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WHITE PAPER

TUNGSTEN CARBIDE CORE PINS

Crafts Technology manufactures custom tungsten carbide core pins for plastic injection molds to produce medical consumables.

Medical Consumable Manufacturers Improve Part Quality and Cycle Time Using Tungsten Carbide Core Pins

ABSTRACT

Core pins are used to form the internal shape of plastic injection molded parts. Typical core pin applications include a wide variety of precision molded commercial products, electrical connectors, household goods, and medical consumables such as blood collection tubes, pipette tips, Luer Lock syringe barrels, laboratory consumables, viral transfer media, plungers, and more. During the plastic injection molding process, a mold is filled with molten plastic, which cools to form the final part. This manufacturing process offers a cost-effective method to produce large volumes of medical consumables with consistent dimensions. Stainless steel and beryllium copper have historically been considered appropriate core pin materials; however, tungsten carbide has proven to provide significant advantages for precision applications experiencing deflection (core shift) and/or heat transfer related issues. Tungsten carbide works exceptionally well in high-cavitation molds where long, thin parts such as test tubes or syringes are molded. The harder and more rigid tungsten carbide tooling significantly reduces deflection. Together with its positive heat transfer characteristics, tungsten carbide allows for the highest possible precision and repeatability with the exacting level of tolerances and design features that high-precision part molders require. In collaborative projects when producing medical consumables, incorporating tungsten carbide core pins has increased productivity and optimized the total cost of ownership by enhancing the part quality, cutting cycle time, and increasing tooling life. Tungsten carbide core pins are often used to manufacture part designs that are not feasible with other core pin materials.

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KEY TAKEAWAYS

- Over the past 15 years, the use of innovative core pin metals has significantly improved high-cavitation plastic injection molding technologies
- Tungsten carbide core pins are appropriate for high-cavitation medical molds such as test tubes, pipettes, and syringes
- The rigidity of tungsten carbide core pins makes possible the absolute minimization of tooling deflection (core shift) during the molding process
- With superior heat transfer characteristics, tungsten carbide's cooling capabilities are maximized (like beryllium copper, but without its health hazards)
- Tungsten carbide core pins offer improved core pin wear life
- Molding cycle times can reduce by 25%-40% with the high thermal conductivity benefits of tungsten carbide
- Defect rates are reduced with increased repeatability and the ability to achieve tighter tolerances, which improves yield and process stability, and offers the highest possible process capability [Cpk] for injection molded parts
- Improved technologies provide the ability to apply various surface finishes, including the Society of Plastics Industry (SPI) Finish A-1 standard
- Existing molds can be retrofitted with tungsten carbide core pins
- Cost benefits increase with economies of scale

INTRODUCTION

Core pins are fixed elements that create a specific cavity shape in plastic injection molded components. They are usually machined separately and assembled into a side of the mold. Over the past few decades, innovative engineers have found new applications for tungsten carbide. Today, it's used in everything from the tip of a rotating ballpoint pen to the working end of mining and earth drilling equipment. As the use of tungsten carbide has expanded, medical consumable manufacturers experiencing quality issues have collaborated with engineering teams that specialize in developing products that demand superhard materials. Today, tungsten carbide has gained acceptance as the preferred core pin material for specific consumable applications throughout the medical industry.

BACKGROUND

Historically, plastic injection tool makers have experimented with different metals to reduce deflection and improve heat transfer when producing core pins. With production volumes for medical plastic injection consumables often reaching the millions, cycle time is critical to profitability. Injection molded parts with deep internal features require long core pins. During cooling, the plastic contracts and heat is transferred through the core pin. Heat transfer is dependent upon the thermal conductivity of the core pin. Before the development of tungsten carbide core pins, stainless steel and copper alloys were the material of choice. However, copper alloys are not rigid, and for high-aspect-ratio configurations, they will deflect during the injection phase. This deflection results in unacceptable part tolerances. In situations where deflection occurs, hardened tool steel is often used, but because steel does not have high thermal conductivity, cycle times suffer.

SOLUTION

Transformational engineering balances materials science, engineering design, and design for manufacturability to develop novel approaches that optimize every aspect of the value stream.

