Фактическое значение относительной обрывности 10,1 обр/т, расчетное значение 11,7 обр/т.

3. Период наработки металлокорда 2х0,30UT: 31.01.2018–30.03.2018. Средние значения механических свойств тонкой проволоки, полученные из 20 результатов испытаний на разрыв тонкой проволоки в течение периода изготовления м/корда: $E = 184742$ МПа, $\sigma_в = 3628$ МПа, $\delta = 2{,}55$ %, объем выпуска N = 22,096 т, скорость тонкого волочения 5 м/с, $\varepsilon_{св} = 2{,}19$, сталь 80. Фактическое значение относительной обрывности 24,75 обр/т, расчетное значение 23,87 обр/т.

Сравнительная характеристика расчетных и фактических величин относительной обрывности показывает на достаточную адекватность полученной зависимости, позволяющую ее использовать в производственных условиях.

OPTIMIZATION OF THE QUALITY OF LARGE STEEL CASTINGS BASED ON COMPLEX NUMERICAL MODELING OF CASTING TECHNOLOGICAL PROCESSES

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This work summarizes the findings of multi-objective optimization of a gravity sand-cast steel part for which an increase of casting yield via riser optimization was considered. This was accomplished by coupling a casting simulation software package with an optimization module [1]–[3]. The benefits of this approach, recently adopted in the foundry industry worldwide and based on fully automated computer optimization, were demonstrated. First, analyses of filling and solidification of the original casting design were conducted in the standard simulation environment to determine potential flaws and inadequacies. Based on the initial assessment, the gating system was redesigned and the chills rearranged to improve the solidification pattern. After these two cases were evaluated, the adequate optimization targets and constraints were defined. One multi-objective optimization case with conflicting objectives was considered in which minimization of the riser volume together with minimization of shrinkage porosity and limitation of centerline porosity were performed.

Metalcasting process simulation is used to provide detailed information about mold filling, solidification and solid state cooling, as well as, information about the local microstructure, non-uniform distribution of mechanical properties and subsequently residual stress and distortion build-up.1-9 Casting simulation tries to use physically realistic models without overtaxing the computer. At the same time the simulations need to give applicable results in the shortest time possible. Unfortunately, numerical simulations can only test one “state”, while conclusions from calculations or subsequent optimization still require an engineer’s interpretation and decision after each of the simulation runs. Understanding the process enables a foundry engineer to make decisions that can affect both the part and the rigging to improve the final quality.

The objectives which drive designers are generally well defined: improve the component quality, achieve homogeneous mechanical characteristics, maximize the casting yield, increase the production rates, etc. It may sound easy, but the truth is that in reality it is very complex and time consuming to achieve all these objectives at the same time, due to the high number of variables involved. In many foundries, the only applied optimization is still based on experience and thus on the trial-and-error method. When using numerical simulation, only a virtual casting is spoiled, in the case of an error. No raw material is wasted, no mould is produced and, above all, no production loss is experienced.

Recently, rapid development of high performance computing has substantially shortened the calculation time needed for one variant of the casting process to be analyzed. It is feasible to calculate numerous versions and layouts in almost unlimited configurations over night. The advantage of having such short calculation times can only be utilized with a computer that can automatically analyze calculated variants with respect to the predefined objectives (e. g. maximum feeding, low porosity, low air entrapment etc.) and subsequently create new variants and analyze them in the same manner to achieve the optimal solution.

This paper details multi-objective optimization of filling and solidification patterns, together with the riser volume of a steel forging ram (Fig. 1) cast into a furan sand mould, and presents the results obtained from the study.

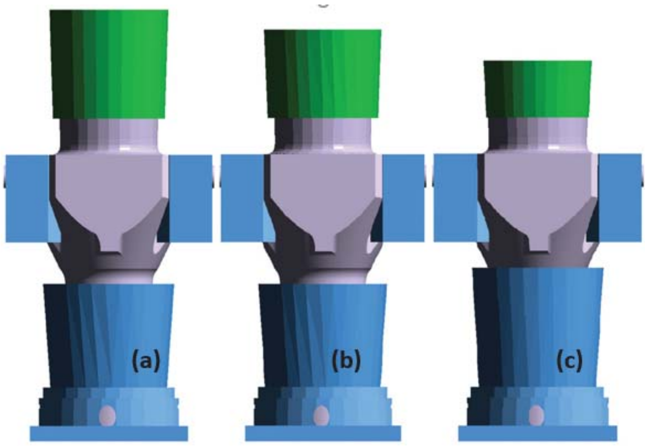


Fig. 1. Design space with the highlighted Pareto set

Before the optimization process can be started, a standard project must be defined in the simulation software environment. This includes a definition of geometry in the pre-processor. Furthermore, a suitable mesh must be generated and all relevant process parameters adequately defined. The optimization itself is based on performing a large sequence of "standard" calculations, each with different design variants. Therefore all design variables must be defined in a parametric way.

