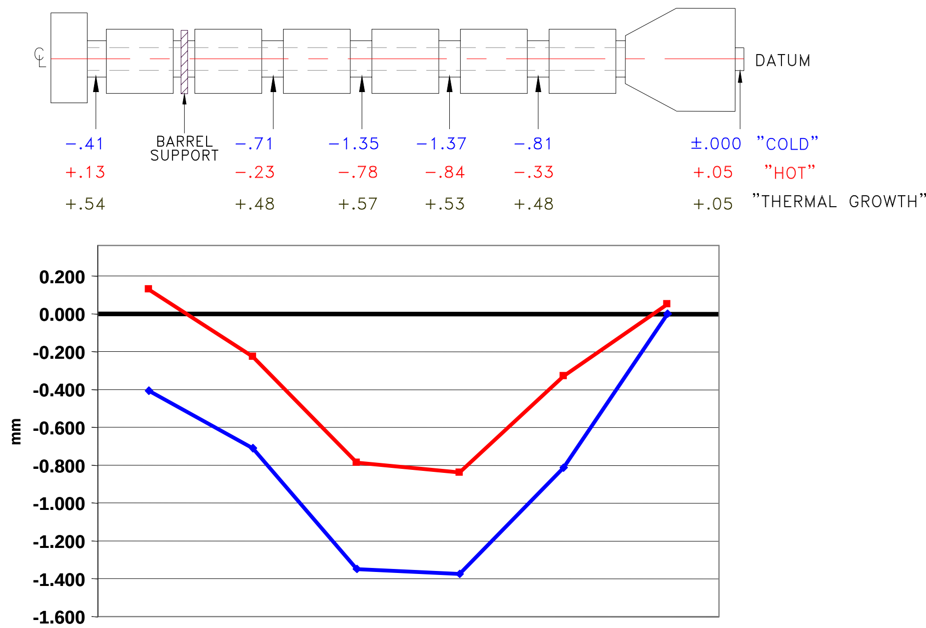

Figure 9. Side view, barrel surface vertical deviation for Hot and Cold.

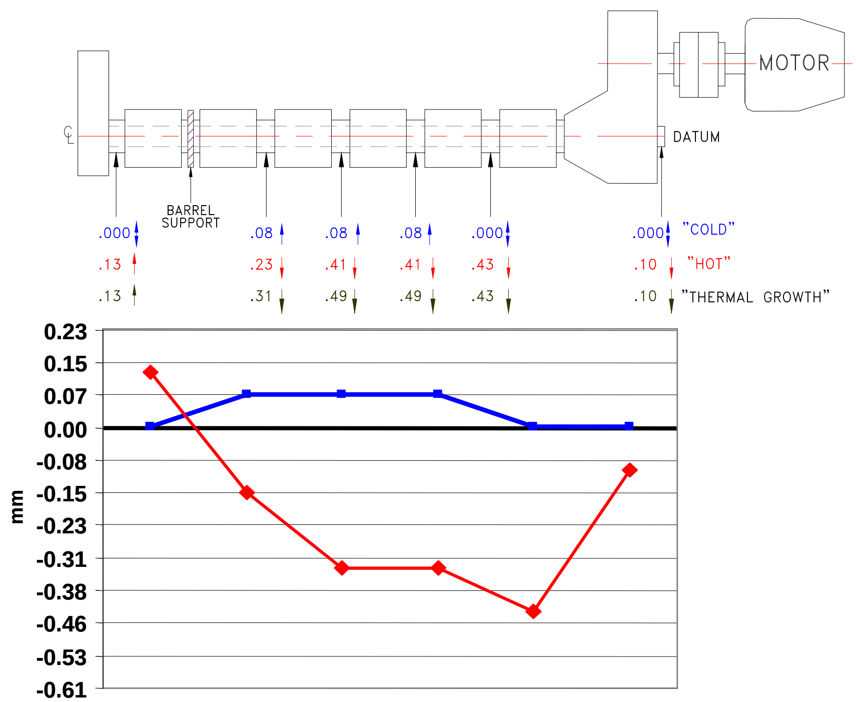

Figure 10. Top view, barrel surface horizontal deviation for Hot and Cold.