By incorporating a harder, more rigid tungsten carbide core pin, deflection (core shift) is significantly reduced. Coupled with its thermal transfer properties, heat dissipation improves with tungsten carbide, allowing for the highest possible manufacturing precision and repeatability with injection molded parts.

OVERALL BENEFITS OF TUNGSTEN CARBIDE

Tungsten Carbide is more expensive than steel or beryllium copper; however, the expense is offset by improvements in part quality, molding speeds, and tool life because of superior rigidity, heat transfer characteristics, and wear resistance.

To further advance the utility of this technology, expert engineering teams balance the properties of tungsten carbide tooling by varying its chemical makeup. Material properties within the tungsten carbide family can differ significantly. Care must be taken to select the correct grade for specific applications. For example, tungsten carbide designed for an end mill would not be the best choice for a core pin application.

HOW TUNGSTEN CARBIDE BENEFITS CYCLE TIME

The effect on cycle time is magnified because of the thermal transfer properties of tungsten carbide (APPX. A). Some molds with steel core pins are run hotter than needed to improve the flowability of the plastic and reduce injection pressure in the name of limiting deflection. With tungsten carbide core pins, molds can run at a lower temperature with no correction for deflection. Running a mold at lower temperatures, even if just a few degrees, will improve the efficacy of cooling sub-systems and prolong the life of sub-systems, such as the hot runner system.

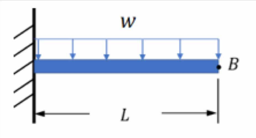
The combination of rigidity, heat transfer, and hardness (wear resistance) capabilities allows molders to improve the process parameters. Tungsten carbide tooling is harder and more rigid than other mold tooling materials, which allows for the highest possible manufacturing precision and repeatability. Maximizing repeatability allows for the absolute minimization of tooling deflection during the molding process.

HOW TUNGSTEN CARBIDE REDUCES CORE PIN DEFLECTION

Core pins are commonly made of 420 SS, H-13, or M-2 tool steel. The Modulus of Elasticity, which is the material's ability to resist bending, of tungsten carbide is more than double that of 420 SS, H-13, and M-2 and about 4X that of beryllium copper alloys. A theoretical calculation illustrates the benefit of this material property on deflection.

It is possible to model a core pin as a simple cantilevered beam with a distributed load, in which case the maximum deflection of Point B is calculated as:

$$\sigma_B = \frac{wL^4}{8EI}$$



Where σ_B is the deflection distance in the downward vertical direction, w is the pressure applied to the beam, L is the length of the beam, E is the Modulus of Elasticity, and I is the Moment of Inertia for the beam profile.

If we calculate the deflection for two scenarios, one with a tungsten carbide core pin and one with a steel core pin, we will see the following:

$$\sigma_{w_c} = \frac{wL^4}{8E_{w_c}I} \qquad \sigma_S = \frac{wL^4}{8E_S I}$$

Where σ_{w_c} is the deflection of the tungsten carbide core pin, and σS is the deflection of the steel core pin. Suppose we maintain the same core pin geometry and pressure: in that case the parameters for w, L and I are the same for each scenario, leaving the modulus of elasticity as the only differentiating factor between the deflection of the tungsten carbide core pin and the steel core pin. Combining the two equations above using the common variables, we can determine a theoretical comparison between the two deflections.

$$\sigma_{w_c} * E_{w_c} = \frac{wL^4}{8I} = \sigma_S * E_S$$

Using 30,000 kpsi for the modulus for steel and 85,000 kpsi for the modulus for tungsten carbide, we find:

$$\sigma_{w_c} = \frac{\sigma_S * E_S}{E_{w_c}} = \frac{30{,}000}{85{,}000}\sigma_S = 0.35\sigma_S$$

In other words, the deflection experienced with tungsten carbide cores is approximately 35% of the deflection experienced with steel cores. Theoretically, if you replace a steel core pin with a tungsten carbide core pin, you can see a 65% reduction in deflection.

Simulation software confirms this calculation and goes a step further by including thermal conductivity effects. Simulation comparisons for tungsten carbide core pins versus 420 SS core pins show deflection reductions around 64% (APPX. B).

HOW TUNGSTEN CARBIDE MAXIMIZES HEAT TRANSFER

Tungsten carbide tooling is used to produce high-precision molded parts at the fastest cycle time possible. The material allows for higher molding speeds due to its superior heat transfer characteristics.