A multi-objective optimization problem (Fig. 2) in the gravity sand casting process of a forging ram is presented. The objectives for this case study are the following: minimize the top riser volume, minimize shrinkage porosity, and limit centerline porosity, by means of an optimized arrangement of the chills.

Most engineering design activities require a solution of multi-objective and multi-disciplinary optimization problems that in many cases deal with conflicting objectives. When considering these objectives, a number of alternative trade-off solutions, referred to as Pareto-optimal solutions, have to be evaluated. None of these Pareto designs can be said to be better than the other without any additional information about the pooblem under consideration. In order to define the Pareto set, one has to apply the concept of domination, which allows comparing solutions with multiple objectives (Fig. 3).

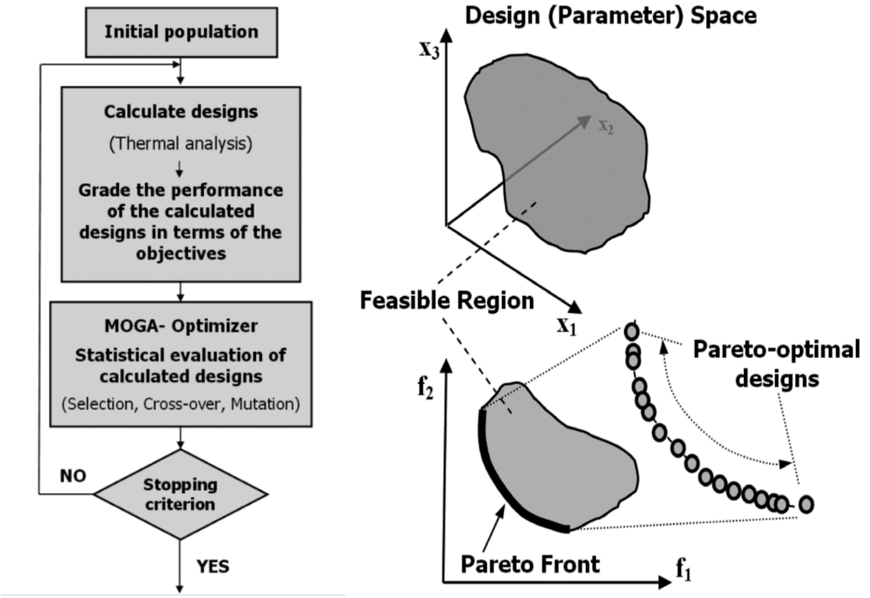
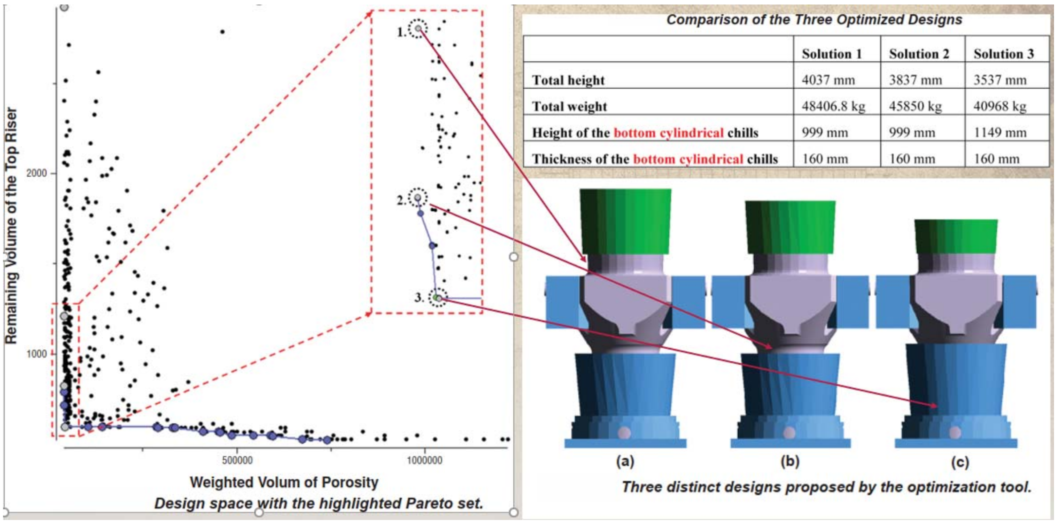


Fig. 2. Flow chart of the optimization process



Design space with the highlighted Pareto set.

Comparison of the Three Optimized Designs

	Solution 1	Solution 2	Solution 3
Total height	4037 mm	3837 mm	3537 mm
Total weight	48406.8 kg	45850 kg	40968 kg
Height of the bottom cylindrical chills	999 mm	999 mm	1149 mm
Thickness of the bottom cylindrical chills	160 mm	160 mm	160 mm

Three distinct designs proposed by the optimization tool.

Fig. 3. A study of a multi-objective optimization problem
that has been carried out for a steel forging ram

The manually optimized solution served as a model for optimizing riser and cooler geometry. In the case of multipurpose optimization, the riser and cooler dimensions were applied as design variables along with the ranges of variation. In addition, optimization goals were introduced into the optimizer along with potential constraints, as well as the number of initial projects and generations in which optimal solutions should be found. Three different solutions were chosen from the design space. The first option was a humble approach (relatively large riser), the middle one was still a safe solution, but the riser was much smaller, and the third solution was a very risky solution with the highest casting yield. It turned out that all three designs gave different curing patterns compared to the original design. This was due to the change in the dimensions of the riser and the rearrangement of the hills. No puddles of residual liquid were found; however, the third solution showed some indications of potential problems. In terms of macro and micro shrinkage in optimized designs, the only areas of concern were the riser head and bottom pins. The casting appeared to be devoid of porosity. In the end, together with the foundry, it was decided not to consider the latter solution for production due to the high risk of production disruption. In other words, taking into account the human factor, the risk of porosity propagation from the riser to the casting body is too high. Finally, the results concerning the casting yield showed that, when used correctly, multi-purpose optimization can significantly increase the casting yield and thus reduce production costs.

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АНАЛИЗ ВЛИЯНИЯ СПОСОБА ДЕФОРМАЦИИ СЛИТКА НА СТРУКТУРУ ШАРИКОПОДШИПНИКОВОЙ СТАЛИ В ПРОЦЕССЕ НЕПРЕРЫВНОЙ РАЗЛИВКИ СТАЛИ

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Одним из важнейших составляющих практически всех механизмов являются подшипники, изготавливаемые из подшипниковых марок сталей. В сталеплавильном производстве основные эксплуатационные характеристики изделий из подшипниковых сталей определяют центральная пористость, подусадочная ликвация, развитие и образование карбидной ликвации при производстве непрерывно литой заготовки (НЛЗ). Для изготовления подшипников наибольшее распространение получила высокоуглеродистая хромистая сталь (~ 1,05 % углерода, 0,4–0,5 % хрома), преимущественно используемая во всем мире. В шарикоподшипниковых сталях считается недопустимым наличие центральной пористости с баллом выше 2,0, что служит основанием для забракования всех партий прутков, соответствующих контролируемому образцу. Поскольку в данной стали требуется высокая однородность физико-химических свойств, то присутствие в ней ликвационных дефектов также ограничивается, ликвация с баллом 2,0 считается недопустимой. Снижение балла карбидной неоднородности особенно актуально для производства подшипниковой стали методом непрерывной разливки.

Целью работы является анализ применения режимов мягкого обжатия на образование и развитие карбидной неоднородности в процессе разливки подшипниковой стали на машине непрерывного литья заготовки (МНЛЗ).

Непрерывнолитые заготовки в сравнении со слитком отлитым в изложницу характеризуются мелкодендритной структурой, менее развитой химической неоднородностью, более равномерным распределением неметаллических включений и газов. Однако проблема структурной, химической, физической неоднородности в заготовках непрерывной разливки все еще является открытым вопросом.