Using tungsten carbide core pins in plastic injection molded medical consumables has resulted in cycle-time savings of as much as 20 to 40 percent without sacrificing the quality of the molded part.

Regardless of core pin material, the smaller the diameter and the longer the exposed length, the more difficult it is to keep cool. Tungsten carbide core pins have a very high thermal conductivity versus their steel alloy counterparts. In a simulation, the tip of a blood tube using tungsten carbide core pins cooled to 61°F, while in the same amount of time, the tip of the blood tube made with 420 SS core pins was still over 80°F during filling and cooling (APPX. C).

Advantages of higher thermal conductivity

- Core pin heat dissipates into the mold faster
- Core pin temperatures rise less during filling
- The part cools faster

Ultimately, the higher thermal conductivity of tungsten carbide allows heat to dissipate from the core pin to the mold faster, resulting in improved quality and cycle time.

HOW TUNGSTEN CARBIDE MAXIMIZES CORE PIN WEAR LIFE

Rounding out the advantages that tungsten carbide presents to molders is the overall wear life of the tooling. Molders have experienced improved wear life when migrating from steel and copper alloys to tungsten carbide, especially in glass-filled automotive, consumer goods, and peek-filled applications.

The wear life of mold tooling is a function of material hardness. When comparing the maximum attainable hardness of beryllium copper alloy (42 HRc) and 420 SS alloys (52 HRc) to tungsten carbide (~76 HRc), it is easy to see why tungsten carbide is chosen to resist wear in many applications. It is common to see a 5X-10X life improvement when moving from steel to tungsten carbide.

CONCLUSION

The use of tungsten carbide core pins has transformed plastic injection molding for medical consumables. By fostering strong synergies between manufacturing, engineering, and materials science capabilities, Crafts Technology has created solutions that significantly enhance the overall performance and productivity of the molding process by reducing defects and decreasing cycle time. While the initial cost of tungsten carbide core pins is more expensive than other traditional materials, the return on investment is justified by quality, productivity, and wear life improvements.

By evaluating the characteristics of the material and the impact of the manufacturing process, to ensure that the part is produced at the exact specifications desired and at a cost-effective price point, innovative design approaches can develop a system that maximizes value.

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Crafts Technology has produced custom injection mold tooling for over 15 years, enhancing hundreds of critical niche molding application processes. We engineer and manufacture precision, complex form tungsten carbide core pins, catheter tip bushings, pin bushings, gate bushings, inserts, ejectors, and other injection molding tooling with the exacting level of tolerances and design features that high-precision medical consumable molders require. At Crafts Technology, we develop solutions to achieve a variety of precise criteria based on your specific application. We invite you to partner with us to determine the cost-effectiveness of our unique solutions.

We invite you to partner with us to determine the cost-effectiveness of our unique setups.

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APPENDIX A

Core Pin Material Properties

Material Type		**Craftalloy™ 10C Tungsten Carbide**	**Craftalloy™ 15C Tungsten Carbide**	**420SS**	**H13**	**P20**	**M2**	**Copper-Beryllium Alloy (98% Cu, 2% Be)**
Young's Modulus of Elasticity	kpsi	85,000	77,600	30,000	31,000	30,000	30,000	19,000
	GPa	586	535	207	214	207	207	131
Thermal Conductivity	Btu/(ft-hr-oF)	60	60	14.4	14.2	17.3	11	75
	W/cm-oC	104	104	24.9	24.5	30	19	130
Thermal Expansion Coefficient	x10-6/oC	5.5	6.2	10.3	10.4	12.1	11	17.3
	x10-6/oF	3.06	3.44	5.7	5.8	6.7	6.1	9.6
Density	g/cm3	14.4	14.0	8.03	7.8	7.86	8.14	8.36
	lb/in3	0.52	0.50	0.29	0.28	.284	.294	.302
Specific Heat	Btu/(lb-oF)	0.051	0.051	0.11	0.11	0.11	0.11	0.091
	J/(kg-K)	213	213	460	460	460	460	380
Hardness	HRc	~80 (92 HRa)	~76 (90 HRa)	52	54	48	66	42
Poisson Ratio	%	0.22	0.23	0.24	0.30	0.29	0.29	0.30
Wear Resistance		Best	Best	Good	Good	Good	Good	Poor
Cost	$	$$$$	$$$$	$$	$	$	$	$

*All values are close approximations - actual values may vary

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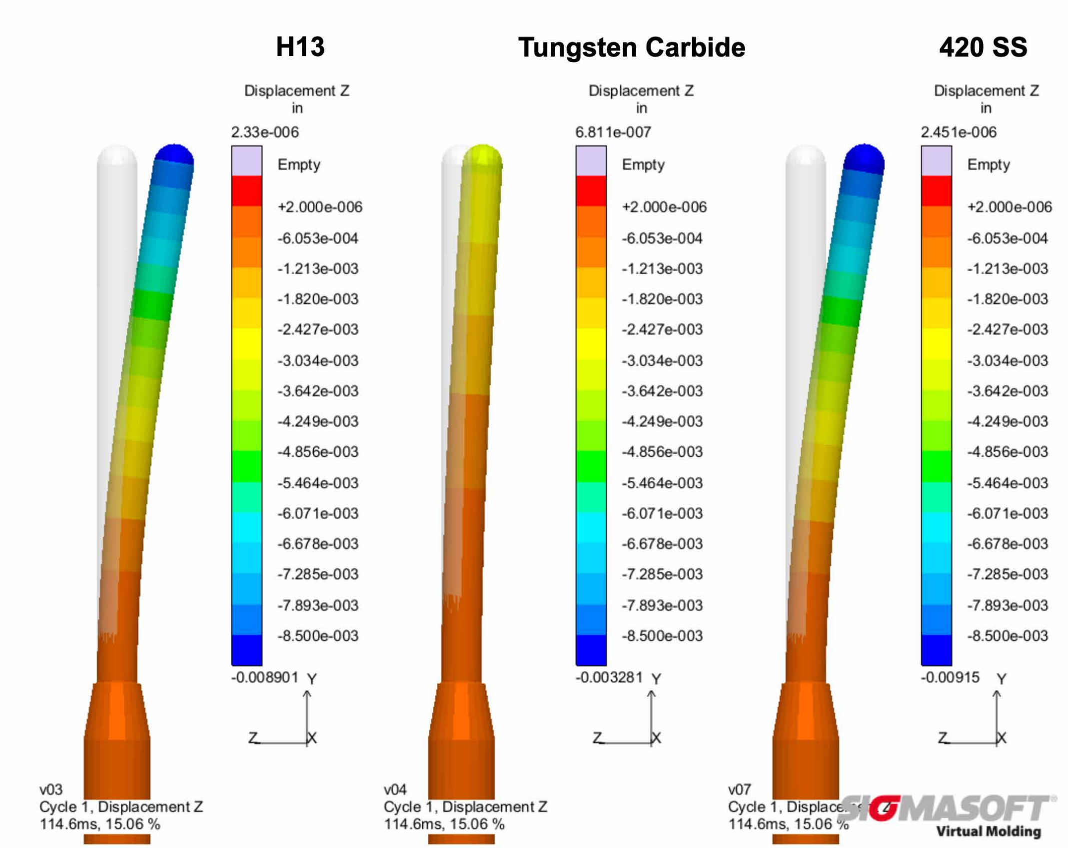
APPENDIX B

Core Pin Deflection - Z Axis, SIGMASOFT Simulation involving H13, CraftAlloy Tungsten Carbide, and 420SS Core Pins

- Image shows the distortion of the core pin in the Z direction during filling with an amlification factor of 50x
- Highest core deflection when the material begins to flow into the cavity at 0.115 sec
- Highest distortion in Z direction:
  - H13 : 0.0089 in
  - Tungsten Carbide : 0.0033 in
  - 420 SS : 0.0092 in
- Tungsten carbide is the most rigid and deflects less
- Tungsten carbide reduces core pin deflection by ~64% in the Z direction



APPENDIX C

Core Pin Filling and Cooling Temperature, SIGMASOFT Simulation involving CraftAlloy Tungsten Carbide and 420SS Core Pins

- Animation shows the mold filling and cooling on the 10th cycle
- Tungsten carbide removes the head at a faster rate in comparison to the 420 SS